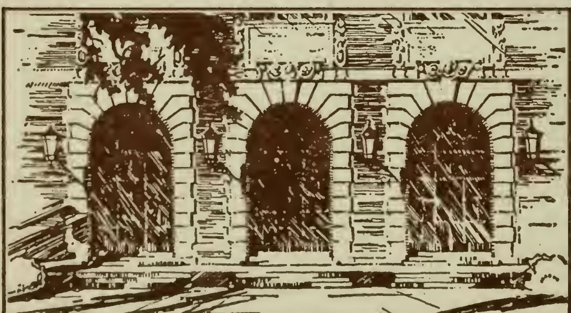

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ELEMENTARY PRINCIPLES OF RADIO TELEGRAPHY AND TELEPHONY

Radio Communication Pamphlet No. 1

(Second Edition)

PREPARED IN THE OFFICE OF THE CHIEF SIGNAL OFFICER

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PREPARED IN THE OFFICE OF THE CHIEF SIGNAL OFFICER

By

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War Department.
Document No. 1064.
Office of The Adjutant General.

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WAR DEPARTMENT,
WASHINGTON, *April 28, 1921.*

The following publication, entitled "Elementary Principles of Radio Telegraphy and Telephony," Radio Communication Pamphlet No. 1, is published for the information and guidance of all concerned.

(062.1 A. G. O.)

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
Major General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

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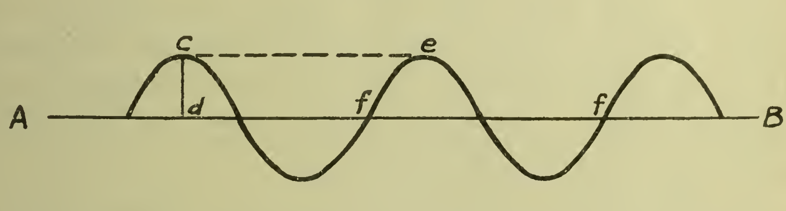
ELEMENTARY PRINCIPLES OF RADIO TELEGRAPHY AND TELEPHONY.

I.

1. This pamphlet is a simple discussion of the principles upon which radio transmission is based. No previous knowledge of radio is assumed. It is for the beginner. It is assumed, however, that the reader has an understanding of the subject matter covered in "Elementary Electricity," which is Training Pamphlet No. 1. If not familiar with that pamphlet the student should secure a copy and study it in connection with the study of this pamphlet.

2. Radio communication is the art of sending information from one point to a distant point by means of free electric waves. The

FIG. 1.



study of radio communication, therefore, embraces three separate subjects: The production of these waves, the waves themselves, and the reception of these waves.

WAVES.

3. Every one is familiar with waves, especially with those that appear on the surface of water. Let us study these water waves. We can represent them by a line as in figure 1, where the curving line represents the surface of the water with waves on it and the straight line, AB, represents the surface of the water when there are no waves. The first thing we notice about a wave is its height. The stronger the breeze the higher the waves. The correct way to measure the height of a wave is to measure from the crest of the wave to the surface of the water when it is smooth. In figure 1 this would be represented by the line *cd*. A better term for this measurement is

amplitude of the wave. Hereafter we will refer to the amplitude of the wave and not to the height.

4. If we have been in a boat or in swimming when there were waves, we are familiar with the fact that the waves have energy. In other words, they have power to move objects that are in the water or that they may strike. It is seen that the bigger the waves the more energy they have. Another way of saying this same thing is to say that the energy of a wave increases as its amplitude increases—a large amplitude gives a large amount of energy—a small amplitude gives a small amount of energy. In radio we use the energy of the radio wave.

5. If we watched water waves we would soon notice that besides height, the waves have length also. There would be a certain distance from one wave to the next. This distance can be measured from the highest part of one wave (called the crest) to the highest part of the next wave. This distance is the *length* of the wave. In figure 1 it is represented by the line *ce*. Also *ff* shows the length of the wave. The wave length then is the distance from any part of one wave to the *corresponding* part of the next wave. A short way of writing the word *wavelength* is "λ" pronounced "Lambda." This symbol means wave length. (Make several of these symbols so as to become familiar with them.)

6. If we stood on the shore and watched the wave go by we would notice that waves, besides having amplitude and length, passed us at regular intervals of time. Count the number of waves passing per second. You have counted the *frequency* of the waves. Frequency, then, is the number of waves passing any point in a *second*. It is represented by the letter "f."

7. Suppose now that we wished to know how fast the waves are traveling. We could find this out in different ways. The easiest way to find it out is to figure it out as follows: Suppose each wave is 10 feet long and there was one wave passing per second. The wave must be traveling 10 feet per second, then, in order to get by. If two waves per second passed, then the waves must be traveling 2×10 feet$=$20 feet per second. If there were 12 waves per second ($f=12$) and each wave was 10 feet long ($\lambda=10$ feet) then the waves must be traveling $12\times10=120$ feet per second. But 12×10 is the same as $f\times\lambda$ so that the rate of travel (velocity) of a wave is $f\times\lambda$. Velocity is always represented by the letter "v" so that $v=f\lambda$.

8. Now we have a very good idea of what water waves are. We can sum it up by saying that water waves are *recurring* displacements of water, traveling at a definite velocity and having definite *amplitude*, *length*, and *frequency*. These waves carry energy. This is true of water waves, and if we say "disturbance" instead of "displace-

ment of water" it would be true of any kind of a wave. Waves are recurring disturbance, traveling at a definite velocity and having definite amplitude, length, and frequency. Waves carry energy.

9. Each different kind of wave has a definite velocity. The velocity of a radio wave is so great that it would go around the earth seven times a second if it could keep on going. That is a great speed. It is 186,000 miles in a second. In radio we do not measure distances in miles—we use meters (a meter is a few inches longer than a yard). The velocity of radio waves is 300,000,000 meters per second.

10. This velocity is *constant*, so that in measuring radio waves, if we can find either the frequency or the length, we know the other. This is true because $v = f\lambda$ and v is always equal to 300,000,000 meters per second. So if we know either f or λ, the other one can always be obtained by dividing the known one into 300,000,000.

Examples: (1) What is frequency if λ is 2,000? Frequency is 300,000,000 divided by 2,000=150,000 waves per second. (2) What is wave length if frequency is 50,000? $\lambda = 300{,}000{,}000 \div 50{,}000 = 6{,}000$ meters. Sometimes one is stated and sometimes the other. Both are known when one is, as we have just shown.

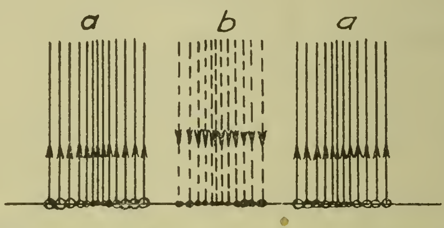
11. In order to have a wave it is evident that there must be some material to carry the wave. This thing in which the wave travels is called the *medium.* The medium that carries water waves is water. Sound is carried by waves in air. Air is the medium for sound waves. So in radio waves there is a medium which carries them. This medium is called the ether. Not much is known about the ether except that it will carry certain waves very rapidly. Besides carrying radio waves, it carries light waves and also heat waves. Another fact that is known about the ether is the fact that it is *everywhere.* It is between you and every other object. It is between the earth and the sun, the moon and the sun, etc. It is in everything, as well as in the space outside. It is in the pamphlet you are reading—it is in your body. It is *everywhere.* There is no exception to that. You can not think of a place where there is no ether—for there is no such place.

12. The radio waves then are carried by ether. Just what are these radio waves? In elementary electricity we studied about the *magnetic lines of force* and showed them by iron filings between magnets. A radio wave consists of these magnetic lines of force and something else. That something else is electrostatic lines of force. Electrostatic line of force are what cause a positively charged body to attract a negatively charged body. They go from a positive to a negative charge and are quite similar to magnetic lines of force. They are caused by a charge of electricity and are always present when a body is charged. A radio wave then is composed of electromagnetic lines of force and electrostatic lines of force.

13. A radio wave is represented in figure 2. This figure shows a radio wave moving from left to right. The electrostatic lines of force are represented by lines, the electromagnetic line of force represented by little circles at the end of the lines. It must be remembered that these are *lines*. They extend at right angles to the electrostatic lines of force. They can not be shown on this diagram as lines, so are represented by circles. This wave is usually represented by a curved line similar to figure 1. Figure 3 shows the usual representation.

14. Figures 2 and 3 are labeled the same and they show how one accurately represents the other. *a* is the crest of one wave and *a′* the crest of the next. The distance from a to *a′* is a wave length. The amplitude is shown by the line *m* in figure 3. In figure 2 this amplitude is shown by the closeness of one line to another. If the

FIG. 2.



Amplitude of wave is represented by the density of the lines of force.

amplitude was greater, there would be more lines packed in a given space.

15. There is one other thing about a wave that we should observe. In the water wave we see that part of the water in the wave is above the level of the water when it is smooth and the other part of the wave is below the level. This is true of all kinds of waves—part of the wave disturbance is on one side of the usual (waveless) condition, and the other part of the wave disturbance is on the opposite side of the usual (waveless) condition. This is true of the radio waves. Look at figure 2 and note that the arrows show that the electrostatic lines of force are directed upward in one part of the wave and downward in another part. This is also true of the electromagnetic lines of force. The open circles represent those that are directed toward you; the solid circles represent those that are directed away from you.

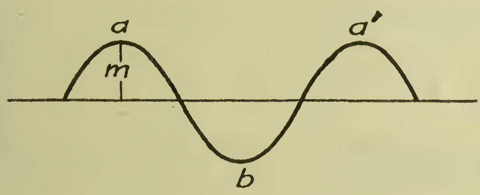
16. It must be clearly understood that this wave travels onward just as a water wave travels onward. This means that any point in the path of the wave is swept by lines of force, magnetic and electro-

static, directed in one way and an instant later the same point is swept by lines of force directed in the opposite way. Between each reversal of these lines of force there is a brief instant in which no lines of force sweep the point. As we have noted in paragraph 9, the velocity of these waves is 300,000,000 meters per second. (They may be of any length; for example, as short as 50 meters or as long as 50,000 meters.)

PRODUCTION OF WAVES.

17. We can produce waves in water by various methods. But whatever method we use, it is always done by something that will cause the surface of the water to move up and down. In other words, we must have some contact between a moving body and the water. For instance, wind will produce waves in water. The moving air comes in contact with the water and imparts motion to the water. Now, radio waves in ether must be produced in a similar way—by

FIG. 3.



something moving capable of affecting the ether. The only known thing that is capable of affecting the ether is the electron. The only way that electrons can produce waves in the ether is by moving rapidly to-and-fro.

18. Thus to get a radio wave we must have a rapid to-and-fro movement of electrons. These moving electrons produce radio waves and the radio waves produced are similar in every respect to the motion of the electrons producing them. Thus, many electrons moving mean that the radio wave has large amplitude (carries much energy). The number per second of to-and-fro movements of the electrons determines the number per second (frequency) of the waves. The wave length is, of course, determined by the frequency. The velocity of the wave is always the same; 300,000,000 meters per second.

19. Thus in order to produce a radio wave we must produce a rapid to-and-fro movement of electrons. In an alternating current, such as we use for electric lighting, the electrons move first in one direction and then in the opposite direction; that is, to-and-fro. But these changes in direction occur only a comparatively few times per sec-

ond—sixty times in most alternating currents. This is not rapid enough for the electrons to start a wave, containing useful energy, in the ether. To start such a wave we must have the alternations (to-and-fro movement) occur *6,000* or more times per second. Alternating currents having 6,000 or more alternations per second are said to have *radio frequency*. The study of the production of these high frequency alternating currents comprises the greater part of the study of producing radio waves.

20. If we take a weight and hang it on a spiral spring, such as is found in ice scales, we can get a vibrating motion of the two. By pulling down on the weight and letting go, the weight will oscillate (move to-and-fro) up and down. We can change the frequency (number per second) of these vibrations by changing the stiffness of the spring or by putting on various weights. A study of this motion will show that it is the spring that pulls *it* back to its normal position and it is the weight which makes it move beyond its normal position. In other words, once we have stretched it further than its normal length, the spring starts it in motion—and the weight keeps it in motion.

21. We can get the same effect in another way. Take the blade of a hack saw and fasten it in a vise, allowing some of it to project. Pull the end to one side and let it go. It will vibrate back and forth. By some means fasten a weight on the end and watch it vibrate. Notice the change in the frequency of vibration. Change the stiffness of the blade (by substituting a different sized blade or by shortening or lengthening the blade). Try different sized weights fastened to it. You will note that it is the combination of weight and stiffness which determines the frequency of vibration. Changing either one or changing both will change the frequency. You will note, too, that once drawn aside (given energy) it is the stiffness of the blade which starts the motion toward the point of rest, and it is the weight which keeps it moving beyond the point of rest.

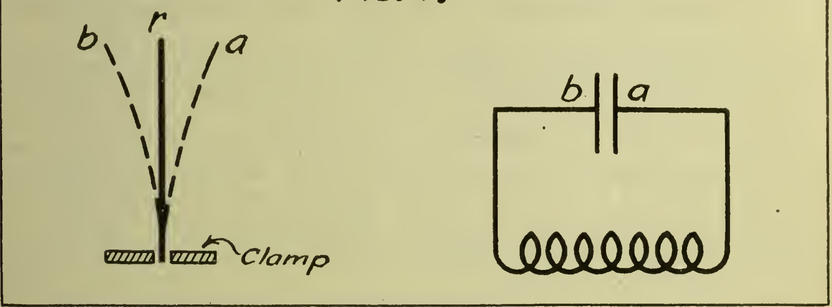
22. Thus you see we can start vibration or oscillation in anything if we have these two factors present; that is, if we have something that will start a movement to a point of rest (when it has been moved from the point of rest) and something that will keep its movement going beyond the point of rest. In electricity we have these two factors, and it is by using these that we can get radio frequency alternations (oscillations) in a circuit.

23. Inductance in an electrical circuit has the property of resisting any *change* in the *current* flowing in that circuit. Consider a circuit which has a large self-inductance. A current is started in the circuit, and the self-inductance of the circuit opposes the building up of

that current. When the current is flowing if we stop it or diminish it in any way, the self-inductance of the circuit opposes the stopping or diminishing of the current. In other words, inductance opposes any change in the current flowing in a circuit. This is exactly the effect of the weight of any moving object. An automobile truck is hard to start because its weight opposes the starting of it. When the truck is in motion and an attempt is made to stop it, it is the weight of the truck which opposes the stopping of it. Inductance in electricity plays the same rôle as weight in objects. In the same way as the weight made the hack saw pass beyond its point of rest, the inductance of a circuit will make a current pass beyond its point of rest (zero current).

24. Capacity in an electric circuit has the property of urging a current to the point of rest (zero current) when it has flowed be-

FIG. 4.



yond the point of rest. Consider a circuit containing a condenser (capacity) and a source of electromotive force. When the circuit is made the condenser gradually charges up from a zero potential to a potential equal to that of the charging instrument. When the potential of the condenser and the charging instrument are the same, the current stops flowing because the potential of the condenser is urging the current in the opposite direction to that of the charging instrument. If the source of electromotive force is removed and the circuit completed the condenser will, because of its potential, cause a current to flow in a direction opposite to that of the first current. The condenser potential will act until it has been all used up; that is, until the condenser has zero potential. Thus capacity plays the same part in an electric circuit that a spring (elastic body) does in a material body.

25. It is seen, then, that weight and inductance are similar and also that elasticity (springiness) and capacity are similar. When both inductance and capacity are in a circuit they will act exactly as a spring and weight act in a material body. That is, if they are fur-

nished with electrical energy and then freed from outside influence they will oscillate in exactly the same way as the hack-saw blade vibrated, due to its stiffness and weight. A study of figure 4 shows this similarity.

HACK-SAW BLADE.	INDUCTANCE AND CAPACITY.
Furnish energy by displacing the hack-saw blade to position at *a*.	Furnish energy by charging the condenser so that electrons gather on plate of condenser marked *a*.
Free the hack-saw blade by removing the hand.	Free the inductance-capacity circuit by removing source of charge.
The stiffness (elasticity) of the hack-saw blade makes it move from its position of displacement, *a*, toward the point of rest, *r*.	The potential of the condenser causes the electrons to move away from *a* to the point of rest. (Point of rest is that point where there are no excess electrons on either plate of condenser.)
When the blade reaches the point of rest, *r*, it has its greatest speed.	When the electrons reach their point of rest the current has the greatest value.
Just at the point of rest the stiffness of the blade ceases to move the blade.	Just at the point of rest the capacity of the circuit ceases to act. (There is no potential.)
The weight of the blade causes the blade to move beyond its point of rest.	The inductance of the circuit causes the current to keep on moving beyond the point of rest. (Zero potential.)
The further the blade moves beyond its point of rest, the more the stiffness of the blade opposes the motion.	The longer the current flows beyond the point of rest the more the capacity of the circuit opposes the current. (Because the condenser is acquiring, by the current flowing into it, a potential opposing the flow of current.)
When the blade reaches the furthest displacement, *b*, on the other side, there is no motion.	When the electrons have reached their furthest displacement (charged *b* to its highest potential) there is no current in the circuit.
The stiffness of the hack-saw blade makes it move from this position of displacement toward the point of rest. This movement is opposite in direction to the first movement.	The potential of the condenser causes the electrons to move away from *b* to the point of rest. This movement, and therefore the current, is opposite in direction to the first movement.
Events repeat themselves as explained.	Events repeat themselves as explained.
The frequency of vibration of the blade depends upon the values of both the weight and elasticity of the blade.	The frequency of oscillation of the current depends upon the values of both the inductance and capacity of the circuit.

26. Thus it is seen that a current will oscillate in a circuit if the circuit has both inductance and capacity. By these to-and-fro movements of the electrons, ether (radio) waves are started. The length of these radio waves, as has been shown, depends upon the

number of the oscillations in the circuit. Increasing either the amount of inductance or capacity in a circuit gives a longer wave length. Increasing both gives a longer wave length. To increase the wave length, increase either the inductance or capacity or both; to decrease the wave length, decrease either the inductance or capacity or both.

HOW TO CHANGE INDUCTANCE AND CAPACITY.

27. There are various methods of changing the inductance in a circuit. A straight wire has very little inductance. Make a coil of the same wire and the inductance is greatly increased. The coil can be made either by winding it smooth over a form, such as a broomstick, or by winding it spirally in the same plane. This is the way electrician's tape comes in the roll. The inductance of a coil is changed by changing the number of turns of the coil in the circuit. This is the most common way.

28. There are also various methods of changing the capacity in a circuit. One method is by changing the number of condensers in the circuit. A second method is by changing the capacity of a single condenser. This is done by having the two sets of plates that make up a condenser movable with respect to each other. When every part of the plates in one set is opposite to the plates in the other the capacity is the greatest. The capacity is made smaller by having only a part of each plate in one set opposite to the plates in the other.

29. The inductance and capacity needed in an oscillating circuit is contained in the antenna of a radio transmitting set. The antenna of a radio set is that part of the set which radiates the energy by setting up the waves in the ether as explained above. The wires making up the antenna give both the capacity and inductance. It, however, is very usual to add extra inductance in the shape of a coil which may be varied. Capacity also is sometimes added by throwing condensers in the aerial circuit.

ENERGIZING AN INDUCTANCE-CAPACITY CIRCUIT.

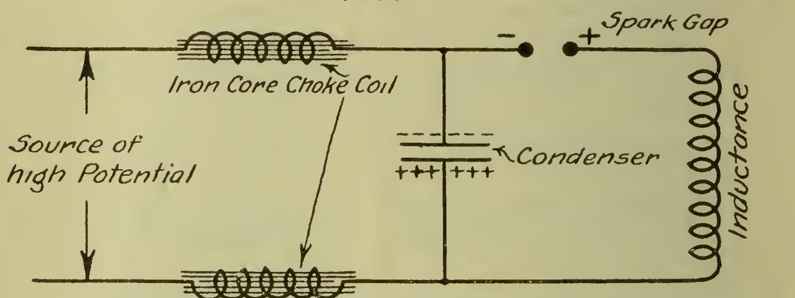
30. In order to have radio waves, the electrons must oscillate at the rate of 6,000 or more times a second. That is, to start a radio wave there must be an alternating current alternating at the rate of 6,000 or more times per second. Up until recent years, there was no generator built capable of producing alternations of so high a frequency. Only a very few such machines are in use to-day and those only at the very high-powered stations.

31. As has been shown, an inductance-capacity circuit will oscillate and it is in this way that the radio frequency oscillations are secured.

In order to get such a circuit to oscillate, it is only necessary to furnish it electrical energy. This energy must be furnished, then the source of energy removed from the circuit, and the inductance and capacity thrown in series in the circuit. This is done by the use of a spark gap.

32. In figure 5, the source of high potential is charging the condenser as shown in the diagram. The two terminals (electrodes) of the spark gap (they are usually metal plates) are also being charged as they are in electrical connection with the source of potential. As the charging goes on both the condenser and the electrodes of the spark gap rise to a higher and higher potential. When this potential reaches a certain high value it is strong enough to cause a spark to jump across the air gap of the spark gap. The instant this spark passes, the air gap changes its electrical character. Instead of being

FIG. 5.



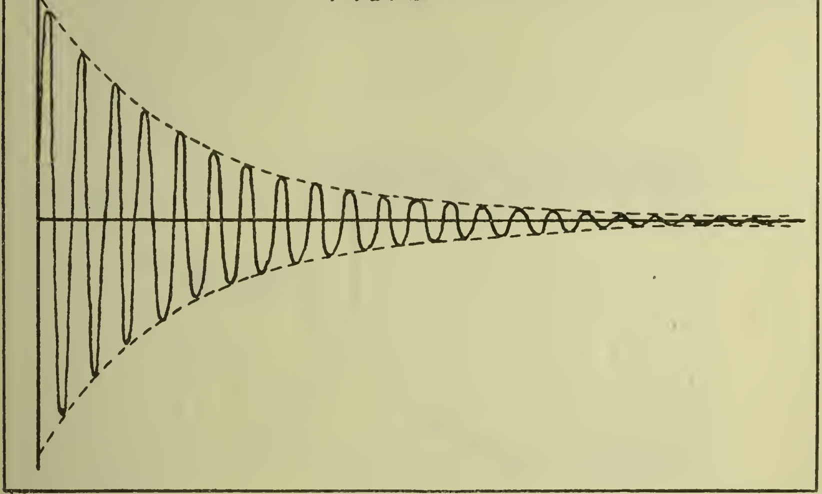
a very good insulator it becomes a fairly good conductor. The condenser and inductance therefore are thrown in series and oscillations take place in the circuit.

33. The oscillations are confined to the condenser-sparkgap-inductance circuit, as the iron-core choke coil prevents their passage through that circuit. The choke coil has a very high self-inductance, due to its iron core. The current of an oscillation changes very rapidly. As this rapidly changing current attempts to enter the choke coil the inductance of the coil opposes the flow of the current. So great is this opposing force of inductance that it altogether chokes off the oscillation. In a great many sources of high potential the inductance of the instrument giving this high potential is so large that no choke coil is needed.

34. The oscillations that occur in the condenser-spark gap-inductance circuit are damped oscillations. That is, the oscillating current grows smaller with each oscillation. If we draw the hack-saw blade aside and then free it, the distance that it moves from the point of rest becomes smaller with each vibration until finally the blade

ceases to move. This is because the moving blade loses energy in various ways. In exactly the same way the current of the oscillation dies away until there is no current, because the current loses energy. The way in which energy is lost will be shown later. The actual oscillations of the circuit are represented in figure 6. This represents a damped oscillation. As has been stated, a radio wave is exactly similar to the oscillations which produce it, therefore figure 6 also represents a damped radio wave. The amplitude of a damped wave becomes smaller with each succeeding wave.

FIG. 6.



SOURCES OF HIGH POTENTIAL.

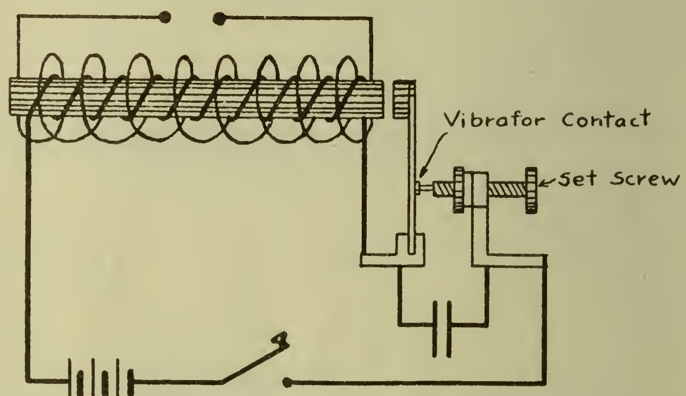
35. The usual way of furnishing the high potential to the condenser in the spark-gap circuit is by the use of an induction coil, or a transformer supplied by an alternating current generator. An induction coil works on a direct current. Figure 7 shows a diagram of the induction coil. The vibrator makes and breaks the primary circuit, thus inducing a high voltage in the secondary which is wound with many turns of fine wire. The vibrator contacts are adjustable by means of the set screw. The condenser across the vibrator contacts produces a higher voltage in the secondary than would be produced if it were not there. It also tends to prevent an arc forming at the vibrator when the circuit is broken there.

36. When an induction coil is used to charge a condenser in a spark-gap oscillating circuit, the condenser is charged to a potential high enough to break down the spark gap each time the vibrator breaks the electrical circuit. The sudden stopping of the current in

the primary produces a surge of high voltage in the secondary, thus charging the condenser. Figure 8 shows the relations of current and voltage in the primary and secondary.

37. To read such diagrams it must be remembered that two things are always shown on such a diagram, and that moving to the right means an increase in one thing and moving upward means an increase in the other thing. In this case (fig. 8) moving to the right means an increase in time and moving upward means an increase in current in the upper part of the diagram, which represents the primary current, and an increase of voltage in the lower part of the diagram, which represents the secondary circuit.

FIG. 7.

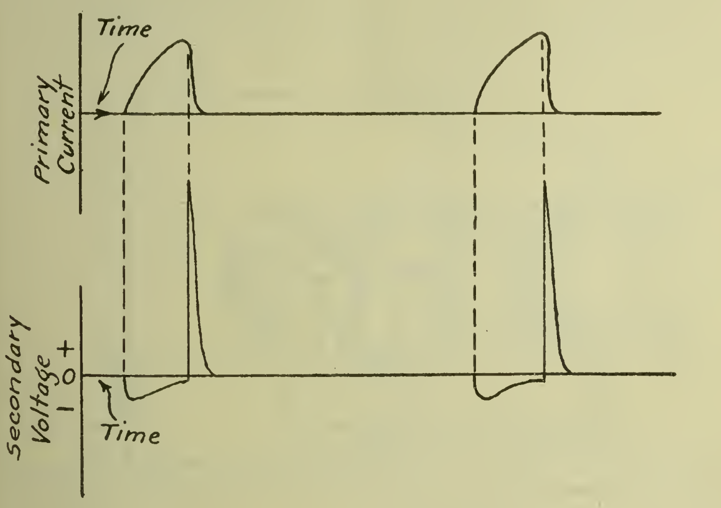


38. A study of this figure shows that at the "make" the primary current gradually rises until it reaches a value great enough so that the electromagnet core pulls the vibrator from the contact, thus causing the break. Meanwhile the secondary voltage has risen to a maximum in the negative direction, and has fallen nearly to zero value. At the break the primary current falls suddenly to zero. This sudden change in the magnetic lines of force cutting the secondary produces a very high voltage in the secondary as shown in the figure. This voltage is the voltage that charges the oscillating circuit to a potential high enough to break down its spark gap. Figure 8 represents the action of an induction coil with no capacity shunted across the vibrator and a high noninductive resistance connected across the secondary circuit. The action with a condenser across the vibrator, and with the secondary terminals connected to an oscillating spark-gap circuit, is more complex but similar in major details.

39. A type of induction coil known as the buzzer transformer is lately coming into use to charge the oscillating circuit from power derived from a low voltage direct current. Figure 9 shows a diagram of the connections of such a buzzer transformer.

40. The buzzer, B, is attached to an electromagnet, NSN′, which is pivoted and free to move. The circuit from the battery is divided, so that part of the current passes through the electromagnet, NSN′, at all times, and a part of the current passes through the vibrator, B, and thence through either one of the two primary windings, EE or

FIG. 8.

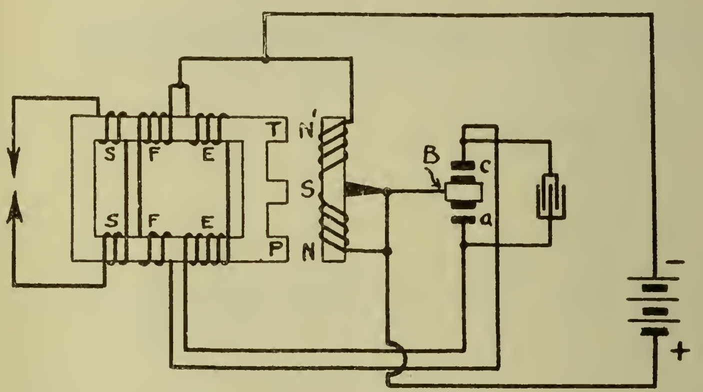


FF. The electromagnet, NSN′, has the direction of its windings reversed at the middle point of the core, so that at each end of the magnet there is a north pole. There are two primary windings, one being wound opposite in direction to the other. Each primary winding is split in two parts, as is also the single secondary winding. The iron core on which the primary and secondary windings are wound has three projections, as shown, one near each end of the electromagnet and one near its center. The secondary, as usual, has a large number of turns while the primaries have a comparatively few number of turns.

41. The action of the apparatus is as follows: Consider the vibrator B to rest on contact *a*, thus completing that part of the circuit. The current then flows through *a*, through the primary winding EE and from there back to the battery. This flow of current in the

primary establishes a magnetic field in the iron core on which it is wound. This magnetic field does two things: it passes through the secondary coil, thus inducing a high voltage in the secondary. It also has the effect of making the core projections P and T poles of a magnet, P being an effective north pole, and T, a south pole. Like poles repel and unlike attract, so that P pushes the N end of the electromagnet away from P and T pulls the N′ end of the magnet toward T. The magnet, being pivoted, turns and carries with it the vibrator, B, which thus breaks the circuit at *a* and makes the circuit at *c*. When the circuit is made at *c*, the current flows through the other primary winding, FF, which it must be remembered is wound opposite in direction to EE. The magnetic field established by this cur-

Fig. 9.



rent is opposite in direction to the one established by the first primary winding and therefore the high voltage induced in the secondary is *opposite* in direction to the first induced voltage. It is of *equal intensity* because the electrical characteristics of the two primary coils are the same. The magnetic field makes T an effective north pole and P an effective south pole, thus turning the magnet so that it pulls the vibrator B away from the contact *c* and makes the contact at *a*. It is to be remembered that the part of the current flowing through the electromagnet, NSN′, is a steady uninterrupted current. The condenser is connected across the vibrator to increase the efficiency of the apparatus and to reduce sparking or arcing at the break.

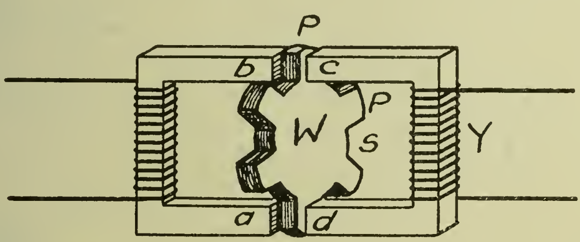
42. The buzzer transformer has many advantages over the induction coil. It is more than twice as efficient. It is capable of making and breaking each primary circuit 500 times per second. The movement of the vibrator can be made to be exactly regular so that the

high voltage in the secondary is induced at regular intervals of time. Also the induced voltage rises to the same values, both positive and negative.

43. The alternating current generators used to charge the condenser in an oscillating circuit system are built to give a higher number of alternations per second than the alternators used on power lines. The frequency (complete cycles consisting of a rise to a maximum of voltage in one direction, a gradual fall to zero voltage, and then a rise to a maximum voltage in the opposite direction, followed by a fall to zero voltage) of the former is most commonly 500 per second, while that of the latter is usually 60 per second.

44. A special machine for the purpose is the inductor type alternator. In figure 10, *ab* and *cd* are iron forms. W is a disk, which has been cut away at the edges to leave the iron projections *p*. The

FIG. 10.



distance between *b* and *p* and *p* and *c* is only a fraction of an inch. The disk W revolves so that the space between *b* and *c* is alternately filled with a projection, *p*, and a slot *s*. A direct current passes through the coil wound on *ab*. This direct current sets up a magnetic field whose complete circuit is *b*, *p*, *c*, *d*, *p*, *a*, *b*. Thus it cuts through the coil Y wound on *cd*. As the wheel revolves, the magnetic circuit is changed as the projections, *p*, and the slots, *s*, come between *b* and *c*. The projections, *p*, being iron, allow a strong magentic flux (field) to pass, the slots, *s*, being air or a nonmagnetic metal, permit only a weak magnetic flux to pass. This change in the magnetic flux passing through the coil Y induces in it an alternating current.

45. The advantage of this type of machine lies in the fact that the revolving part can be made of solid metal so that it can be turned at a high rate of speed without danger of flying apart. By use of this style of generator, Alexanderson has produced a machine which gives a frequency of 100,000 cycles per second. There are 300 slots in the inductor (wheel, W) which turns at a speed of 20,000 revolutions per minute. The particular use of the Alexanderson

alternator will be shown later. Although the Alexanderson alternator is not used to charge a condenser in a spark gap oscillating circuit, an inductor-type alternator giving a moderate frequency (around 500 per second) is often used.

46. It has been shown so far what a wave is and the various terms used in describing waves; that a wave takes its characteristics from its source; that a radio wave is a wave in ether traveling with a velocity of 300,000,000 meters per second; that radio waves are produced by rapid to-and-fro movements of electrons (high frequency oscillations of current); that these oscillations will be produced in an electrical circuit containing inductance and capacity; that the frequency of the oscillations in the circuit, and hence the frequency of the resulting wave, can be varied by varying either the inductance or capacity (or both) in a circuit; that a change in frequency of a radio wave makes a corresponding change in wave length so that the wave length is varied by varying either the inductance or capacity (or both) in the radiating circuit. It has also been shown that in order to add effective electrical energy to a capacity inductance circuit, it is necessary to open the circuit while the condenser (capacity) is being charged and then to close it; that this opening and closing of the circuit is done automatically by means of the spark gap. Various instruments used in charging the condenser have also been described.

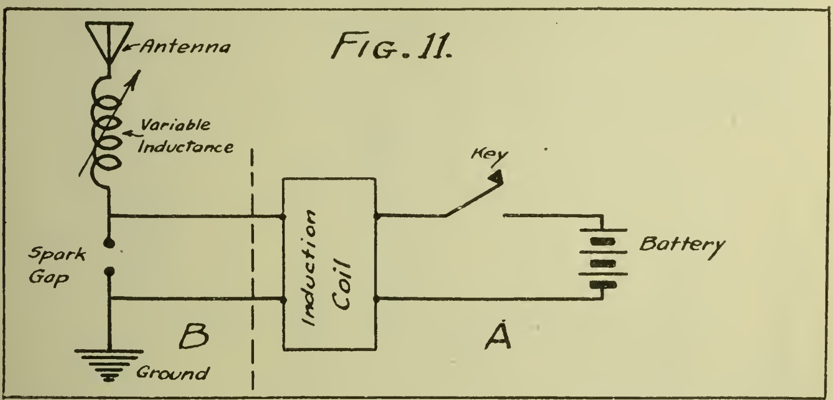
ANTENNA.

47. A high frequency oscillating current in a circuit will radiate waves, but it has been discovered that some forms of circuit will radiate much better than other forms. An air-cooled gas engine, such as on a motor cycle, has a specially formed cylinder so that it will radiate heat well; the radiator of a water-cooled-engine automobile has a special form so that it will radiate heat well. In the same way specially formed circuits are made to radiate the electric waves. They are of various types, but are all called antenna. The antenna then of a transmitting station is that part specially built to radiate the waves.

48. An antenna usually consists of a ground connection and one or more wires elevated above the ground and insulated. The usual forms are the inverted L, the T, the V, and the umbrella, each of these terms being descriptive of the method of arranging the wires in the antenna. As it has been found that the wire arranged as antenna has capacity, another condenser in the antenna circuit is not a necessity. The antenna wire has inductance also, but it is usual to add variable inductance in the form of a coil so as to be able to control the wave length.

49. Lately there is coming into use antenna in the form of loops which are from 1 to 2 meters across their diagonal. Another form of antenna is a cylindrical coil of large dimension compared to the coils used in other parts of a radio set. Both the coils and the loops are less effective than the common form of antenna, and must be specially designed to give even fair radiation.

50. It has been found that some forms of antenna radiate more energy in one direction than in another. This is similar to the fact that when a man uses a megaphone more sound energy is radiated in the direction in which the megaphone points than in any other direction. In the inverted L antenna more energy is radiated in the direction along which the horizontal wire or wires extend and toward the lead-in wire in that direction than in any other direction.



In the V antenna more energy is radiated in the direction in which the V points than in any other direction. In the T antenna most energy is radiated in both directions along the line of the horizontal wires. In the loop most energy is radiated in both directions along the plane of the loop.

51. It is well to think of the wires in the antenna (except in the loop and coil types) as one plate of a condenser. The other plate is the earth. Thus it is just as necessary to have the antenna wires *well insulated* as it is to have condenser plates well insulated.

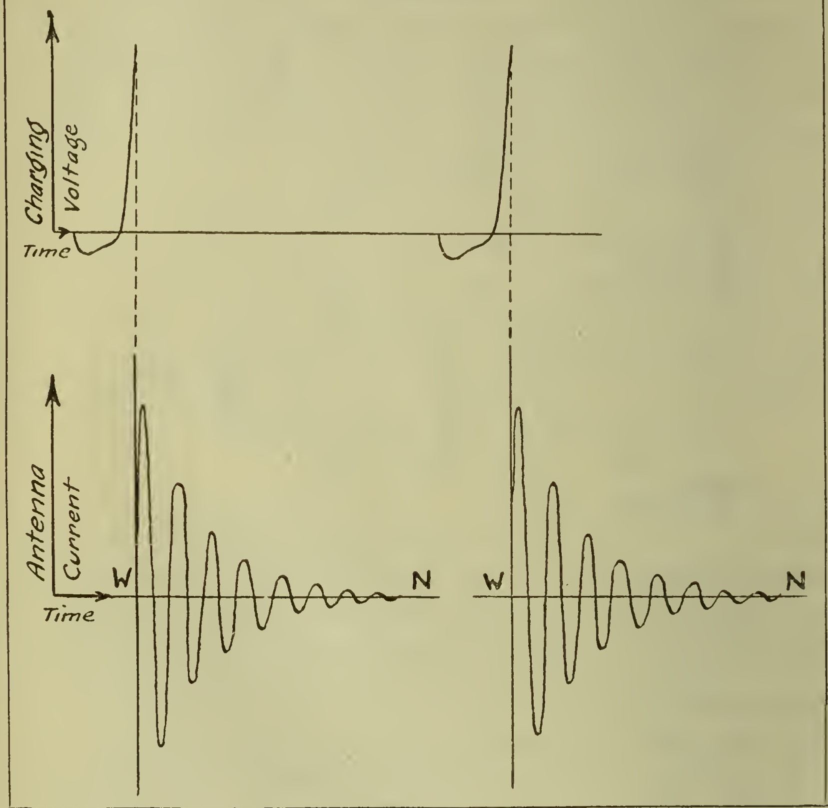
A SIMPLE TRANSMITTING SYSTEM.

52. A transmitting system is shown in figure 11. The symbols used are standard. This is the simplest type of a transmitting equipment. The broken line divides the apparatus into two parts. Part A is the apparatus necessary to charge and control the charging of the condenser in the spark-gap circuit. Part B is the radio frequency circuit. The arrow through the inductance denotes that

the inductance can be varied in value. It is to be remembered that the antenna furnishes the capacity in the spark-gap circuit.

53. A study of the action of this apparatus will clarify ideas up to this point. Figure 8 depicts what happens in an induction coil when it is in action. It is to be remembered that the high peaks of voltage in the secondary occur each time the vibrator breaks the circuit, which is usually about 400 times per second. As the secondary voltage of the induction coil mounts higher and higher, it charges the antenna circuit to a higher and higher potential. The potential finally becomes high enough to break down the spark gap which allows the indutcance-capacity circuit of the antenna to oscillate. This oscillation takes place as shown in the lower part of the diagram. Notice that the oscillations and hence the waves are highly damped. The unbroken serise of waves W-n is called a *wave train.* Immediately after the last wave of the wave train passes the spark gap regains its nonconductive property, and hence

FIG. 12.

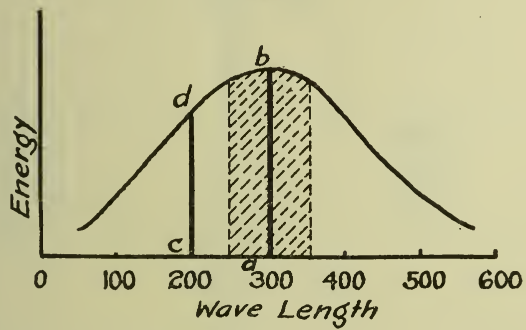


when the next surge of high voltage from the charging apparatus begins to charge the spark-gap circuit it must raise it to the same high voltage necessary in the first case to break down the gap. Events repeat themselves as long as the key is pressed down.

54. Thus it is seen that when the key is pressed in part A, figure 11, there are 400 wave trains per second radiated from the antenna. If the buzzer contacts were changed so as to make the vibrator move 700 times per second, there would be 700 wave trains per second. This applies to any rate of vibrations. The number of wave trains per second is the same as the number of vibrations.

55. If an alternating-current generator were used as the source of power (used in A, fig. 11), the number of wave trains would be twice the frequency of the alternations, for the spark gap would break

FIG. 13.



down at the highest positive voltage and again at the highest negative voltage—that is, twice in one cycle. (NOTE.—Using an alternator it is possible to arrange circuits so that the breakdown does not occur as indicated above; hence that statement is not *always* true.)

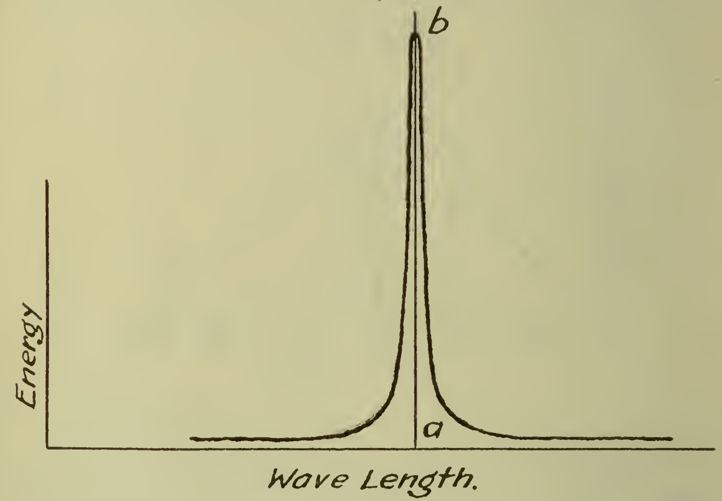
56. In figure 12 the time scale used in the upper part of the diagram is vastly different than that used in the lower part. This has to be done or otherwise the whole train of waves would be represented by a figure no larger than a pencil dot. Figure 12 does not show the action in the charging voltage after the spark gap has broken down.

57. A radiating circuit arranged as shown in figure 11 radiates a great amount of energy, but it radiates a broad wave. This statement means that the radiant energy is not carried by a single wave length, but is carried by a broad band of wave lengths. Figure 13 shows this graphically.

The wave length 300 carries the most energy which is represented by the length of the line *ab;* but in addition to that wave, there is a continuous band of waves having all possible wave lengths near the wave length of 300. Thus the wave whose length is 200 is radiated with an energy represented by the length of the line *cd*. Now, as only the energy represented by a very narrow band of wave lengths (shaded area around *ab*) can be received, all the other energy is wasted.

58. For this reason and for another which will be taken up later it is very desirable to radiate all the energy at a single wave length. No way has as yet been found to do this, but a method has been found to radiate waves so that a great part of the energy is at a single wave length and the rest of the energy is radiated in wave

FIG. 14.



lengths very close to the main wave length. The curved line in figure 14 shows the practical result that can be obtained.

The straight line shows the ideal kind of wave. Of course, if all the energy were put into this single wave, it would contain a very large amount of energy. To represent this, the straight line would have to be drawn longer.

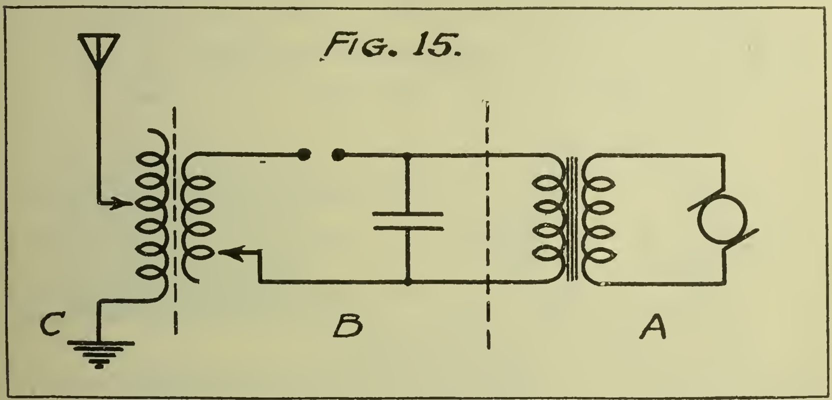
59. The production of an impure wave (the broad band of wave length is sometimes spoken of as an impure wave) is not uncommon. A person gets a cold and becomes hoarse. His voice sounds hoarse because his vocal cords produce an impure wave. A man who is not a musician blows a cornet and produces a disagreeable sound. He has produced an impure wave. Training and practice will enable him to produce a pure wave. Allow a bell to fall, it makes a noise, that is, it gives forth an impure sound wave. Strike the bell with a clapper and it gives forth a clear musical sound—a pure wave.

TYPICAL SPARK TRANSMITTING CIRCUIT.

60. To produce a nearly pure wave, it has been found necessary to add another circuit in a radio transmitter to the one shown in figure 11. This is shown in figure 15, which is a typical diagram of a transmitter. It shows three distinct circuits which have been divided by broken lines in the diagram. Circuit A is the power circuit. Circuit B is the spark-gap circuit. Circuit C is the radiating circuit.

Note that the inductance in both circuits B and C is variable as shown by the method of having an arrow point on the wire leading to it. This method of showing variable inductance, and also variable resistance is frequently used.

61. Circuit C is *coupled* to circuit B by means of the inductance in circuit C, which is shown opposite to the inductance in circuit B.



These two inductances together form an oscillation transformer. The name is given because it transfers oscillations from one circuit to another. In an oscillation transformer the *oscillations* in one circuit are transferred to the other circuit. There may or may not be a change in voltage. Thus, in circuit C there is induced, by means of the oscillation transformer, oscillations of the same frequency that occur in B.

62. A study of the action of the circuits in figure 15 shows more clearly the function of each. A *special* spark gap is supposed to be used in circuit B. Circuit A furnishes the power to circuit B, which acts as a trigger circuit. It stores up the energy until the spark gap breaks down and this breaking down allows the oscillations to occur. These oscillations are transferred to circuit C where they are radiated. Figure 16 shows this.

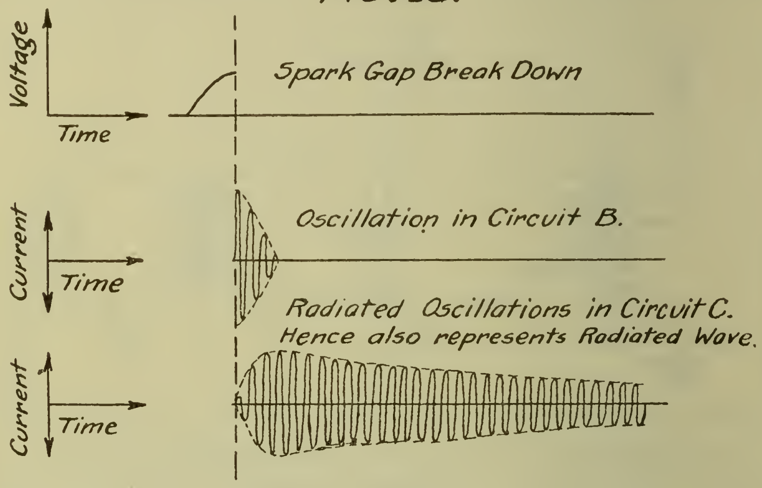
63. It is to be noted that the radiated wave train shown in figure 15 contains many more waves than the radiated wave train shown in figure 12. Circuit C has a long wave train because it has no spark

gap. A spark gap, even after it breaks down, has considerable resistance, and resistance in a circuit quickly dampens out a wave, thus giving only a few waves to a wave train.

SPARK GAPS.

64. Figure 16 shows the action in the circuits when a special spark gap is used. If there were not a special spark gap the oscillation transformer would be in action all the time, and having transferred the oscillations from circuit B to circuit C, would retransfer them back to circuit B and thus reduce the energy in circuit C. This transfer and retransfer would take place several times before the waves

FIG. 16.



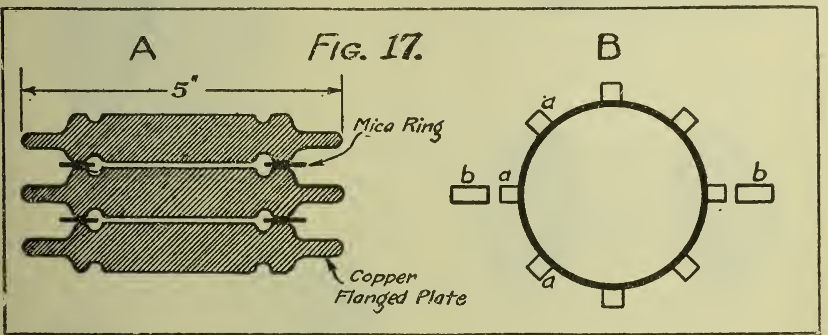
died out. If this happens, of course a great deal of the energy is wasted in the spark-gap circuit instead of being radiated from the antenna circuit.

65. There are two types of spark gaps in common use which prevent this retransfer of energy. Energy can not get back in the B circuit if that circuit is broken immediately after it has transferred its energy to the antenna circuit. In other words, no oscillations can be set up in a broken circuit. Both types of spark gap work on this principle.

66. One type does this by electrical action. Instead of only one gap, there are a number of gaps placed in series. The electrodes of the gap are broad pieces of metal accurately ground to a smooth, even surface. There is a groove around each plate, and the plates are separated by the mica rings. Figure 17–A shows this type of gap. The

flange assists to keep the plates cool. Sometimes a fan is used also for this purpose. This arrangement is called a quenched spark gap, and it has the property of recovering its nonconductance in a very short time, that is, after only a few oscillations have passed.

67. The other type is the rotating spark gap. Figure 17-B shows the principle of such a spark gap. There is a rotating metal wheel carrying the metal projections *a*. As the projections approach the ends *b* of the circuit, they get near enough for the spark to pass. The rotation of the wheel carries the projections past *b* and gradually make the gap longer, so that it soon becomes too long to carry the oscillations. Thus only a few oscillations are permitted to pass. If the wheel is made to rotate at such a speed that *a* approaches *b* each time the secondary of the changing circuit (A, fig. 15) reaches its high voltage, the gap is said to be synchronized. If no provision is made to obtain this, the gap is called a nonsynchronous gap.



68. In practical operation the appearance and sound of the spark gap when the spark is passing tells much about the operation of the set. Spark gaps are usually adjustable. The spark should occur regularly (told by the sound) and should give bluish-white stringy sparks. A yellowish color indicates an arc instead of a spark. If an arc is established in the gap, the efficiency of a set is much reduced. A set works best when the longest gap giving regular sparking is used.

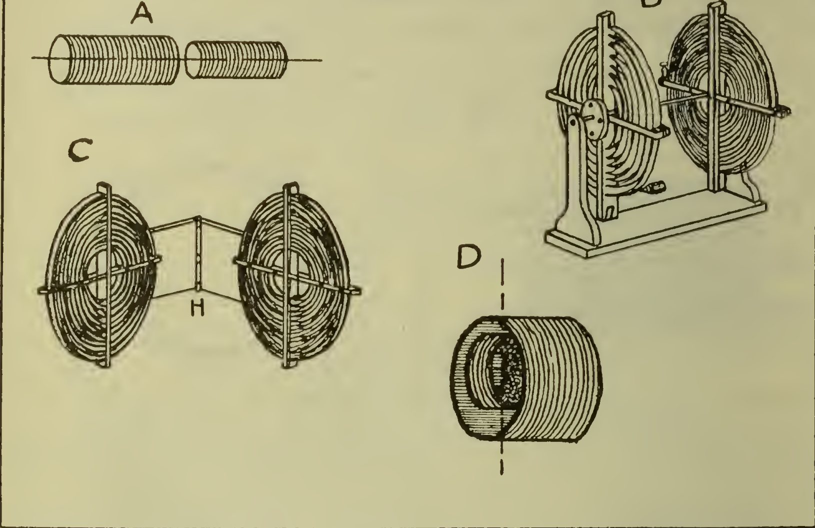
OSCILLATION TRANSFORMERS—COUPLING.

69. As has been noted, an oscillation transformer transfers by electromagnetic induction oscillations from one circuit to another. Whether or not there is a change in voltage of these oscillations depends upon the capacity, inductance, and resistance of each circuit. There are various types of transformers in use. However, they have the same general characteristics, that is, an induction in one circuit always acts upon an inductance of the other circuit. Figure 18 shows some of the types in use. A represents two coils of wire, one larger

than the other, and both mounted on the same axis, along which one is movable. The smaller one can be slid into the larger one. B shows a flat, spiral type whose coils can be made to approach each other. C shows an arrangement for mounting the flat spirals and moving them on a hinge at H. D shows two coils, the small one mounted inside the other. The inside one can be rotated around an axis, so that it can be made to be at any angle with the outside one.

70. When one circuit acts in any way upon another circuit, the two circuits are said to be coupled. In figure 15 circuits B and C are coupled. An oscillation transformer always couples two circuits together. Another method of coupling circuits is shown in figure 19.

FIG. 18.



An arrangement such as this is called an autotransformer. Other methods of coupling are used in receiving circuits and will be discussed later.

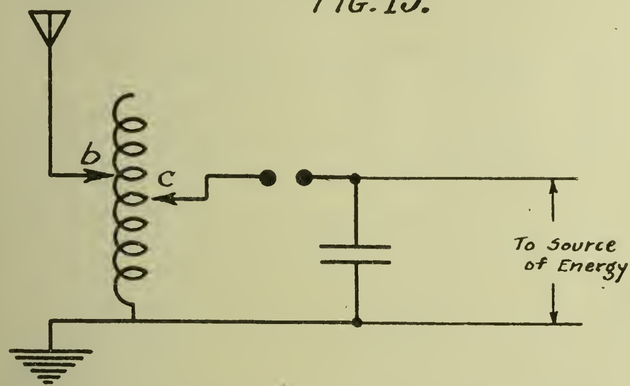
71. It is to be noted that each type of transformer shown above contains a variable factor. This variable factor is for the purpose of varying the degree of coupling. If one circuit acts with considerable force upon another circuit, the coupling is said to be *close* or tight. If one circuit acts with very little force upon the other circuit, the coupling is said to be *loose*. All degrees of coupling between close and loose are possible.

72. The following example will illustrate more fully how various degrees of coupling are possible. Suppose it was desired to swing an occupied hammock. This could be done by attaching a cord to the hammock and pulling the cord at the proper time. The cord

acting upon the hammock acts with considerable force—it represents a tight coupling. Instead of using a cord, replace it with a light elastic band. Pulling upon the elastic band at the proper time will cause the hammock to swing, but it will take many more pulls than with the cord, for the force acting upon the hammock at each pull is very small. This represents a loose coupling.

73. In the oscillation transformer the degree of coupling is varied by moving the inductances with respect to each other. Coupling is the tightest when the coils are parallel and as close together as possible. If the coils are moved farther apart, or if they are moved at an angle with each other, the coupling is made looser. The loosest coupling is obtained when the coils are at right angles, or when the coils are as far apart as the design allows. In the autotransformer

FIG. 19.



the coupling is varied by varying the position of the contacts *b* and *c* (fig. 19). The fewer coils between these points, the looser the coupling.

74. A change in the amount of inductance in either part of the coupling transformer varies the degree of coupling, as does also a change in the rapidity with which the oscillations of either circuit are damped. But these factors are not taken into account, because the latter is a part of the design of the apparatus and the former, if changed at all, is done for the purpose of tuning, and not for the purpose of varying the degree of coupling.

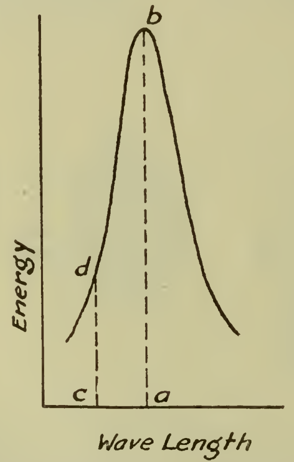
TUNING OF CIRCUIT—RESONANCE.

75. It has been shown that the frequency of oscillations occurring in a circuit depends upon the values of the capacity and inductance of the circuit. A change in either or both will change the frequency of oscillations. The frequency referred to is the natural frequency

of the circuit. It is possible to produce oscillations in a circuit with a frequency other than the natural frequency, but these are forced oscillations, the force coming from without the circuit. In the same way a suspended ball has a natural frequency of swing, but it is possible to cause it to swing at another frequency by an outside force—moving it back and forth with the hand, for example.

76. To change the natural frequency of a circuit it is necessary to change either the capacity or inductance, or both. When this change is being made in a circuit to make its frequency agree with that of another circuit, it is called *tuning* the circuit. If one circuit is tuned to another, resonance exists between them. Resonance, then, exists between two circuits if their natural frequencies are the same. This

FIG. 20.



condition of resonance must exist between circuits coupled together in any way if there is to be an efficient transfer of energy.

77. The fool who rocked the boat understood the principle of resonance. He found that by swaying his body from side to side at a certain frequency he could set the boat rocking through a wide arc. In other words, he made the frequency of his swaying equal to the natural frequency at which the boat rolled and thus secured a large effect. In the same way, in making a child's swing move, if it is pushed at the proper time it can be made to swing very high, but only by properly *timed* pushes. Being properly timed (in resonance) each push adds its energy to the energy already in the swing. Another example is in practicing with the punching bag. If each blow is timed the bag is kept moving in a regular way. Get out of time (out of resonance) and the bag will move irregularly.

78. So in circuits that are coupled together. If they are not in resonance the effect of one on the other is very little. If the circuits are in resonance very much energy is transferred from one to the other. So that, when circuits are coupled it is necessary to have them tuned to each other in order to transfer energy from one to the other.

79. A study of figure 20 shows clearly how the energy will vary in a circuit as it approaches resonance. The curve shows the energy in the secondary circuit as its LC value (induction capacity value) was being changed. At *a*, it had the same LC value as the primary circuit, therefore was tuned to that circuit. The energy transferred to the circuit is the greatest at that point. It is represented by the length of the line *ab*. At *c* the circuit was slightly out of resonance (tuning not exact) and the amount of energy it received is represented by the length of the line *cd*. The circuits used in obtaining the data for this curve were loosely coupled.

DAMPING—EFFECTIVE RESISTANCE.

80. An oscillating current once started in a circuit would continue oscillating indefinitely if it did not lose energy. But a loss of energy always takes place and hence the oscillations die away—it is a damped oscillation and gives rise to a damped wave. The measurement of this damping is called the decrement of the wave. Thus a wave having a decrement of 0.2 dies away much more quickly than a wave having a decrement of only 0.01.

81. The losses in the antenna circuit are due to the ohmic resistance of the wires; to the fact that currents are induced in the earth near the antenna and in neighboring circuits; to the leakage of the charges of electricity, and to the energy expended in radiating the waves. The latter is of course desirable, as it is the purpose for which the antenna is constructed. All the other losses mean wasted energy, so it is desirable to make these losses as small as posible.

82. The loss by induced currents in neighboring circuits should be taken care of in the design of a transmitting set. The use of a quenched spark reduces this loss as the quenching effect quickly breaks the primary circuit. Presence of trees and other objects may make a circuit which will absorb energy by having induced currents established in them. Aside from this, trees absorb energy from the radiated wave so that it is well not to set up a radio station near a tree or trees.

83. A certain amount of electricity will leak off the wires. This can be cut down by having no sharp ends and by taking great care to have proper insulation. A frequent source of such leakage in

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portable sets is in the wires themselves, where they become frayed and the loose ends of strands project.

84. The ohmic resistance is the resistance of the wire itself which gives rise to heat. It is oftentimes called the Joulean resistance—Joulean referring to heat. It has been found that when oscillations at radio frequency are flowing in a circuit, the ohmic resistance is much greater than when a direct current flows in the same wire. An increase in frequency of the oscillations gives an increased resistance. The explanation of this increased resistance lies in the fact that the self-induction of the high frequency currents allows a current to flow only on the surface of the wire. This is, in effect, the same as reducing the cross section of the wire, thus increasing the resistance. For this reason a wire used in a radio circuit should have a large surface. Wire made up of small strands gives a large surface without materially increasing the diameter of the wire. Stranded wire is, therefore, generally used.

85. It must not be overlooked that the ground is a part of the antenna system. Therefore the ground resistance is a part of the antenna resistance. Thus great care must be taken to keep the ground resistance as low as possible. This is done by driving into the ground a number of metal stakes and connecting them together; by burying metal mats; and by the use of a counterpoise. A counterpoise of an antenna consists of a number of conductors stretched under the wires forming the antenna, and insulated from the ground. This is used instead of the ground. In an airplane, the metal parts of the plane are connected electrically and form a counterpoise. In a ship, the metal plates of the ship form the counterpoise. In some cases in land stations, no precaution is taken to insulate the counterpoise wires from the ground.

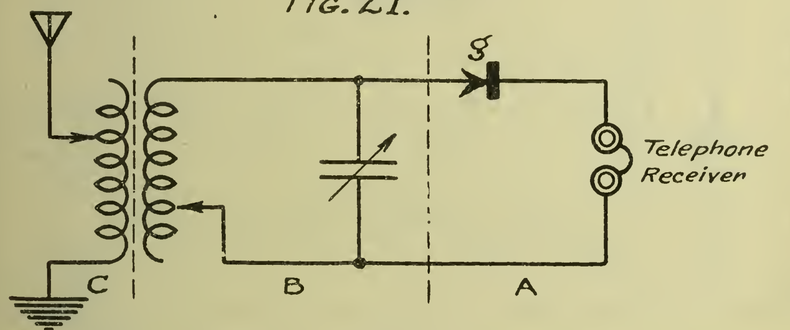
RECEPTION OF DAMPED WAVES.

86. It has been shown that radio waves consist of ether waves having electrostatic and electromagnetic lines of force. A method of producing damped waves of this character has been described. These waves travel through space and are detected by means of special apparatus. Much of this special apparatus is similar to that used in the transmitting station as will be noted. The action that takes place at a receiving station may be briefly summed up as follows: The received waves set up an oscillating current in the receiving circuit that has the same frequency as that from which the wave started. These oscillations are changed in character so that they will actuate a telephone receiver, thus making an audible signal.

87. In the circuit which receives the waves is the antenna. It is exactly like the antenna used in the transmitting station, and in

most stations the antenna that is used for transmission is used also for reception. Considering only the electromagnetic lines of force in the wave, the oscillation induced in the receiving antenna is caused by electromagnetic induction. This is the same phenomena that occurs in the induction coil, the transformer, and various other instruments. Considering the electrostatic lines of force, it must be remembered that these lines are the result of potential and that they will induce a potential on any conductor which they sweep. They sweep the antenna and thus induce a potential on it. As the intensity of the impinging electrostatic lines of force varies and changes in direction, the resulting potential varies and changes in direction; that is, it is oscillating and has the same frequency as the impinging wave. The electromagnetic and electrostatic lines of force are inseparable in a wave and it is their combined effect which produces the oscillation in the receiving antenna.

FIG. 21.



88. The simplest type of receiving circuit is shown in figure 21. Note that circuit C is the same as circuit C in the transmitting circuit. (See fig. 15.) That circuit B is also the same except that it contains no spark gap. Circuit A is the circuit distinctive of the receiving apparatus.

89. A telephone receiver is an instrument which transforms alternating currents or pulsating direct currents into sound. It does this by means of a small electromagnet placed in rear of a thin round piece of iron, called the diaphragm, which is held around its edge. As each pulse of current (or each alternation in an alternating current) passes through the electromagnet the electromagnet pulls the center of the diaphragm inward. As the pulse of current passes the stiffness of the diaphragm causes the diaphragm to spring back. Another pulse of current again pulls the diaphragm inward, and so on. Thus the diaphragm vibrates with a frequency equal to the frequency of the pulses of current. This vibration of the diaphragm

causes the air to vibrate, thus giving rise to sound. These vibrations must have a frequency within the limits 30–3,000 per second in order to be plainly heard. Thus frequencies within these limits are called audio frequencies. (Compare audio frequency with radio frequency as stated in paragraph 19.)

90. A telephone receiver can not be inserted directly in a radio-frequency oscillating circuit for the reception of signals. The reason for this is that the diaphragm of the receiver is not capable of vibrating with the rapidity of a radio-frequency oscillation. Even if it were capable of this high rate of vibration, the human ear would not respond to such a high frequency. Thus some method of changing the oscillations is necessary. This is done by means of a detector.

91. It has been discovered that certain materials—galena crystal, for example—have a peculiar electrical property. They allow the passage of a current of electricity through them in one direction, and

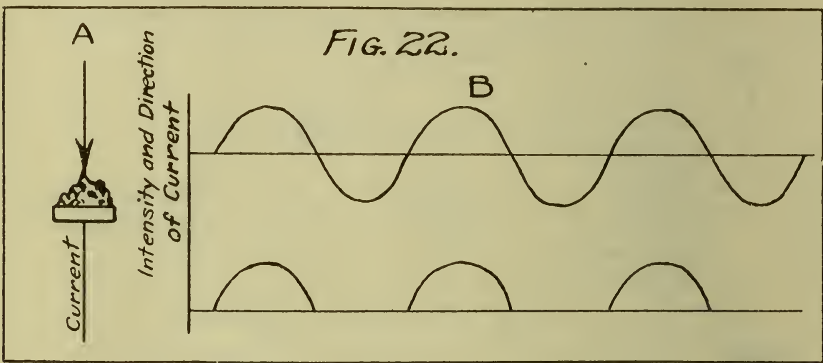


FIG. 22.

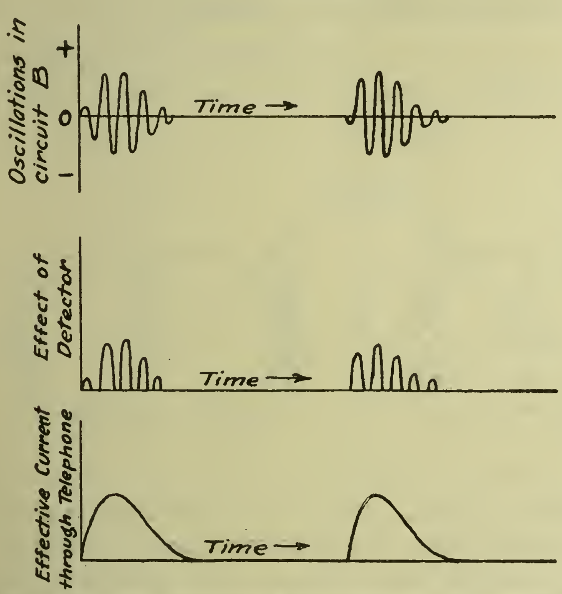
will not allow a current to pass in the opposite direction. Thus in figure 22–A the detector will allow a current to pass downward through it as shown by the arrow but will not allow a current to pass upward through it. If a detector is put in a circuit having alternating current of the usual form (upper part of B, fig. 22) the resulting current passing through the circuit would be as shown in the lower part of B (fig. 22). This is because that part of the current which would usually flow in the direction represented below the line is not allowed to flow because of the action of the detector.

92. Thus in figure 21 the impinging waves set up oscillations in circuit C. These oscillations are transferred to the circuit B, which contains inductance and capacity, and will therefore oscillate when tuned to circuit C. Therefore at g, in circuit A, there is an alternating voltage as that point is directly connected with circuit B. This alternating voltage agrees in frequency with the frequency of oscillaations in circuit B, since it is produced by these oscillations. As has

been noted in the above paragraph, the detector allows the passage of a current in only one direction and hence only the voltage in this direction is effective. The result is that there is a pulsating direct current flowing in circuit C. The pulsations occur at the radio frequency of the oscillation in circuit B.

93. A study of figure 23 will aid in understanding the action of the receiver. The upper curve represents the oscillations that occur in circuit B and, as has been stated, the voltages that present themselves at point *g* in circuit A. Because of the action of the detector, one-half

FIG. 23.



of the oscillations are cut out so that there remains a pulsating direct current as shown in the middle curve. The telephone has a very high inductance. This inductance and the inertia of the telephone receiver causes this pulsating direct current to act as a single surge of current as shown in the lower curve. Each surge of current pulls the telephone diaphragm inward. Figure 23 shows only two surges of current, but in a dot of the Morse code there are from 30 to 50 surges, thus causing the diaphragm to vibrate from 30 to 50 times. This produces a sound.

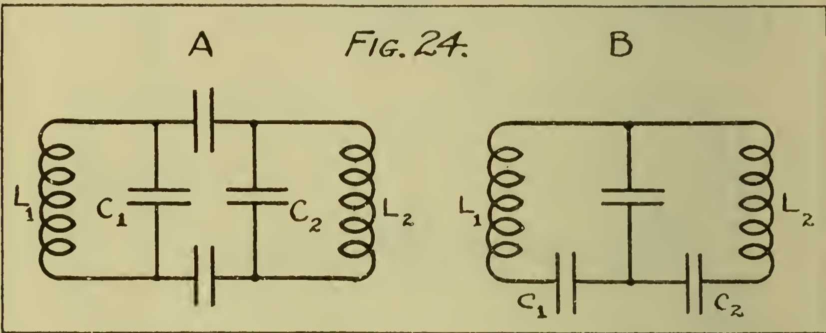
94. It is to be particularly noted that it takes a *complete* wave train to give *one* vibration of the telephone diaphragm. For example, for a certain moderate damping, there are 40 effective waves in the wave

train. These 40 waves establish one surge of current through the telephone receiver. Thus the radio frequency waves give rise to audio-frequency pulses of current.

95. A small condenser is sometimes shunted across the telephone receiver. This condenser is charged with every pulse of the high frequency current shown in the middle curve of figure 23. It discharges through the telephone receivers in the interval between pulses. This has been found to increase the effect upon the diaphragm of the telephone receiver. However, such a condenser is not a necessary part of the receiving apparatus and is sometimes omitted with special kinds of telephone receivers.

OTHER METHODS OF COUPLING.

96. In addition to the methods of coupling described in paragraphs 69ff, used in transmitting circuits, there is also another type some-



times used in receiving circuits. This is called electrostatic coupling, as it depends upon the linking of electrostatic lines of force in two circuits to transfer the oscillations instead of the linking of electromagnetic lines of force. In electrostatic coupling, one set of plates of a condenser is in one circuit and the other set of plates of the same condenser is in the other circuit. Figure 24 shows two methods of electrostatic coupling. The inductance and capacity of each circuit is marked; the unmarked condensers are the condensers used in coupling the circuit. There are various other methods besides those shown. Electrostatic coupling takes the place of an oscillation transformer. Such an arrangement of circuits may be called an electrostatic transformer.

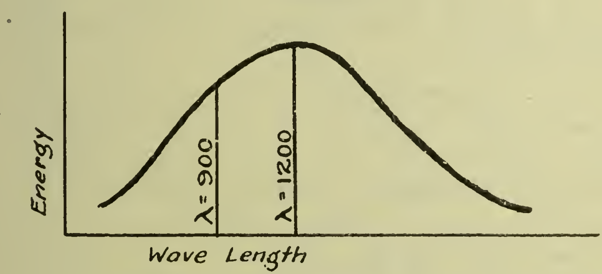
WHY TUNED CIRCUITS ARE NECESSARY.

97. A radio wave is started by the transmitting apparatus. This transmitting apparatus has two distinct radio circuits—B and C in figure 15. Both must be tuned to the same wave length (frequency)

to give the best results. The radio wave travels through space and induces an oscillation in any antenna which is tuned to that wave length—that is, the receiving antenna must have its inductance and capacity adjusted so that its natural frequency of oscillations is equal to the frequency of the wave which it receives. The oscillations in the receiving antenna are then transferred by some form of coupling to another oscillating circuit, which in turn must be tuned to the antenna receiving circuit. The detector and telephones are shunted on this second circuit.

98. Thus the total number of tuned circuits in the transmitting and receiving instruments is four. The desirability of two circuits in the transmitter has been partly explained in paragraph 57ff. Additional reasons for these two circuits and for two receiving circuits are shown in the discussion below.

FIG. 25.



99. It has been stated that a circuit containing a spark gap radiates a broad wave. The broad wave contains a great deal of energy, much of which is useless, inasmuch as it can not be utilized by the receiving station. Hence stations are designed to transmit as sharp a wave as possible. Another very important reason for designing stations to transmit a sharp wave is to prevent interference between stations. This is very important, as the number of radio stations is constantly increasing. The sharper the wave radiated the less interference it gives to stations not desiring to receive this wave.

100. This is illustrated in figure 25. A station is radiating a broad way of the shape shown. The most energy is contained in a wave whose length is 1,200. Figure 25 also represents the distribution in wave lengths of the energy of the wave. This energy reaches the receiving station of this set. But it also reaches and affects all other receiving stations. Suppose, now, that two entirely distinct stations were trying to work on a wave length of 900 meters, at the same time the 1,200-meter station was transmitting. They could not do it, because the station working on 1,200 is also radiating at 900. Hence

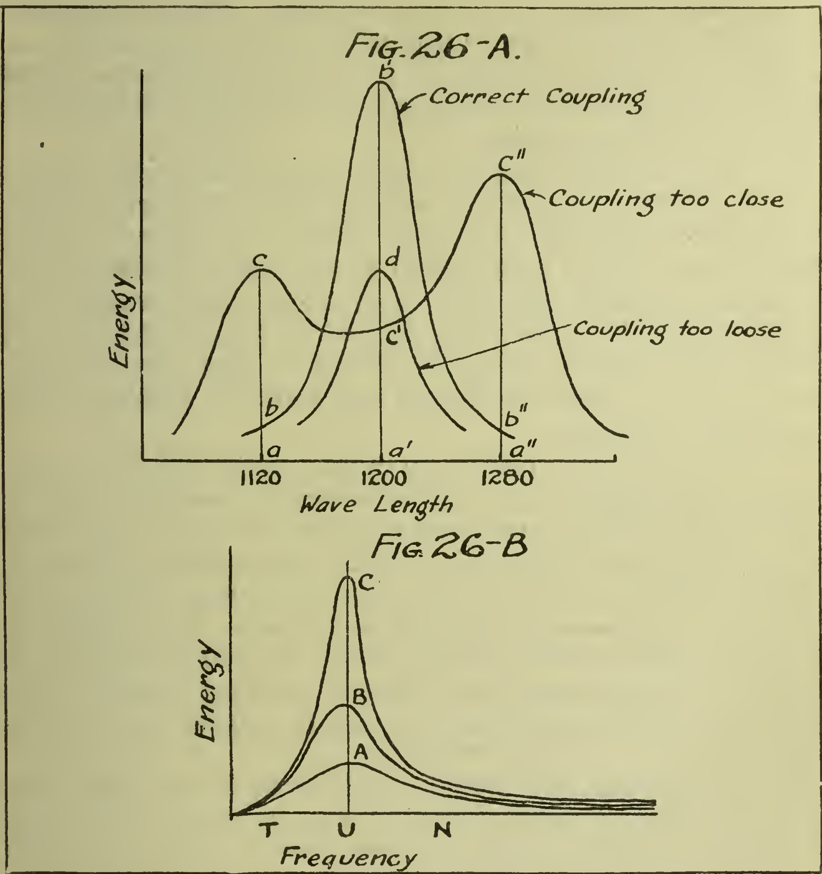
the receiving station for the 900 is picking up energy from both sending stations. Of course the result is a jumble of dots and dashes in the receiver with no meaning to them. That is, the receiving station is hearing the dots and dashes of the two transmitting stations and can not distinguish between them.

101. This condition would apply not only to the 900-meter station but to all stations trying to work with a wave length anywhere near 1,200 meters. Thus it is desirable to transmit the very sharp wave shown in figure 14. This is a sharp wave and carries most of its energy at wave lengths very close to the peak wave length represented by the vertical line—1,200 in this case. With such a wave it is possible for stations to work without interference on wave lengths very close together. In practice the wave lengths must be separated at least by a 5 per cent difference. That is, two stations, one at 1,200 meters and one at 1,120 could work without interference, but it would be impossible for two stations, one at 1,200 meters—the other at 1,195 meters to work without interference. The narrower the curve (fig. 14) the nearer together in wave lengths can stations work without interference.

102. The main reason that two circuits are placed in the receiving station (circuit C and B, fig. 21) is to avoid interference. Each circuit makes a selection of wave-length energy from the received waves and thus the final energy is nearly all of one wave length. A comparison of this action would be as follows: It is desired to pick the best drilled squads from a company. One inspector watches the company drill and eliminates certain squads. The remainder of the squads appear before a second inspector. This inspector eliminates certain squads and hence the retained squads are the best drilled squads as a result of this double selection. So in the receiving station each circuit eliminates the energy of certain wave lengths and the result is that only the energy of a very narrow band of wave lengths arrives at the detector.

103. The curves shown in figure 26, in addition to the curves of previous figures, will give a more comprehensive view of the whole subject of interference, resonance, and coupling. The three curves shown in figure 26–A show the variation of the energy received at different wave lengths with a variation in coupling. Thus the lengths of the lines ab, $a'b'$, and $a''b''$ represent the energy received at the wave lengths 1,120, 1,200, and 1,280, respectively, when the coupling is correct. The length of the lines ac, $a'c'$, and $a''c''$ represents the energy received at the same wave length when the coupling is too close. The double hump curve marked "Coupling too close" would be obtained with close coupling in any receiving set. Note that there are two frequencies (wave lengths) that receive

a large amount of energy. The explanation of this lies in the fact that an oscillating circuit coupled to another oscillating circuit is affected by the circuit to which it is coupled. It has two frequencies at which it will oscillate well. One of these frequencies is slightly higher and the other slightly lower than its natural frequency when oscillating alone. The closer the coupling the farther apart are these two frequencies of oscillation. These circuits are tuned to each other;



that is, the inductance-capacity value of one is equal to the inductance-capacity value of the other.

104. As is shown in the figure, the result of this double oscillation is to give the circuit a wide band of wave lengths from which it will absorb energy. This band can be narrowed by making the coupling just right. The result is shown in the curve marked "Correct coupling." Care must be taken not to make the coupling too loose or the full energy will not be transferred from one circuit to the other. This is shown in the curve marked "Coupling too loose."

105. Figure 26-B shows the resulting energy absorbed by a circuit as it was tuned to another circuit to which it was coupled. At T it was out of tune—at U it was tuned—at N it was out of tune. The closer to U, the nearer tuned it was. Thus any of the three curves shows that the greatest energy was absorbed when the circuit was in tune with the circuit from which it received its energy.

106. The three different curves in B represent the same thing for three different circuits just alike except that A has a high resistance, B a medium resistance, and C a low resistance. Thus it is seen that the circuit having the least resistance has a sharp well-defined point at which it is tuned. Resistance in a circuit decreases the possible sharpness of tuning in the circuit as well as making a damped wave when the circuit is radiating.

107. The curves in A and B of figure 26 represent energy absorbed by a circuit when coupled with another circuit. The same identical curves would represent the energy radiated by the same circuits. Thus a circuit closely coupled with another circuit would radiate a broad band of wave lengths with two prominent wave lengths. If a quenched spark is not used in a damped-wave transmitting station, this condition applies. A circuit of high resistance will radiate a broad band of waves, as has already been noted in a radiating circuit containing a spark gap.

108. To sum up, it is desirable to radiate energy confined to nearly a single wave length for (*a*) only this energy is useful in reception; (*b*) in order to avoid interference with other stations. This is done by having two tuned circuits, one with a quenched gap. These two circuits should have the proper degree of coupling. They should have as low resistance as it is possible to attain. It is desirable to have two circuits in the receiving station, in order to eliminate the effects of other waves than those which it is desired to receive. This elimination is best effected by two loosely coupled tuned circuits, with resistance as low as possible.

109. In receiving there may be interference due to other causes than transmitting stations. This is due to the antenna being swept by waves caused by the forces of nature (thunderstorms, etc.). Also the antenna may receive direct static changes due to the presence of charges upon surrounding objects including the air. All of these *strays* cause oscillating currents in the antenna and thus produce noises in the receiver. Their effect upon the antenna is similar in character as the effect of a heavy blow upon a child's swing. A heavy blow would cause the swing to swing back and forth even though it were not timed to the period of the swing. A circuit caused to oscillate in this manner is said to receive "shock" excitation. Having a second circuit in the receiving station considerably

reduces the noise in the receivers caused by these strays. The term static is oftentimes used to include the cause of all sounds in the receiver not due to a transmitting station.

110. Whether or not interference will occur among stations depends not only upon the factors outlined above but also upon their distance apart. For instance, a small-powered station in Kansas would not interfere with stations in New York even if it were working on the same wave length. This is because the radio waves get weaker the further they travel. They eventually become too weak to affect a receiving station. There are many factors affecting the distance to which a radio wave will carry its energy. It will carry energy further over sea than over land; further over some kinds of soil than over others. A radio wave casts shadows. If a transmitting station is at the foot of a hill or mountain, a receiving station on the other side of the hill or mountain will receive very faint signals because of this shadow effect. Trees and buildings absorb the energy of the wave so that the placing of either a receiving or transmitting station among them reduces the distance at which communication may be maintained. Other factors, such as the time of day, and the climatic conditions have various effects upon the distance at which communication can be maintained.

COMPARISON OF DAMPED AND UNDAMPED WAVES.

111. A damped wave is originated by an oscillating body whose oscillations are gradually fading out. In radio this gradual fading out of an oscillation means that the current of the oscillation gradually decreases in value. An undamped wave is originated by an oscillating body whose oscillations always retain their maximum value. In radio this means that the current of the oscillation always retains its maximum value. Thus in an undamped radio set the oscillation, and hence the wave generated by the oscillation, is continuous as long as power is applied (as long as the key is held down.) *This means that there are no wave trains in undamped waves as there are in damped waves.* An undamped wave is also a *continuous wave*, but a continuous wave is not necessarily an undamped wave. Any unbroken wave is a continuous wave. This continuous wave may vary in amplitude. Continuous waves are used in radio telephony. (See par. 169.)

112. To produce an undamped wave it is necessary to add energy to an oscillating body as fast as that body loses energy. For example, a child's swing once started will gradually come to rest. It loses energy due to the friction of the air; the friction of the ropes where they are attached to the support, etc. If it is desired to keep it swinging through a constant arc, a push must be given it at each swing:

this push adding just the same amount of energy as was lost during the swing. So in electric oscillation the current decreases because it loses energy by radiating some in the wave; by the resistance of the wire causing heat losses, and by losing energy to other circuits and objects. To keep the current constant, it is necessary to furnish just the same amount of energy during each oscillation as is lost in that oscillation. There are various methods of doing this and these will be described later.

113. Undamped waves have certain advantages over damped waves for use in radio communication. They carry much more energy in the same amount of time. For instance, suppose a dot used in radio telegraphy lasts one-twentieth of a second. Using a wave length of 1,500 meters, there would be in undamped wave transmission, 10,000 waves in this dot. If this dot was sent by damped waves there would be, if a spark discharge occurred 1,000 times a second, 50 wave trains in the dot. If each wave train consists of 40 waves—a reasonable number—the total number of waves in a dot would be 2,000. Thus there are five times as many waves in the undamped wave dot as in the damped wave dot. But the damped wave has only one of its waves at maximum amplitude and the rest gradually die away while the undamped waves have every wave at maximum value. For this reason, the energy of each undamped wave is in this case about five times the average energy of the damped wave, providing the maximum amplitude of the damped wave has the same value as the undamped wave's amplitude. Thus the energy in a dot carried by the undamped wave is 25 times the energy in a dot carried by the damped waves. This is a great advantage especially as it does not take much more power to generate the undamped waves than it does to generate the damped waves.

114. An undamped wave is a very pure wave and therefore has none of the disadvantages of a broad wave. These disadvantages have already been discussed. Because of the reasons stated in the preceding paragraph, the maximum steady energy of an undamped wave need not be nearly so large as the initial energy of a damped wave to establish communication over the same distance. A direct result of this is the fact that voltages used in undamped waves are not nearly so high as in undamped waves, thus making easier the design of the instruments. Still another advantage is in receiving. This will be explained later.

PRODUCTION OF UNDAMPED WAVES.

115. One method of generating an undamped wave is by the use of the Alexanderson alternator described in paragraphs 44 and 45. This alternator is capable of generating alternating currents of

radio frequency. The energy lost in each oscillation is therefore supplied direct by the generator. There are other generators that are capable of generating radio frequency oscillations. Prominent among these are the Goldschmidt's machines. As the output of these generators are radio frequency oscillations, the output current may be fed directly to the antenna. However, this is not usually done because of the necessity to control the radiation from the antenna in order to give the dots and dashes used in telegraphy. The arrangement for doing this varies in different sets and is usually more or less complex. There must be some special arrangement to control the speed of rotation of these machines. The speed of rotation controls the frequency, and if this varies it changes the wave length, hence the speed *must* be kept constant. As the speed is very great, the speed-control system is quite complex. Owing to the great expense, these alternators are not used except at high-powered stations, and only a few of each type are in use at the present time.

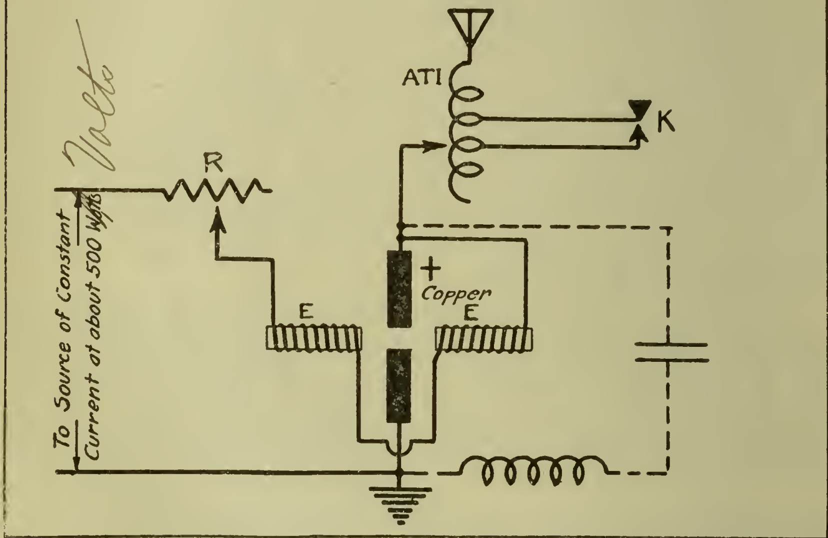
116. Another method of generating undamped waves is by means of the arc. The arc transmitters are less costly than the alternators mentioned above, and there is no difficulty in controlling the wave length, as this is determined by the inductance-capacity value of the circuit. This will be explained later. The sets are easily designed to give any power required. Those in use range from a power of 2 kilowatts to 1,000 kilowatts.

117. When a current passes continuously or nearly continuously through a small break in a circuit which is filled with air or other gas at atmospheric or greater pressure it is said to form an arc. This differs from a spark in that a spark is a disruptive discharge and the current passes only intermittently. A familiar example of an arc is the arc light used for lighting streets, etc. An arc has an unusual feature in that it seemingly does not obey Ohm's law. It differs in the fact that it takes less voltage to cause a heavy current to pass across the arc than it does to cause a small current to pass.

118. If capacity and inductance of proper value are shunted around the arc under proper conditions (shown by dashed lines in fig. 27), there will be radio frequency oscillations produced in the circuit. These oscillations are produced because of the characteristics of the arc stated in the preceding paragraph. This comes about as follows: Consider the circuit to the arc formed and fed from a *constant* current source and the condenser uncharged. The current feeding the arc will now also feed the condenser, thus charging it. But the current charging the condenser has been subtracted from the current passing through the arc, thus making the arc current less. The smaller arc current makes a higher voltage across the arc because of the arc characteristic mentioned. This higher

voltage causes more current to pass into the condenser. This process goes on until the potential across the arc no longer rises rapidly with a decrease in current. Thus there is no higher potential available to charge the condenser, and hence part of the total current stops flowing into the condenser and the total current now flows through the arc. This lowers the potential across the arc, and hence across the condenser. This lower potential allows the condenser to discharge and add its current to the feeding current of the arc. The inductance in the circuit causes the condenser to be charged in the opposite direction. It immediately begins to discharge, and this time

FIG. 27.



opposes the current flowing through the arc. These opposing currents neutralize each other, whereupon the first condition is brought about. In good operation the back discharge of the condenser is great enough to stop the arc current from flowing. This extinguishes the arc, which, however, immediately re-forms.

119. The frequency of the cycle described above can be varied by varying the inductance-capacity value of the shunt circuit around the arc. Thus the wave length may be changed. The oscillations are undamped because the source of current feeding the arc also supplies energy at each oscillation to the oscillating circuit, as has been described.

120. Figure 27 shows a diagram of such an arc set. The circuit shows the conditions under which the arc will work. The first con-

dition is that the arc must be between copper and carbon electrodes, the copper being the positive electrode and being kept cool by a stream of water. The carbon must be slowly rotated around its own axis. The mechanical arrangement for doing this is not shown. The second condition is that the arc must be subject to a strong magnetic field. This magnetic field is furnished by the electromagnets EE. The third condition is that the arc is formed in a gas containing hydrogen. Therefore the arc is inclosed and this gas is furnished to the inclosure. In practice this can be done by dropping a few drops of alcohol in the arc container at regular intervals. This is accomplished by an arrangement similar to the oil dropper used on many machines. The fourth condition is that the value of the capacity and inductance of the shunt circuit must have a proper ratio. In the diagram of figure 27 the antenna is the condenser and the antenna tuning inductance, ATI, furnished the inductance. The dashed circuit shows the equivalent of these.

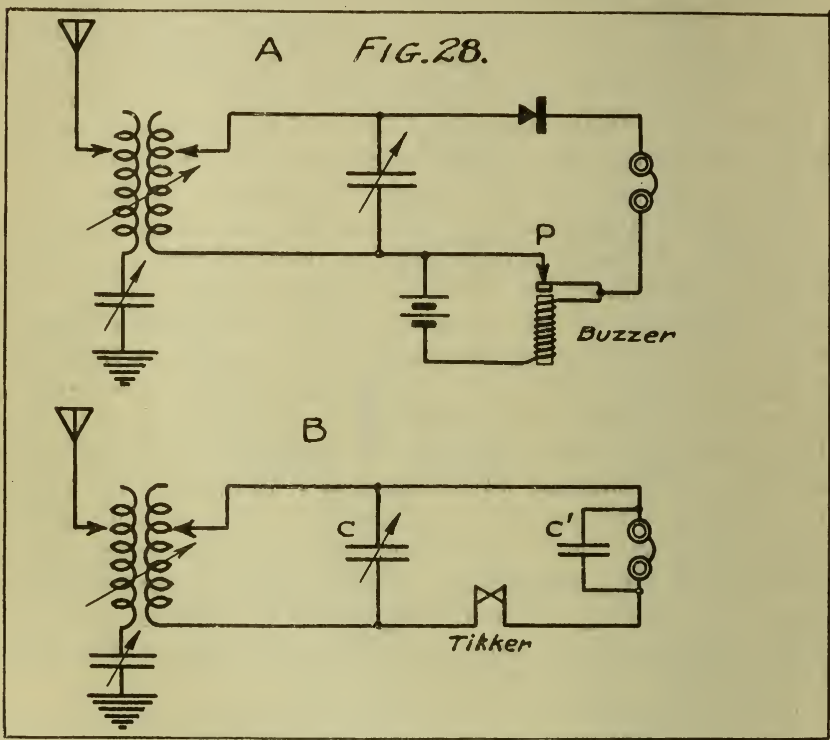
121. Various arrangements of the key for controlling the output are possible. It has been found that the dots and dashes can not be made by interrupting the source of constant current supply. This would extinguish the arc, which would have to be struck again by hand; that is, by touching the carbon to the copper and then withdrawing it to make the arc. In the arrangement shown in figure 27 the key cuts out some of the inductance in the antenna circuit. This changes the wave length radiated and the receiving antenna is not affected by this changed wave length, as it is tuned to the proper wave length. The key is so arranged that when it is closed the proper inductance is in, and when it is open the inductance is changed from the proper value. Another method of controlling the output is by having a nonradiating circuit in addition to the antenna. Closing the key throws the output of the arc to this nonradiating circuit. Other methods are also used.

RECEPTION OF UNDAMPED WAVES.

122. The reception of damped waves has already been described. It was possible to receive them in that manner, because each signal (dot or dash) contained a number of wave trains and each wave train produced a vibration of the telephone diaphragm. The successive vibrations produced by successive wave trains made the tone heard in the telephone receiver. As has been noted, an undamped wave signal is not broken up in wave trains but consists of an unbroken series of waves of the same amplitude. The effect upon the diaphragm of the telephone receiver would then be to distort it at the beginning of a signal and release it at the end of the signal.

This would result in a click being heard in the receiver, but this would not be distinctive enough to be recognized. Therefore, some other method must be employed.

123. A common method where only a crystal detector is used to receive undamped waves is by making use of an interrupter in the receiving circuit, as shown in figure 28–A. This is ordinarily a buzzer which is arranged to vibrate at suitable frequency. The vibration of the buzzer interrupts the circuit at P and thus breaks up into pulses the current flowing through the telephone. Each pulse pro-



duces a vibration of the diaphragm and the successive pulses produce the note heard.

124. Another method is by the use of the tikker. The circuit is shown in figure 28–B. The condenser, C′, shunting the telephone receiver has a very large capacity compared to the variable condenser at C. The tikker is a specially designed interrupter. No detector is needed. The action of the tikker circuit is as follows: When the tikker "makes" the circuit, only a very small part of the current passes through the telephone. Most of the current passes into the condenser C′, thus charging it. When the tikker opens the circuit,

the charge condenser discharges through the telephone. As the condenser has a large capacity, the discharge gives a current large enough to actuate the telephone diaphragm. A discharge occurs each time the tikker interrupts the circuit. This is at audio-frequency, so that a note is heard in the receiver. Other methods of receiving undamped waves will be discussed under vacuum tubes.

VACUUM TUBES.

125. Within the past few years a new device is being much used in radio communication. This device is called various names, such as vacuum tube, vacuum valve, special lamp, audion, ionic tube, thermionic tube, pliotron, and others. It will be called a vacuum

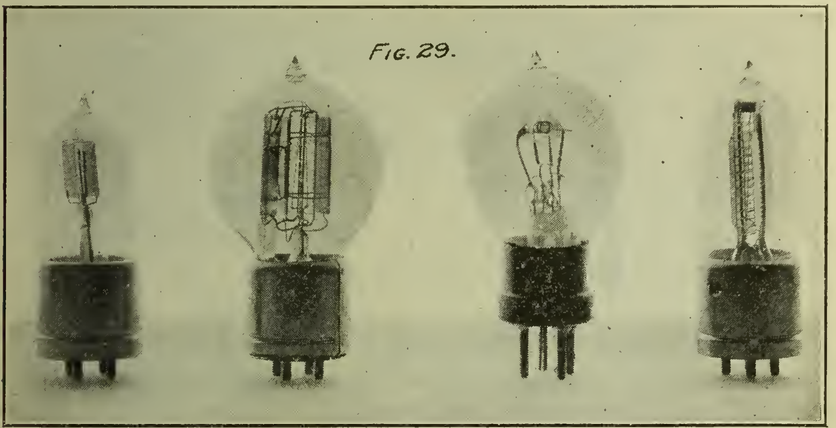


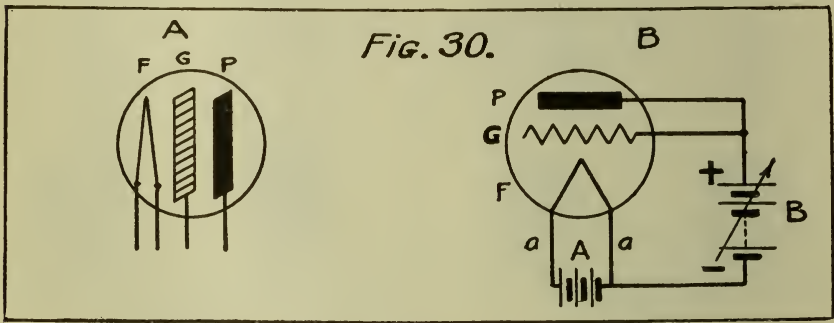
FIG. 29.

tube in this pamphlet. Vacuum tubes are used to generate undamped radio waves; to detect waves; to amplify oscillations both at radio and audio-frequencies; and in radio telephony. They are very important and are gradually supplanting other radio apparatus because they are very light and portable, and because they are more efficient than other devices. Various forms of vacuum tubes are shown in figure 29.

126. A vacuum tube consists of a container, usually glass, from which the air has been pumped out. In this glass tube is mounted the filament, the grid, and the plate. Each of these elements is separated from the other by a space. The filament has two outlets, the grid one outlet, and the plate one outlet. The filament is surrounded by the grid, which in turn is surrounded by the plate. These may be distinguished in the figure. The solid piece is the plate, the lattice-like piece is the grid (a spiral coil in one), and the fine wire in the center is the filament.

ELECTRIC ACTION OF A VACUUM TUBE.

127. To understand the action of a vaccum tube it is necessary to remember the following facts: A current of electricity is simply a flow of electrons, the electrons flow in one direction, which makes a current which is said to flow in the opposite direction. Electrons are small charges of negative electricity. All material contains electrons. There are two kinds of electricity—positive and negative. Like electricity repels and unlike attracts. These facts are already known to the reader. The following additional facts must be grasped before the action of the vacuum tube can be understood. It has been discovered that metals, if heated, will throw off into space some of the electrons which the metals contain. Also it has been discovered that the hotter the metal, up to a certain degree of heat, the more electrons it discharges. These electrons travel at a high rate of speed. If air or any other gas is present in the space around



the metal, the electrons strike the minute particles of the air or gas and are soon stopped.

128. The facts stated above are applied in the vacuum tube. The air is pumped from the tube (hence the name vacuum) so that the passage of the electrons will not be stopped. The filament, marked F in figure 30–A, is heated so that it becomes red or white hot. This is usually done by an electric current furnished by a battery. G represents the grid and P the plate. These actually are made as shown in figure 29, but are represented in the method shown in figure 30 for ease of explanation. Suppose that the filament is hot and the grid and plate are not connected to outside circuits. The electrons are thrown off from the filament and strike both the grid and the plate. These acquire a negative charge, as they have acquired electrons. The space inside the tube has also a negative charge as the space is filled with electrons. Like electricity repels and hence the negative charge on the plate, the negative charge on the grid, and the negatively charged space inside the tube are all repelling the elec-

trons which the hot filament is trying to throw off. As each electron is thrown off of the filament it adds its charge, either to the plate, grid, or space. The stronger charge causes a stronger repulsion of the escaping electrons. In a very short while the repulsion is strong enough to prevent the escape of any more electrons from the filament.

129. Figure 30–B shows a battery, A, used to heat the filament and a battery, B, with its positive terminal connected to the plate and its negative terminal connected to the filament. The grid is shown connected to the plate, so that in effect it is a part of the plate. This is done for sake of clarity in explanation. The use of the grid will be shown later. By connecting the battery as shown in the figure, two things have been done. First, a positive potential has been placed on the plate; second, a metallic circuit containing a battery has been made outside of the tube from the plate to the filament. This leaves only the space between the filament and the plate inside of the tube to complete the circuit. The battery marked A is used simply to heat the filament.

130. The heated filament throws off electrons. The plate is positive and attracts the electrons which are negative. The electrons travel through the space (no air or gas particles being present to hinder them as it is a vacuum) from the filament to the plate. Thus there is a flow of electrons from the filament to the plate—and a flow of electrons is an electric current. Thus the combination of the heated filament, the vacuum, and the positively charged plate has caused a current to flow; that is, in effect, it has completed the circuit which contains the battery, B. This complete circuit is (fig. 30–B) B *a* F P B.

131. The action of the battery, B, is, as well known, comparable to a pump. When it forms part of a circuit it pumps electrons out of its negative terminal and into its positive terminal. In the tube just described it pumps the electrons coming from the filament, from the plate to the battery and out of the battery to the filament. The filament again throws them off and they go to the plate—being attracted by it as it is positive. Thus the electrons flow around the circuit. This flow of electrons is a current of electricity. It can be measured by an ammeter placed at any convenient point in the circuit.

132. Consider the effect of changing the number of cells in the B battery. Changing the number of cells in the battery would change the positive potential on the plate. If the positive potential on the plate became greater it would have a greater attraction for the flying electrons in the tube, and hence in a given time more electrons would arrive at the plate and be pumped around the circuit by the battery.

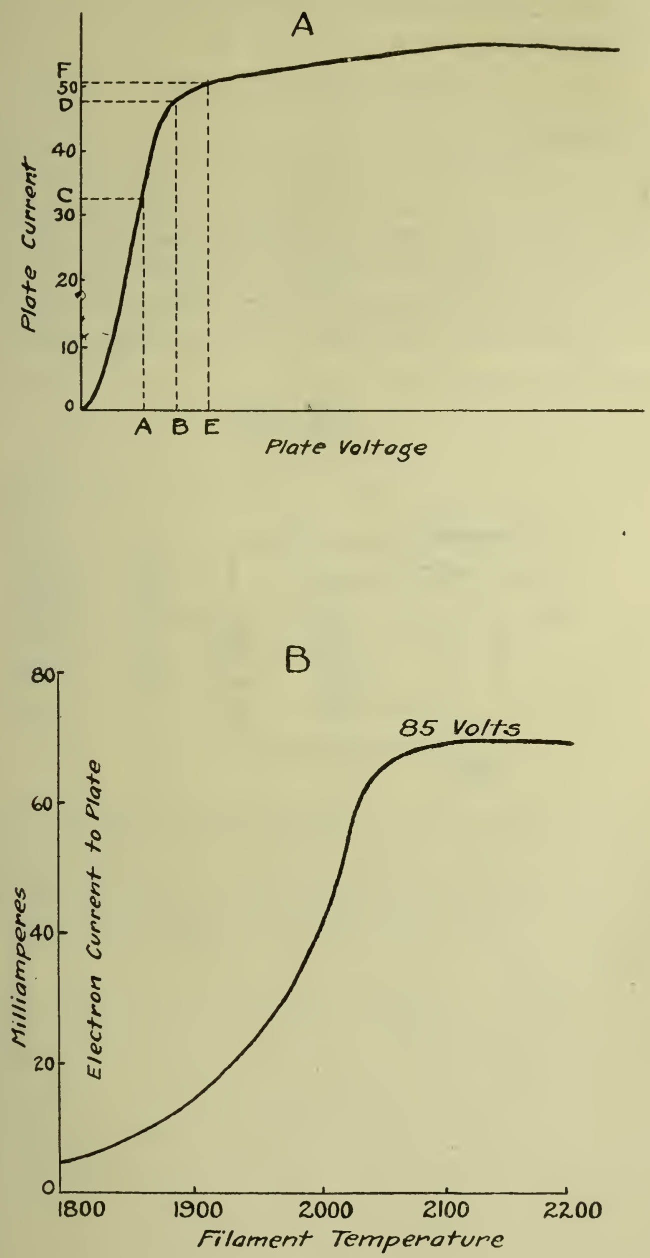
An increased flow of electrons means an increased current. In the same way a decreased potential on the plate would cause a smaller current to flow. This change in current with a change in potential *does not* follow Ohm's Law. That is, doubling the potential does not double the current as it does in a wholly metallic circuit. Figure 31–A shows how the current varies with varying potential on the plate. Figure 31–B shows how the current varies with varying temperature of the filament.

133. In A the filament temperature has been kept at a constant value and by means of a milliameter the current passing through the plate circuit has been measured when the plate potential has a certain value. The value of the plate potential has then been changed and the plate current again measured. The curved line shows the result of a large number of these measurements. Note that a change of plate potential from value A to value B changes the current from value C to value D; a change of potential from value B to value E changes the plate current from value D to value F. In the case of this particular tube the exact figures are as follows: Raising the plate potential 20 volts, starting at 40 volts, increases the plate current 16 milliamperes; raising the plate voltage 20 volts, starting at 60 volts, increases the plate current only 2 milliamperes. If the circuit obeyed Ohm's Law, the same change of potential would always *produce* the same change in current.

134. In figure 31–B, the plate voltage has been kept at a constant potential (85 volts) and the filament temperature varied. The plate current has been measured at each value of the filament temperature. The curve shows the result of a large number of measurements at different temperatures. It is seen that at a temperature of about 1,800° (dull red glow) very little current flows. This means that at that temperature very few electrons are thrown off by the filament. From that point up to a temperature of about 2,050 (white hot) there is a rapid increase in the rate of emitting electrons with an increase in temperature, thus giving an increased current. An increase in temperature after this point has been reached does not increase the rate of emissions of the electrons.

135. A current flows in the tube because the filament emits electrons. The electrons pass from the filament to the plate and grid. Neither the plate nor grid can emit electrons as they are not heated. This means that the electrons can pass only one way through the tube and hence an electric current can pass *only one way* through the tube. This is exactly what the galena crystal (see par. 91) does. A vacuum tube with only a filament and plate (grid connected to the plate or not built in the tube) may be used as a detector in place of the galena crystal. Such a tube may also be used as a rectifier of

Fig. 31.

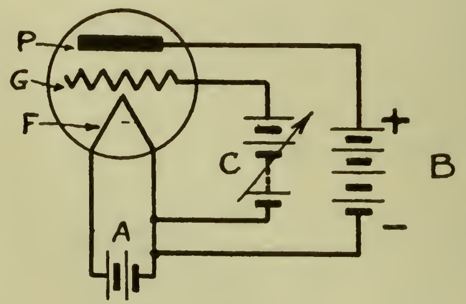

A
F
50
D
40
C
30
20
10
0
Plate Current
A B E
Plate Voltage
B
80
60
40
20
0
85 Volts
Milliamperes
Electron Current to Plate
1800
1900
2000
2100
2200
Filament Temperature

alternating currents, because it allows current to pass only in one direction. The use of the grid greatly improves the action of the tube and will be explained before taking up the action of a vacuum tube used as a detector.

ACTION OF THE GRID.

136. As has been explained the plate current may be controlled by variation of the filament temperature and also by variation of the plate potential. It was discovered that putting a third element in the tube gives a more sensitive method of control. This third element is the grid which has already been described. In the discussion above the grid has been connected with the plate, and hence really formed a part of the plate. In *actual use* it is in a *different*

FIG. 32.



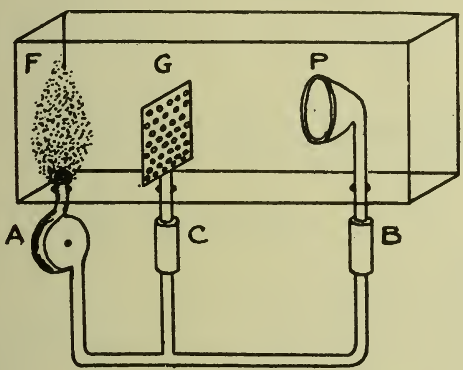
circuit from the plate. A study of figure 32 will show the action of the grid. It must be remembered that the grid is of latticelike construction and is placed very near the filament and between the filament and the plate.

137. The battery, C, allows a potential to be placed on the grid. This can be made stronger or weaker by changing the battery. It can be made positive or negative by reversing the connection of the battery. Suppose a positive potential be placed on the grid. This attracts the electrons just as the positive potential on the plate did. Making the potential of the grid higher causes it to attract the electrons with more force, and thus causes a greater current to flow in the tube. The grid itself has a very small surface and does not catch many of the flying electrons. Most of the electrons therefore go past the grid and reach the plate. Thus the *plate* current is increased by an increase of potential on the *grid*. Putting a negative potential on the grid causes the grid to repel the electrons and thus decreases

their rate of flow to the plate, as they can not get through the grid. If this negative potential is made large enough, its repulsion of the electrons will entirely stop their flow and hence stop the passage of any current in the tube. Because of the nearness of the grid to the filament, a slight change in the potential on the grid makes a large change in current to the plate. The effect of changing the grid potential is much greater than obtained by changing the plate potential.

138. It is important to understand this action of the grid, for upon it depends the use of the vacuum tube. The following mechanical device illustrates the action of a vacuum tube. F, G, and P are all mounted in an inclosure from which most of the air has been pumped. The pipes are filled with flour—each particle of which

FIG. 33.

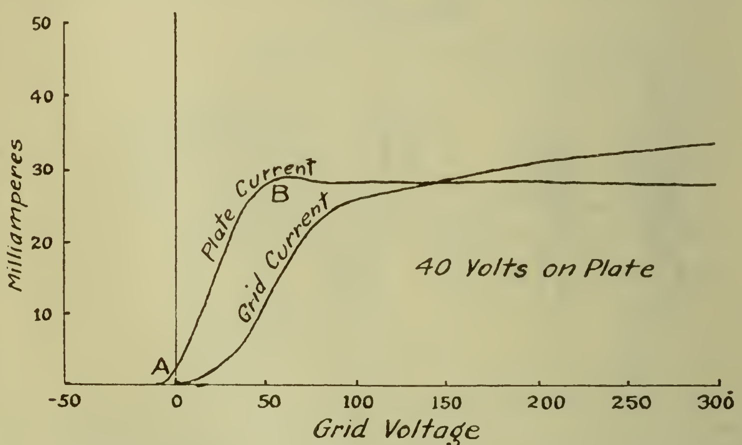


represents an electron. A is a blower which is just strong enough to keep a fountain of flour, F in the diagram, in the space above its opening. A corresponds to the battery A in figure 32, which heats the filament causing it to throw off electrons. B is a suction pump with a large funnel-like opening at P. B *sucks* the flour in at P and forces it through the pipe back to A. The pump B corresponds to the battery B in figure 32; the funnel P corresponds to the plate. It is evident that the stronger the suction at P, the more flour will be attracted. In the same way in the vacuum tube, the stronger the positive potential of the plate the more electrons will be attracted. If the pump B was reversed it would blow at P and no flour would enter, as it would be repelled. So in the vacuum tube, if the B battery is reversed it would put a negative potential on the plate and no current would flow, for the electrons would be repelled.

139. The pump C corresponds to the battery C of figure 32. The inlet, G, corresponds to the grid of the vacuum tube. It consists of

a large number of small openings connected to the pump. There is nothing between these openings so that the flour can pass directly from F to P without meeting any obstacles except at the openings themselves. With the pump B maintaining a uniform suction at P, let the pump C be started, starting a suction at G. G is much nearer to the fountain of flour than P and its effect is much greater. It sucks the flour towards it with great speed. Most of the flour does not enter the openings of G as they are so small, but pass right by them and enter the funnel at P, thus increasing the amount entering P. In the same way placing a positive potential on the grid attracts the electrons and these fly past the grid to the plate. An increase of suction at C gives an increased flow of flour through P, in the same

FIG. 34.

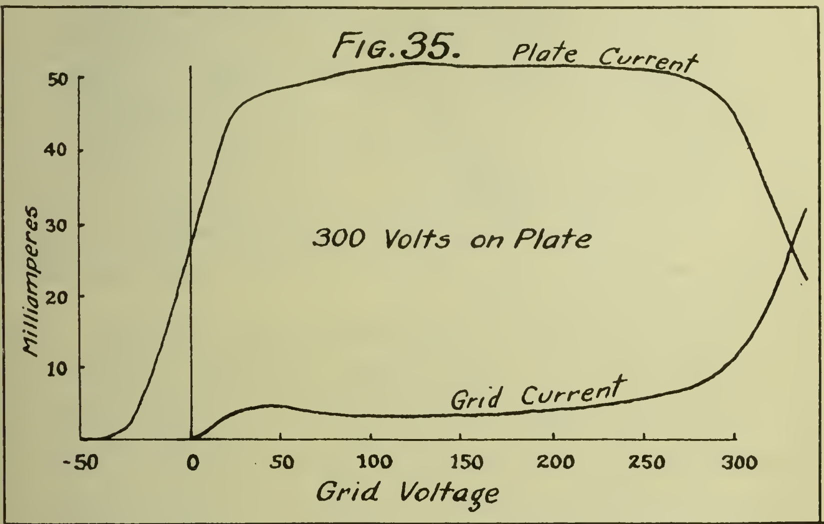


way as an increased potential on the grid causes an increased current of electricity through the plate circuit. If the suction at C is made strong enough, however, the particles of flour are sucked with such force that, instead of flying past the openings at G, they are drawn from their straight path and made to enter them. They do not get to P and hence the flow to the plate is decreased. In the same way placing too great a potential on the grid causes the electrons to fly to the grid instead of the plate, and hence the plate current is decreased at such high potential of the grid. Reversing the pump at C has the same effect of stopping the flow of flour as reversing the pump at B. If the pump C were reversed so that it acted as a blower it would tend to prevent any flour passing from F to P, as it would tend to neutralize the effect of the pump B. The blower action would not have to be very strong to completely overcome the effect of the pump

B. In the actual tube, giving the grid a negative potential has the same effect as making the pump, C, a blower.

140. The actual change in current in the plate circuit due to change in potential on the grid is shown in figure 34 by the curve marked "Plate current." This was taken by measuring with a milliammeter the amount of plate current passing when there was a definite voltage on the grid. The grid voltage was changed and the plate current again measured. The curve shows the result of a large number of these measurements. The plate potential was kept constantly at 40 volts during the measurements. Note that the curve has two distinct bends, one at A and one at B. These bends are sometimes spoken of as the knees of the curve. It is to be noted

FIG. 35.



that a rise of grid voltage starting at B does *not* make the same change of plate current as an equal lowering of grid voltage starting at the same point. The same fact holds for point A. Actual figures for a similar knee are given in the latter part of paragraph 133.

141. In figure 34 the curve marked "Grid current" was obtained by taking a series of measurements of the value of the grid current with different values of the grid potential. Note that when the grid potential becomes nearly equal in value to the plate potential (40 volts) the grid current rapidly rises, as it attracts the electrons so strongly that they go to the grid rather than the plate. Figure 35 shows the same series of measurements, except that the plate voltage was kept constantly at 300 volts.

142. All the curves except that in 31 B are taken from actual measurements made on the same vacuum tube. This vacuum tube

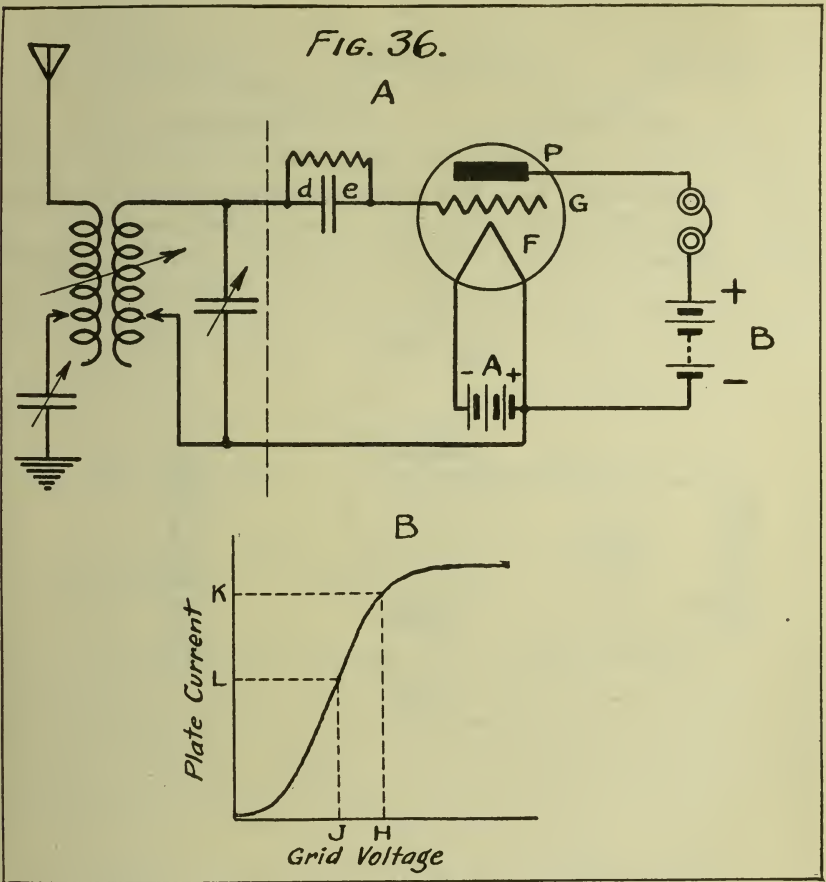
was designed to have 300 volts on the plate and to be used as a generator of oscillations in a manner to be explained later. It would not be efficient using 40 volts on the plate, as the grid current is too large for small values of its potential. Some vacuum tubes are designed to have 40 volts on the plate and to have very small values of the grid current with this voltage.

THE VACUUM TUBE AS A DETECTOR.

143. *First method.*—In this method a small condenser *c*, which is shunted by a very high resistance, *r* (about 1,000,000 ohms), is inserted in the lead to the grid. The high resistance is called the grid leak. Figure 36 shows the circuits. Note that the circuits to the left of the vertical dashed line are exactly like the receiving circuits described previously. The vacuum tube has the battery A (about 4 volts) to heat the filament. The plate battery, B, is connected through the telephone receivers to the plate. A variation in plate current therefore means a variation in the telephone current. There is no battery in the lead to the grid. The antenna is caused to oscillate by the incoming signal waves. These oscillations are transferred to the secondary circuit. The terminal, *d*, of the condenser is directly connected to the secondary circuit and hence it alternately becomes positive and negative.

144. With no oscillation in the circuit the grid maintains a steady value, and therefore the plate current maintains a steady value. Let the oscillation begin and let the terminal, *d*, become positive. The positive electricity on that side of the condenser attracts the negative electricity to the other side and repels positive electricity so that "e" becomes negative and the grid becomes positive, or rather less negative than it was. This takes place because the "e" side of the condenser and the grid are practically insulated from any other conductor—the grid leak has such a high resistance that no loss of electricity occurs through it in the short time taken by one oscillation—and any gain of electrons by the "e" side of the condenser must be compensated by an equal loss of electrons by the grid. Thus, as explained, the grid becomes positive (less negative) when the "d" side of the condenser becomes positive. The grid being positive now attracts the electrons coming from the filament and some of these electrons are added to the grid. These electrons are *trapped* on the grid and can not escape. When the second half of the oscillations reaches *d*, *d* becomes negative, causing the grid side of the condenser to become positive and the grid itself to become negative. The grid being negative no electrons are added on this half of the oscillations. The net

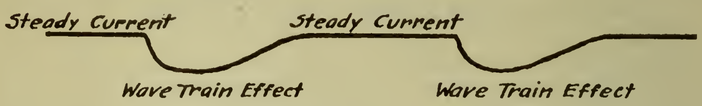
result of one complete oscillation is that the potential of the grid has been lowered, as electrons were added during the first half of the oscillation. Each succeeding oscillation adds its effect to the preceding one and hence the result of a *complete wave train* is to considerably reduce the potential of the grid.



145. The result of reducing the potential of the grid is to reduce the plate current flowing in the valve. In figure 36 B, the steady potential (with no oscillations) is represented at H. This gives a steady value of the current represented by the point K. The wave train reduces the grid potential to J which reduces the plate current and therefore the telephone current to L. Between each wave train there is sufficient time for the electrons on the grid to leak away through the grid leak. The grid therefore rises to its steady potential and hence the plate current rises to its steady value.

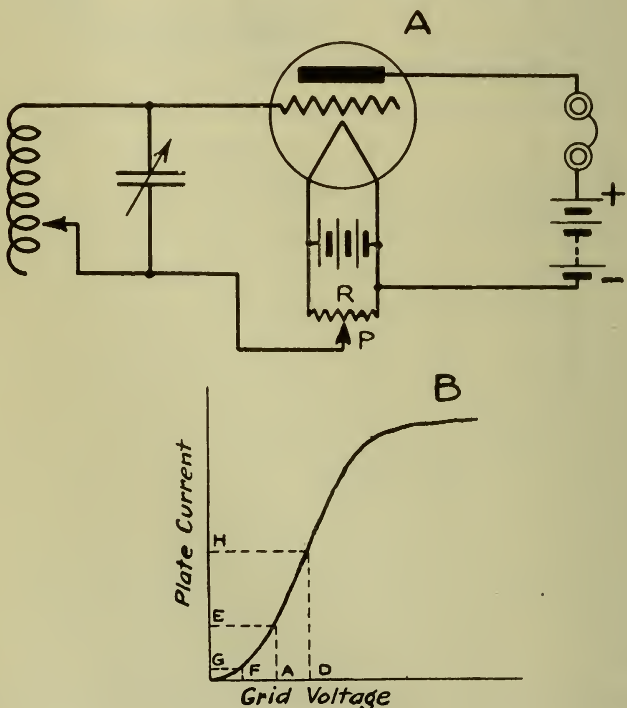
146. The actual current is shown in figure 37. Each pulse of the current actuates the telephone diaphragm and hence a note is heard whose tone corresponds to the frequency of the received wave train.

FIG. 37.



147. *Second method.*—In this method the knee of the plate current curve is used. The tube is connected as shown in figure 38 A. The sliding contact, P, on the resistance, R, allows the grid potential,

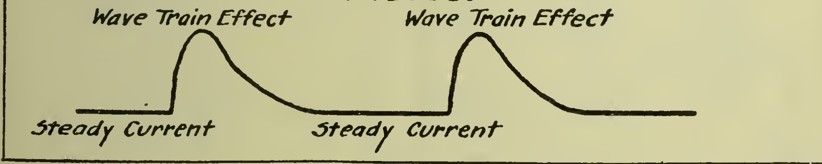
FIG. 38.



which results from its being connected to the filament battery, to be adjusted so that its steady potential is at the knee of the curve. (A device allowing potential to be varied in this manner is called a potentiometer.) The variation of potential due to the oscillations set up in the oscillating current is communicated to the grid, whose potential therefore alternately rises and falls.

148. Suppose the potentiometer has been adjusted so that the steady potential of the grid is at A (fig. 38 B). The oscillations cause the potential to rise to D and to fall to F; the rise and the fall being equal to each other. When the grid has a steady potential at A, the steady plate current is represented by the point E; when the first half of the alternation raises the grid potential to D, the plate current is increased to H; when the second half of the oscillation reduces the grid potential to F the plate current is reduced to G. It will be seen that the increase in current due to one half of the oscillation is much greater than the decrease due to the other half, for EH is much longer than EG and these two lengths measure the change in current. The result of this is that the current flowing through the telephone receiver is increased by an oscillation. This increase of current lasts through one wave train, after which the current drops to its steady value. This is illustrated in figure 39.

FIG. 39.



Each pulse actuates the telephone as previously described. In the explanation of both methods of detecting it is assumed that the telephone smooths out the pulsation that would otherwise occur at each oscillation. In employing the second method it is possible to design circuits so that the proper steady value of the grid potential may be obtained without the aid of a potentiometer.

THE VACUUM TUBE USED AS AN AMPLIFIER.

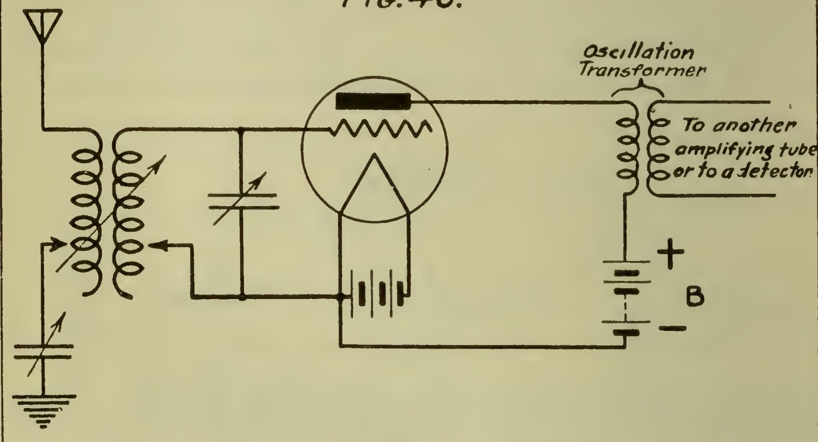
149. It is possible by use of the vacuum tube to receive oscillatory currents at one strength and send them out at a much higher strength. When a tube is used for this purpose it is said to be used as an amplifier. The energy added by the use of the tube is furnished by the batteries connected to the tube. The amplification affected by one tube is considerable, in some cases the output energy of the tube being 100 times the input energy.

150. A vacuum tube acts as an amplifier because, as has been noted, a small change of voltage on the grid makes a large change of current in the plate circuit. This is comparable to the fact that a small amount of pressure used by an engineer upon the throttle

of a locomotive releases a large amount of pressure in the cylinders of the engine. The vacuum tube is often called a valve because the grid will turn off and on the energy of the plate current.

151. Figure 40 shows the type of connection necessary for use of a vacuum tube as an amplifier. This arrangement differs from that of a detector mainly in the fact that there is no grid condenser or grid leak, and the steady voltage of the grid is at neither the upper nor lower knee of the curve (fig. 38 B), but is between the two. It is to be noted that this part of the curve is practically straight. The oscillating circuit communicates its oscillating potential to the grid. As the grid potential increases more electrons pass from the filament to the plate; as the grid potential decreases fewer electrons

FIG. 40.



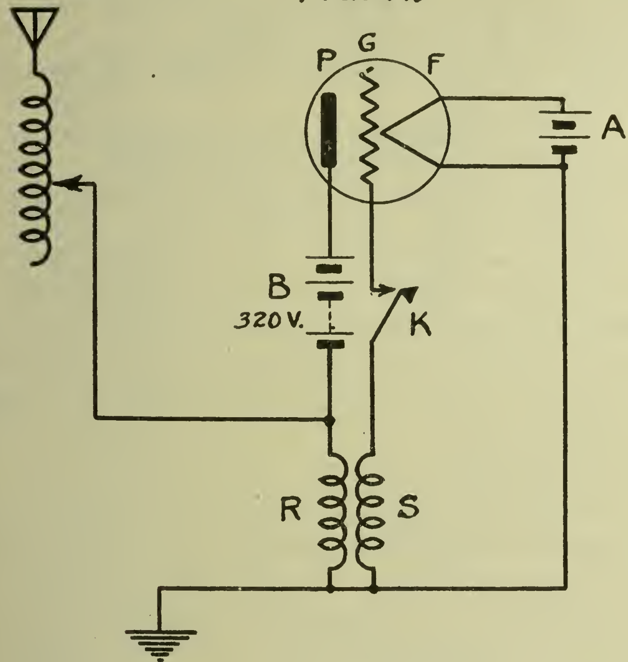
pass from the filament to the plate. Thus the grid acts as a valve which turns on and off the current passing through the plate and furnished by the battery, B. The current oscillates with the same frequency as the grid potential, but carries much more energy than that acting upon the grid, because the battery, B, has added energy to the oscillation.

152. A vacuum tube will amplify oscillations at any frequency, so that in radio apparatus some tubes are used to amplify radio frequency oscillations before they are detected, and some tubes are used to amplify oscillations after they have been acted upon by a detector and have been changed to audio frequency. The design of the circuits for both radio-frequency and audio-frequency oscillations requires minute attention to details which are beyond the scope of this pamphlet.

153. Tubes used as shown in figure 40 are said to be connected in cascade—the output of one tube being the input of another tube.

This transfer of energy is usually made by means of an oscillation transformer having either an iron or an air core. The energy may be transferred by means of electrostatic coupling which has been previously described. Still another method much used in Europe is to have the output of one tube lead to the next tube through a high resistance. In this method the drop of potential through the high resistance causes a variation of potential on the grid of the tube to which it leads.

FIG. 41.



VACUUM TUBE AS GENERATOR OF UNDAMPED OSCILLATIONS.

154. Vacuum tubes are used to generate undamped waves. It has been noted that undamped waves are produced by adding energy to the oscillations at each oscillation. The batteries connected to a vacuum tube are the source of the energy when undamped waves are produced by the tube. A tube may be made to oscillate by coupling the grid and plate circuits of the tube and having in each circuit the necessary capacity and inductance. Figure 41 is a simplified circuit of a vacuum tube transmitter. B is a battery of 320 volts. S and R are the coils of an oscillation transformer. K is a key to control the oscillations.

155. Before the key is closed the grid has a slight negative potential due to electrons from the filament being trapped on it. Therefore only a very small current is passing from the plate to the filament. Close the key and:

(1) The grid acquires a zero potential (being connected to the ground) which

(2) Increases the current in circuit B–R–F–P–B. (The grid, having a zero potential, does not prevent the passage of electrons through the tube.) The increasing of the current through coil, R, of the oscillation transformer

(3) Builds up a potential in coil, S, so that the grid end of the coil and the *grid itself* become negative, which

(4) Decreases the current in circuit B–R–F–P–B. . The *decreasing* of the current through coil, R,

(5) Builds up a potential in coil, S, so that the grid end of the coil and the grid itself become strongly positive, which

(6) Greatly increases the current in circuit B–R–F–P–B, which is the beginning of another cycle. (See 2 above.)

156. The oscillations are generated as long as the key is closed. It is to be noted that the oscillations have energy from the battery, B, added. Hence, they are undamped oscillations. The circuit containing the antenna determines the frequency of the oscillations. The coupling between R and S must be close enough to cause the voltage of the grid to vary over a range sufficient to keep the oscillations flowing in the circuit.

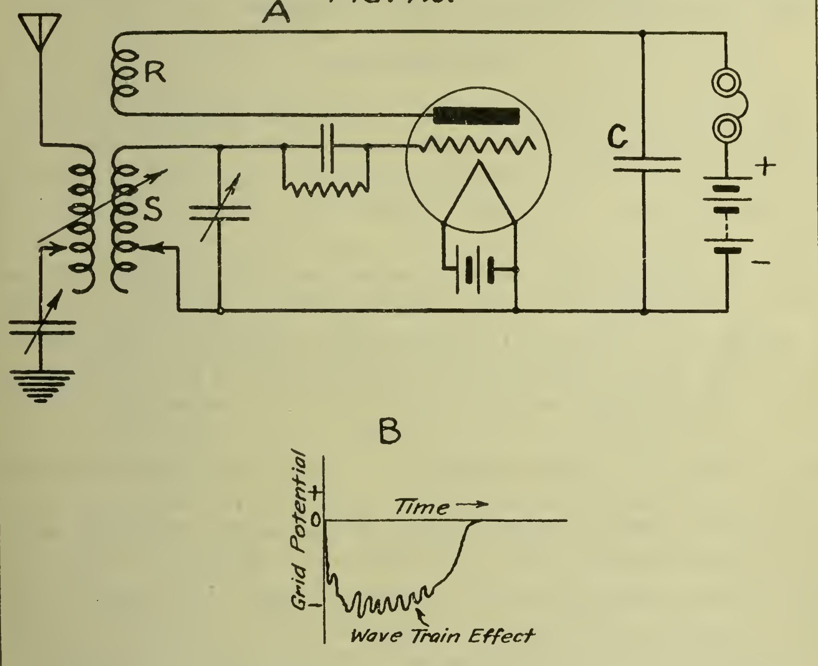
157. Thus a vacuum tube will generate undamped waves when the grid and plate circuits are coupled together. It is, of course, necessary that the degree of coupling be great enough for the reaction between grid and plate to continue as long as power is supplied or the coupling maintained. The circuits may be coupled by any means. A capacity coupling is often used, as is also a combined capacity and inductance coupling.

REGENERATIVE AMPLIFICATION.

158. It is possible to use the same vacuum tube as a detector and amplifier simultaneously. There are numberless methods of arranging the circuits of a tube and each different arrangement is designed to accomplish some object. A knowledge of the principles of radio circuits and the action of the tube itself, as heretofore described, will enable one to explain the action of any particular circuit. An example of an ingenious circuit is shown in figure 42. This is the same arrangement as shown in figure 36, where the tube was used as a detector, except that the coil, R, and the condenser, C, have been added.

159. The coil R is coupled with the coil S, which is the secondary of the oscillation transformer. When radio waves start oscillations in coil S, they are communicated to the grid as explained in connection with figure 36. The effect of the wave train upon the grid is to lower the potential of the grid as has been explained. Referring to paragraph 144, it is seen that the grid varies in potential with the radio frequency of the received oscillations. This radio-frequency variation in potential of the grid causes a radio-frequency variation of plate current strength (that is, an oscillation). This is in addi-

FIG. 42.



tion to the lowered potential produced by the wave train considered as a whole. Figure 42–B shows the combined results. The radio-frequency variation of potential in the grid superimposed upon the audio-frequency change in potential produces both a radio-frequency oscillation and an audio-frequency pulse in the plate circuit. The audio-frequency pulse gives rise to the tone heard in the receiver. The radio-frequency oscillations, in passing through the coil, R, which is coupled to coil S, react upon coil S and strengthen the oscillations already existing in that coil. Thus the effect of the regenerative amplification is to strengthen the original oscillations and because of this strengthening make them persist longer than they otherwise would.

160. The condenser, C, is used to allow the high frequency oscillations to by-pass both the receiver and the battery used. It offers a low resistance path to high frequencies while the high inductance of the receiver offers a high resistance to the high frequencies. It is a common practice in radio to use a condenser for such a purpose. A condenser is oftentimes used in a circuit to permit alternating currents to flow and at the same time to stop the passage of a direct current. In much the same way a large inductance is often used to stop the passage of high frequency variation in the current, as it offers a very high resistance to such oscillations.

HETERODYNE.

161. In addition to the methods of receiving undamped waves explained in paragraphs 122–124, the heterodyne method is used. As this is the most sensitive method known it is gradually displacing all other methods. The word "heterodyne" means "other force" (hetero—other; dyne—force). The name arises from the fact that besides the energy of the radio wave received by the antenna another radio wave is generated at the receiving station, and this wave adds its energy to the first one; the second wave being the "other force."

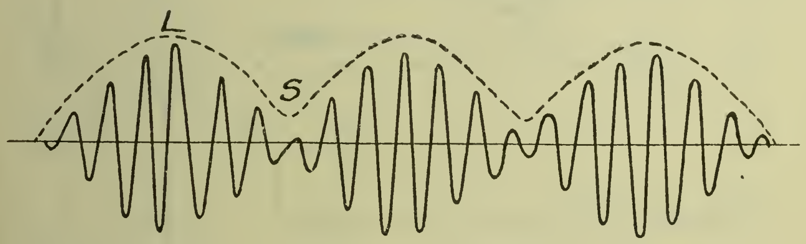
162. The result of adding two waves together is the formation of a wave which has the energy of each of the two waves which forms it. It is seen that if two waves having the same amplitude and the same frequency are added together, the result may be either the formation of a wave having double the amplitude of either one of the waves or the complete neutralization of the waves. The first result will be obtained when the two waves are in phase, i. e., when the crest of one coincides with the crest of the other. The second result will be obtained when the two waves are exactly opposite in phase, i. e., when the crest of one coincides with the trough of the other.

163. Now, if we combine two waves of different frequencies, both conditions will be brought about, for if the crests coincide at one point they can not coincide at adjacent points because the waves have different frequencies and therefore have different wave lengths. The result is that the wave formed has varying amplitudes. These variations in amplitude occur at regular intervals. Figure 43 shows the type of wave obtained. Notice that the wave varies from a large amplitude at L to a small amplitude at S and that this variation of amplitude repeats itself in a regular manner. These waves travel with the same velocity as ordinary waves. It has been found that the number of times per second the amplitude waxes and wanes when two waves are combined is equal to the difference in fre-

quencies of the two combined waves. Thus if a wave having a frequency of 350,000 is combined with a wave having a frequency of 351,000, the resulting wave will wax and wane 1,000 times per second (351,000—350,000). The result of this waxing and waning of amplitude is, after being acted upon by a detector, to give the effect of another wave shown by the dotted line in figure 43. This is sometimes called the beat wave and follows the variation in amplitude of the wave from which it results. This beat wave therefore has a frequency equal to the difference in frequencies of the two simple waves forming the varying amplitude wave.

164. The oscillations set up in the receiving circuits have the same characteristics as the waves. The detector eliminates that part of the oscillation shown below the line, giving a pulsating direct current which is represented by the dotted line in figure 43. This beat oscillation is made to occur at audio frequency and hence can be heard

FIG. 43.

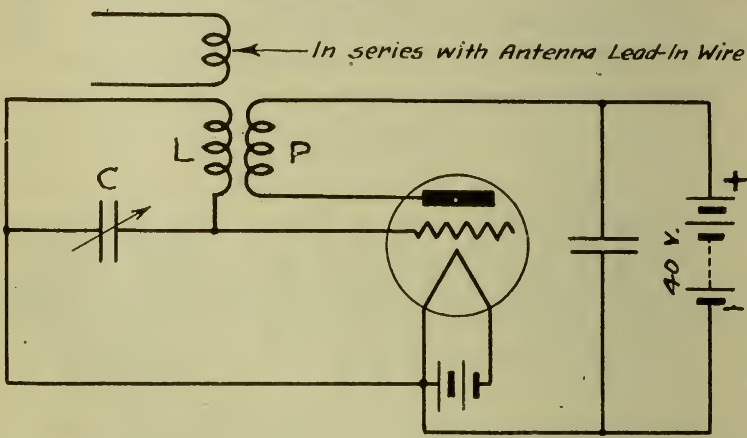


when passing through the telephone receivers. The frequency of the beat oscillation is easily controlled. The antenna receives the wave sent out by the transmitting station. This has a definite frequency. The other wave is generated at the receiving station and its frequency may be changed at will. As explained, the difference in the two frequencies determines the frequency of the beat wave and hence this latter can be made any frequency by varying the frequency of the local oscillation. The pitch of the note heard in the receivers depends upon the number of beats, so that the pitch may be varied by varying the number of beats. In practice the pitch is made so that it can be easily distinguished from other noises in the telephone receivers.

165. The local oscillations are usually generated by a vacuum tube. Figure 44 shows the circuits of an instrument used to generate such local oscillations. This instrument is usually called a heterodyne. Compare the circuits of figure 44 and figure 41, both of which are designed to generate oscillations. The main oscillating circuit

is the circuit containing L and C, and the frequency of this circuit determines the frequency of the oscillations. This frequency may be varied by the condenser, C. The grid circuit and the plate circuit react through the oscillation transformer composed of the coils L and P. The output oscillations are fed into the regular receiving circuits by means of a few turns, K, of the antenna lead-in wire, which make the coupling with the coil L. In many heterodynes no special arrangements are made for coupling the heterodyne to the other circuits, as it is found that it is sufficiently simple to place the heterodyne near the other circuits.

FIG. 44.



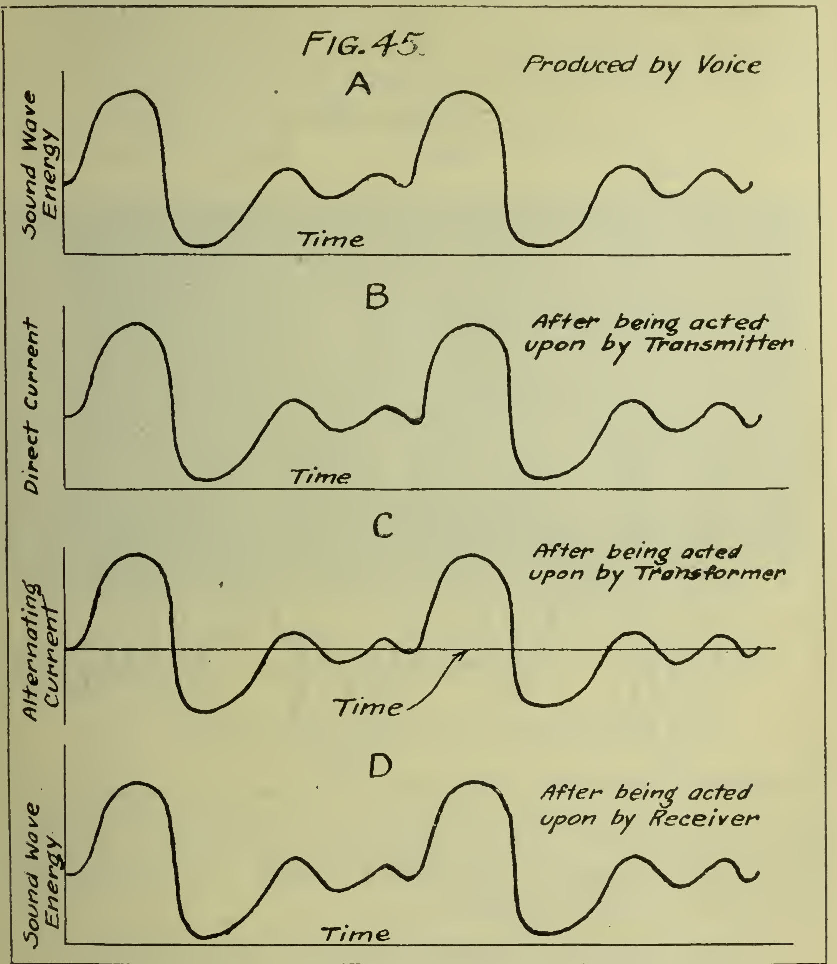
RADIO TELEPHONY.

166. The practice of radio telephony involves the elementary principles of radio telegraphy previously described, and in addition new principles by which transmission of speech is made possible between radio stations.

SUMMARY OF WIRE TELEPHONY.

167. In ordinary wire telephony the sound waves produced by the voice are caused to produce, by means of a transmitter, a variation in a direct current; the variation in the current being identically similar in amplitude and frequency to the sound waves which produce it. This variation in direct current is usually converted, by means of a transformer, into a variation in alternating current which is similar to the variation in direct current. The variation in alternating current is then by means of a receiver converted into sound waves, the sound waves being identically similar in amplitude and

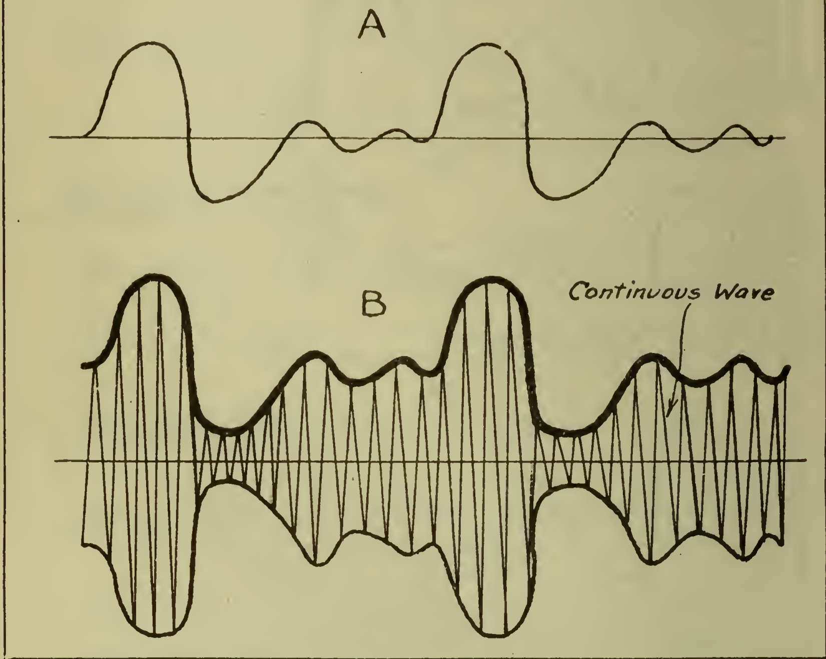
frequency to the alternating current which causes them. As this identical similarity of amplitude and frequency has been maintained throughout the complete cycle, the sound waves produced by the receiver are identical with those originally produced by the voice. The series of events outlined above are represented by the curves of figure 45.



168. The instruments peculiar to wire telephony are the transmitter and the receiver. The transmitter, sometimes called a microphone, has two conductors separated by granules of carbon. The sound waves strike a flat piece of metal, called a diaphragm, and cause it to vibrate. The diaphragm acts upon the carbon granules, alternately increasing and decreasing the pressure of the granules upon one another, as it vibrates to-and-fro. This variation in pressure

between the carbon granules varies the resistance of the granules. A direct current which is flowing through the granules is varied by this varying resistance. This varying direct current is changed into a varying alternating current by means of a step-up transformer. The alternating current acts upon the receiver. This receiver consists of an electromagnet through which the alternating current passes, and a permanent magnet which forms the core of the electromagnet. Mounted in front of the poles of this combination magnet is a flat piece of

FIG. 46.



metal containing iron. This is also called a diaphragm. The alternating current causes the diaphragm to vibrate, thus producing the sound made at the transmitter.

FUNDAMENTAL METHOD OF RADIO TELEPHONY.

169. In radio telephony methods are employed to produce at the transmitter and reproduce at the receiver a sound wave, that is, a wave similar in character to that of figure 45. It has been found possible to do this by varying the amplitude of the radiated high-frequency waves so that this variation in amplitude follows in detail the wave variation produced by the sound. In figure 46, curve A

represents a simple sound wave. By means of methods to be described later, the amplitude of a *continuous* radio wave is varied so that the variation in amplitude follows identically the amplitude and frequency of the sound wave. This is shown by the heavy line in B of figure 46. This line, together with lower inclosing line, is called the envelope of the radio wave. Note that the upper and lower inclosing lines have the same shape. This wave establishes oscillations identical with it in the receiving antenna. When these oscillations are rectified by the detector and passed through a telephone receiver the rectified current is similar to the heavy line of the envelope. This is necessarily so as the *rectified* telephone current does not follow the change in each individual radio frequency oscilla-

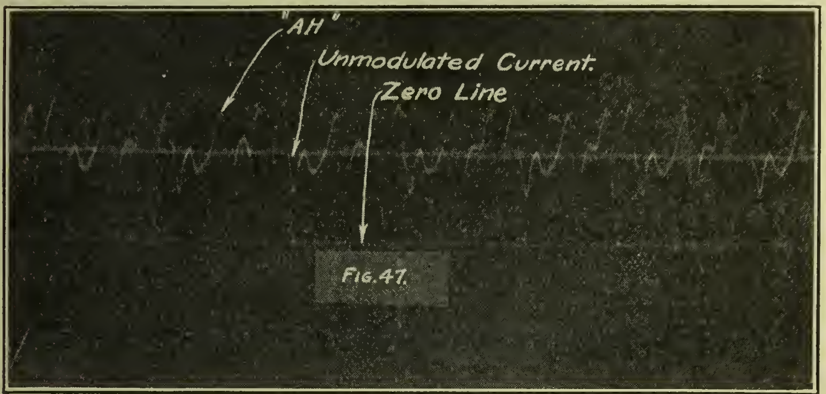


FIG. 47.

tion, but follows the change in the amplitude of these oscillations. This change is represented by one of the envelope lines as stated.

RECEPTION OF RADIO TELEPHONY.

170. Apparatus used for the reception of damped wave radio telegraphy is suitable for the reception of radio telephony. In some methods of radio telephony a heterodyne must be used, but these methods are not in common use and will not be described in this pamphlet. Although radio telephony can be received by apparatus used to receive damped radio telegraphy, special design of the elements of the circuits for radio telephony improves the quality of the reception. Figure 47 (an oscilligram) shows the rectified current produced when the sound "ah" was transmitted by a telephone set. Note that the unmodulated current is practically a straight line. The modulated current when rectified is shown by the wave-like line. This current passing through the telephone receiver causes it to produce the sound of "ah."

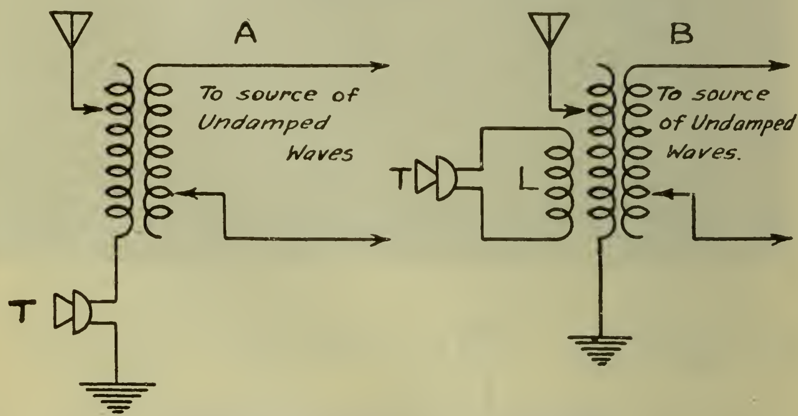
MODULATION.

171. When a radio wave has its amplitude varied so that its envelope is made to assume any desired curve the wave is said to be modulated. The instrument or apparatus that accomplishes this object is called a modulator.

METHOD OF MODULATING.

172. The simplest way of modulating a radio wave is by changing the resistance of the antenna. This change in resistance changes the intensity of high-frequency current in the antenna. This changes the amplitude of the oscillations as the amplitude varies with the intensity of current in the oscillation. Figure 48–A shows this simple arrangement where T is a microphone transmitter.

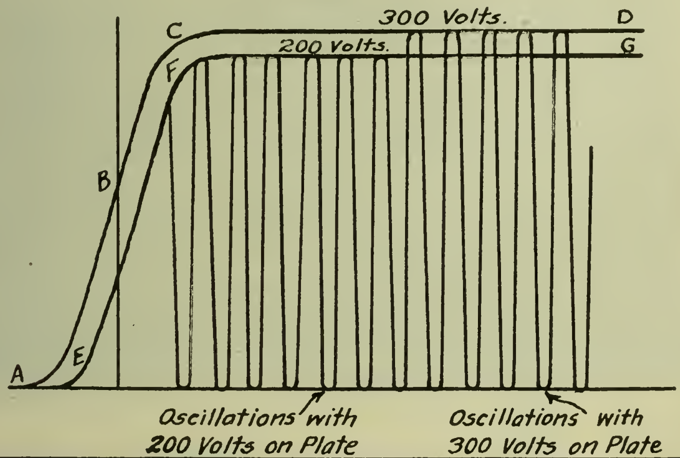
FIG. 48.



Speech in the mouthpiece of the microphone varies the resistance of the aerial circuit, thus causing a variation in the current. A modification of this method is to have the microphone shunt a condenser in the antenna circuit or a part of the inductance in the circuit. By this method not only is the resistance varied but the antenna has its natural period of oscillation varied by the action of the microphone. This change in natural period throws the antenna circuit out of tune with its primary and hence changes the amount of current in it. This change in resonance can be made to add its effect to the change in resistance caused by the microphone. The methods of modulating described in this paragraph are not used very much because both of them waste a great deal of energy. In addition, the first method does not allow very large currents to be used, as a microphone can carry only a limited current, and the second method uses a very broad band of wave lengths. This is objectionable because of the interference it produces with other stations.

173. Another method of modulation is called the absorption method. Figure 48–B is a schematic (simplified) diagram of the circuits. When the antenna is oscillating a part of its energy is absorbed by the circuit LT which is coupled to it. The amount of energy absorbed by this LT circuit depends upon its resistance. The resistance of this circuit is changed by the action of the microphone when its diaphragm is caused to vibrate by sound waves. The total energy in the antenna circuit is constant and hence any energy absorbed by the LT circuit is taken away from the radiated energy. Therefore the radiated energy is varied by the varying absorption of the circuit in which the microphone is placed.

FIG. 49.



174. Referring to figure 31–A and its accompanying discussion, it is shown there that a variation of plate potential produces a variation in plate current. The following method of modulation depends upon that fact. In figure 49 the line ABCD represents the characteristic curve of a vacuum tube with a plate potential of 300 volts: the line EFG represents the characteristic curve of a vacuum tube with a plate potential of 200 volts. Start the tube oscillating when the plate potential is 200 volts. The oscillation would be as shown in the figure. Let the plate potential be increased to 300 volts. The oscillations then increase in amplitude as shown in the figure.[1]

[1] For the sake of clearness in this explanation, as in others in this pamphlet, the fact that the dynamic characteristic of the tube is different from that shown in figure 49 is neglected. Explanation based upon this dynamic characteristic would be more involved but would lead to the same result, i. e., a variation in plate potential varies the amplitude of the oscillations.

The effect upon the radiated wave of this variation in plate potential is clearly shown in figure 50. The curves shown are the *rectified* current of the oscillation produced by an oscillating tube whose plate voltage was supplied by dynamotors (a particular form of direct current dynamo) whose output voltages were not constant. The "Line of reference is a straight line.

The voltage given by the two dynamotors in series was practically constant. The voltage given by type CG–1141 No. 893558 varied very little. The voltage given by type CG–1141 No. 893559 varied very much. A schematic diagram of the circuits which may be used to produce such curves is shown in figure 51. It must be understood that the curves of figure 50 have the same shape as the envelopes of the high frequency oscillation produced by the oscillating tube.

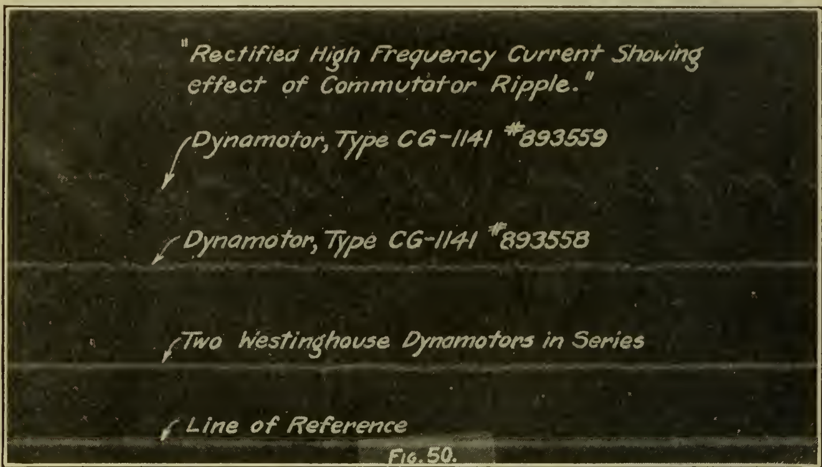


Fig. 50.

175. The circuits for modulating a radio wave by means of varying the plate potential with a microphone are shown in figure 52. The coils marked R, F, C, are inductances of values large enough to prevent the passage of radio frequency oscillations. RFC_1 prevents the oscillation from passing through the plate battery. The grid and filament are connected by the resistance, R, and the choke coil, RFC_2. As the filament is connected to the negative terminal of the plate battery, the grid, being connected with the filament, acquires through the resistance, R, the proper negative potential at which it works efficiently. The choke coil in this circuit forces the oscillations to pass through the condenser, C, to which the filament is also connected. The condenser, C, assures the proper oscillating voltage between the filament and the grid. The condenser, C_2, prevents the positive potential of the plate battery from reaching the grid through the coils of the autotransformer which couples the grid and the plate circuits.

176. Speech into the microphone which is in circuit with a battery and the primary of a transformer varies the current passing through the circuit. This varying current in the primary induces a varying

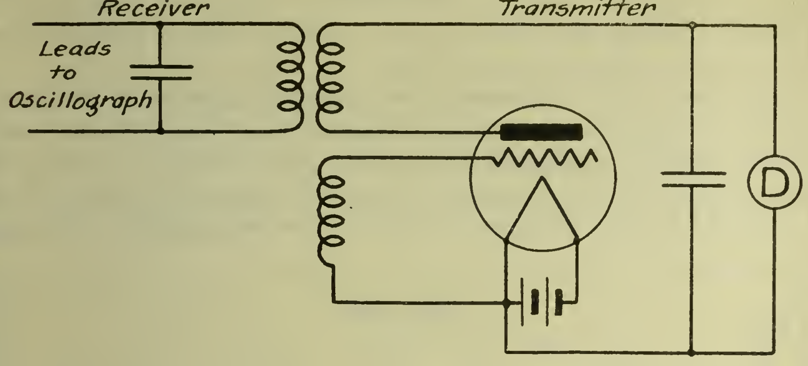


FIG. 51.

potential in the secondary. This varying potential in the secondary is impressed on the plate, thus varying the amplitude of the oscillations as has been explained. This arrangement is very simple but

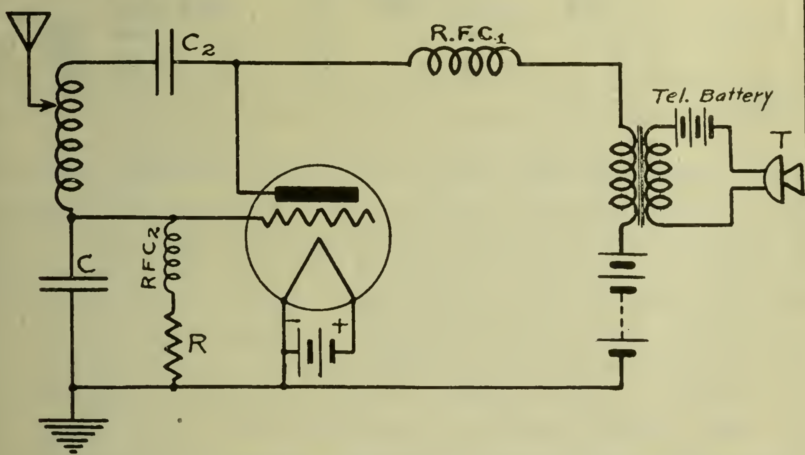


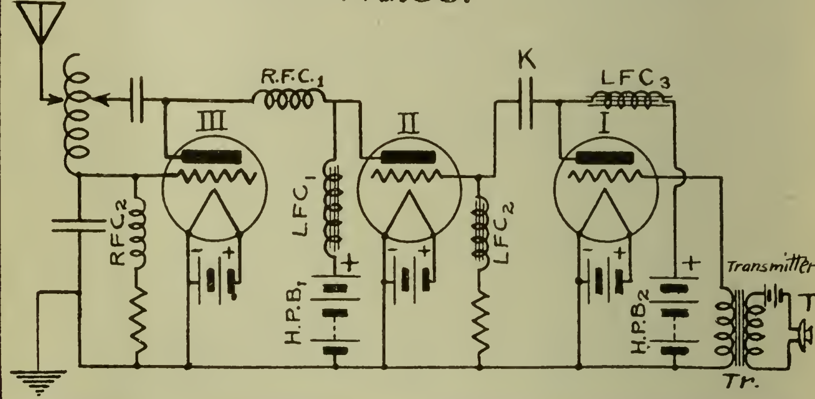
FIG. 52.

has the disadvantage of being limited in the amount of variation that can be produced in the plate potential. This limits the degree of modulation so that the set is not very effective. This method of modulation is very effective, however, when modified as explained below.

177. Figure 53 is a simplified diagram of a complete radio telephone set. LFC are inductances of such values as to choke out not only radio-frequency oscillations, but audio-frequency oscillations as well. They prevent the passage of audio-frequency oscillations or of audio-frequency variations in direct current through the circuit in which they are located. HPB_1 and HPB_2 are high-potential batteries feeding the plates of the vacuum tubes. T is a microphone, Tr is a step-up transformer.

178. Speech into the microphone varies the current in its circuit. This varying current, passing through the primary of the transformer, induces a varying potential in the secondary. This varying potential in the secondary is impressed upon the grid of tube I. Tube I is a low-frequency amplifier (see par. 149 ff). The plate

FIG. 53.

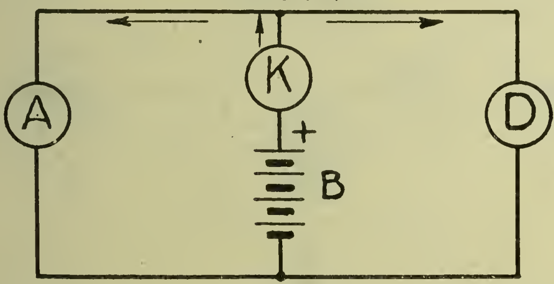


current passing through tube I is therefore an amplified reproduction of the microphone circuit current. This current has audio-frequency variations in current which pass to the condenser K and through the condenser to the grid of tube II. They can not take any other path as the low-frequency choke coil in other paths reject them. The condenser K is in the circuit to prevent the current and positive potential of HPB_2 from reaching the grid of tube II. By action of the condenser K, the low-frequency variations of the direct current reaching it from the plate circuit, tube I, are changed into low-frequency alternating current, which is the current that reaches the grid of tube II.

179. Tube III generates continuous oscillations (compare with fig. 52). Its plate is connected with the plate of tube II. The high-potential battery, HPB_1, feeds both the plate of tube II and the plate of tube III. It furnishes a *constant* current because it has a low-frequency choke coil in series with it and this choke coil pre-

vents any variation in current that takes place in either of its branch circuits from affecting the battery. As noted in connection with figure 52, the high-frequency choke coil, RFC_1, stops all radio oscillation in its circuit. No radio-frequency oscillation, therefore, can reach the plate of tube II. The audio-frequency variation in the potential of the grid of tube II produces an audio-frequency variation of current in the plate circuit. This variation of current can not come directly from the battery, as the low-frequency choke coil prevents; it must come from tube III. When the current in tube II is increased, the current in tube III is decreased; when the current in tube II is decreased, the current in tube III is increased. Thus the amplitude of oscillation in tube III is modulated by this increase and decrease of current. It is the output of tube III which is radiated by the antenna.

FIG. 54.



180. Figure 54 illustrates the transfer of energy between tubes II and III. The battery, B, furnishes a constant current passing through K. This current divides, half of it going through tube A and half of it through tube D when both have the same resistance. If the resistance of D is decreased, more current will flow through it. But K does not allow any variation in current, therefore the extra current passing through D must come from the circuit in which A is located. In other words, the current passing through K does not split 50–50, but, say, 80–20, the larger part going through the D circuit. When the resistance of D is increased the reverse of this takes place, the larger current passing through A. A and D represent the tubes and K represents the low-frequency choke coil of figure 52. The varying potential on the grid of tube II has the effect of changing the resistance of that tube.

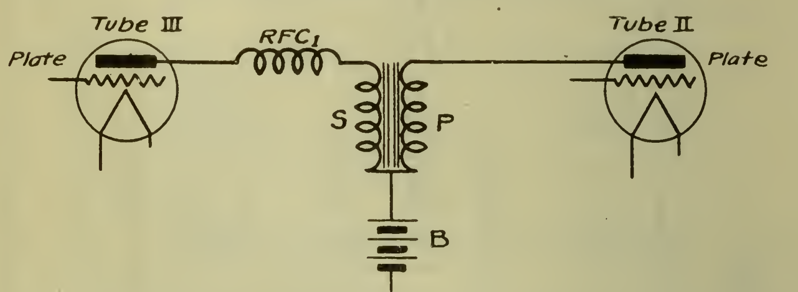
181. A variation of the above method is to make the sum of the *potential* of the plates of tubes II and III constant, instead of having the sum of their currents constant. This is done by replacing LFC_1 (fig. 53) by a transformer, as shown in figure 55. This transformer

has a ratio of 1 to 1; that is, the voltage produced in the secondary is the same as the voltage in the primary. A variation in the current passing through the plate of tube II takes a path through the primary of the transformer and through the battery. The transformer is so arranged that an increase of current through P reacts through the transformer to produce a decrease in voltage at the plate end of the secondary. An increase or decrease in potential of the plate of tube II is therefore compensated by an equal decrease or increase in potential of the plate of tube III. By proper design such an arrangement can be made to work with a transformer of ratio other than 1 to 1.

BUZZER MODULATED RADIOTELEGRAPHY.

182. A radiotelephone transmitting set is readily adapted to send telegraphic signals by means of the buzzer modulator method. An

FIG. 55.



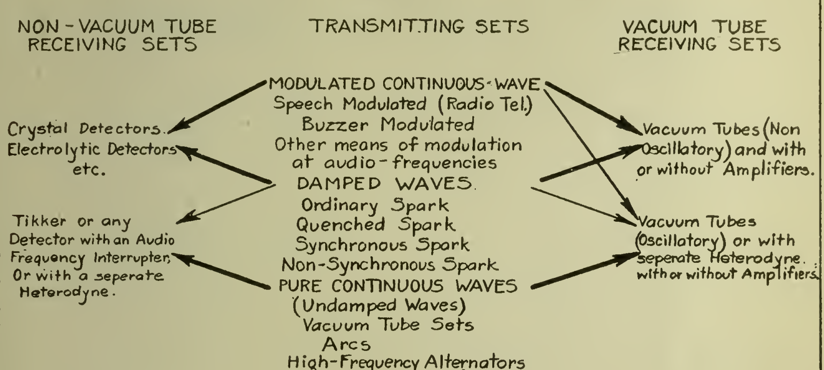
ordinary buzzer replaces the telephone transmitter. The buzzer, by making and breaking the circuit, modulates the output of the transmitter in much the same way as is done by a microphone. The effect is to chop up the output into groups of waves, each succeeding group differing in amplitude from the preceding one but each alternate group having the same amplitude. As there are a number of such groups in the time it takes to make a dot or dash, such transmission can be received by any method suitable to damped wave radiotelegraphy.

WAVE METER.

183. A wave meter is a small powered sending and receiving set with very accurate inductances and capacities determining its wave length. A pointer connected to the shaft moving the variable capacity (the inductance is usually fixed or variable by only one or two steps) moves over a scale which reads in wave lengths. To transmit at a given wave length, have the wave meter act as a receiver. Set

the pointer to the wave length desired. Vary the inductance-capacity value of the transmitting set until the sound in the receiver of the wave meter indicates that the transmitting set is in tune with the wave meter. To tune a receiving station to receive a given wave length, have the wave meter act as a transmitter. Set the pointer to the wave length desired. Vary the inductance-capacity value of the receiving set until the sound in the receiver of the receiving set indicates that it is in resonance with the wave meter. A pamphlet entitled "Theory and Use of Wave Meters" describes this subject in detail.

FIG. 56.



Remarks:
Receiving sets must be capable of being tuned to the wave lengths used by the transmitting station.
Heavy lines show normal methods of reception.

RADIO COMMUNICATION CHART.

184. In order to summarize the various kinds of radio communication, the various types of transmitters and receivers are shown in a chart (fig. 56). This chart also shows the possible methods of reception from any type of transmitter. For example: It is seen from the chart that radiotelephony transmission (speech modulated continuous waves) is usually received by crystal detector or by a non-oscillating vacuum tube, but may also be received by an oscillating vacuum tube.

Engin.

FOR OFFICIAL USE ONLY

Radio Receiving Sets

Type SCR-54
Type SCR-54-A

and

Detector Equipment

Type DT-3-A

Confidential

Radio Pamphlet
No. 3

Signal Corps, U. S. Army

Third Edition, Revised to
10-24-18

Radio Receiving Sets
Type SCR-54 and
Type SCR-54-A
and
Vacuum Tube Detector Equipment
Type DT-3-A

THE RADIO receiving sets, type SCR-54 and SCR-54-A form the standard units for the reception on the ground of signals from airplanes, and in general, of all damped wave signals or modulated wave signals. The principal use for these sets may perhaps be said to be that in connection with the work of the fire control airplanes in directing the fire of the artillery. But in addition, they are used for so many other classes of radio work, that they may indeed be considered among the most important radio sets.

The type SCR-54 set is very similar to the French type A-1 receiving set. The type SCR-54-A set is an improved American product, designed along the same general lines as the type SCR-54 but differing in some respects, both mechanical and electrical, to improve the operating characteristics. The type A-2 and A-2-B antenna units are normally furnished as parts of these sets. These antennæ are fully described in Radio Pamphlet No. 2. With their use the receiving sets have a wave length range of approximately from 150 to 650 meters. If properly operated, they afford quite sharp tuning. This feature and their compact, rugged and simple construction have made them of very considerable value on the Western front.

Type SCR-54 Set

As shown in the wiring diagram, Fig. 1, the type SCR-54 receiving set comprises a primary (antenna) circuit and a secondary circuit, both of which may be tuned by means of the variable capacitance and variable inductance comprised in both circuits. The secondary circuit may also be made aperiodic by placing the switch M on the position marked "AP." This connects the condenser in or disconnects it from the circuit. Across the secondary condenser is connected the detector and telephone circuit. A separate buzzer circuit is installed in the cover of the box to excite the set when adjusting the crystal detector.

The adjustable capacitance in each circuit is a variable air condenser which is adjusted by means of an insulating handle, marked "Primary" or "Secondary," mounted directly on the rotating shaft of the condenser. The relative amount of capacitance in the circuit, corresponding to the various positions of these handles, is indicated by a pointer fastened to the shaft, which moves over a dial graduated from 0 to 90. The position 0 corresponds to the minimum and the position 90 to the maximum capacitance of the condenser. The two condensers are

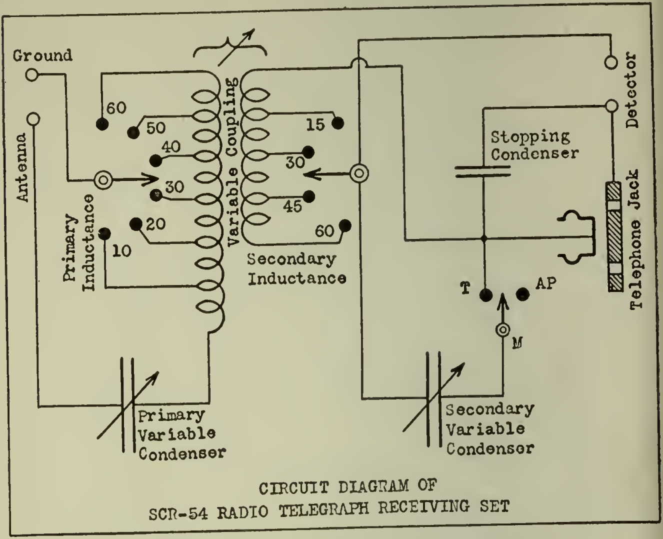


Fig. 1—Schematic Wiring Diagram of the Type SCR-54 Set.

identical in design, and have a maximum capacitance of 500 micro-mfd.

The primary and secondary inductances are varied by means of two dial switches marked "P" and "S," respectively. The primary inductance comprises 60 turns of wire divided into six steps of 10 turns each, while the secondary inductance comprises 60 turns divided into four steps of 15 turns each. These two inductance coils are wound on separate wooden cylinders so arranged that their relative positions may be readily varied.

The coupling of the two circuits, which is accomplished by the mutual induction effect of these two coils, is varied by changing the relative mechanical positions of the coils. The secondary coil may be rotated by means of a handle marked "Coupling," and a pointer moving over a scale graduated from 0 to 90 indicates its position. When in the zero position, the axes of the two coils are at right angles to each other, and the degree of coupling is zero. When in the position "90," their axes are parallel, and the coupling is a maximum.

The telephone and detector circuit shunts the secondary condenser. This circuit consists of a crystal detector connected in series with the telephone receivers, which are shunted by a so-called stopping condenser. The latter is a .002 mfd. mica condenser. Two crystal detectors are furnished with the set; one of them is enclosed in a glass tube, which protects the crystal from dust or dirt. The other is open, having no such protective casing. Either one may be used by screwing it to the two binding posts of the set marked "Detector."

The buzzer circuit is mounted in a compartment of the set box cover, and consists of a small buzzer connected in series with a dry battery, type BA-4 and a switch. The buzzer is energized when this switch is closed.

A spare dry battery for the buzzer, a screw-driver, the enclosed detector, some spare wire and spare crystals are normally stored in compartments or metal clips in the cover. Two type P-11 telephone head sets are kept in a special compartment in the box. The set box, when closed, may be carried by a leather strap attached to it.

Method of Operating

The first step in putting the set in operating condition is to select a suitable place and set up the antenna. The set box is then installed in a dry and protected place, and the aerial and ground (or counterpoise) leads are connected to their respective terminals on the operating panel, and the telephone head set plugged into the jack.

With the installation thus completed, the first step is to adjust the crystal detector. To do this, place the "coupling" handle near the maximum position, and connect a short piece of wire from the terminal clip in the buzzer circuit to the "antenna" or "ground" terminal of the operating panel. Close the buzzer switch to energize the buzzer, and carefully explore the surface of the crystal with the spring contact point until a sensitive spot is found, as evidenced by a good audible sound in the telephone receiver. The short wire running from the buzzer to the panel is then removed and the buzzer stopped by opening the buzzer switch. Care should be taken not to disturb the crystal adjustment by mechanical vibration or shock. This adjustment is very delicate, and, if destroyed, it must be restored before any signals can be received.

With the crystal adjusted, the set is then ready for tuning. The procedure varies somewhat according to whether the wave length of the station it is desired to receive is known or not.

(a) **Wave Length of Signals Unknown.**—The switch M in the center of the panel is thrown to the position "AP" (aperiodic). This disconnects the secondary condenser, and makes the secondary circuit responsive to signals of any wave length. The coupling is made a maximum, and the secondary inductance dial switch S placed at the position "60." The primary inductance switch P is then placed successively at the positions marked 10, 20, 30, 40, 50 and 60, and, at each point, the handle of the primary condenser is slowly turned over its full range, until the loudest signals are obtained in the telephone. The station is then identified by its call letters, and if it is the station desired, tuning of the set is completed as explained below. It may happen however, that in this search for signals, several stations are heard, simultaneously or for different positions of the handles. The process of searching is kept up until the desired station, as identified by its call letters, is heard with the greatest intensity.

The coupling pointer is then moved towards the minimum position, so that the signals will be just loud enough to be easily read. The switch M is placed in the position T (tune), which connects the secondary condenser in the secondary circuit. The secondary circuit is then tuned by operating the secondary inductance dial switch S and the secondary condenser in the same way that was followed in tuning the primary. The secondary circuit is in tune when the signals are heard loudest. The set is then ready for operation.

If necessary, the strength of the signals may be increased by increasing the coupling, but this should not be done unless the signals become too faint to be read, since increasing the coupling increases the likelihood of interference by other sending stations. When the coupling is changed, some slight adjustments of the primary and secondary condensers will be found to improve the signals.

(b) **Wave Length of Signals Known.**—When the receiving operator has been advised of the wave length of the signals he is to pick up, the process of tuning in is somewhat facilitated by the use of the table of wave lengths which is pasted in the cover of the box.

The primary circuit of the set is first tuned, as explained above, with the switch on "AP," the secondary inductance

"60," and with maximum coupling. After the signals have been identified and the primary has been tuned to give maximum loudness, the coupling is reduced as before, and the switch M moved to T. The secondary inductance setting to be used is then given in the table. Thus, for a wave length of 280 meters, the setting may be 30 or 45. It is best to use the higher value 45. The final secondary adjustment is then made as before by means of the secondary condenser.

Use of a Vacuum Tube Detector with the SCR-54 Set

It is sometimes desirable to use a vacuum tube detector in place of the crystal detector supplied with the set. In this case, the telephone stopping condenser of the set must be short circuited by inserting a dummy brass plug in the telephone jack. The crystal detector is then disconnected, and wires are connected from the detector binding posts of the set to the proper terminals of the vacuum tube detector set. The telephone receivers should not be plugged in, as before, in the jack of the set box, but must be connected to the proper terminals or jack of the vacuum tube detector box.

Precautions, Sources of Trouble, Maintenance

In using this set, care should be taken to always keep it in as dry a place as possible. It should be kept in a clean condition, especially the operating panel, the contacts, binding posts, dial switch studs, etc., and the telephone jacks. Oil or grease on these contacts will make the connections uncertain and unsteady and impair or even prevent the satisfactory operation of the set. The set should be handled carefully to avoid warping the condenser plates or otherwise damaging the set. No foreign substance should be placed in the set box.

Care should be taken that the telephone receiver cords do not get wet, for the resulting leakage of current in them would considerably decrease the strength of the signals and introduce annoying noises. The telephones do not require any adjustment, and the ear-pieces should always be kept screwed up tight. The telephone receivers should never be taken apart, since their adjustment at the factory is very accurate and permanent. If it becomes necessary to remove the cord connections from either the telephones or the plug, the wires must be reconnected as found, according to their different colors. This is important since otherwise the permanent magnets will be partially demagnetized and the efficiency of the telephone receivers will be seriously impaired.

In packing the set for transportation, the telephone head set receivers are placed face to face so that the diaphragms will be

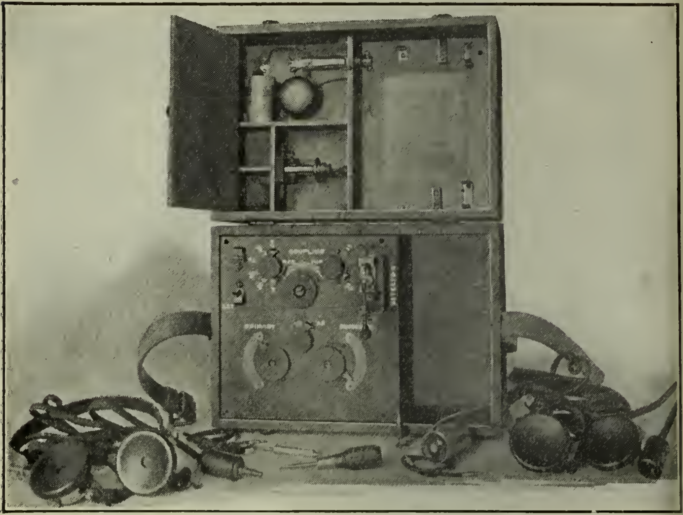


Fig. 2—Operating Panel and Cover Accessories of the Type SCR-54 Set.

protected and kept free of mud and dirt. The telephone cord is then wound around the head band in such a way as to hold the receivers together. The telephone plug is finally slipped inside the coil thus formed by the connection cord, and the entire set is carefully replaced in its compartment in the set box.

Among the troubles most frequently encountered are those considered below.

It may happen that the buzzer does not work. This may be due to a poor adjustment of the buzzer vibrator, or to a run down dry battery.

If the radio set does not work it may be because the crystal detector is not making contact with a sensitive spot. Readjust it with the aid of the buzzer.

No sound in the receivers may be due to the fact that the telephone plug is not all the way in the jack, or that it is dirty. In this case see that the plug is clear in, or remove it and wipe it off with a clean cloth. Also, the dummy brass plug may be in the telephone jack. This would prevent operation entirely with the crystal detector.

Scratching noises in the telephone may be the result of a wet connection cord, or the connection at the plug or at either telephone receiver may be loose.

If the antenna or ground connection is loose, or if the aerial or lead-in wire is grounded through a branch of a tree, or in some other way, the set will fail to operate. Make sure of good insulation all around.

It sometimes happens that a wire will break inside the set box. This generally occurs to one of the wires connecting the secondary inductance coil to the various taps of the secondary dial switch. One way to discover this fault is to turn the "coupling" handle back and forth; the signals may then suddenly stop for a certain position of the handle, although they will be audible with the handle on either side of this position. Finally, a plate of one of the variable air condensers may become warped and short circuit the condenser. This is generally evidenced by the fact that the condenser, when varied over its whole range, does not change the loudness of the signals.

In active service, receiving sets are required to be in continuous working condition. To insure this, spare parts must be kept on hand at all times in order to replace defective parts with the least possible delay. Such spare parts should include spare crystals, telephones and telephone cords. Complete extra sets should always be in stock at the central radio supply station to provide for replacements promptly when sets are destroyed. The sets in use should also be frequently tested to determine their condition and readiness for an intensive and continuous activity. The condenser and inductance circuits should be tested to make sure that each part of each circuit is in perfect working condition. Testing of circuit parts may be simply done with a head phone and dry cell, a click through closed circuits, and the absence of a click through the condenser circuits, being the indication which should be noted.

Reception of Airplane Signals

When receiving signals from an airplane, such as in fire control work, some special precautions are necessary, due to the constantly changing distance between the sending and receiving sets, and the possibility of the airplane going so far away that the signals become too faint to be read.

In the case of a prearranged shoot, the airplane will always fly above or near his receiving station before starting out over the target, and will send his call letters. This will give the receiving operator an opportunity to tune his set. He should tune in accord with the procedure outlined in an earlier paragraph, but he should not reduce the coupling as much as he would if communicating with a ground station. This rule is followed in order that the signals, which grow fainter as the airplane flies farther away, may be audible for the greatest range which will be needed. The operator thus constantly remains in touch with the airplane without readjustment of his set. Once the airplane has reached the target, and his distance to the battery no longer increases, the operator should reduce the coupling in order to reduce interference with the signals from his airplane.

Another point of importance is that sometimes good reception is obtained with the secondary circuit aperiodic (switch M in the position AP), and the primary alone tuned to the sending station. This may occur when very few stations are working, but that adjustment of the set gives no protection against interference from a nearby station which may start to send while communication is going on. It is therefore absolutely necessary to always tune both the primary and secondary circuits.

Type SCR-54-A Set

As previously stated, the SCR-54-A radio receiving set is in many respects identical with the SCR-54 set. A wiring diagram of the former is given in Fig. 3. The main point in which the newer set differs from the SCR-54 set is that the buzzer circuit, instead of being installed independently in the cover of the box, is mounted on the operating panel, with a pull type switch which closes it on the primary radio circuit. The buzzer circuit consists of a dry battery, type BA-4, a small buzzer, a switch, and the first section (10 turns) of the primary inductance coil. The dry battery used to energize the buzzer is mounted in spring clips in the same compartment in which the telephone head sets are packed. The switch is in the center of the panel, and is closed when the button is pulled up. The buzzer winding is shunted by a 45-ohm resistance.

The switch M, which connects or disconnects the secondary condenser, is placed to the right of the buzzer switch, and is marked as on the SCR-54 set.

Only one glass enclosed crystal detector is furnished with this set, and this is permanently mounted on the operating panel. The two binding posts marked "Detector" are to permit the use of a vacuum tube detector or any other kind of detector

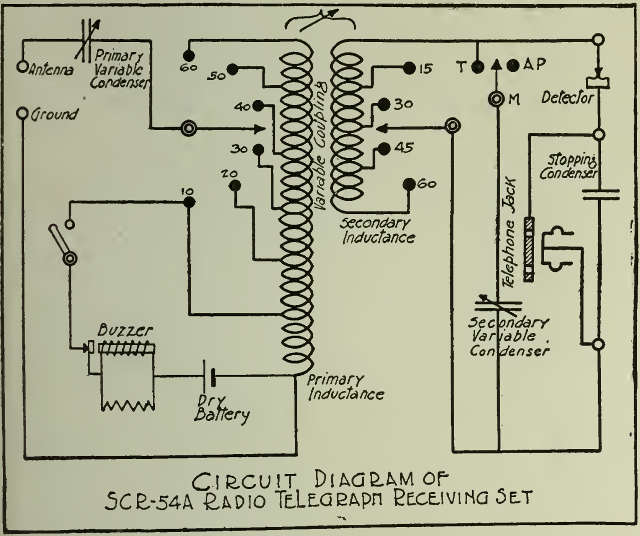


Fig. 3—Schematic Wiring Diagram of the Type SCR-54-A Set.

as explained in a later paragraph. Two emergency telephone binding posts on the operating panel are connected in parallel with the telephone jacks, to allow the use of telephone receivers having no connection plug.

Each set is calibrated individually, throughout the range of wave length, and this greatly facilitates the operation of tuning in, as will be seen below.

In the cover of the box is a screw-driver, a spare dry battery for the buzzer, some spare wire, spare crystals, and replacement parts for the crystal detector. In all other respects, the set is not fundamentally different from the type SCR-54 set.

Method of Operation

The method of operating the type SCR-54-A set will be explained only wherein it differs from that of the type SCR-54 set. The telephone head set is first plugged in, and the coupling handle placed near the maximum position. The buzzer is then energized by pulling out the buzzer switch button. The surface of the crystal is explored with the spring point until a sensitive

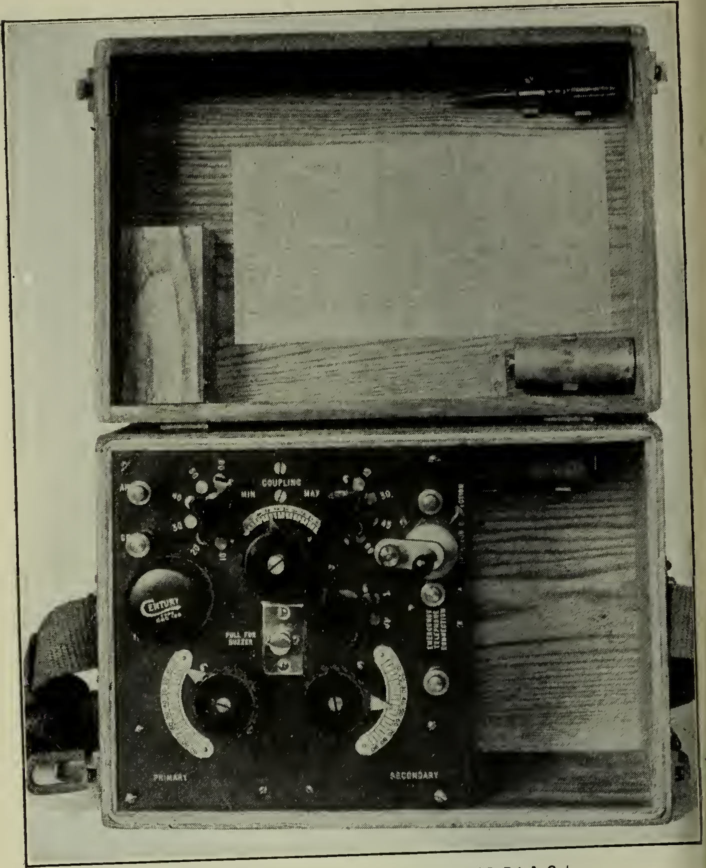


Fig. 4—Operating Panel of the Type SCR-54-A Set.

spot is found. The buzzer switch is then pushed in to stop the buzzer. This should be done gently, so that the vibration will not cause the crystal adjustment to be disturbed.

If the wave length of the signals to be received is unknown to the receiving operator, the method of tuning the set wil be exactly the same as that outlined for the SCR-54 receiving set.

When the wave length of the signals to be received is known, the procedure is quite different. The proper settings of the secondary inductance and of the secondary condenser are obtained from the calibration table pasted in the cover of the set box for the wave length it is desired to receive. The secondary adjustments being thus made, the switch M is placed in the

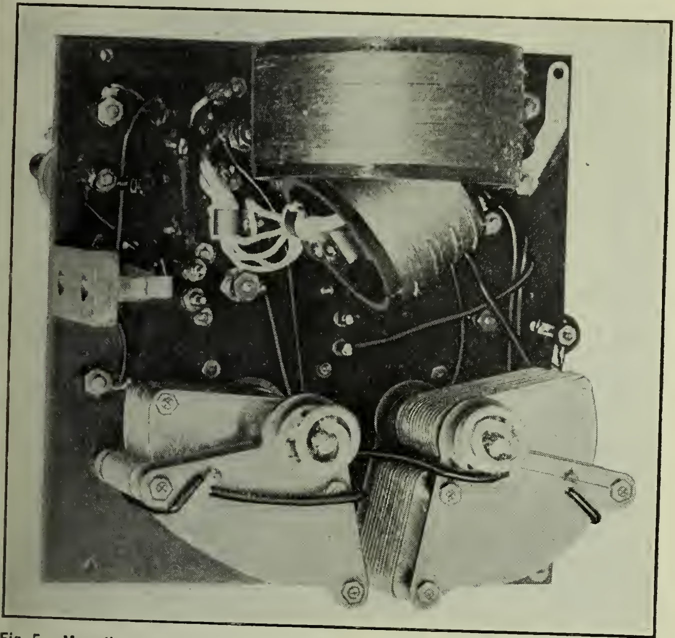


Fig. 5—Mounting of Apparatus on Under Side of Operating Panel, Type SCR-54-A Set.

›osition T, and the coupling handle turned near the "60" or naximum mark. The primary circuit is then tuned by placing he primary inductance dial switch successively in its various ›ositions, and for each position rotating the primary condenser andle until a maximum sound is produced in the telephone eceiver. The coupling handle is then turned toward the ninimum mark so that the signals will be just loud enough to be asily read. Some very slight changes in the settings of both ariable condensers may then be found to improve the tuning.

This method of tuning is very much more rapid and certain than that used with the SCR-54 set. If the value of wave length it is desired to pick up is not marked in the table, the settings of the nearest wave length should be used. Some slight changes in the final adjustments, after the coupling has been reduced, will bring them to the correct value.

It is also possible to tune the set approximately to the wave length which has been predetermined, even before signals are received. The wave length of the secondary circuit is calibrated for all positions of the secondary inductance and capacitance switches. The secondary circuit may thereby be used as a wavemeter for adjusting the primary circuit. This is accomplished as follows:

The secondary inductance and condenser handles are adjusted to the values indicated in the table opposite the wave length nearest to the one at which it is desired to receive. The buzzer is then started and the primary adjusted to produce the maximum sound in the receivers. This will indicate that the primary and secondary circuits are in tune at approximately the desired wave length. The coupling should then be reduced and the set may be considered ready for the expected signals. When these actually come, a slight readjustment of both primary and secondary will probably produce a sharper tuning.

Use of a Vacuum Tube Detector with the SCR-54-A Set

When it is desired to use a vacuum tube detector, or any other form of detector, with the SCR-54-A receiving set, the wire point of the crystal detector of the set should be lifted off the surface of the crystal, and the emergency telephone binding posts short circuited by means of a piece of wire. (If avoidable, do not use the wire furnished in the cover of the box, as this is intended for repairs in case of trouble in the radio circuits of the set.) Wires are then connected from the "Detector" binding posts of the set to the proper binding posts or clips of the vacuum tube detector box. The telephone receiver should not be plugged into the jack of the set, but, instead, should be connected to the proper terminals or jack of the vacuum tube detector box.

For information on "precautions, sources of trouble, and maintenance," and on the special work of "reception from airplanes" with the SCR-54-A set, see the corresponding subheads of the instructions pertaining to the type SCR-54 set, these being identical for both sets.

Vacuum Tube Detector Equipment Type DT-3-A

When using the SCR-54 or SCR-54-A receiving sets for receiving long distance signals, it may be found that the crystal detector of the set is not sensitive enough and will give only very faint signals. A vacuum tube detector may then be used to advantage. Such a device is provided in the Type DT-3-A equipment. While this detector is used primarily with the two

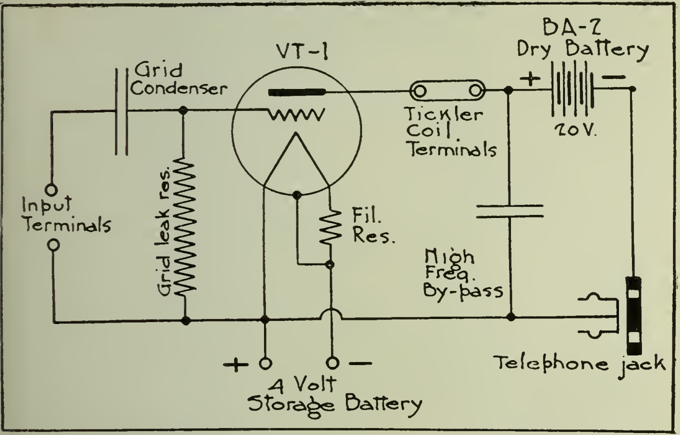


Fig. 6—Schematic Wiring Diagram of the Type DT-3-A Detector Equipment.

receiving sets described in this pamphlet, it does not form a component part of these sets and must be ordered separately, if needed.

A circuit diagram of this equipment is given herewith, from which the principle of operation may be easily understood. The detector comprises an ordinary three-electrode vacuum tube and a grid condenser and grid leak resistance. The filament is heated to the proper temperature by a 4-volt storage battery, and the plate current is furnished by a 20-volt type BA-2 dry battery. The tube used is a type VT-1. No grid battery is required, the grid potential being obtained through the grid leak resistance.

To connect up the vacuum tube detector box to the set box of the type SCR-54 or SCR-54-A set, proceed as directed in the paragraphs under the directions for operating the receiving sets, which are headed "Use of Vacuum Detector, etc." The two wires are brought from the detector terminals of the SCR-54 or SCR-54-A set box to the "Input" terminals of the vacuum tube detector box. The 4-volt storage battery is connected to the "Battery" terminals, with the proper polarity, and the telephone receivers are plugged into the telephone jacks of the vacuum tube detector box. No detector adjustment is required and the operation of tuning in the receiving set is not altered in any way.

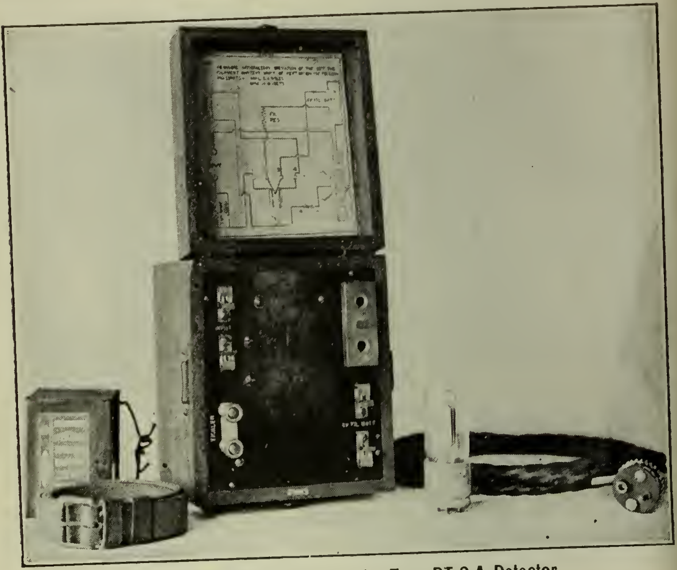


Fig. 7—Operating Panel of the Type DT-3-A Detector.

The DT-3-A equipment also permits the reception of undamped wave signals with the SCR-54 or SCR-54-A receiving set, although this should be considered a makeshift and one not to be depended upon for work of any great importance. To receive undamped waves, connect a suitable tickler coil to the "Tickler" terminals of the detector, after having removed the short circuiting strap which is normally connected across these terminals. Couple this coil with the receiving set inductances with such a degree of coupling that a note will be heard in the telephone receivers. The principle of heterodyne reception is explained in Radio Pamphlet No. 1.

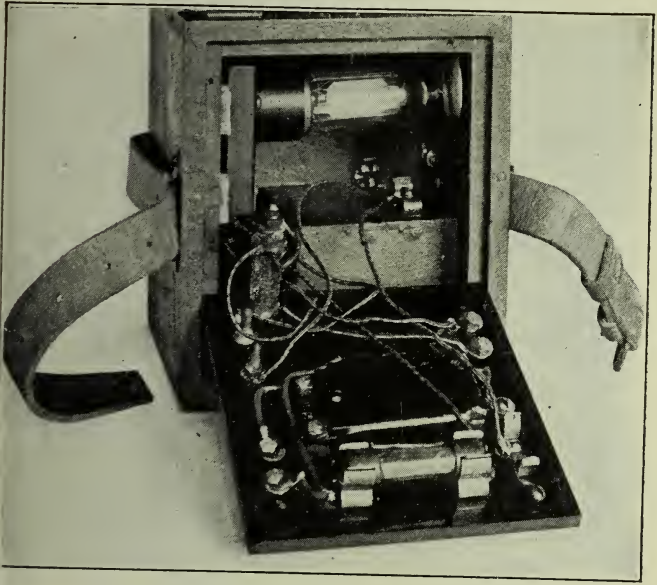


Fig. 8—DT-3-A Panel Removed Showing Vacuum Tube.

Parts Lists

In ordering this set or parts of this set, specification must be made by names and type numbers as listed below, exactly. The designation printed in bold face type *only*, will be used in requisitioning, making property returns, etc.

In ordering *complete* sets, it is not necessary to itemize the parts; simply specify, "2 Sets, Radio Receiving, Type SCR-54." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment, Type RC-1."

The set is not complete unless it includes all of the items listed in the component parts table, below.

SET, RADIO RECEIVING, TYPE SCR-54

EQUIPMENT, TYPE RC-1; Receiving

- 1 **Set Box, Type BC-14**; receiving
- 1 **Strap, Type ST-5**; carrying, for BC-14
- 2 **Head Sets, Type P-11**; telephone
- 4 **Crystals, Type DC-1**; mounted detector; 1 in use, 3 spares
- 2 **Batteries, Type BA-4**; buzzer; 1 in use, 1 spare
- 1 **Screwdriver, Type TL-2**; Stanley No. 25, or equivalent, 4 in. long
- 30 ft. **Wire, 7-Strand, No. 30 B&S Gauge, Rubber Covered, White Silk, Braided**; spare
- 3 **Springs, Detector Contact**; 1 in use, 2 spares

EQUIPMENT, TYPE A-2; Antenna

- 2 **Mast Sections, Type MS-1**; top; same as type MS-2, but without steel coupling tube
- 8 **Mast Sections, Type MS-2**; intermediate
- 6 **Guys, Type GY-1**; 43 ft., complete
- 3 **Guys, Type GY-2**; 22 ft., complete
- 4 **Reels, Type RL-3**; hand; one for antenna and lead-in wire, and one for each set of 3 guys
- 6 **Stakes, Type GP-1**; guy; 3 in use for each mast
- 2 **Plates, Type MP-2**; upper guy; complete with mast tube; one for each mast
- 1 **Plate, Type MP-3**; lower guy; for 29-ft. mast
- 2 **Plates, Type MP-1**; antenna, complete with Electrose No. 4500 insulators connected to plate with closed wire link; other end provided with open wire hook to receive antenna wire thimble

1 **Antenna, Type AN-1;** 150 ft. antenna wire with thimble at each end; the thimble for the 29-ft. mast end has connected to it a 50-ft. lead-in of No. 16 B&S gauge, single conductor, new code lamp cord, weather-proofed

2 **Connections, Type GD-1;** ground; ground mat with 20 ft. No. 16 B & S gauge, single conductor, new code lamp cord, weather-proofed; 1 in use, 1 spare

2 pr. **Bags, Type BG-1;** carrying; for masts

1 **Bag, Type BG-2;** carrying, for antenna and accessories

1 **Hammer, Type HM-1;** 2 lb.; two-face engineer's 16-in handle

1 **Twine, Type TW-1;** coil; 35-ft.; for measuring distance of guy pins from masts

1 **Marker, Type MR-1;** guy pin; for locating direction of ground pins from masts

SET, RADIO RECEIVING, TYPE SCR-54-A

QUIPMENT, TYPE RC-1-A; Receiving

1 **Set Box, Type BC-14-A;** radio receiving; weight, 11 lb. 8 oz.

1 **Strap, Type ST-5;** carrying, for BC-14-A

2 **Head Sets, Type P-11;** telephone

6 **Crystals, Type DC-1;** detector, mounted, spare; galena

2 **Batteries, Type BA-4;** dry; for buzzer; 1 in use, 1 spare

1 **Screwdriver, Type TL-2;** Stanley No. 25, 4 in. long, or equivalent

30 ft. **Wire, Type W-20;** wound in coil; 1½ in. outside diameter

2 **Springs, Type M-14;** detector contact; spares

QUIPMENT, TYPE A-2-B; Antenna

6 **Mast Sections, Type MS-5;** bamboo; 13 ft. long; iron tipped at both ends; total weight, 16 lb.

6 **Insulators, Type IN-7;** mast top; 3 in use, 3 spares

750 ft. **Wire, Type W-1;** antenna; No. 22 B & S gauge, 7 strand, soft tinned copper, bare; net weight 8 lb. 12 oz.; to be in one piece and wound on spool of 6 in. outside diameter

75 ft. **Wire, Type W-4**; lead-in; No. 16 B & S gauge, modified N. E. C. lamp cord, Spec. 3040. wound on 8 in. coil; total weight, 1 lb. 8 oz.

2 lb. **Wire, Type W-2**; No. 14 B & S gauge, soft drawn copper, bare; in one piece wound in 7 in. coil

1 **Mat, Type MT-2**; ground; 9 ft. x 20 in.; total weight, 3 lb. 4 oz.

14 **Stakes, Type GP-3**; ground; 1 in. x 1 in. x 1/8 in. angles; total weight, 35 lb.

8 **Insulators, Type IN-5**; hard rubber; 5 1/2 in. x 5/8 in.; total weight, 10 oz.

6 **Couplers, Type FT-2**; pole; 4 in. x 5 in. x 1 in.; total weight, 4 lb.

200 ft. **Cord, Type RP-3**; sash; No. 5; olive drab

4 **Reels, Type RL-3**; hand; 11 3/4 in. x 10 in.

1 **Pliers, Type TL-20**; universal; 8 in.; similar to Fairbanks combination pliers No. 70; drop forged steel with blue handle and polished head

1/4 lb. **Tape, Friction, Spec. 569-B**; 3/4 in.

1 **Hammer, Type HM-1**; 2 lb.; 16 in. handle

1/4 lb. **Marlin, Type RP-2**; wound in 2 coils

CHEST, TYPE BC-26; carrying

Carrying Units

The above parts of the type SCR-54-A set are assembled in two carrying units, as follows:

1. Carrying Chest; 1 ft. 3 7/8 in. x 3 ft. 9 5/8 in. x 11 1/2 in. containing receiving and antenna equipments, but not including bamboo masts; total weight, 155 lb.
2. Six Bamboo Mast Sections; 13 ft. long; total weight, 16 lb.

EQUIPMENT, TYPE DT-3-A; Vacuum Tube Detector

1 **Set Box, Type BC-19-A**; vacuum tube detector; 7 1/2 in. x 7 1/8 in. x 6 5/8 in.; weight, 4 lb. 12 oz.

1 **Strap, Type ST-6**; carrying; 2 ft. 8 in. x 1 in. x 1/8 in.

2 **Tubes, Type VT-1**; vacuum; 1 in use, 1 spare

2 **Batteries, Type BA-2**; dry; 1 in use, 1 spare

2 **Cords, Type CD-40**; extension; 6-ft., No. 16 B & S gauge, 2-conductor, battery plug on one end, spade clips on other end; 1 in use, 1 spare

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

CONFIDENTIAL! *For Official Use Only*

Airplane Radio Telegraph Transmitting Sets

Type SCR-65
Type SCR-65-A

RADIO PAMPHLET No. 5

Second Edition, Revised to November 16, 1918

Signal Corps, U. S. Army

Washington : Government Printing Office : 1918

AIRPLANE RADIO TELEGRAPH TRANSMITTING SETS

Types SCR–65 and SCR–65–A.

THE GENERAL use for which the radio telegraph transmitting sets, types SCR-65 and SCR-65-A are intended is that of sending messages from airplanes to the ground. The type SCR-65 set is modeled after the Sterling type transmitting set, which is used almost exclusively by the British in artillery fire-control work. The type SCR-65-A set differs from the type SCR-65 only in minor details. Both have proved very efficient and well suited to conditions of actual warfare on account of their simplicity and ruggedness. They are tuned spark-coil transmitting sets, producing damped waves. When used with

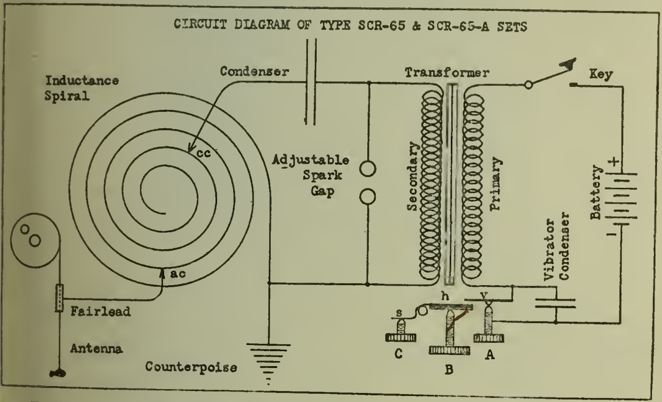


FIG. 1.—Schematic Wiring Diagram of the Type SCR-65 Set.

the usual airplane trailing antenna, 150 to 250 ft. in length, and with the bonded wire stays of the machine as a counterpoise, the wave length is from 100 to 300 meters, depending upon the adjustments.

The essential parts of either set are the spiral tuning inductance, the induction coil, spark gap and sending condenser. The induction (or spark) coil, sending condenser and spark gap are mounted in a box measuring $7\frac{7}{16} \times 6\frac{3}{8} \times 3\frac{1}{4}$ in. over all. The flat spiral of 12 turns of $\frac{1}{4}$-in. brass strip and four binding posts, marked "Antenna," "Counterpoise," "Key," and "Battery," are mounted on a hard rubber panel set in the top of the set box. Hard rubber markers are placed at a number of different points around the spiral to indicate the position of connection for the condenser clip for various wave lengths of the closed oscillatory circuit.

Fig. 1 shows the diagram of connections for either the type SCR–65 or type SCR–65–A set. It will be noticed that the tuning inductance of the closed oscillatory circuit is the same coil as the tuning inductance of the open oscillatory circuit, thus giving conductive and inductive coupling between the two circuits. Selectivity between sets is obtained by differing the transmitted wave length and also by differing the spark tone according to predetermined schedules. The change in tone is accomplished by the adjustment of the vibrator on the induction coil.

The vibrator, as shown in Fig. 1, consists of a hammer *h* which is held against the screw B by the tension of the spring *s*. This iron hammer is mounted opposite one end of the transformer core and at a distance from it which may be varied by means of the screw B. The vibrator spring blade *v* projects out into the gap between the hammer *h* and the core and normally rests against the contact point of the screw A. The principle of operation of this vibrator is as follows:

As the telegraph sending key is closed, the current from the battery flows in the primary circuit, comprising the screw A, spring blade *v*, and primary coil of the transformer. A magnetic field builds up in the latter, increasing until it is strong enough to overcome the tension of the hammer spring *s*, at which time the hammer *h* is attracted toward the core. After leaving the screw B on which it was resting, the hammer strikes the end of blade *v*, which, upon being lifted off the tip of screw A, breaks the primary circuit, thus stopping the current flow in it, and the hammer falls back, due to the tension of spring *s*. This, however, permits the blade *v* to reestablish contact with A, closing the primary circuit, and the operation repeats itself.

It will be seen from the above discussion that the strength of the magnetic field, and therefore the intensity of the primary current, required to lift the hammer from its position, depends on the spring tension adjustment (screw C) and on the hammer stroke adjustment (screw B). Also, as the hammer is moved by means of the screw B, it is necessary to adjust the vibrator contact screw A in order to keep the blade *v* in proper position. The method of making these adjustments is explained in a later paragraph.

In order to reduce the sparking at the vibrator and make the break quicker a 0.6 mfd. condenser is shunted across the contact points.

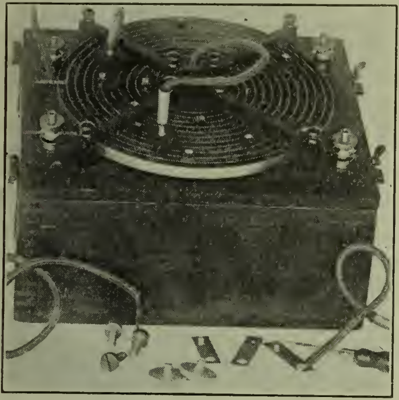


Fig. 2.—Inductance Spiral on Set Box Type BC–15 of the Type SCR–65 Set.

The spark gap consists of two zinc electrodes, one of which is mounted on a finely threaded brass screw with a knurled hard rubber handle by means of which the length of the gap may be readily adjusted. The stems of the two electrodes are provided with cooling flanges which cool the electrodes by increasing the area of contact with the surrounding air. This, together with the metal of the electrode sparking surface, results in a fairly good quenching action of the gap.

The sending condenser is made up of 15 sheets of brass placed alternately between 16 sheets of mica and inclosed in a fiber case. The capacity is approximately 0.009 mfd.

Method of Operation.

The set is adjusted on the ground before being installed in the airplane. A phantom antenna is used for this purpose, having the same inductance, capacitance, and resistance as the particular airplane antenna to be used in the flight. The 10-volt storage battery and a telegraph sending key (or a switch) are connected to the "Battery" and "Key" terminals of the set box, while

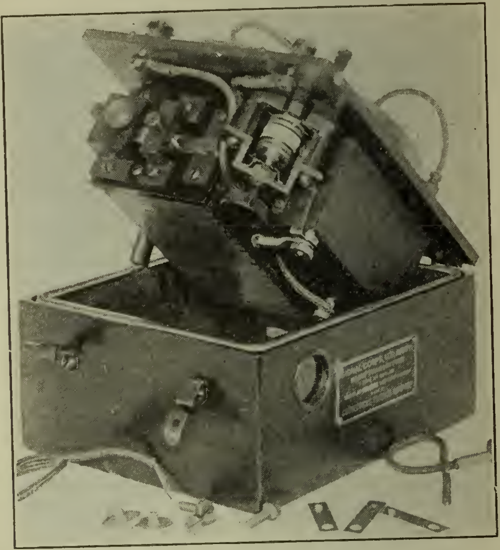


FIG. 3.—Induction Coil, Spark Gap, and Condenser Mounting in Typ BC–15 Set Box of the SCR–65 Set.

the phantom antenna is connected to the "Counterpoise" an "Antenna" terminals. A hot wire ammeter should be include in the phantom antenna circuit. The method of adjusting th set is then as follows:

1. Place the closed circuit clip, *cc* (the clip coming out of th center of the panel) on the spiral inductance next to the mark corresponding to the wave length at which it is desired to tran mit. This will make the constants of the closed oscillatory ci

:uit of such values as to give it the natural wave length marked ›n the spiral inductance. As may be seen on the circuit diagram, Fig. 1, the closed oscillatory circuit comprises the spark gap, the fixed sending condenser, and that part of the inductance spiral connected in the circuit by the closed circuit clip *cc*.

2. Open the box by lifting the operating panel and loosen the spark gap clamping screw.

3. Turning the movable spark gap electrode, bring the two electrodes together so they will just touch, and note the position of the movable electrode adjusting screw knob. Then open the spark gap by turning this screw back three-quarters turn to one turn, and tighten the clamping screw.

4. Place the antenna clip *ac* (the clip coming from the "Antenna" binding post) on the inductance spiral one turn away from the closed circuit clip. This will couple the antenna circuit to the closed oscillatory circuit.

5. Adjust the vibrator, proceeding as follows:

(*a*) Loosen the vibrator clamping screws just enough to allow adjusting.

(*b*) Loosen the hammer stroke adjusting screw B, and tighten the hammer spring adjusting screw C so that the hammer stands well away from the vibrator spring *v*.

(*c*) Make sure that the vibrator contact points A are clean, and directly in line, one above the other.

(*d*) Adjust the vibrator contact screw A until it just makes contact with the vibrator spring, and then tighten it up another one-quarter or one-half turn.

(*e*) Tighten screw B until the hammer almost touches the contact spring.

(*f*) Loosen screw C until contact with the hammer tension spring is barely made. This will decrease the current in the primary winding.

(*g*) Close the telegraph key, and if required make such slight readjustments of A, B and C (in the order mentioned) as will produce a clear tone with minimum sparking at the vibrator. Adjustments of B and C should always be made in opposite directions, so that the tension of the hammer spring will remain about the same. Also make a slight adjustment of the spark gap, so that white sparks will occur, these taking place between various points on the electrode surface.

(*h*) Set all clamping screws.

6. Close the set box.

7. Tune the antenna circuit by moving the antenna clip *ac*, along the inductance spiral while the telegraph key is closed, until a point is found giving maximum current on the antenna hot wire ammeter. At this point, the clip is securely fastened.

8. The vibrator should now be readjusted slightly so that the set will produce fairly good radiation with the least sparking at the vibrator contact points.

9. Disconnect the phantom antenna and install the set on the airplane.

Installation of the Set.

The method of installing the set on an airplane varies with the type of machine. The fittings required are furnished by the Bureau of Aircraft Production. The principles underlying the installation of the type SCR–65 or SCR–65–A sets are the following:

The set box and storage battery should be mounted near each other, so that the connecting leads may be as short as possible, in order to reduce to a minimum the energy losses in those wires. Also, the set box should be of easy access, as it is almost always necessary to remove it from the plane for tuning and inspection. In fact, a frequent practice is to have a number of sets all ready and tuned on the ground, so that when an airplane comes down to the ground with a defective set, another may be substituted immediately. To effect this, a sliding wooden tray is often used, on which the set box is mounted together with its battery. It is then simply necessary to make the connections to the "Counterpoise" and "Key" binding posts of the set box.

In service, the vibrator contacts soon become pitted due to sparking, and then give a ragged spark and greatly lower the efficiency of the set. The contacts must therefore be watched closely and kept smooth by the use of a very fine, flat file or replaced with the spare contacts provided. The antenna, counterpoise, battery and key leads should be attached securely to their respective binding posts so that the vibration of the airplane will not loosen them and make the set inoperative at possibly a critical moment. It should be noted that the key is not mounted on the box containing the set. The keys used are of a special airplane type (type J-7), and are mounted on small battens located at the sides of the cockpits, Fig. 4, one on either side of the pilot's cockpit and one on the right of the observer. These are all connected in parallel.

The zinc spark electrodes should be removed at regular intervals and cleaned and trued up. When the electrodes are in place, the faces should be exactly opposite and parallel. A zinc oxide deposit is formed around them and should be removed frequently. It is very essential that this set be thoroughly inspected before being used in the air.

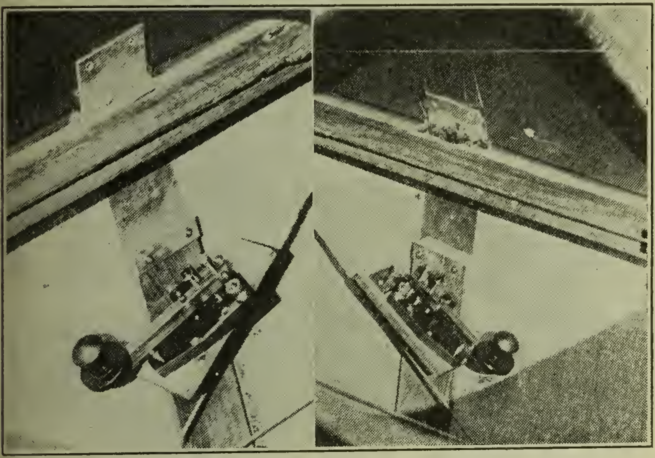


FIG. 4.—Mounting of Sending Keys on Either Side of Pilot.

PARTS LISTS.

In ordering this set or parts of this set specification must be made by names and type numbers as listed below, exactly. The designation printed in bold face type *only*, will be used in requisitioning, making property returns, purchasing, etc.

In ordering *complete* sets, it is not necessary to itemize the parts; simply specify, "2 Sets, Airplane Radio Telegraph Transmitting, Type SCR-65." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment, Type RT-1."

These sets are not complete unless they include all of the items listed below under the respective set names.

SET, AIRPLANE RADIO TELEGRAPH TRANSMITTING, TYPE SCR-65.

EQUIPMENT, TYPE PE-21; Power.

2 Batteries, Type BB-11; lead storage; Liberty; 8 volts; discharge rate 3 amp. for 3 hours; 1 in use, 1 spare.

EQUIPMENT, TYPE RT-1; Transmitting.

1 Set Box, Type BC-15; airplane radio telegraph transmitting.

1 Stone, Type TL-3; carborundum, No. 53 medium India.

1 Screwdriver, Type TL-4; steel wire; 5 in. long.

3 Contacts, Type CN-3; upper; vibrator; spare.

3 Contacts, Type CN-4; lower; vibrator; spare.

2 Electrodes, Type CN-5; spark gap, spare.

1 Switch, Type SW-9; battery.

2 Keys, Type J-7.

1 Cord, Type CD-27; extension; BC-15 to ground.

1 Cord, Type CD-28; extension; BC-15 to fairlead.

1 Cord, Type CD-29; extension; BC-15 to battery.

1 Cord, Type CD-30; extension; battery and set box to observer's key and switch.

1 Cord, Type CD-31; extension; observer's key to switch.

1 Cord, Type CD-32; extension; observer's key to pilot's key

6 Lamps, Type LM-3; for blinker keys; 2 in use, 4 spares.

EQUIPMENT, TYPE A-21; Antenna.

1 Reel, Type RL-2; antenna.

2 Drums, Type DR-2; antenna reel.

3,000 ft. Wire, Type W-5; probable maximum length of antenna, 300 ft.

10 Weights, Type WT-1; antenna; 1 in use, 9 spares.

2 Fairleads, Type F-1; type F-2 when type F-1 is not available; 1 in use, 1 spare.

20 ft. Cord, Type RP-6; approximately 2 ft. in use.

SET, AIRPLANE RADIO TELEGRAPH TRANSMITTING. TYPE SCR-65-A.

EQUIPMENT, TYPE **PE-21**; Power.

2 Batteries, Type BB-11; lead storage; Liberty; 8 volts; discharge rate, 3 amp. for 3 hours; 1 in use, 1 spare.

EQUIPMENT, TYPE **RT-1-A**; Transmitting.

1 Set Box, Type BC-15-A; airplane radio telegraph transmitting; weight, 6 lb. 12 oz.

1 Stone, Type TL-3; carborundum; medium India; No. 53.

1 Screwdriver, Type TL-4; steel wire; 5 in. long.

1 Screwdriver, Type TL-22; for spark coil clamping screws; similar to Stanley No. 55; 1½-in. blade, $\frac{5}{32}$ in. diameter; ⅛-in. tip; 4 in. over all.

3 Contacts, Type CN-3; assemblies; spare.

3 Contacts, Type CN-4; assemblies; spare.

2 Electrodes, Type CN-5; spark gap; spare.

1 Switch, Type SW-14; battery.

2 Keys, Type J-7; with winker light sockets.

6 Lamps, Type LM-3; for keys; 2 in use, 4 spares.

30 ft. Cord, Type W-8; lamp; No. 16 B. & S. gauge, special braid, N. E. C.; wound on 8-in. coil; total weight, 1 lb. 6 oz.

15 ft. Cable, Type W-9; high tension; Packard; No. 30 B. & S. gauge, 40-strand; outside diameter of cable, $\frac{31}{64}$ in.; wound on 8-in. coil; total weight, 3 lb.

1 Lead, Type CD-2; spiral inductance; 11⅝ in. long; spare.

1 Lead, Type CD-3; spiral inductance; 6⅝ in. long; spare.

EQUIPMENT, TYPE **A-21**; Antenna.

1 Reel, Type RL-2; antenna.

2 Drums, Type DR-2; antenna reel.

3,000 ft. Wire, Type W-5; Antenna; probable length of antenna, 300 ft.

10 Weights, Type WT-1; antenna; 1 in use, 9 spare.

2 Fairleads, Type F-1; type F-2 when type F-1 is not available; 1 in use, 1 spare.

20 ft. Cord, Type RP-6; approximately 2 ft. in use.

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

FOR OFFICAL USE ONLY

LOOP RADIO TELEGRAPH SET
TYPE SCR-77-A

Radio Communication Pamphlet No. 6

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

January, 1923

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

CERTIFICATE: By direction of the Secretary of War the matter contained herein is published as administrative information and is required for the proper transaction of the public business.

WAR DEPARTMENT
Document No. 1115
Office of The Adjutant General

WAR DEPARTMENT,
WASHINGTON, *January 30, 1923.*

The following publication, entitled "Loop Radio Telegraph Set, Type SCR–77–A," Radio Communication Pamphlet No. 6, is published for the information and guidance of all concerned.

[A. G. 062.1 (1–9–23).]

BY ORDER OF THE SECRETARY OF WAR:

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

OFFICIAL:
ROBERT C. DAVIS,
The Adjutant General.

TABLE OF CONTENTS.

LOOP RADIO TELEGRAPH SET, TYPE SCR-77-A.

Section I.

PURPOSE OF SET—RANGES.

1. *Purpose of set—Ranges.*—The Loop Radio Telegraph Set, Type SCR-77-A, is a light portable vacuum tube transmitting and receiving set, designed to furnish radio telegraph communication between units whose headquarters are usually from 3 to 5 miles apart. It will furnish reliable communication up to 3 miles. Under favorable conditions, such as open terrain, etc., this distance is increased to 5 miles. The range of wave length is from 74 to 76 meters and the set is so arranged that there are nine different wave-length settings in this range. Thus, nine stations in a communication net can work together without interference.

Section II.

GENERAL DESCRIPTION OF SET.

2. *Special features of the set.*—In addition to the arrangement which enables tuning so sharp that nine stations can work with a wave-length range of 2 meters, the set has a loop antenna and a "break-in" feature. The use of the loop antenna enables the set to be so designed that it is very portable and quickly set up. A moving unit furnished with this set can keep in constant communication within its transmitting range with other units furnished with a like set. The loop antenna is small and of low visibility, as its height when set up is only 4 feet. The break-in feature enables the receiving station, which must also be an SCR-77-A set, to interrupt the transmitting station at any time. This greatly facilitates communication. There is no change in the adjustment needed to reverse the direction of communication. Another feature of the set lies in the fact that, because of its method of reception, it is practically im-

possible to have a set receiving signals interferred with by a radio station transmitting damped waves.

3. *Carrying units of set—Weight and bulk.*—The whole set is assembled in five carrying units, each provided with a carrying strap. The loop antenna folds up and is carried in a bag, which is $28\frac{1}{2}$ inches long, $4\frac{1}{2}$ inches in diameter, and weighs 6 pounds with the loop in it. The transmitting and receiving apparatus is in an operating chest measuring $14\frac{5}{8}$ inches by $9\frac{15}{32}$ inches by $12\frac{9}{32}$ inches high and weighs $20\frac{1}{2}$ pounds complete. The four-volt storage batteries are carried in a case measuring $5\frac{5}{32}$ by $10\frac{9}{16}$ inches by $8\frac{13}{16}$ inches high and weighing 27 pounds with the batteries in it. The equipment box has two distinct compartments, one of which carries the dry batteries and the other the spare vacuum tubes and the telephone head set. Its dimensions are 13 by $4\frac{5}{8}$ inches by $15\frac{5}{16}$ inches high, and when filled it weighs $17\frac{1}{2}$ pounds. The spare transmitting dry batteries, which like those in use are contained in a wooden case, are carried in a carrying bag which measures 10 by $3\frac{1}{2}$ inches by 8 inches, and weighs $7\frac{1}{2}$ pounds with the case in it. The case containing the transmitting dry batteries in use is contained in the equipment box. There is room for two extra BA–2 dry batteries in the carrying bag in addition to the case. It is a wise precaution to carry these two extra batteries, though they are not provided in the parts list. They weigh only 15 ounces each.

SECTION III.

DETAILED DESCRIPTION OF THE SET.

4. *The radio transmitter and receiver* (*type BC–9.*)—The transmitting and receiving apparatus is assembled in one operating chest. There are three VT–1 vacuum tubes used in the set. One of these is used as an oscillator. At the same time this oscillating tube acts as a detector. The other two tubes are used as audio-frequency amplifiers. Associated with these tubes are the various capacities, inductances, resistances, transformers, etc., necessary for their operation. The equipment, except for the head set, the loop and the plate batteries, is self-contained in the chest. The back of the operating chest is provided with sockets for connecting the loop antenna. The operating chest, when the set is in use, is placed on the equip-

ment box and is provided with hooks to which clamps on the battery box can be fastened. All the controls necessary for sending and receiving are mounted on a panel, a view of which is shown in Figure 1. The legend used is as follows:

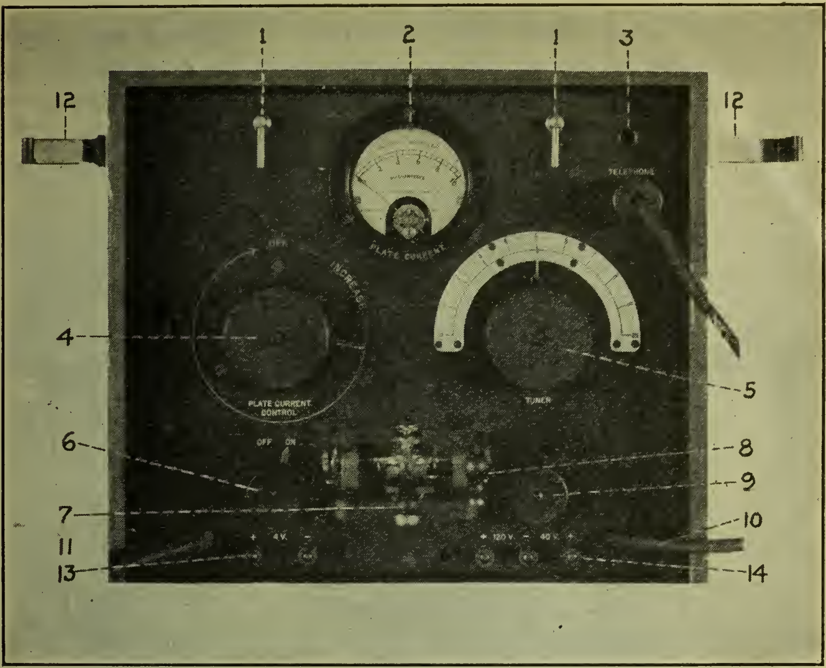


FIG. 1.

1. Fasteners to lock panel in place. 2. Direct-current milliammeter (0–10). 3. Telephone jacks. 4. Plate current control; controls grid circuit potentiometer. 5. Tuner graduated from 0–10; controls a variable air condenser. 6. Battery switch; turns off and on the filament battery and also the potentiometer battery. 7. Telegraph key. 8. Switch for short-circuiting telegraph key. 9. Fine adjustment control for tuner. 10. Cord to plate batteries. 11. Cord to filament battery. 12. Fastener to lock up front of box. 13. Auxiliary binding posts for filament battery. 14. Auxiliary binding posts for plate batteries.

The panel is protected by a cover which is hinged at the lower end. When lowered it rests upon the projecting end of the equipment box, thus forming a shelf for the operator. The telegraph key is hinged and is to be pushed up against the panel when the front of the chest is closed. Electrical connections to the key are provided by knife contacts, all flexible leads being eliminated in this way. The panel is locked in position when the handles of its fasteners are pointing downward. Turning the handles in either direction to the horizontal position unlocks the panel, which may be swung forward, as it is hinged at the bottom.

The back of the box is a wooden panel which has been specially treated so that it will not absorb moisture. Various pieces of apparatus are mounted on the inside of this panel. A small single-leaf condenser used in calibrating the set is so mounted. The adjustment of this condenser is made by means of a machine screw projecting through the wood panel, thus being made accessible on the outside of the chest.

The bakelite panel can be entirely removed from the box by swinging it forward and then lifting it from its bearings and disconnecting the three flexible leads connected to the floor of the box. Figure 2 shows the view when the panel is swung forward as for putting in vacuum tubes or dry batteries. Figure 3 shows a view of the apparatus entirely removed from the box. The legend used in these two figures is as follows:

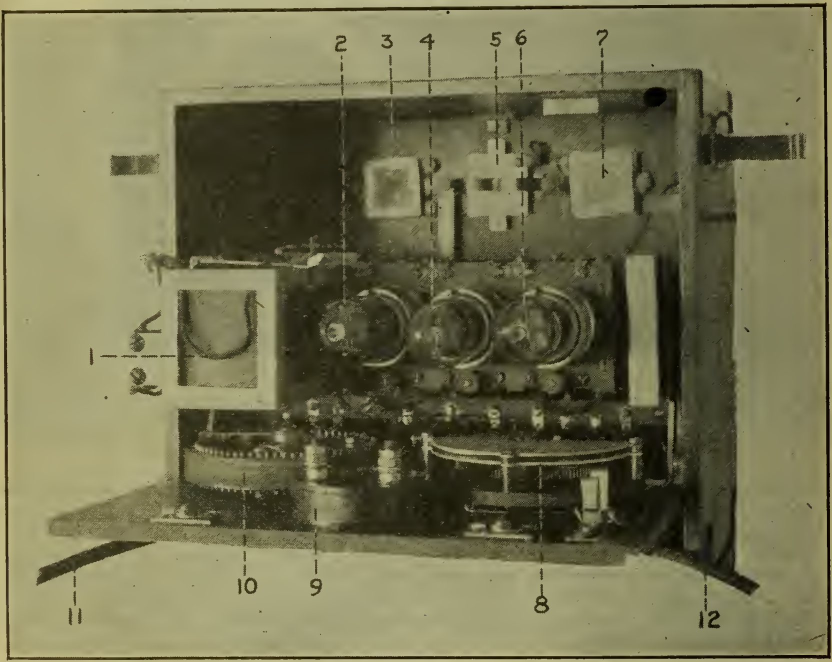


Fig. 2.

1. BA–2 battery for potentiometer. 2. VT–1 oscillator tube. 3. Grid oscillatory circuit condenser (1745 m. m. f.). 4. First audio-frequency amplifier tube. 5. Single-leaf variable condenser used in calibrating set. 6. Second audio-frequency amplifier tube. 7. Plate oscillating circuit condenser (720 m. m. f.). 8. Variable air condenser (tuner). 9. 0–10 d. c. milliammeter in plate circuit of oscillator tube. 10. Potentiometer for varying grid-filament biasing potentiometer of oscillator tube. 11. Filament circuit cord to storage battery. 12. Plate circuit cord to dry batteries (3-conductor). 13. One-to-one ratio transformer coupling plate circuit of second audio-frequency amplifier tube to telephone head set. 14. Two 5,000 resistances, forming part of potentiometer circuit. 15. Filter-circuit inductances. 16. Filter-circuit condensers. 17. Switch-controlling filament and potentiometer circuits. 18. Transformer (C–21) coupling oscillator tube plate circuit to first audio-frequency amplifier tube. 19. Stopping condenser (0.02 m. f.), prevents direct-current potential on oscillator tube plate from reaching the grid. 20. Transformer (C–21) coupling first audio-frequency amplifier to second audio-frequency amplifier.

It is to be noted that much of the apparatus is mounted on the tube shelf which rests on sponge rubber in order to minimize noise in the receiver due to shocks and vibration. If it ever becomes necessary to remove the rear panel, the three copper strip connections going to the floor of the box should be disconnected by removing the screw at the upper end of each one.

5. *The loop* (*type LP–2*).—The loop is a single-turn one made of brass tubing provided with hinges so that it can be folded up to fit in its carrying case. The joints are provided with wing nuts to enable the loop to be firmly fastened together. The threads at the ends of the bolts on which the wing nuts screw are scored so as to

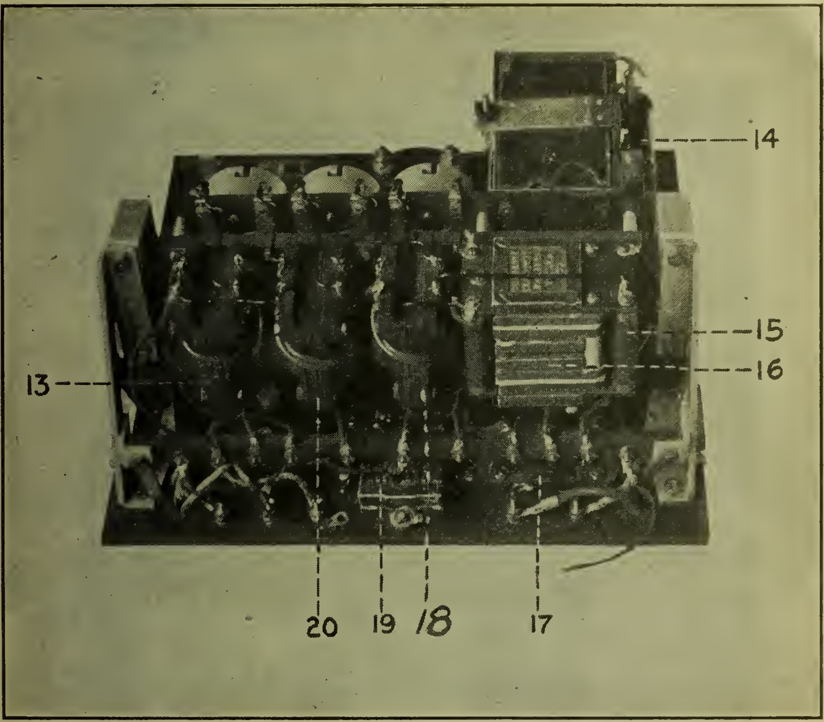


FIG. 3.

prevent the removal or loss of the nuts. Two slotted supports for the loop are provided on the back of the operating chest, and the ends of the loop are made to fit firmly into these supports. The length of the loop is 48 inches, and its height from the support is 36 inches. The whole loop is given an extra heavy black nickel finish.

6. *The equipment box*, *type BE–48*.—This box carries auxiliary equipment and serves as a base upon which is fastened the operating chest when the set is in use. There are two main compartments in the box, one of which contains the dry batteries furnishing the plate potentials for the tubes. A view of the box showing this compartment is shown in Figure 4. The other main compartment which

is also furnished with a cover on the opposite side to the one shown in the illustration carries three spare vacuum tubes and a telephone head set. The box is fitted with clamps for the covers, a carrying strap, and means of fastening the operating chest to it. The leads from the batteries carried in the box are brought to a jack having tip, ring, and sleeve connections. Into this is plugged the telephone plug on the cord leading to the operating chest. The jack is inside

FIG. 4.

of the equipment box, but a small recess is provided to allow the cover to be clamped down over the cord.

7. *Dry batteries used with the set.*—There are nine type BA–2 dry batteries used with the set. Six in series furnish plate potential for the oscillator tube; two in series furnish plate potential for the amplifier tube; and one is used in the potentiometer circuit. The po-

tentiometer battery is mounted within the operating chest; the two amplifier tube batteries are carried in the equipment box as are also the six oscillator tube batteries. The latter, however, are all assembled in a battery case (type CS–17) which therefore may be considered as a 120-volt battery. Figure 4 shows a view of this case, as well as the two amplifier tube batteries, both being mounted in the equipment box. The six type BA–2 batteries in the battery case have their terminals firmly soldered together and taped. The end leads project from the case. It is intended that when the 120-volt battery becomes exhausted in field service the complete CS–17 battery case will be replaced by one containing fresh batteries. Fresh BA–2 batteries are installed in the case at the supply base or other designated point. An extra 120-volt unit in its case is carried with the set. The bag in which the case is carried has room enough to also carry two BA–2 dry batteries. These should be carried when obtainable so as to provide spare batteries for the potentiometer and for the amplifiers.

8. *Storage batteries used with the set.*—The filament current is furnished by a BB–41 lead storage battery. This is a small battery having a rating of 16 amp. hour. The cell containers are made of hard rubber and are fitted with a nonspill plug. The battery case is made of steel and it is fitted with a cover which is removable. Slots alongside of this cover are provided so that the cover may be placed on the battery while it is in use. The batteries are $4\frac{5}{8}$ by $5\frac{5}{32}$ inches by $8\frac{11}{16}$ inches high and weigh approximately 11 pounds. The normal charging rate is $1\frac{2}{3}$ amperes. The normal discharge rate is 3.2 amperes for 5 hours, the final voltage being 3.5 volts. There are three BB–41 storage batteries furnished with the set. It is intended that two of these, fully charged, be carried in the field in the case provided with the set and one be at the charging plant. Of the two carried with the set in the field, one is in use and one is a spare. For further information about storage batteries, see Training Pamphlet No. 8.

Section IV.

INSTALLING THE SCR–77–A.

9. *Preparing the equipment box.*—Place the battery case (CS–17) containing the 120-volt unit in its compartment in the equipment box. Connect the terminals to the binding posts marked "—120 volts+," being sure to observe the correct polarity and to make firm connections.

Place two BA–2 batteries in the smaller compartment on the same side of the equipment box. Connect the terminals of one to the left-hand pair of binding posts, marked " –20 V+," and of the other to the right-hand pair marked in the same way. Observe the proper polarity and make clean, tight connections. Close and fasten the cover of this side of the equipment box.

Open the other side of the equipment box, remove the telephone head set and also the vacuum tubes, if some are not already in the operating chest. Plug in the plate battery cord (the one attached to the lower right side of the operating chest). Having run the cord through the slot provided in the cover of the equipment box, close and fasten it. Place the box on a level spot of ground with its fasteners up.

10. *Preparing the operating chest.*—Place the operating chest on the top of the equipment box and fasten it in place by the catches provided. Open the cover of the operating chest, allowing it to rest upon the projecting end of the equipment box. Turn the "Off—On" switch to the "Off" position. Turn the handles of the two fasteners at the top of the box to a horizontal position and pull the panel forward. Place a BA–2 battery in its holder alongside of the vacuum tube. Connect its terminal to the binding posts alongside the holder. Observe correct polarity and make tight connections. Secure the battery in place by means of the clamp. Place a VT–1 vacuum tube in each of the three sockets. Close the front panel and lock it in place by turning the handles of the fastener downward. Pull the top of the telegraph key downward to its operating position. Plug in the telephone head set.

Place the storage battery carrying case near the operating chest and connect to *one* of the storage batteries the terminals of the cord extending from the left-hand side of the operating chest. Observe the correct polarity as marked. The cover of the battery should then be closed.

11. *Preparing the loop.*—Remove the loop from its case and unfold it. Jam the ends of the loop firmly into the sockets on the back of the operating chest. Tighten up all wing nuts on the loop. The set is now ready for operation, if the tube in the left-hand socket (oscillatory circuit) will oscillate.

12. *Selection of oscillator tube.*—Because of minute differences that arise in the process of manufacture, some VT–1 vacuum tubes work better in the oscillatory circuit than others. The tubes received with the set should be tested and the best one used in the oscillator tube socket. The test can be made very easily. When the left-hand side of the loop is touched with the bare hand the plate current, as shown by the milliammeter, will decrease in value when the tube is oscillating. Of course the set must be transmitting

when this test is made. Thus each tube in turn is placed in the oscillator tube socket and tested. The best two oscillators are marked and one of these is used in the set and the other is held as a spare.

Section V.

CALIBRATION OF SET.

13. *Necessity for calibration.*—The feature by which break-in communication is obtained in the SCR–77–A sets necessitates that reception be accomplished by the heterodyne method. One oscillation used in the heterodyne method is produced by the transmitting set, the other oscillation is produced by the receiving set. Thus both the transmitting and the receiving set are oscillating and, in order to produce beats of good audibility, their oscillation frequency must not vary by more than 1,000 per second. As the frequency at a wave length of 75 meters is 4,000,000 per second, this allows of a variation of only 1 part in 4,000. Sets can not be manufactured with such precision, so means are provided to adjust the frequency of the sets so that one set can be made to have a frequency very nearly that of another set when the tuners of the two sets are in the same position.

14. *Selection of the master set.*—When a number of sets are to work together in a communication net all sets must be calibrated alike. In order to do this one set is selected as the master set. At first this selection of the master set must be made arbitrarily, but after several days of operation the peculiarities of each set in the net become known. The master set should then be selected from the group. It must be a good transmitter and receiver. It should be the set whose frequency of oscillation is most constant and not easily changed by accidental factors and whose range of frequency of oscillation is so limited that all the other sets to be in the net can be calibrated with it.

Note.—The adjusting screw (on the rear of the operating chest) of the master set should usually need no adjustment, for the sets as delivered by the manufacturer have all been calibrated, and so it should be possible to calibrate all sets in the net with the master set. However, if it is found impossible to calibrate all sets in the net, it may be necessary to change the adjusting screw of the master set. It should be turned to that position which permits the other sets to be calibrated with it. The head of the adjusting screw is quite large, but the screw itself is small. Do not force the screw too far either way. To do so will either strip the threads or break the upsetting on the end of the screw, thus permitting the screw to become detached from the movable part of the condenser.

15. *Method of calibration.*—Having selected the master set, the calibration is done as described below. It must be remembered that each set in the net must be calibrated in turn, always using the same master set. The calibration must be done with the sets outdoors and resting on the ground. The set to be calibrated is placed at a distance of at least 200 feet from the master set and turned so that its loop is at right angles to that of the master set. Turn the "Tuner" condenser of the master set exactly to the No. 5 position. The master set transmits while the set being calibrated is adjusted. The latter set is acting as a receiver. With the head set on, the "Tuner" of this set is turned to the No. 5 position and then its adjusting screw is turned backward or forward until low-pitched signals from the master set are received. No further adjustments are made with the adjusting screw. The tuner of the master set is then turned successively to positions 4, 6, 3, 7, etc. In each position the master set transmits. The tuner of the set being calibrated is turned to the corresponding position on its scale and then, if the signal is not picked up, is slowly turned back and forth until low-pitched signals are heard. The position at which signals are heard is then marked with a lead-pencil line on the scale. This is done for each different position of the master set tuner.

It may happen when the master set tuner is in position No. 5 that the variation in frequencies produced by turning the adjusting machine screw on the back of the set being calibrated is not sufficient to enable signals to be heard when its tuner is exactly on the No. 5 position. In this case turn the adjusting screw either to the right or to the left as far as it will go (see footnote on page 9), using that position of the adjusting screw which will place the pointer of the tuner nearer the No. 5 mark when the low-pitched signals are heard. The position of the pointer of the tuner should then be marked with a lead-pencil line. The other positions are found and marked in the usual way.

After all sets that are to work together in a net have been calibrated, it is well to try out intercommunication between the different sets while the sets are all in the same vicinity. Any faulty calibration can then be checked up and corrected without the confusion that would result if the sets were taken into the field before the faulty calibration were discovered.

16. *Permanency and limits of calibration.*—The calibration of the set as described above is quite permanent and reliable. However, any heavy jar or shaking up of the set is liable to disarrange the adjustment. If the set is operated at a station where the surroundings or earth conditions are different from those under which the set was calibrated, the frequency of the set will probably be slightly changed. This is most apt to occur when the loop of the set is near some object.

The position of the set should be changed if practicable. In some cases it will be necessary to recalibrate the set in the position at which it is to be used. This should be done under the direction of the officer in charge of the net. In extended operations the calibration of the sets should be checked up at least every day by comparison with the master set. This may be done by the operator transmitting for a definite length of time with his tuner upon each position. The other stations within the net should then, one at a time, make any correction to the markings on their scale that may be necessary.

17. *Number of sets in a net.*—The number of sets in a net when each set has assigned to it an exclusive wave length is limited by the number of different settings on the tuner. The permanent markings on the tuner scale are set as closely together as is practicable. They are numbered from 0 to 10, thus indicating 11 different wave length settings. However, only the wave length range of each set that overlaps the wave length range of all other sets in the net can be used. This limitation makes it practical to use only nine different wave length settings in a net.

SECTION VI.

OPERATION AND CARE OF SET.

18. *Break in communication.*—As has been stated, the SCR–77–A set is so designed that the operator receiving the message can interrupt the transmitting operator at any time. When receiving, the key switch is closed; when transmitting, the key switch is open. Thus because the switch is closed the receiving set is generating oscillations continuously. The transmitting set, however, is generating oscillations only when the key is operated to make the dots and dashes. The transmitting set is also acting as a receiver. Hence, when the sending operator works his key he hears his own signals because the oscillations produced by the receiving set heterodyne his own signals, thus making them audible. Now if the receiving operator opens his key switch, he stops his set from producing oscillations and the sending operator can not hear his own signals because of the lack of the heterodyne effect which was produced by the oscillation of the receiver. This failure to hear his own signals informs

him that the receiving operator desires to send. The sending operator closes his key switch and listens for the message from the other operator. In other words, the stoppage of the audible signals in the operator's own telephone when he is transmitting is a signal that the receiving operator desires to send. The closing of the key switch on the set enables the message in the reverse direction to be received.

19. *Adjustments for transmission.*—The only regular adjustments for transmission are the tuner and the plate current control. The tuner should be turned to the wave length of the station with which it is desired to communicate, using the calibration mark. With the key pressed down the control handle of the plate current should be turned until the milliammeter shows a reading of 5. If, after this adjustment is made, no beat note is heard in the receivers of the transmitting set, the tuner may be moved slowly back and forth until the beat note is heard. The failure to hear the beat note when the tuner is first set means that either one or the other, or both, of the sets are incorrectly calibrated.

20. *Adjustments for reception.*—The set is put into condition to receive by closing the key switch and placing the tuner pointer on the calibration mark that represents the wave length of the station. If the plate control current has not already been adjusted so that the milliammeter shows the proper reading, this should be done. If it is desired to break in on the transmitting operator, it is only necessary to open the key switch for a few seconds and then transmit.

By reducing the plate current below 5 milliamperes it is possible to reduce the interference that may occur in a congested area. This reduction of plate current reduces the power of the set, thus effecting a reduction in interference. Reducing the power of the set also makes it a more sensitive receiver, as it brings the amplitude of the local and the received oscillations into a more effective ratio. However, in reducing the power it is necessary that care be taken not to reduce it so much that the oscillations fail to produce the heterodyne effect in the distant transmitting set; otherwise the sending operator will stop transmitting, as he will expect a break-in message.

21. *Limitation in distance of break-in communication.*—The fact that reducing the strength of the oscillations of the receiving set increases its efficiency as a receiver makes it possible to communicate over a much greater distance with these sets if the break-in feature is not used. Thus, if break-in communication is not desired, the transmitting set may have its power increased, by adjustment of the potentiometer, to the limits of the set, as the decrease in the receiving ability of the set is no longer a factor to be considered. Also the receiving set may have the strength of its oscillations reduced to that point which gives the maximum reception, as these oscillations

are not used by the transmitting station. These two factors make for a greater possible distance of communication. It is often possible, therefore, to obtain ordinary radio communication between two SCR–77–A sets when break-in communication can not be established.

22. *Troubles and remedies.*—If the set is inoperative after being installed, go over carefully all connections made in installing the set. Especially examine the loop joints to see that they are clear and bright and make good electrical contact. If the set is still inoperative, pull forward the operating chest panel and see if all their filaments are lighted. If not, trace out the circuit for poor or broken connections. The tube socket contact springs sometimes make poor contact with the contact pins of the tube, due to dirty contacts or weak-spring tension. Of course a run-down storage battery may be the cause of the failure of the tubes to light up.

If the instrument still fails to operate properly, as indicated by failure of meter to read as much as 5 milliamperes and by failure to obtain a marked drop in plate current when the left-hand side of the loop is touched with the bare hand, note whether the telephone click produced in this manner is louder while operating the key when the meter is shunted. If so, the meter is burned out. If the clicking is the same and quite weak, the trouble probably lies in faulty or run-down BA–2 batteries or faulty connections between the batteries or otherwhere in this circuit.

If the milliammeter is burned out or otherwise becomes open-circuited, it can be shunted until replaced or repaired. To shunt the meter, connect its two terminal posts together by a piece of wire. To test whether or not the set is oscillating when there is no meter, touch the left-hand side of the loop with the bare hand. A distinctive click in the telephone receiver is heard if the set is oscillating.

If it is impossible to cause the meter to read as low as 5 milliamperes by adjustment of the plate control current knob, it is due either to reverse polarity of storage-battery connections or a run-down or wrongly connected grid potentiometer battery. It may happen, however, that an exceptionally good oscillator tube will cause a plate current that can not be reduced to the proper value.

23. *General care of the set.*—The sets are made as rugged as possible with this type of apparatus. However, they should not be subject to any heavy jars or severe shaking, as this will break connection or injure the apparatus. The set should not be unnecessarily exposed to rain or dampness. If it becomes wet it should be thoroughly dried out but not exposed to intense direct heat. Care should be taken to keep all terminals bright and clean, including the

joints of the loop. If the sets are stored they must be kept in a dry place. Instructions for the care of the head set are given in Figure 5.

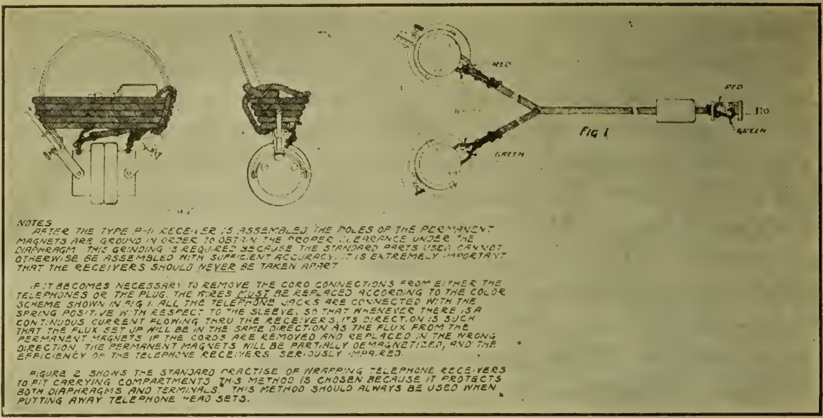


FIG. 5.

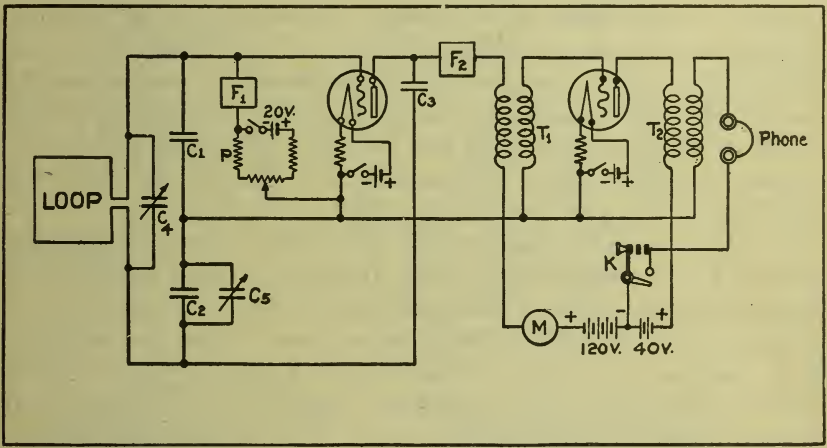
SECTION VII.

PRINCIPLES EMBODIED IN THE SET AND ITS CIRCUIT DIAGRAM

24. *Principles of operation.*—The SCR-77-A set uses three VT-1 vacuum tubes. One of these is connected as an oscillator, using a capacity coupling between the plate and the grid. The other two tubes are used as audio frequency amplifiers to amplify the heterodyne note produced, as explained below. The oscillating circuit is so designed that at the same time it is oscillating this tube will also act as a detector. It is performing both of these functions simultaneously, so that the set is always being used as a transmitter and as a receiver. The set receiving the message has its key short-circuited by a switch, and hence is generating undamped waves continuously, i. e., not broken up into dots and dashes. The set transmitting the message generates undamped waves, which are interrupted to form dots and dashes. As the two sets in communication have been so adjusted that their difference in frequencies of oscillation is equal to an audible frequency, the heterodyne effect produced by the two oscillations gives rise to an audio frequency note when detected. As

both sets are detecting as well as generating, the signals sent out are heard in both sets. If either set should stop oscillating, the signals would disappear, for there would be no heterodyning wave. Thus, when the operator sending the message ceases to hear his own message, he knows that the receiving operator has stopped his set from oscillating. This is a signal that the receiving operator desires to break in. The operation of the sets may be thought of as follows: The set receiving the message is acting as an autodyne (self heterodyne) for itself and also as separate heterodyne for the set transmitting the message. Both sets are able to receive the heterodyne note. The circuits of the set are so designed that the scheme outlined above will be effective with a loop antenna.

25. *Simplified diagram of set and explanation.*—A simplified diagram of the circuit is shown in Figure 6. The loop gives an induc-



(For legend, see Fig. 7.)

FIG. 6.

tance large enough to permit stable oscillations at the frequencies used by the set to be established. Across this loop is the grid condenser C_1, and the plate condenser C_2, which supply the coupling between the plate and the grid necessary to build up and maintain oscillations. The plate voltage of the oscillator tube is supplied by a 120-volt battery, which is also connected to the filament through a key. The closing of this key suddenly throws a high negative potential on the filament, thus upsetting its stable nonoscillating condition and starting oscillations. A milliammeter in the plate circuit enables the operator to determine the amount of power being used by the tube. A condenser of large capacity C_3 in the lead from the plate to the oscillating circuit prevents the 120-volt direct current potential from passing through the loop to the grid. Because of its large capacity, it offers little impedance to the radio frequency oscillations.

A very small single-leaf variable condenser, C_4, is shunted across the loop to permit an adjustment of the frequency of the oscillating circuit. This is the condenser used in calibrating the set. A variable air condenser C_5 is shunted across the plate-coupling condenser. This also provides an adjustment of the oscillation frequency of the set. It is controlled by the tuner knob on the front panel.

26. *The potentiometer and filter circuit.*—The grid and filament of the oscillating tube are connected by a filter, which replaces the radio frequency choke coil commonly used, and a potentiometer. The potentiometer consists of a 20-volt battery (BA–2) and three resistances, one of which is provided with a sliding contact. The biasing potential between the grid and filament is controlled by the potentiometer. A change in this biasing potential will produce a change in the power output of the tube. The adjustment is needed so that the strength of the oscillation produced by the tube may be limited to such values as will enable the tube to act as an efficient detector at the same time that it is producing oscillations. The filter in this circuit prevents any radio frequency oscillations from passing directly from the grid to the filament. The oscillations produced by the tube, therefore, are forced to follow the circuit to the filament through the grid condenser, C, thus giving the proper coupling between the circuits of the tube.

27. *Detection and amplification.*—The radio frequency oscillations produced by the tube and the radio frequency arising from the radio wave produced by the set with which the first set is working are both present in the oscillating circuits of each set. These two oscillations give rise to a composite radio frequency wave whose amplitude varies periodically with a frequency equal to the difference in frequency of the two original oscillations. This difference of frequency has been adjusted, by the process of calibration, to be equal to an audio frequency. The composite wave is detected by the oscillating tube and because of its periodically varying amplitude gives rise to an audio frequency pulsation in the plate circuit of this tube. These audio frequency pulsations, because of the high impedance of the condensers, C_3, C_2, and C_5, to them can not follow this path to the filament and are forced to follow the circuit through the filter, F_2, the primary of the first audio frequency transformer, the 120-volt battery, and the key to the filament. The functioning of the amplifier tubes is very similar to that of an ordinary amplifier.

It is to be noted that the plate circuits of the amplifier tubes are fed by a 40-volt battery (two BA–2) and that the telephone receivers are in a separate circuit from the tube, being coupled to the plate circuit of the last tube by a special one to one transformer. The circuit in which the telephone receivers are placed is closed and opened by the operating of the telegraph sending key, which has two contacts. The complete circuit of the set is shown in Fig. 7.

28. *Filters.*—Filters may be made for different purposes. One type of filter allows low-frequency current to pass through it and prevents high-frequency oscillations from passing through. Another type permits the passage of high-frequency oscillations and prevents the passage of low frequency. Another type of filter prevents

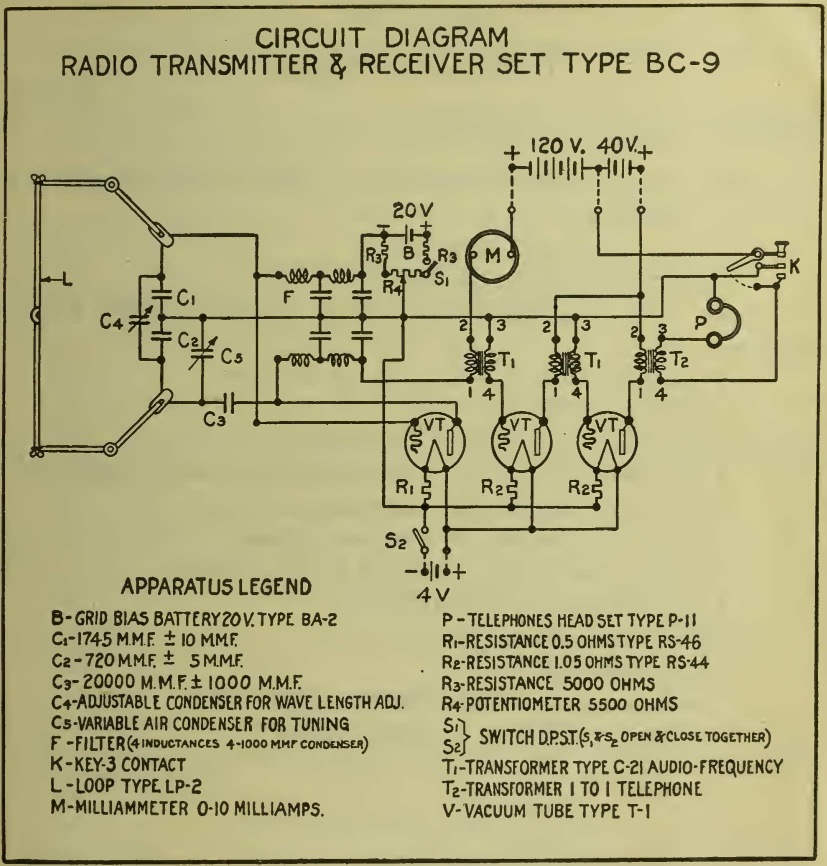


FIG. 7.

the passage of all frequencies except of a band which can be made as narrow or as broad as desired. Still another type of filter permits the passage of all frequencies except a band. Filters are made of combinations of inductances, capacities, and in some cases resistances. The filters used in the SCR–77–A set are both alike and permit the passage of low-frequency but not of high-frequency currents. In each filter there are two condensers having a capacity of 1,000 micro-microfarads each and two inductances having a value of 22.8 microhenries each. (Value measured at a frequency corresponding to a wave length of 85 meters.) Each inductance is made of 105 turns of No. 34 (0.0069 inch) "beldenamel" copper wire, 69 threads to an inch, wound on a bakelite spool 0.316 inch in diameter. For further information concerning filters, see Principles of Radio Communication, by Morecroft; Electric Oscillations and Electric Waves, by Pierce; United States Patent 1,227,113, "Electric Wave Filter."

Section VIII.

PARTS LISTS OF SET.

29. *Equipments in the SCR–77–A set.*—There are two equipments in the set, as follows:

Power equipment, type PE–37.
Radio equipment, type RE–23.

30. *Parts lists of equipments.*—Power equipment, type PE–37, comprises:

3 batteries, type BB–41; 1 in use, 2 spare.
1 case, type CS–19.

Radio equipment, type RE–23, comprises:

1 bag, type BG–13; for carrying battery case, type CS–17.
1 bag, type BG–18; for carrying loop.
15 batteries, type BA–2; 9 in use, 6 spare.
2 battery cases, type CS–17; 1 in use, 1 spare.
1 equipment box, type BE–48.
2 head sets, type P–11.
1 loop, type LP–2.
1 radio transmitter and receiver, type BC–9.
6 tubes, type VT–1; 3 in use, 3 spare.

SIGNAL CORPS PAMPHLETS.

(Corrected to February 1, 1923.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated "Radio Pamphlets.")

No.

1. Elementary Principles of Radio Telegraph and Telephony (edition of 4–28–21.) (W. D. D. 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, Types SCR–65 and 65–A.
6. Loop Radio Telegraph Set, Type SCR–77–A (W. D. D. 1115).
9. Amplifiers and Heterodynes. (W. D. D. 1092.)
11. Radio Telegraph Transmitting Sets, Types SCR–74 and 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 and 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.)
27. Sets, Radio Telephone and Telegraph, Types SCR–109–A and SCR–159. (W. D. D. 1111.)
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 Type 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. (W. D. D. 1020.) (2d edition.)
11. Elements of the Automatic Telephone System. (W. D. D. 1096.)

Training Pamphlets.

1. Elementary Electricity (edition 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 (edition of 6-9-22). (W. D. D. 1112.)
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.

Training Regulations.

(Signal Corps subjects.)

165-5. Wire Axis Installation and Maintenance Within the Division.

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PRIMARY BATTERIES

RADIO PAMPHLET No. 7

Second Edition, Revised to January 25, 1919

Signal Corps, U. S. Army

Washington : Government Printing Office : 1919

PRIMARY BATTERIES.

General Theory and Characteristics of Various Kinds of Primary Cells and Descriptions of Signal Corps Types.

103608—19

IT WAS AN early discovery in electrical phenomena that all metals had certain characteristics peculiar to each, such hat if two different metals were brought into contact, a difference of potential was established between them. If a circuit nade up of various substances and including no source of energy s closed on itself, the various contact emfs. will just compensate nd the resultant emf. of the circuit will be zero. However, if he circuit includes a source of energy such as heat or chemical eaction, an unbalance of emf. will be produced and a current stablished. The current thus established tends to reduce the mf. of the source and restore the static balance of the system. 'his action of the current is called "polarization" and may be vercome to greater or less degree by the use of certain substances called "depolarizers."

A battery consists essentially of two metallic conductors or oles dipping into an electrolyte. Copper or carbon is commonly sed for the positive pole and zinc for the negative pole. The ositive pole or terminal of a battery is the one which is at the igher potential, and the other pole is called the negative pole r terminal. The negative pole is the anode or positive electrode or plate and the positive pole is the cathode or negative lectrode or plate. For example, in a copper-acid-zinc battery, he copper is the positive pole but the negative electrode or late. The electrolyte of a primary cell may be sulphuric or itric acid, or sal ammoniac, caustic soda or other salt or ydroxide. The open circuit emf. of batteries made of given naterials is always the same, providing the temperature, degree of concentration of the electrolyte and the purity of the naterials are the same. The terminal emf. or potential difference on closed circuit is always less than the open circuit emf. ue to three characteristics of the battery; namely, the internal esistance, the polarization and the degree of exhaustion.

The internal resistance of a battery may be determined from he following formula:

$$r=\frac{E-e}{I},$$

here I is the current drawn on closed circuit, e the potential ifference when this current is flowing and E the open circuit emf. measured immediately upon interrupting this current that is, before the load condition of the cell has had time t change.

Polarization of a primary cell may be explained as th change produced in the relative concentration of the electrolyt around the poles of a cell; or, as the formation at the poles new chemical substances such as hydrogen, which adhere t the poles. A depolarizer, then, is any substance which place in the electrolyte or on the poles of a cell will partially wholly prevent these changes. Polarization always tends to r duce the effective emf. of a cell. The chief cause of polarizati is the formation of hydrogen gas at the positive pole. This brought about by the transfer of the metal from the negati pole to the positive pole in accord with the following:

Chemical Generation of Electrical Energy.

A primary cell is essentially a device for converting chemi energy directly into electrical energy. If a plate of chemica pure zinc and a plate of copper are immersed in dilute s phuric acid, no chemical action takes place. As soon; howev as the zinc plate and copper plate are connected by electri conductors outside the liquid, a vigorous chemical action set up, the zinc dissolving in the acid to form zinc sulphate liberating hydrogen at the positive pole. The hydrogen erated accumulates on the copper plate and causes the chemi action to weaken and the intensity of the electric current diminish for two reasons: the hydrogen coating acts as electrode of the cell and sets up a local emf. opposed to the e of the cell; and it also acts to decrease the effective area of plate. This polarizing effect may be largely overcome by ut ing an oxidizing agent to change the hydrogen or metal liber at the positive pole to a form readily soluble in the electro and thereby prevent its accumulation at the positive plate. oxidizing agent most frequently used in dry batteries is ganese dioxide, MnO_2. Other good depolarizers are copper phate, $CuSO_4$, strong nitric acid, HNO_3, chromic acid, C copper oxide, CuO, and silver chloride, AgCl.

Another deteriorating effect present in the usual bat which must be overcome is what is termed "local action."

mpurities which are always present in the zinc, form with the inc small short circuited voltaic cells acting to waste away the inc without producing any current in the external circuit. This vasteful action can be largely prevented by amalgamating the inc, that is, coating it with mercury. This is easily done by lipping the zinc electrode into diluted sulphuric acid to clean he surface and then rubbing mercury over it.

The emf. of a given type cell is the contact emf. and is there-ore, independent of the dimensions of the battery. The total nergy capacity of a battery, however, is directly affected by he dimensions. For a given battery, the capacity stands in lirect ratio to the weight of active material. The ampere-hour apacity of a given number of cells in series is determined by the rea of the plates. The emf. of a given type of battery is of ourse dependent only on the number of cells in series.

There are a great many different types of primary cells in ise, all of which operate according to the same general prin-iples, but differ in the kind of electrodes, electrolyte and de-olarizing agent, and the voltage, internal resistance, etc. The voltage, however, of almost all makes of cells, will be between he limits of 1 and 2 volts when new, the average battery deliver-ng about 1.5 volts. A new cell on short circuit through an mmeter should give a current of from about ½ amp. to 20 amp. lepending on the size of electrodes. The internal resistance of rimary cells when newly made will vary from .07 ohms up to 3 or 4 ohms. This resistance gradually increases due to polar-ization and the formation of insulating substances on the plate, until it becomes perhaps several times this amount. This high ultimate internal resistance and rapid rise of internal resist-ance when heavy currents are demanded, are inherent char-acteristics of the primary battery which limit its practical use to service where relatively large currents are required for only a few moments, or where for continuous service over long periods only a few milliamperes are required.

Various Types of Primary Batteries.

Primary batteries may be divided in two general classes, known as open circuit and closed circuit batteries, and while there is a great variety of each class, the basic principle is the same.

Open circuit cells are used for intermittent service where current is required for only short intervals of time, such as in operating electric bells. Open circuit cells kept in continuous service for some time become polarized or completely exhausted, but will recuperate to a considerable degree on open circuit. The so-called dry battery is a good example of the open circuit type.

Closed circuit cells are adapted for supplying current continuously until the chemical reaction producing the current flow is complete. This form of primary cell is used most extensively in telegraphy, where a small but continuous flow of current is required. The so-called wet battery is generally used for closed circuit work.

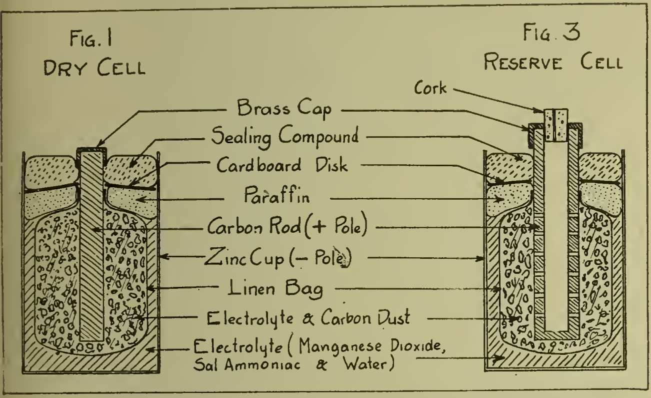
Dry Batteries.

The general construction of a dry battery is illustrated in Fig. 1. A central carbon rod forms the positive pole of the cell. The upper extremity of this carbon rod is provided with a tight fitting brass cap, to which a connection wire may be soldered. The rod is set in the center of a linen bag which is then packed with a mixture of carbon dust, manganese dioxide, and ammonium chloride (sal ammoniac). The bag is then pressed into a cylindrical zinc container which serves also as the negative pole of the cell. The mixture is then impregnated with water and a special electrolyte paste, and is carefully sealed with paraffin and an asphalt compound.

The chemical reaction taking place within the cell between the carbon rod and the zinc container to produce the electric current is thus seen to occur in a pasty solution of ammonium chloride in water. The reaction taking place when the cell is closed through some external circuit, is quite complex. One of the products of the reaction is free hydrogen gas, which if allowed to collect around the carbon rod, would soon prevent contact of the latter with the electrolyte and would thus make the cell inoperative. This is called polarization of the cell. This effect is counteracted by the manganese dioxide of the mixture which thus forms the depolarizing agent. The hydrogen unites with some of the oxygen of the manganese dioxide to produce water. By this means, the operation of the cell is continued satisfactorily over a much longer period of time than would be possible without the depolarizer.

After a cell has been used for some time, the chemicals in the electrolyte mixture are used up completely, and the cell becomes inoperative, and must be discarded. The length of life of a cell depends to some extent on the rate of discharge, but also on the dimensions of the carbon rod and of the zinc container, and on the quantity of electrolyte mixture present.

The type of cell described above, if manufactured properly, using materials of high purity, will remain in good condition when not in use, since the electrolyte is completely sealed in and hence will not deteriorate. Frequently, however, some slight



Figs. 1 and 3.—Cross sectional sketches showing internal make-up of dry and reserve type cells.

impurities are present in the zinc making up the container of the cell, which produce local action and decomposition of the electrolyte, even though the cell terminals may not be connected to any outside circuit. This gradually weakens the electrolyte and may completely exhaust the cell. For this reason, it is generally best not to store dry cells for periods longer than a few months.

The type of cylindrical cell described above is manufactured for the Signal Corps in various sizes, and a number of identical cells are grouped in series to form a dry battery. The standard types are briefly described below.

Battery, Type BA-1.—This battery, formerly known as type A, is a 2-cell battery with the two cells connected in series by placing them end to end in a cardboard tube which holds them together and protects them mechanically. The approximate dimensions of the battery are 6¼ in. in length by 1¼ in. in diameter. The terminal voltage is about 3.5 volts.

Battery, Type BA–2.—This battery is made up of 15 cylindrical cells connected in series. Each cell is about 1⅝ in. high and ⅝ in. in diameter. The 15 cells are assembled in a cardboard box 3½ in. x 2½ in. x 2 in. weighing a little less than 1 lb. The entire assemblage of cells is covered and sealed with an asphalt compound, through which two terminal wires are brought out. The polarity is marked in the compound. The terminal voltage of the battery is 22.5 volts when new. The battery may be used safely until the voltage runs down to 17.5 volts. Care should be taken when handling these batteries, not to bring the two terminal wires in electrical contact, since this would short circuit the battery, and exhaust it in a very short time.

This battery is intended primarily for use with the three-electrode vacuum tubes, where it supplies the potential in the plate circuit. The discharge rate is 0.3 milliamp. when connected to a type VT–1 tube used as a detector, and 3 milliamp. when the tube is used as an amplifier. The approximate life of the battery is 75 to 100 hours.

Battery, Type BA–3.—This is a 3-cell, 4.5-volt cylindrical battery, 9½ in. long and 1-5/16 in. in diameter. The three cells are placed end to end in a cardboard tube and connected in series. The normal discharge rate is 0.3 amp. when used on the type SCR–57 or SCR–57–A airplane interphone sets for which the battery was originally designed.

Battery, Type BA–4.—This is a single cell battery, cylindrical in shape, 3-1/16 in. long and 1¼ in. in diameter. The open circuit voltage is about 1.5 volts. This battery is used to energize small buzzers, such as the detector adjusting buzzer of the type SCR–54 or SCR–54–A radio receiving set.

Battery, Type BA–8.—This is a 15-cell battery, of the same electrical characteristics (voltage and discharge rate) and intended use as the type BA–2. The individual cells are, however, of larger size, which results in a greater life (500 hours) under similar conditions of use. The 15 cells are sealed in a cardboard box 4 in. x 3 in. x 6-11/16 in., and the entire battery weighs about 3.9 lb. It should be noted that, due to its larger size the type BA–8 battery is not interchangeable with the type

A-2. It may be used on the same sets however, by placing near the radio set box, and connecting the battery terminal ires to the proper terminals of the radio set box.

Battery, Type BA-9.—This is a 3-cell battery, having the ap·oximate dimensions of 2⅝ in. x $2\frac{7}{16}$ in. x ⅞ in. It is the well ıown dry battery for use in pocket flash lights.

Batteries, Type 4, 6 and 8.—These batteries were used to quite ome extent by the Signal Corps, and are fully described in the ignal Corps Manual No. 3. They are obsolete, however, and are ıerefore simply mentioned in this pamphlet.

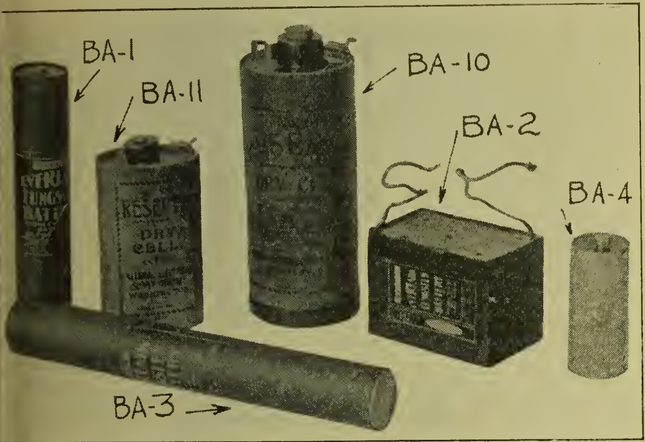


Fig. 2.—Various Signal Corps types of dry and reserve batteries.

Reserve Type Batteries.

As was explained above, the dry cell contains a mixture of ectrolyte salts, absorbent material (carbon dust), and water, ıe cell being then sealed air tight, and ready for operation. It as also pointed out that, due to local chemical reactions, the ·ll may deteriorate while in storage, though not used at all. his is a serious objection to the use of dry batteries which has ·en overcome in a measure by the so-called reserve type dry ıtteries. These batteries differ from the ordinary dry battery ·scribed above in that they do not contain any water or moisture hatsoever, so that no chemical reaction can take place inside the cell. This also makes the cell inoperative when connected to an external circuit, so that it is necessary to add water to the cell before using it. This may be done shortly before placing the cell into use, after which it will operate exactly in the same manner as the ordinary type of dry cell. Before water is added, it may be stored without deterioration for a long period.

In order to permit the addition of water to the cell, which is sealed by an asphalt compound, the carbon rod electrode is made hollow and porous. (See Fig. 3.) While the cell is in storage, this carbon tube is sealed by means of a cork dipped in paraffin. To place the cell in service, proceed as follows:

1. Remove the cork from the carbon electrode.

2. Fill with distilled or rain water and continue adding sufficient water to keep the cell full during the first hour. Then fill every 30 minutes until no more water is absorbed.

3. During the entire operation, take care not to spill any water on the top of the cell, as this establishes a circuit between the two terminal clips and discharges the cell rapidly.

4. When the watering is finished, that is, when no more water is absorbed, empty out the water and replace the cork.

Battery, Type BA–10.—This is a one-cell, cylindrical battery $6\frac{3}{4}$ in. high and $2\frac{1}{2}$ in. in diameter; formerly known as the No. 6 reserve battery. It will absorb $3\frac{1}{2}$ oz. of water before being ready for service. The terminal voltage is about 1.4 volts.

Battery, Type BA–11.—This is a one-cell battery, having the shape of an oval base cylinder, $4\frac{3}{4}$ in. x $2\frac{1}{4}$ in. x $1\frac{3}{16}$ in. This was formerly called the No. 4–O reserve battery. It will absorb $1\frac{1}{4}$ oz. of water, and has a voltage of about 1.4 volts.

Battery, Type BA–5.—This battery is essentially the same as the type BA–2 dry battery, the only difference being that it is of the "reserve" type.

Wet Batteries.

While dry and reserve type batteries find very extensive use in the field for open circuit work, due to the absence of any breakable jar or corrosive liquid, they are not well suited to closed circuit work where a continuous flow of current is required for extended periods of time. They also have a comparatively high internal resistance so that their output is not as great as may be derived from other types of cells. For pr

)oses where these characteristics of current supply are required, ' wet " batteries are used, especially in stationary installa-ions. These wet cells consist essentially of a jar containing ı liquid electrolyte solution, into which the two electrodes are nserted. The advantages of this type of cell are the ease vith which the electrode plates may be cleaned and the pos-ibility of renewing them and the electrolyte solution. The dis-ıdvantages are the breakable jar, the possibility of spilling the olution which is generally corrosive, and the gradual evapor-ıtion of the electrolyte. The three types of wet cells used by he Signal Corps are described below.

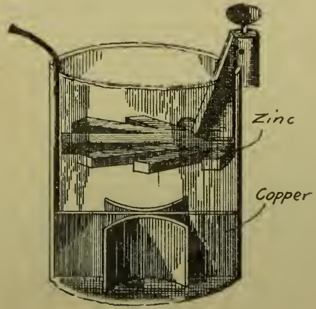
Battery, Type BA–12.—This battery is commonly known as the gravity cell." (See Fig. 4.) It comprises a glass jar 5 in. x 7 in., t the bottom of which is placed the positive pole consisting of hree copper strips riveted together and having a rubber-ısulated wire attached to one of them to form the terminal. 'he zinc electrode forming the other pole is cast with a hook hich rests over the edge of the jar, and supports the electrode ı the electrolyte about 3 in. above the copper electrode. The inc is given a special shape from which the cell derives the ften used name of " crowfoot battery."

To set up the cell, 3 lb. of copper sulphate (blue vitrol) are laced in the jar around the copper electrode. The zinc is then ung in place and the jar filled with water, without stirring. The ell is then short circuited by connecting the terminals together, nd left this way until, after several days, part of the copper ılphate has dissolved, giving a blue solution in the lower por-on of the jar. The clear solution above is zinc sulphate. The ıttery is then ready for service.

If it is necessary to make the cell ready in a hurry, a table-oon of salt may be dissolved in the water before pouring it ıto the cell. However, this should be avoided if possible, as it ıortens the life of the cell.

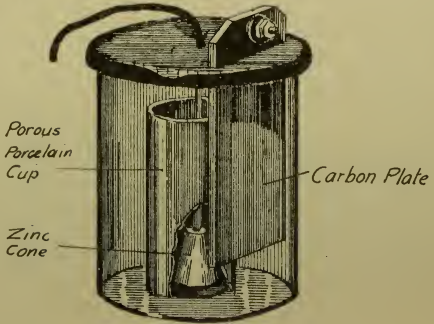
As the cell is being used, the zinc sulphate solution becomes ronger and stronger, white crystals forming at the surface. hese climb up the side of the jar and along the zinc electrode, rroding the connections and damaging the insulation. The st practice to avoid this trouble is to withdraw part of the nc sulphate solution with a battery syringe as soon as the ystals appear, replacing it with pure water. A good practice r preventing evaporation of the solution is to pour a layer

FIG. 4



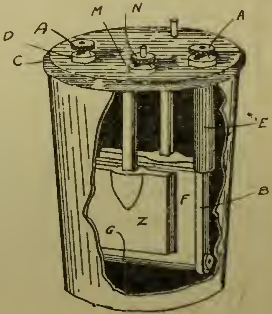
GRAVITY CELL

FIG. 5



FULLER CELL

FIG. 6



EDISON CELL, TYPE V.

of good paraffin oil over the electrolyte as soon as the cell is set up. Bluestone or blue vitriol is added from time to time as required, to keep the blue solution up to the proper level.

Frequent inspection of the cells is a good practice. In cleaning them out, wet cotton waste dipped in sand will clean the electrodes of any oil adhering to them.

The approximate emf. of this cell is 1 volt and the internal resistance about 3 ohms.

Battery, Type BA-13.—This battery is commonly known as the "Fuller cell battery." It belongs to the class commonly called "acid batteries." The cell has high electromotive force, a comparatively low internal resistance (0.5 ohm), and is much used as a transmitter battery on long distance heavily worked telephones or local battery telephone switchboards. Its only disadvantage is that it uses a corrosive solution containing sulphuric acid, necessitating much care in handling.

The Fuller cell consists of a glass jar about 8 in. high and 6 in. in diameter fitted with a wooden cover treated with asphaltum or P.&B. paint. (See Fig. 5.) This supports a carbon plate about 4 in. wide, 9 in. long and ¼ in. thick which extends down into the jar and forms the positive pole. The top of this plate is coated with paraffin to prevent corrosion of the connection. In the center of the jar is placed a porous earthenware cylinder measuring 7¼ in. high x 3 in. in diameter, in the bottom of which is about 2 ounces of mercury. The cylinder is filled up with distilled water in which a tablespoon of salt has been dissolved. A conical zinc casting to which is fastened a copper wire extending out of the top of the cell, forms the other pole of the battery. The electrolyte or "electropion" solution, is made by slowly adding 1 lb. of strong sulphuric acid to 9 lb. of distilled water, and then stirring in 3 lb. of pulverized bichromate of potash or 2½ lb. of bichromate of sodium. The latter is preferable as the crystals formed in the action of the cell are not so hard and insoluble as those produced by the potash solution.

This cell will usually require little attention for three or four months. When the solution assumes a muddy bluish tinge, it is about exhausted. If the copper wire at its junction with the zinc is covered with paraffin or ozite, or if the copper wire is well amalgmated by rubbing with mercury after dipping it into acid, it is not as likely to be eaten off at the junction as it otherwise is under heavy service. The Signal Corps issues the material for the solution in dry form, which when dissolved, forms the electrolyte. This is purchased under various commercial names such as chromac, voltac, chromite, etc., the first being the usual designation. It is packed in tin cans with thin cut-out top, containing one pound, which is the amount for one charge. Full directions for using are marked on each can.

The carbon of this cell lasts indefinitely but it should be soaked in warm water when renewals are made. The zinc may last through several renewals of the electropoion fluid. The mercury should be saved and used repeatedly.

Battery, Type BA–14.—This battery is commonly known as the "Edison primary cell." The cell shown in Fig. 6 is the standard Edison cell. This cell has a very low internal resistance (not exceeding 1/8 ohm) and will remain set up on open circuit for a long time without appreciable deterioration. It has a capacity of about 150 ampere-hours, which means that it will furnish about 210 days' continuous service on a line where the current is 30 milliamp. and 40 days' service when the current is about 0.16 amp. It gives an emf. of but 0.67 volt in steady work.

The following complete directions for setting up, use and renewal of these cells are furnished by the company manufacturing them:

To make the solution, fill the cells with water up to 1½ in. of the top. Add the caustic soda gradually to the water, stirring until the soda is entirely dissolved. When the solution cools, more water should be added to bring it up to 1½ in. of the top. Then pour the contents of the bottle of heavy paraffin oil furnished for each jar of the solution, into the electrolyte. Care should be taken in handling the cell, as the caustic soda will burn the skin and clothes. In stirring the liquid, avoid splashing it.

To set up the cells, unscrew the nut *N* and the jamb nut *M* (Fig. 6) from the screw on the brass neck of the double zinc plate and remove the leather washer. Pass the screw from below through the two round holes in the cover *C*. Replace the leather washer and the jamb nut *M* on the screw and tighten down the jamb nut until the zinc plate is rigid to the cover. The thumb nut *N* can then be screwed on.

Unscrew the nuts *AA* and jamb nut *D* from the screw on the two side pieces *BB* of the copper frame, leaving the flat leathe ıshers in position on the screws and pass the screws from low through the two round holes in the cover C. Replace the mb nut on one of the screws and one of the thumb nuts on other screw and tighten both down until the frame sides are idly clamped to the cover. Replace the other thumb nut on screw holding the jamb nut. Then slip the hard rubber ulating tubes EE over the sides of the frame, one on each e.

o fill the copper frames, slide the oxide plate F sufficiently into the frame to enable the copper bolt G to be passed derneath it through the slots in the bottom of the frame sides l the copper nut H tightened up on same.

Be careful that the zinc plates do not touch the copper oxide tes or the cells will be short circuited.

The copper connection is made between the thumb nut A l the jamb nut D on one end of the copper frame and the c connection between the thumb nut N and the jamb nut M the brass bolts suspending the zincs.

After the oxide and zinc plates are properly connected to the er, as above, soak them in water and while still wet, insert m in the jar filled with caustic solution. (Wetting the tes prevents the oil in the jar from adhering to them.)

n order to make the cover on the jar go in place easily, it is visable to wet the rubber gasket ring. This will cause the er to slip on easily and will make the cell liquid tight.

t is a[illegible]ly necessary that the upper edge of the oxide tes be sub[illegible]rged at least 1 in. below the surface of the ıstic soda solution in the jar; also, on no account can the er of oil on top of the solution be omitted.

When the cell becomes exhausted, the solution and the reins of the zinc and oxide plates must be thrown away. The er parts can be used again.

o take the cells apart, lift the lids, unscrew the bolts, and reve the zincs and oxide plates. Wash off (with water) the per frames, bolts and rubber insulators, brightening up the al, where corroded, with emery paper, especially the inside oves of the copper frame sides. Pour away the solution efully and set up cells with new caustic soda, oxide plates, l zincs according to directions.

n taking the cells apart, the parts that have been immersed he caustic soda must be washed before they can be handled.

To ascertain if the oxide plates are exhausted, pick into the body of them with a sharp pointed knife. If they are re throughout the entire mass they are completely exhausted and need renewing. If on the contrary there is a layer of black in the interior of the plate there is some life still left, the amount being dependent entirely upon the thickness of the layer of black oxide still remaining.

When renewing the battery it is desirable to clean the inside grooves of the copper frames, where the copper oxide plates make contact, so as to insure a good electrical connection. Thi is especially important where the batteries are required to give heavy current for cautery or motor purposes. These frames ca be easily cleaned by wrapping a small piece of emery pape around a stick which will just fit into the groove, or by immers ing them in a dilute solution of 1 part of sulphuric acid and parts water, and then carefully rinsing them in clean water t remove all traces of the acid.

Caution.—The oxide plates should never be removed from th caustic soda solution and allowed to dry in the air, since this is done, the surface of the plates becomes oxidized b absorbing the oxygen from the air and the oxide thus forme is much more difficult of reduction than the original oxide which the plates are formed. The internal resistance is co sequently very greatly increased and the current material diminished.

Where batteries are placed in warm places they should examined every two or three months to see that the solution h not evaporated as this will gradually take place in spite of t oil, if the batteries are in a hot room. If the solution is fou to be evaporated, add more water to bring it again to the prop height. It is of the first importance that all binding posts a connecting wires should be kept clean and bright at the poi of connection.

The type BA–14 cell is excellent for use as an ignition b tery, or in lieu of small capacity storage batteries where charging current source exists. The Signal Corps uses t type of battery quite extensively in connection with the Alas Military Cable and Telegraph System.

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

AMPLIFIERS *and* HETERODYNES

Radio Communication Pamphlet No. 9

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

December, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

War Department

Document No. 1092

Office of The Adjutant General

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WAR DEPARTMENT,
WASHINGTON, *December 19, 1921.*

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.

TABLE OF CONTENTS.

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.

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

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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

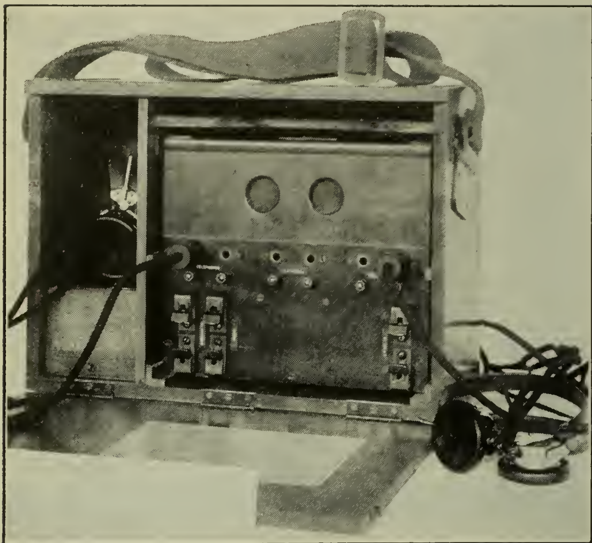

FIG. 1.—AMPLIFIER SET BOX, TYPE BC-17, IN ITS CARRYING CASE.

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 $10\frac{1}{2}$ by 6 by $10\frac{1}{4}$ 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

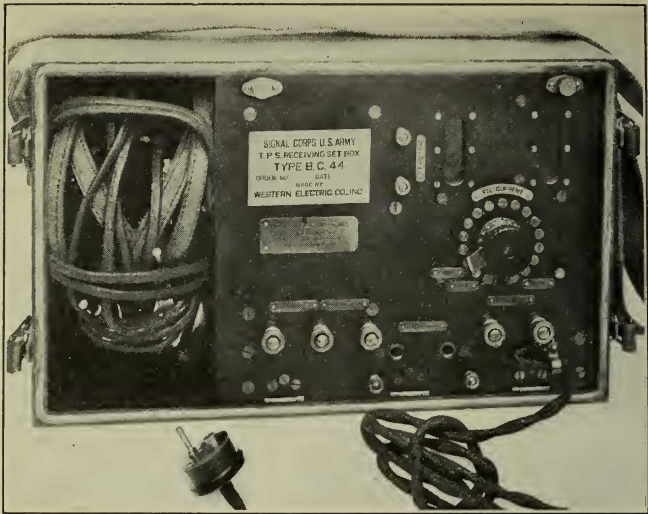

FIG. 2.—AMPLIFIER SET BOX, TYPE BC–44, FRONT VIEW.

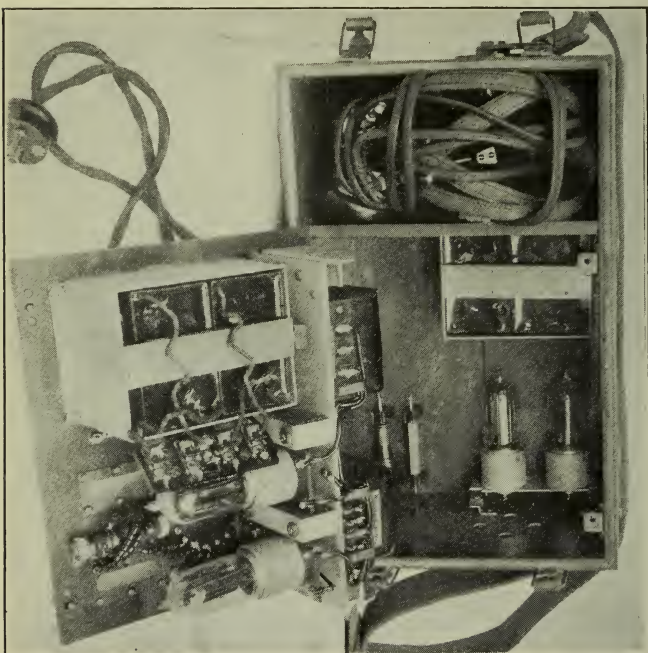

FIG. 3.—AMPLIFIER SET BOX, TYPE BC–44, INTERIOR VIEW.

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.

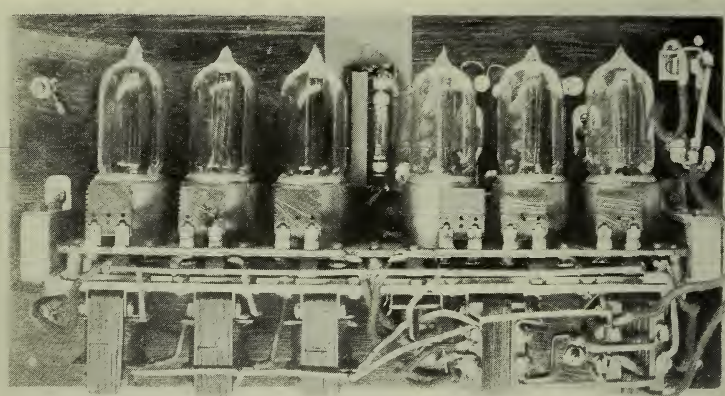

FIG. 5.

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 8½ inches by 6¾ inches by 10 inches high and weighs 10½ 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-

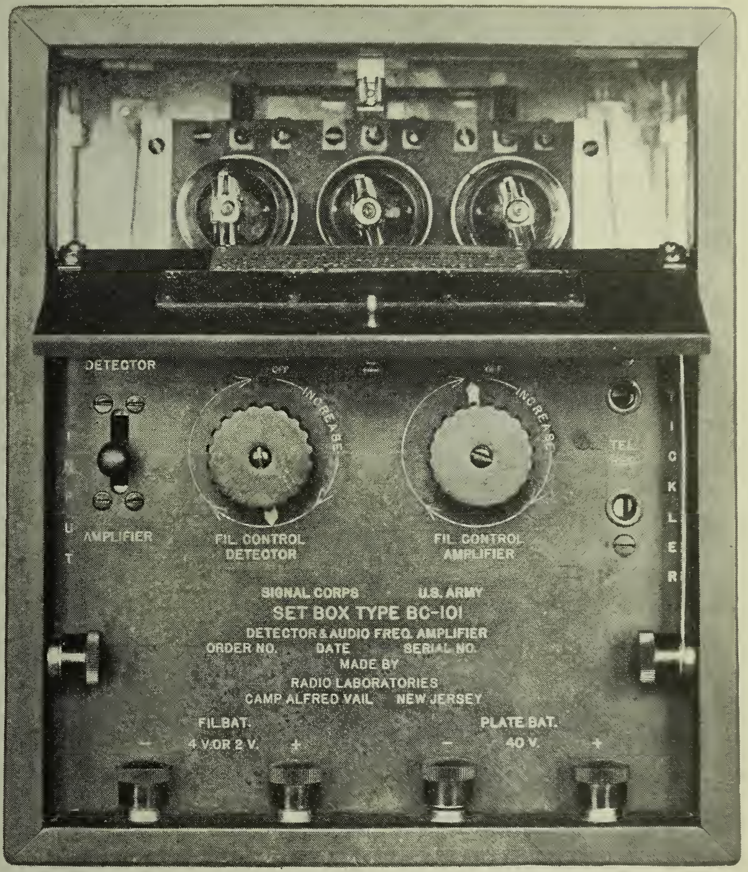

FIG. 6.

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

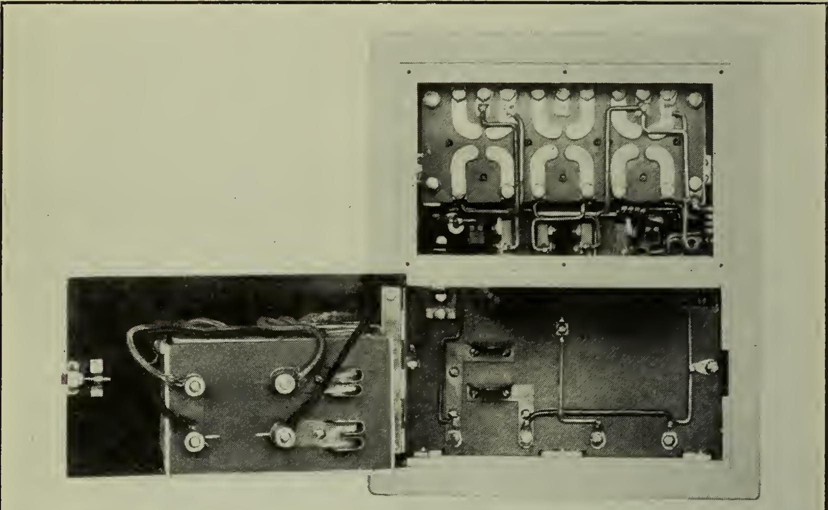

FIG. 7.

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 $15\frac{1}{2}$ by 6 by $8\frac{1}{4}$ 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*.

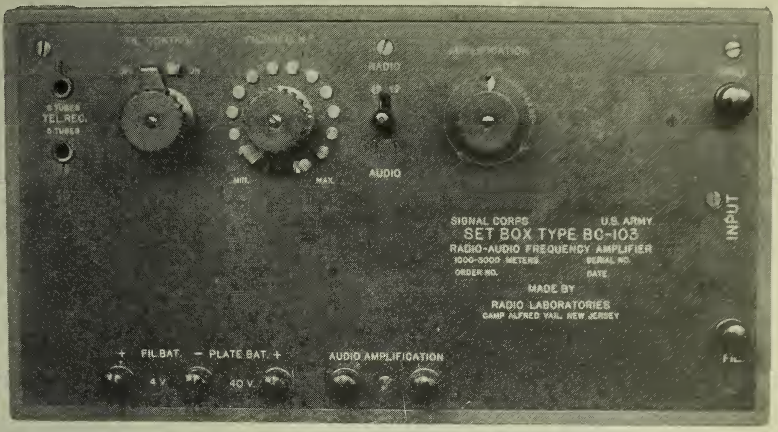

FIG. 8.

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

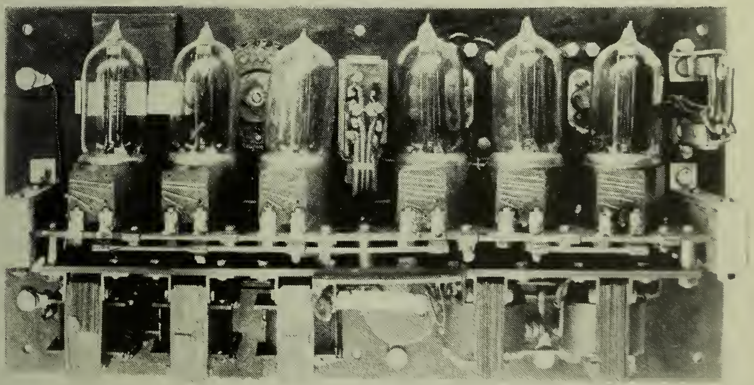

FIG. 9.

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

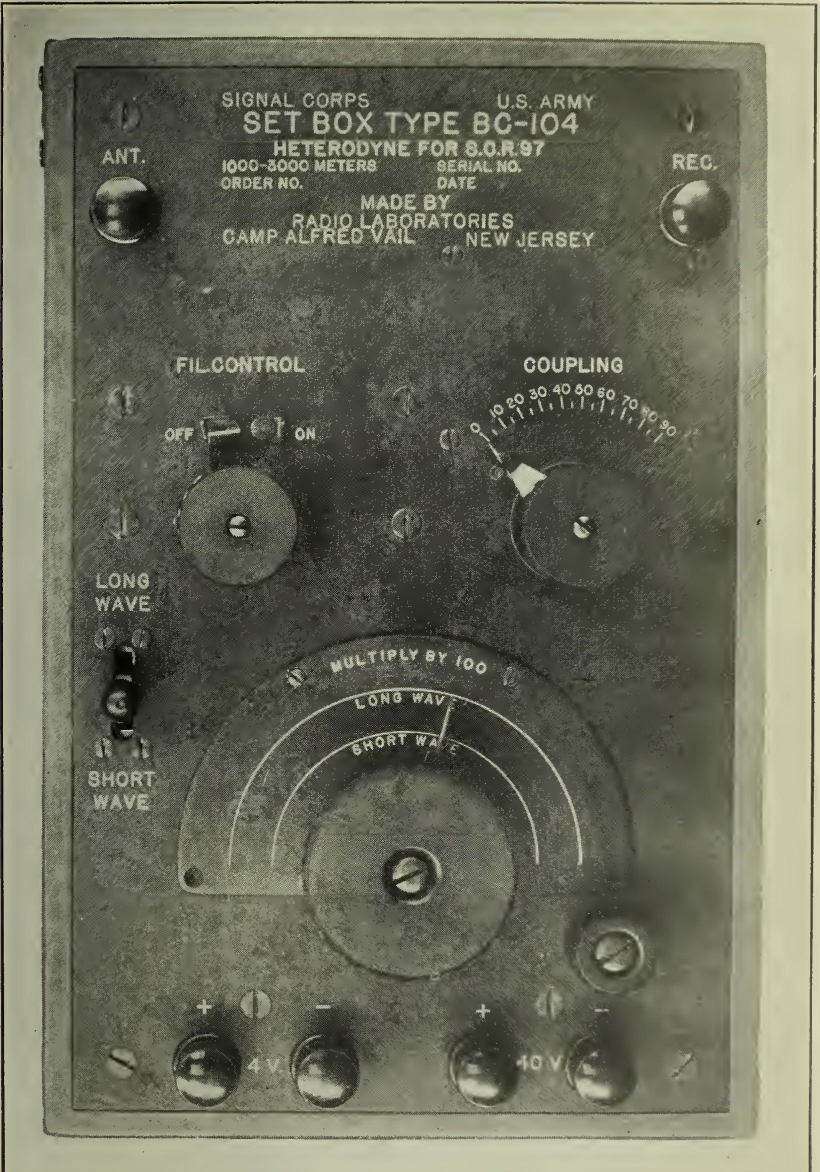

FIG. 10.

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

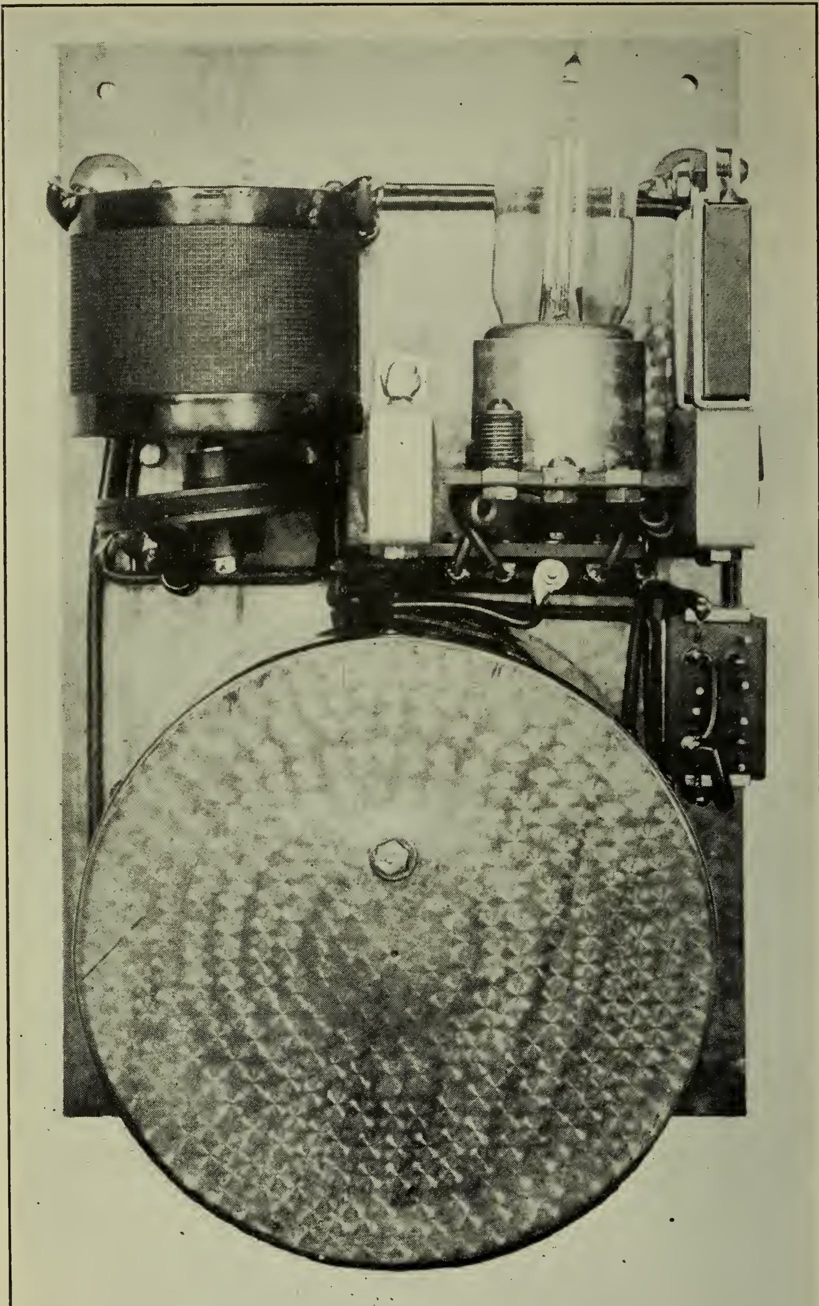

FIG. 11.

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

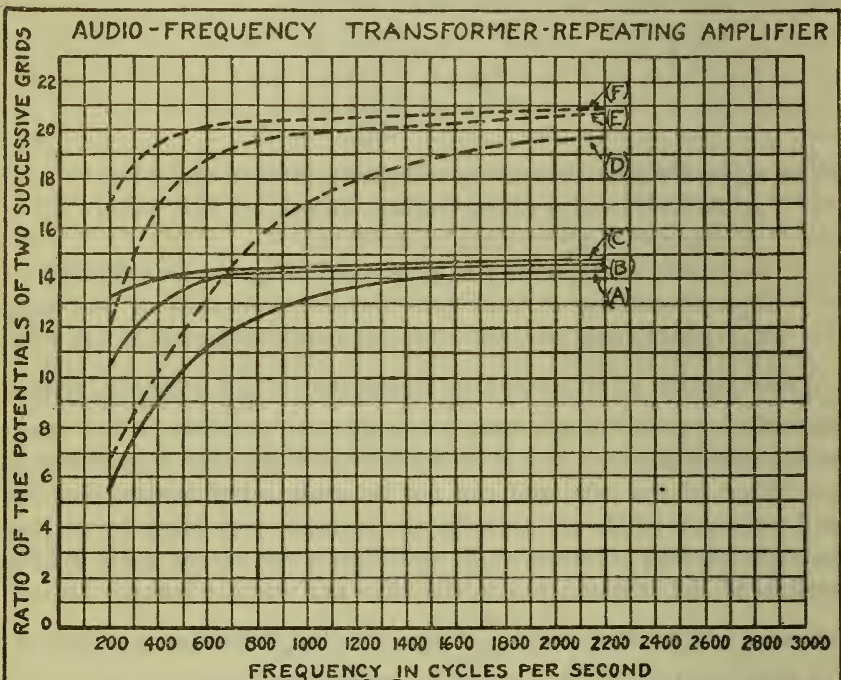

FIG. 12.

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.

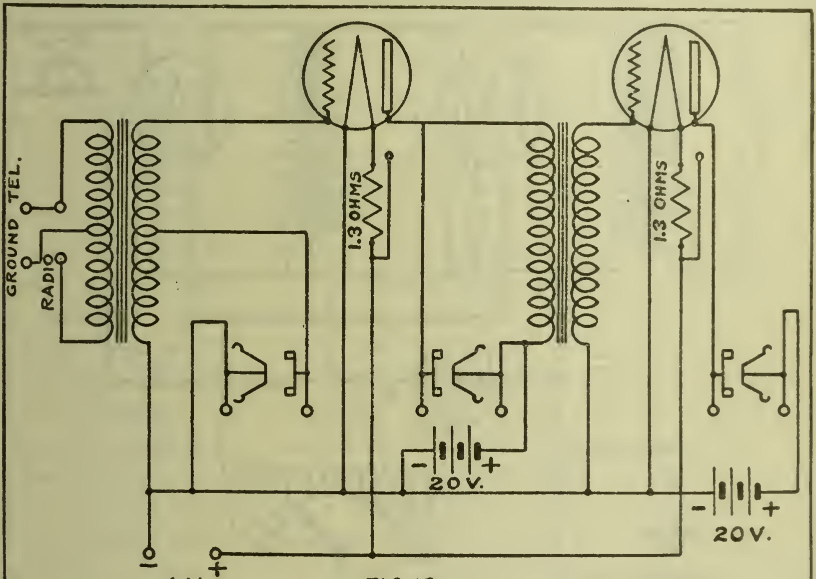

FIG. 13.

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 telephones 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

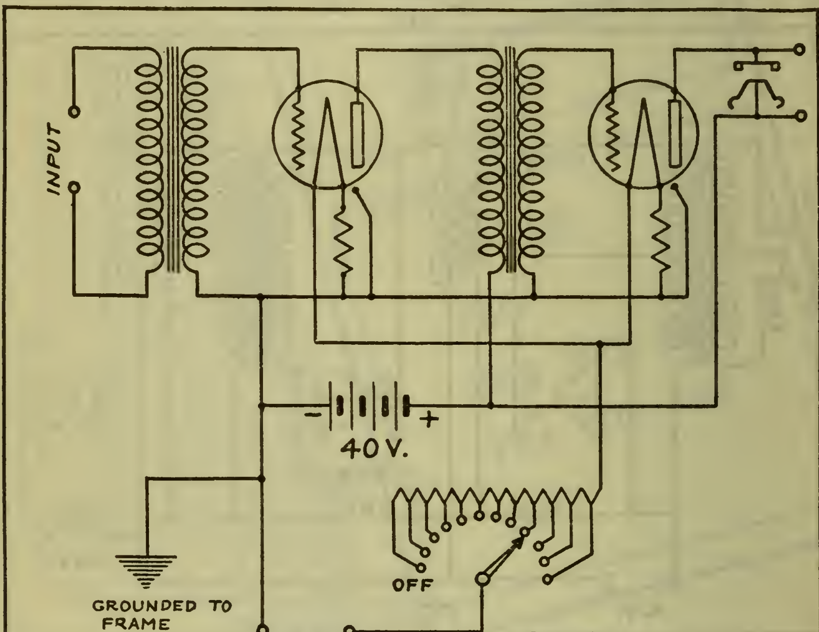

FIG. 14.

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

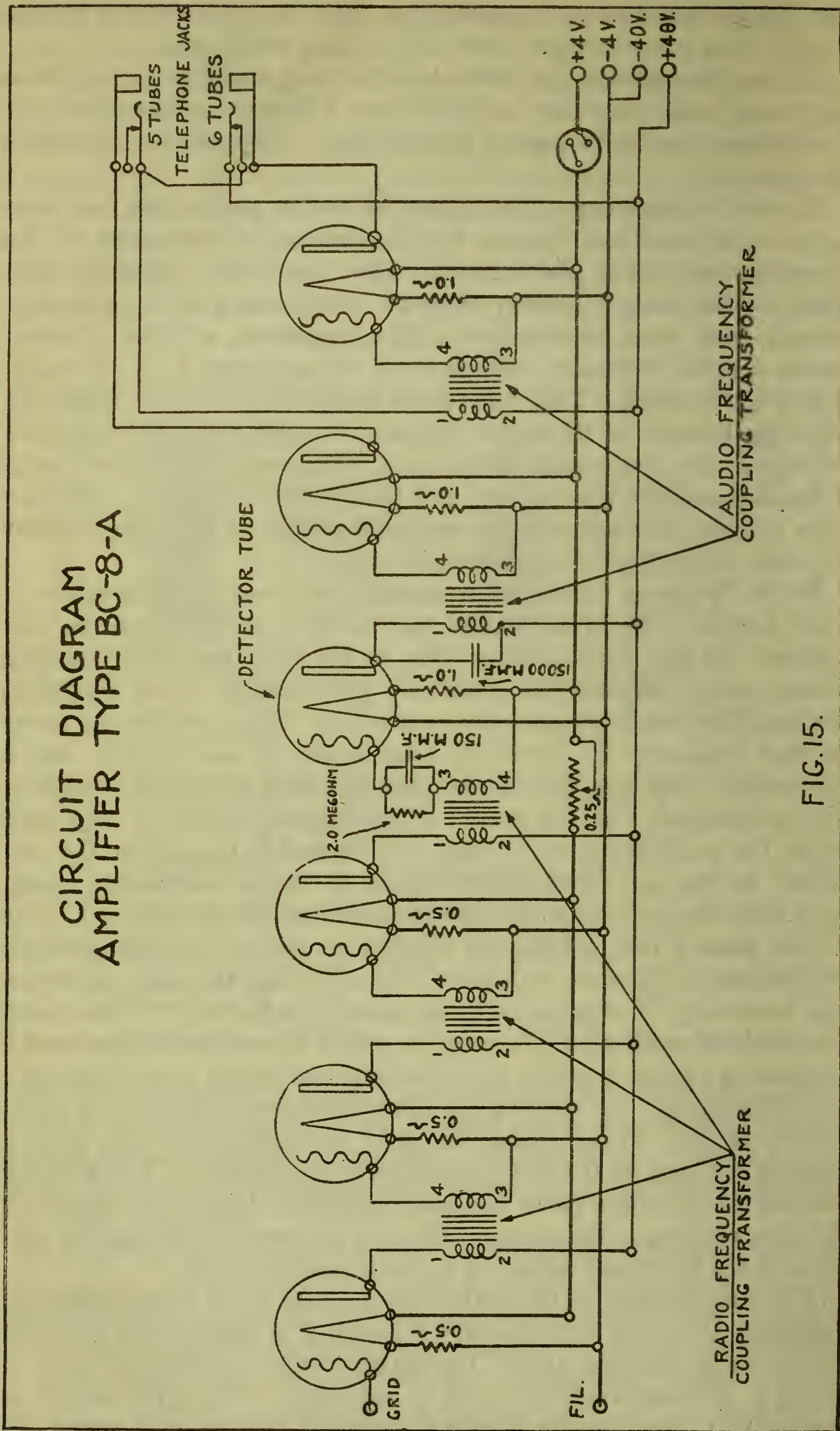
CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-8-A
5 TUBES
TELEPHONE JACKS
6 TUBES
+4 V.
-4 V.
-40 V.
+40 V.
DETECTOR TUBE
15000 M.M.F.
150 M.M.F.
2.0 MEGOHM
0.25Ω
AUDIO FREQUENCY
COUPLING TRANSFORMER
RADIO FREQUENCY
COUPLING TRANSFORMER
GRID
FIL.

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.

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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-

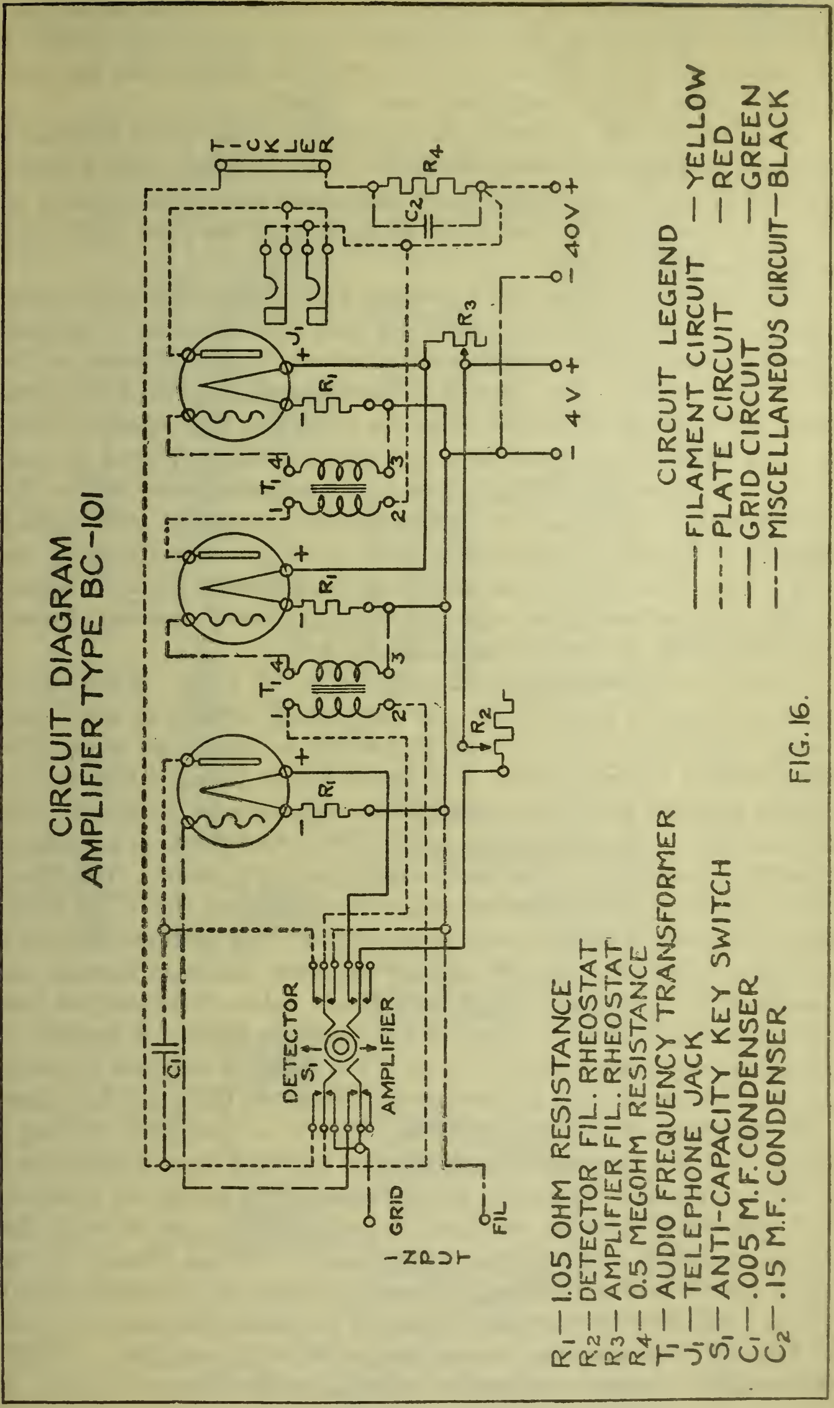

CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-101
TICKLER
R4
C2
J1
R3
40V
4V
R1
T1
R2
C1
DETECTOR
S1
AMPLIFIER
GRID
INPUT
FIL
R1 — 1.05 OHM RESISTANCE
R2 — DETECTOR FIL. RHEOSTAT
R3 — AMPLIFIER FIL. RHEOSTAT
R4 — 0.5 MEGOHM RESISTANCE
T1 — AUDIO FREQUENCY TRANSFORMER
J1 — TELEPHONE JACK
S1 — ANTI-CAPACITY KEY SWITCH
C1 — .005 M.F. CONDENSER
C2 — .15 M.F. CONDENSER
CIRCUIT LEGEND
FILAMENT CIRCUIT — YELLOW
PLATE CIRCUIT — RED
GRID CIRCUIT — GREEN
MISCELLANEOUS CIRCUIT — BLACK

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

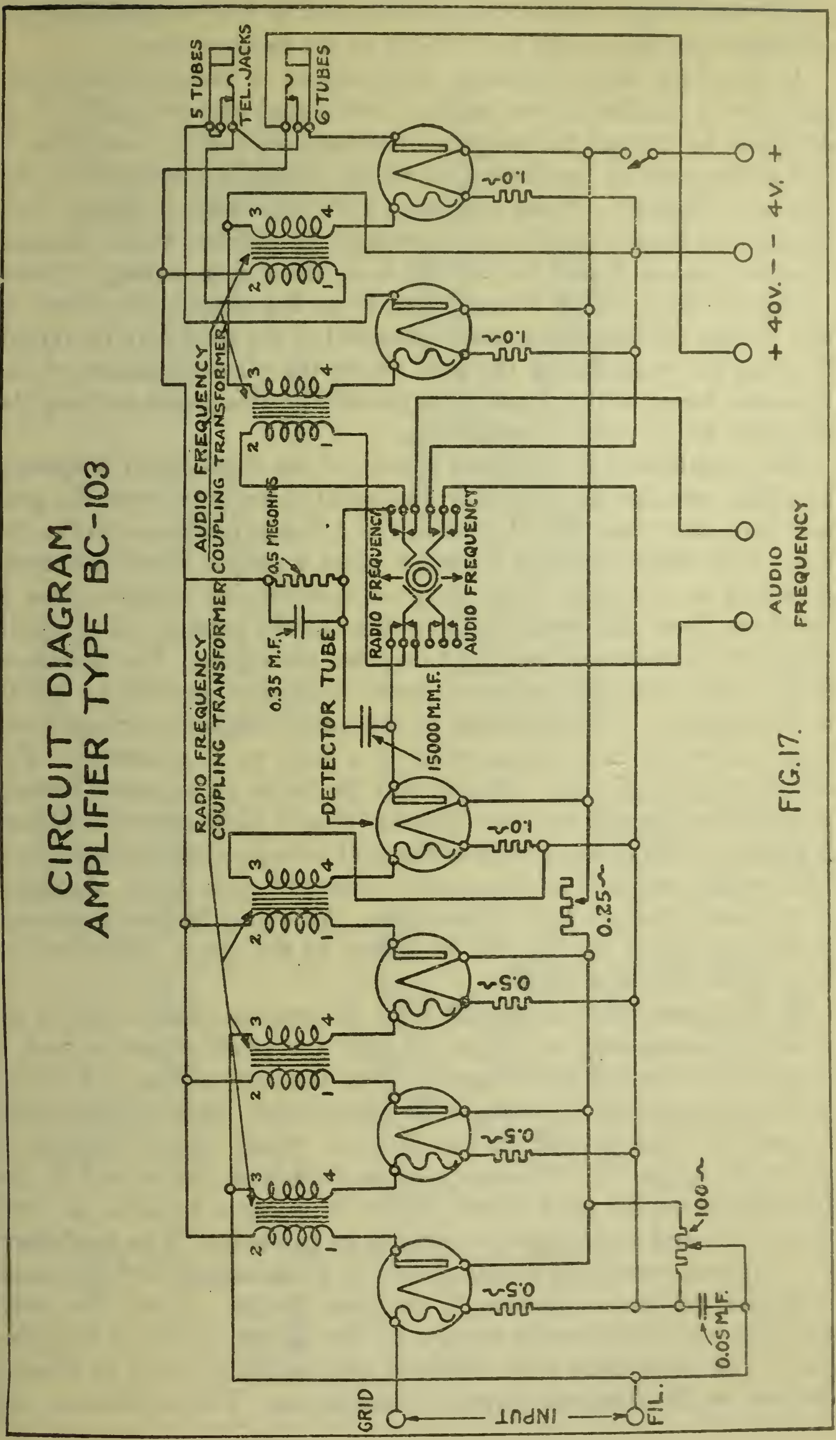

CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-103
RADIO FREQUENCY
COUPLING TRANSFORMER
AUDIO FREQUENCY
COUPLING TRANSFORMER
5 TUBES
TEL. JACKS
6 TUBES
0.5 MEGOHMS
0.35 M.F.
DETECTOR TUBE
15000 M.M.F.
RADIO FREQUENCY
AUDIO FREQUENCY
1.0~
0.5~
0.25~
100~
0.05 M.F.
GRID
INPUT
FIL.
+ 40V. −
− 4V. +
AUDIO FREQUENCY

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

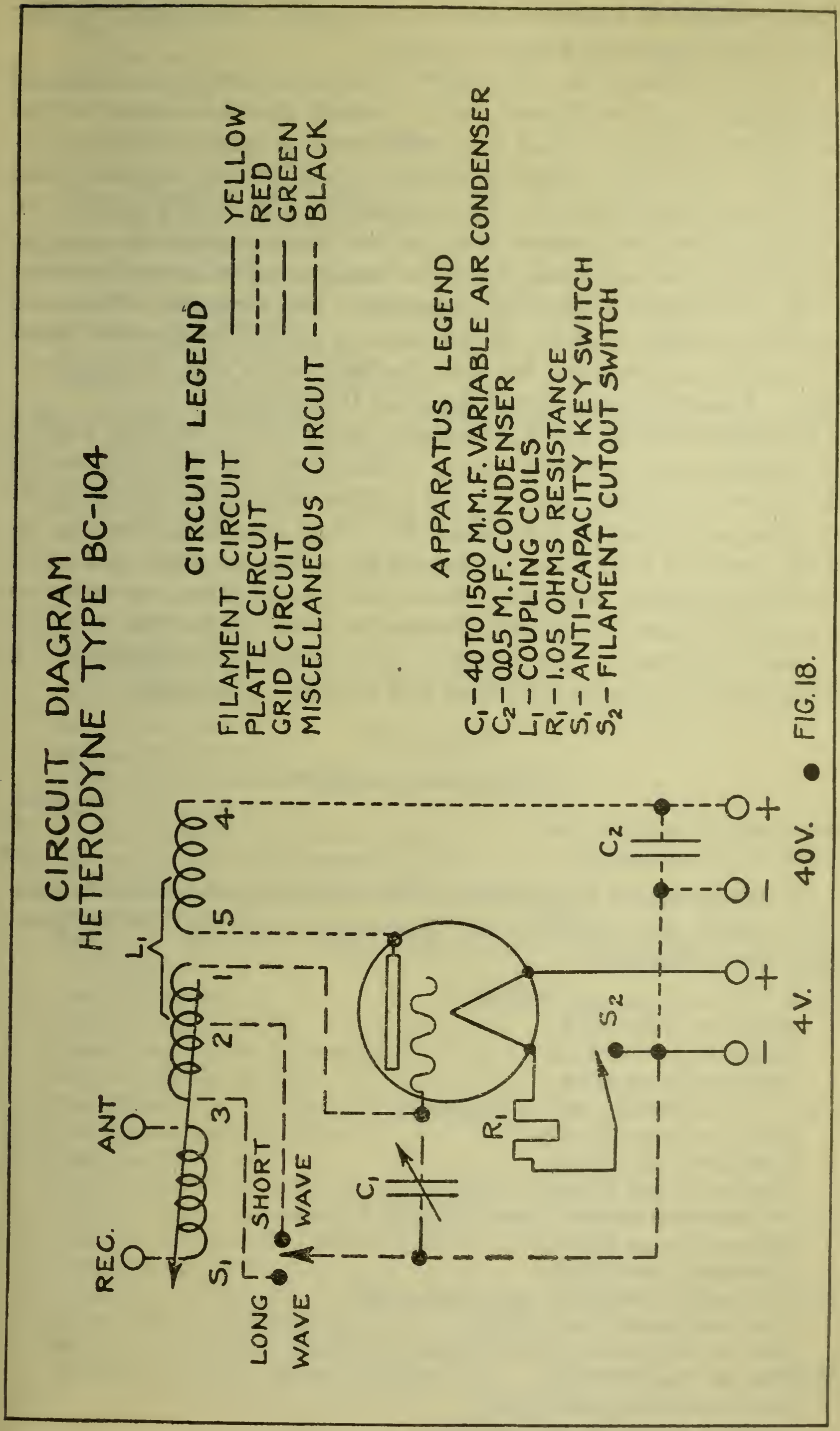

CIRCUIT DIAGRAM
HETERODYNE TYPE BC-104
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS CIRCUIT BLACK
APPARATUS LEGEND
C1 – 40 TO 1500 M.M.F. VARIABLE AIR CONDENSER
C2 – 0.05 M.F. CONDENSER
L1 – COUPLING COILS
R1 – 1.05 OHMS RESISTANCE
S1 – ANTI-CAPACITY KEY SWITCH
S2 – FILAMENT CUTOUT SWITCH
REC.
ANT
S1
LONG WAVE
SHORT WAVE
L1
1
2
3
4
5
C1
R1
S2
C2
4V.
40V.
+
–

FIG. 18.

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 (¼ 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).

FOR OFFICIAL USE ONLY

Radio Telegraph Transmitting Sets

Type SCR-74
Type SCR-74-A

(Confidential)

Radio Pamphlet
No. 11

Signal Corps, U. S. Army

Second Edition, Revised to
10-18-18

Radio Telegraph Transmitting Sets
Type SCR-74
Type SCR-74-A

THE TYPE SCR-74 and SCR-74-A radio telegraph sets are used for the transmission of radio messages between regiment and brigade headquarters. Only in exceptional cases are these sets used at battalion headquarters. They are similar to the French set "*Poste Portatif No.* 3."

These sets produce damped wave signals. The only way in which the wave length can be changed is to alter the dimensions of the antenna. On account of the broad, non-musical wave emitted, a special inverted "L" antenna, type A-3 or type A-3-A, is used because of its marked directional effect. This antenna also lends itself well to the necessity of having one which can be easily repaired under shell fire. Its characteristics permit the simultaneous use of a comparatively large number of sets within a limited area. It is described in a later paragraph.

The signals emitted by both these sets may be received with any damped wave receiving set of suitable wave length range, but the type SCR-54 or SCR-54-A set is generally used for this purpose.

Description of the Sets

The two sets are identical in their electrical characteristics and operation. They differ only in the arrangement of the various parts within the set box, and in that the cover of the set box of the type SCR-74-A set is equipped with rubber gaskets, to make the box waterproof.

The principle of the sets is illustrated in the circuit diagram of Fig. 3. Both sets comprise an open magnetic circuit induction coil, the primary of which is energized by a 10-volt storage battery when the telegraph sending key is closed. The primary circuit also comprises an ammeter which serves to indicate by its deflection whether or not the set is operating properly. The secondary winding of the induction coil is connected to an adjustable spark gap of the open-gap type. The two electrodes of the gap are connected to the aerial and ground respectively. The vibrator contacts are shunted by a 6-mfd. mica condenser, which greatly reduces the sparking at the vibrator and produces a more abrupt interruption of the primary current.

The set box contains the induction coil with its vibrator, vibrator condenser, telegraph key, ammeter, antenna spark gap, aerial and ground binding posts, and battery binding posts, to which is connected an extension cord with a plug for connection to the 10-volt battery. A screwdriver and file for making adjustments and keeping the vibrator contacts in shape, are also furnished with the box.

All these parts are arranged in the set box as shown on the photographs. A glass covered hole in the cover over the ammeter and over the spark gap, and a rubber covered hole over the key, permit operating the set with the cover closed to exclude the rain or snow, etc.

Fig. 1—Type BC-18 Set Box and Operating Panel of the Type SCR-74 Set

Installation and Operation

The method of installation is the same for both types of set and is given below. The following steps should be followed exact and in the order given.

1. Choose a location suitable for the installation of the statio This should be done with due regard for the screening effect trees and houses, and also for protection from enemy shell fire

observation. The set box itself may be installed under a protected shelter, but precautions must then be taken to thoroughly insulate the lead-in wires at the points where they enter the shelter.

2. Install the antenna, with due regard to its directional effect. The method of setting up the type A-3 antenna, which is the standard antenna for this set, is illustrated in Fig. 5. The length of this antenna is 150 feet, its height about 3 feet. The aerial wire and the two counterpoise wires are unreeled, so that their general direction

Fig. 2—Vibrator Mounted in the End of the Type BC-18 Set Box

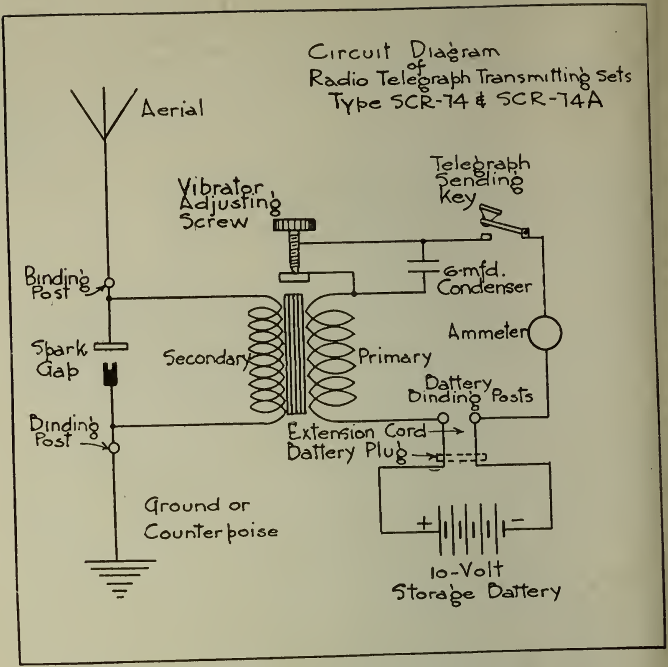


Fig. 3—Schematic Wiring Diagram for the Type SCR-74 and Type SCR-74-A Sets

will point toward the station with which it is desired to communicate and with the lead-in end of the aerial wire and plug end of the counterpoise wire at the end nearest to that station. Open the two wooden antenna supports, fasten the aerial wire to the insulators and guy the supports in position by tying the guy ropes to one or two stakes driven in the ground. The counterpoise lead-in wire is then knotted around the strut cord of the wooden support so that the connecting block will be held off the ground. Plug the two counterpoise wires into the connecting block, and bring the free ends of the two lead-in wires to the set box, taking care to keep them separated and off the ground.

The antenna used with the type SCR-74-A set is the type A-3-A, which differs but little from the type A-3 described above in conjunction with the type SCR-74 set. The main difference is that a ground mat is used in place of the two-wire counterpoise. This alters the electrical constants to only a slight degree, and oes not appreciably affect the directional characteristics. When orking on a damp ground, it is best to bury the mat about ne foot deep, or deeper if possible, and to pack the earth well ound and above it. If on dry ground, the mat is simply laid n the surface of the ground. In all cases, the location for the at is directly underneath the aerial wire.

An advantage of the type A-3-A antenna is the use of snap ooks to fasten the aerial wire to the insulators. This makes ne installation more secure. In its general aspect, this antenna ppears similar to that shown in the sketch, Fig. 5, the counter-oise being replaced by the mat.

3. Connect the antenna and counterpoise lead-in wires respective- to the "antenna" and "ground" binding posts of the set box.

Fig. 4—Type BC-18-A Set Box of the Type SCR-74-A Set

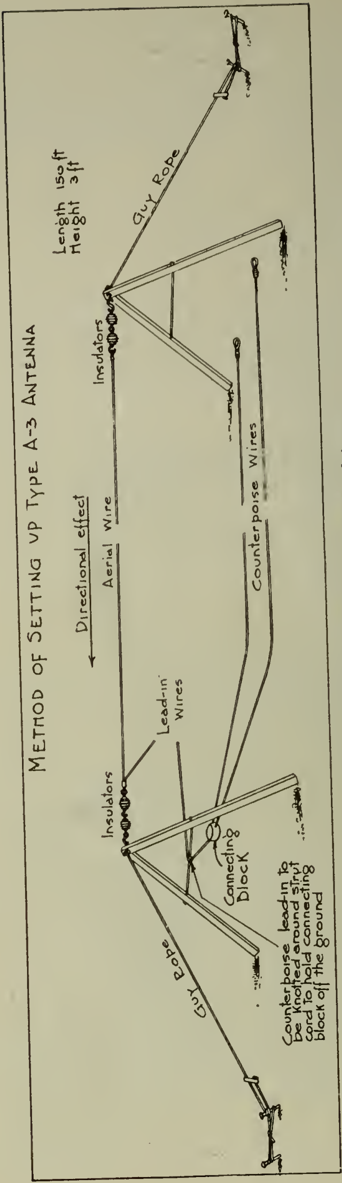


Fig. 5—Method of Setting Up the Type A-3 Antenna

4. Connect the 10-volt storage battery by means of the battery plug and connector. If no connector has been furnished with the set, use short and heavy wires, and give due regard to the polarity, as marked on the "Battery" binding posts o the set box, and on the ter minals of the battery.

5. Open the antenna spar gap all the way out.

6. Close the telegrap sending key, and adjust th vibrator by means of th vibrator screw until a goo clear, steady note is obtaine

7. Release the key, an gradually decrease the dis tance between the spark ga electrodes, turning the dis electrode about one turn a time, and closing the ke for each position, until a goo spark is obtained across t gap. The adjustment is co pleted when, upon closing the key, a rapid successi of fine, white-blue spar takes place across the ga The distance between t electrodes should be t smallest distance possil which will give such wh blue sparks in abundan without establishing a "pow arc," easily recognizable its flaming, yellowish aspe

Care should be tak during the operation, to ne touch the spark gap el trodes or lead-in wires, while the telegraph key is held down, as a serious shock will result.

8. The current indicated by the ammeter, with the gap and vibrator properly adjusted, and the battery fully charged, should be from 7 to 11 amp.

Special Precautions in Operating and Maintaining the Sets

The following rules should be strictly observed when operating the SCR-74 and SCR-74-A sets:

1. Never touch any part of the antenna circuit (lead-in wires, spark gap, etc.) while the telegraph sending key is closed.

2. Never connect the battery to the set before both the counterpoise and aerial are connected to their respective terminals on the set box.

3. Under no circumstances should the set be tried out with the counterpoise or aerial disconnected. If the telegraph key is closed after the set is connected up but without the antenna, an emf. will be induced in the secondary winding of the coil of such high voltage that there will be great likelihood of breaking down the insulation, thus rendering the set inoperative.

4. Care must be taken to have all parts of the aerial, counterpoise and lead-in wires well insulated from the ground at all points.

As was mentioned before, the type A-3 or A-3-A antenna equipment, furnished as part of these sets, is particularly well suited for the kind of service intended. The sets may however be used with antennae of different dimensions. A higher antenna, of about the same length will give good results when a longer distance of transmission is required.

These types of antennae have the advantage of being easily hidden from enemy observation. When desired or necessary, the antenna supports can be camouflaged with paint or otherwise, to meet local conditions. In general, painting the supports will be found sufficient, but in no case should any method be used whereby any material other than the insulators provided, comes in contact with the aerial wire or lead-in wire. The insulators should not be painted as this may reduce their insulating qualities.

By tying the feet of the antenna supports with cords, to pins driven in the ground adjacent to each foot, thus hinging them at the ground, it is possible to lower or raise the entire antenna by releasing or tightening one of the end guys. This may prove convenient, as the antenna can be lowered and effectively protected during periods when the set is not in use.

As a general precaution, it is well to always keep the set in as clean and dry a condition as possible.

If it is desired to use the set for longer distances, the range may be increased by using a higher antenna. This makes the antenna more vulnerable to destruction by shell fire and hence should ordinarily be used only in rear positions or in well protected forward locations. The change in dimensions might also alter the wave length, which must be taken into consideration.

Parts Lists

In ordering this set or parts of this set, specification must be made by names and type numbers as listed below, exactly. The designation printed in bold face type *only*, will be used in requisitioning, making property returns, purchasing, etc.

In ordering *complete* sets, it is not necessary to itemize the parts; simply specify, "2 Sets, Radio Telegraph Transmitting, Type SCR-74." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example "1 Equipment Type RT-3."

The Type SCR-74 Set or SCR-74-A Set is not complete unless it includes all of the items listed below, under the respective headings.

SET, RADIO TELEGRAPH TRANSMITTING, TYPE SCR-74

Equipment, Type PE-13; Power.

- 2 **Batteries, Type BB-3**; Edison storage; 10 volts, 30 amp-hr. includes powdered electrolyte in separate container.

Equipment, Type RT-3; Transmitting.

- 1 **Set Box, Type BC-18**; radio telegraph transmitting.
- 1 **Cord, Type CD-20**; extension; set box to battery.
- 1 **Bag, Type BG-4**; carrying; canvas.
- 2 **Cords, Type CD-21**; extension; set box to antenna and ground.
- 1 **Screwdriver, Type TL-2.**
- 1 **File, Type TL-5**; contact.

Equipment, Type A-3; Antenna.

- 2 **Supports, Type MS-4**; antenna; complete with guys.
- 1 **Antenna, Type AN-2**; antenna cord, 150 ft. complete with 20-f lead-in wire and 4 Electrose No. 4500 insulators, of whic 2 in series linked to each end of antenna wire; free end (insulator provided with open wire hook.
- 1 **Counterpoise, Type CP-1**; two 150-ft. lengths counterpoise wir spec. 416-I, with terminal plug on one end.

1 **Block, Type BL-3**; connecting; at one end of 20-ft. lead-in.
4 **Stakes, Type GP-2**; ground, standard.
3 **Reels, Type RL-3**; hand; for antenna and counterpoise wires.
1 **Bag, Type BG-8**; carrying; for ground stakes, antenna and accessories.
2 **Hammers, Type HM-1**; 2 lb.

SET, RADIO TELEGRAPH TRANSMITTING, TYPE SCR-74-A

QUIPMENT, TYPE PE-11; Power.

3 **Batteries, Type BB-23**; lead storage; 10 volts, 20 amp-hr.; electrolyte is not included; concentrated acid for electrolyte supplied separately in carboys; 1 in use, 2 spare.

QUIPMENT, TYPE RT-3-A; Transmitting.

1 **Set Box, Type BC-18-A**; radio telegraph transmitting.
1 **Contact, Type CN-10**; moving; with vibrator spring and screws; spare.
1 **Contact, Type CN-11**; stationary.
1 **File, Type TL-30**; contact.

IUIPMENT, TYPE A-3-A; Antenna.

2 **Supports, Type MS-4-A**; antenna; complete with guy rope type RP-5, insulator type IN-5, ground stake type GP-5 and guy rope fastener type FT-9.
1 **Antenna, Type AN-5**; with snap hooks on both ends.
1 **Stake, Type GP-6**; ground.
1 **Reel, Type RL-3**; hand; for antenna wire.
1 **Bag, Type BG-15**; carrying; for ground stakes, antenna and accessories.
1 **Hammer, Type HM-1**; 2-lb.
1 **Mat, Type MT-3**; ground.
1 **Pliers, Type TL-19**; combination.
$\frac{1}{4}$ lb. **Tape, Friction**; $\frac{3}{4}$-in.

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

FOR OFFICIAL USE ONLY

RADIO TELEGRAPH TRANSMITTING SET

Type SCR-69

(Confidential)

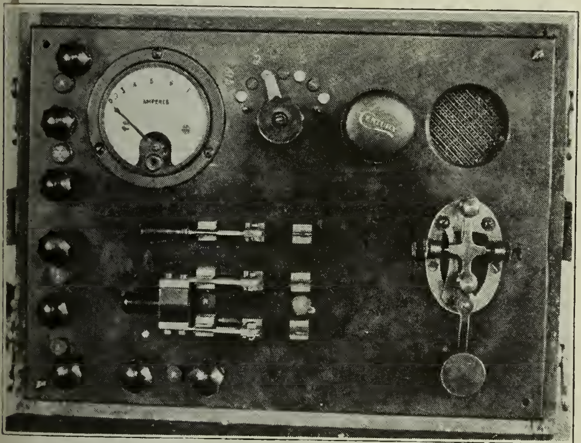
Radio Pamphlet
No. 14

Signal Corps, U. S. Army

Second Edition, Revised to
10-30-18

Radio Telegraph Transmitting Set
Type SCR-69

THE RADIO telegraph transmitting set, type SCR-69, is an undamped wave set which is intended primarily for use as an instruction unit. It is designed to serve somewhat the same urpose as the French E-3 or E-10 sets and is issued only to organizaons in training. Light weight, high efficiency and sharp tuning e its special characteristics. Three kinds of undamped wave nding may be used with the one set, making it possible to comunicate with a receiving station, whether the latter is equipped ith a heterodyne or an ordinary rectifying detector set. This ature makes it more or less universal in character and particularly



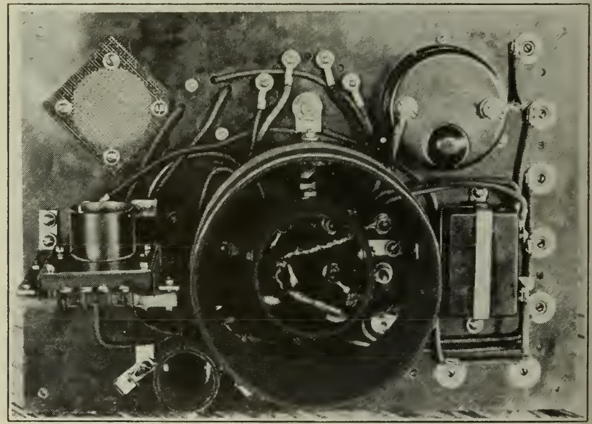
Operating Panel of Type SCR-69 Transmitting Set

ited to use under training conditions where several types of ceiving sets may be employed. In case the batteries of a eterodyne or autodyne receiving unit working with this transitting set should fail, it would still be possible to use this same t by sending buzzer-modulated waves and receiving by ordinary rystal detection.

As the operating characteristics of this set have not been satis factory, only a comparatively small number of sets will be manu factured, and it is anticipated that these will be displaced in th near future by the type SCR-79 set, described in Radio Pamphl No. 17.

Description of the Set

The type SCR-69 set consists essentially of a three-electroc vacuum tube, type VT-12, having its grid and plate circui inductively coupled together and to the antenna. The thr coupling coils (antenna, plate and grid coils) are mounted on tl same axis. The antenna and grid coils are about 7 in. in diamet and the plate coil is about 3 in. in diameter, and these coils are wound that the capacitance between the turns is reduced to a lo value. The wave length of the set may be changed by means the four taps on the antenna coil, whereby four different wa lengths ranging between the limits of about 600 meters and 15 meters with a type A-6 antenna, can be secured. A definite spe fication as to the type of antenna to be used with this set h



Mounting of Apparatus on Under Side of Panel

not been made. Its operation with the type A-6 antenna s somewhat improved by opening the "V" to a greater angle th the standard 60 deg., in order to increase the capacitance of e antenna. The greatest capacitance is obtained when the are is 180 deg. The three masts should then be erected in a strai ne with the station it is desired to signal, the lead-in wires being onnected as usual at the center.

The vacuum tube plate current is supplied by a dynamotor unning on a 10-volt storage battery to supply 325 volts potential etween the plate and the filament. The high voltage side of this ynamotor is shunted by a condenser which serves the double urpose of smoothing out the small variations in the 325-volt direct urrent supply, and of providing a path for the high frequency scillations generated by the tube which would otherwise be choked ut by the impedance of the dynamotor windings. A negative rid potential of about 20 volts is supplied by a BA-2 dry battery hich is contained inside the case. The filament is heated by a volt storage battery which forms part of the auxiliary apparatus companying the set. The filament circuit includes an adjustable eostat which should be set to limit the filament current to 1.36 np. This corresponds with the VT-12 tubes to a reddish yellow ow and with the VT-2 tubes, should these happen to be used in

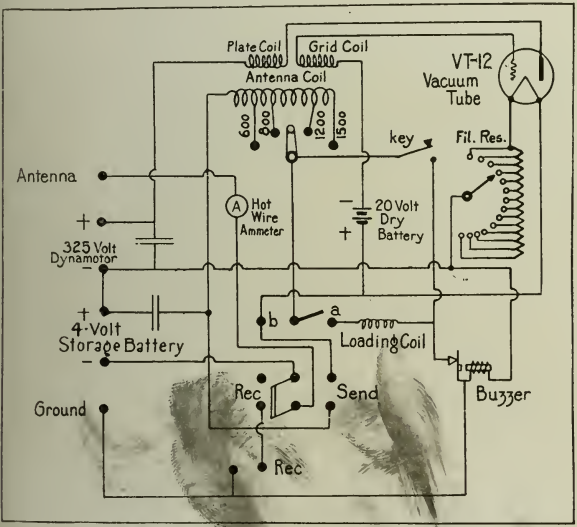


Fig. 1—Wiring Diagram of the Type SCR-69 Set

ergency, to a dull red glow. The rheostat is not shown in the of the panel, but it forms part of the panel equipment on the s now under construction.

A sending key and hot wire ammeter are inserted in the antenn circuit. The latter indicates whether or not the vacuum tube oscillating. A double pole double throw switch mounted on th panel provides a connection such that the antenna and ground the sending set may be readily connected to any receiving s which may be connected to the "Receiving" terminals on th panel of SCR-69.

Method of Operation

The set being properly connected up to the antenna, groun dynamotor and batteries, and the d. p. d. t. switch closed to th right (sending position), there are three methods of radiating th oscillations generated by the tube which correspond to the thr positions of the single pole double throw switch marked ab, Fig. and mounted on the panel of the set. The character of wav radiated, corresponding to each of the three positions of this switc is as follows:

Compensated Wave Sending

S. P. D. T. Switch Closed to the Right.—Closing the switch the right places the small loading coil in parallel with the sending ke The equivalent circuit is shown in Fig. 2, first diagram, for simplicit With these connections, the oscillations generated by the tube a radiated continuously from the antenna, and are of a wave length λ determined by the size of the antenna and the tap used on t antenna coil. When the key is now closed, in sending signals, t small loading coil is short circuited, thus reducing the inducta of the antenna and shortening the wave length to a value λ_2. T condition is shown in Fig. 3, first series of waves. The sm loading coil, which has about ten turns of wire and a diameter about 2 in., is so calculated that the difference between the wa lengths radiated with the key open and with the key closed is fr 5 to 10 meters. As these waves are undamped, they are recei by the heterodyne method which affords very sharp tuning a thereby makes it entirely possible to tune the receiving set to t shorter signal wave λ_2, and cut out the interference from the lon wave λ_1, corresponding to the key open. It is also possible receive both waves simultaneously if so desired. With this adju- ment, two notes are heard in the receiver, a high pitched note the spaces and intervals and a low pitched note for the dots a dashes. This method of sending is called the "compensated wa or "detuning" method.

Cut-In Sending

S. P. D. T. Switch Open.—The equivalent circuit for this connection is shown in the second diagram of Fig. 2. In this case, the key is placed directly in the antenna circuit so that it opens and closes that circuit. The result is that the oscillations generated by the tube are radiated from the antenna only when the key is

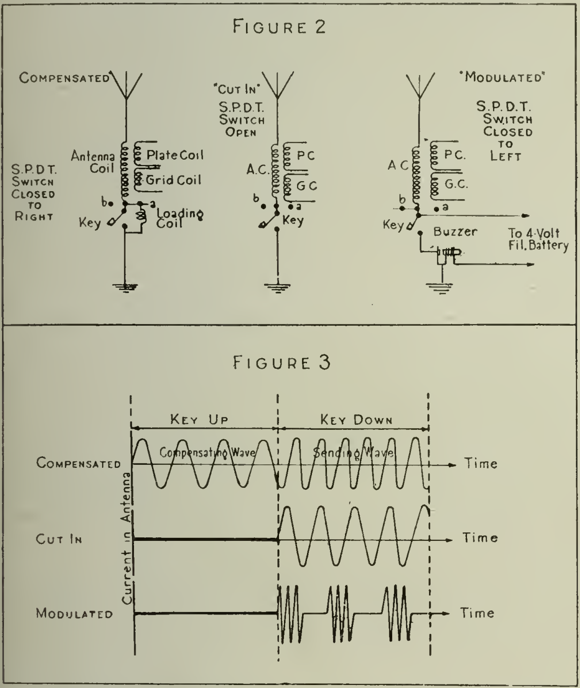


Fig. 2 and 3—Schematic Representation of Different Sending Connections and Waves Radiated

losed, no energy leaving the antenna when the key is open. A lot or dash will then be sent out as a train of undamped waves Fig. 3, second series of waves), while a space will correspond to no nergy sent out. As for the compensated method, reception of hese signals must be made by the heterodyne method, the only ifference in the signals heard at the receiving station being that o note will be obtained for spaces or intervals. This method of ending is called the "cut-in" method.

Modulated Sending

S. P. D. T. Switch Closed to Left.—The equivalent circuit for this position of the switch is shown in the third diagram of Fig. 2. In this case, the antenna circuit is opened when the key is up, and no energy is radiated. When the key is down, energy is radiated in a manner similar to that of the cut-in method, except that the closing of the key not only completes the antenna circuit, but also a circuit through a small buzzer, the vibrator of which opens and closes the antenna circuit. The undamped wave thus sent out is interrupted at regular intervals by the buzzer vibrator and a dot or dash is consequently made up of a series of short trains of undamped oscillations (Fig. 3, third series of waves). While the frequency of the oscillations is above audibility, the wave train or group frequency is equal to the buzzer vibrator frequency and therefore within the range of audibility. These waves can therefore be received by an ordinary receiving set and rectifying detector, just as damped wave signals. This method of sending is called the "modulated" method.

Choice of the Method of Sending

Each of the above sending methods has its respective advantages and disadvantages which determine and limit its use. The compensated method is the best of the three, in that the constants of the various circuits are changed very little by the closing of the key and there is therefore no danger of the tube being stopped from oscillating. The ammeter in the antenna circuit should give a practically constant reading whether the key is closed or open. This method has the disadvantage that it requires a certain amount of skill on the part of the operator, as no sound is produced by the transmitter and he must therefore make his dots and dashes purely by touch and not at all by ear. At the receiving end, it is not always possible to completely tune out the compensating waves; that is, the waves corresponding to the spaces, and the signals may be somewhat harder to read and cause an untrained operator some trouble. In tuning a set to receive waves sent out by the compensated method, it is important that the sending and not the compensating wave should be tuned in, as the former is made up of the signalling dots and dashes, while the latter is made up of the spaces between the dots and dashes.

The cut-in method gives no radiation of electric waves when the key is up. When the key is closed, the antenna circuit is suddenly coupled to the tube circuit. This is generally sufficient to produce an initial change in the potential of the grid of the tube ınd thus start it oscillating. However, due to various conditions, ıt sometimes happens that the resulting change is not sufficient, and oscillations may not take place when the key is closed. This method is therefore not as reliable as the compensated method, but it may be more easily read at the receiving station, as it produces only one note in the receiver. It has the same disadvantage for the sending operator as the compensated method—no sound to aid the hand.

The modulated method of sending has the same defects and advantages as the cut-in method. It has the additional advantage that the buzzer emits a sound which may assist the operator in sending. However, due to the breaking up of the waves, less energy is radiated by the antenna. The modulated method is the only one of the three by which signals can be received by means of an ordinary crystal detector such as is supplied with the SCR-54 receiving set.

Particular care should be taken that the antenna and lead-in wire are completely insulated from the counterpoise and the ground, as a leak from antenna to ground, due to contact with a tree or shrubbery, or even leakage due to rain or damp weather, will not only cut down the radiation considerably, but may also prevent the tube from oscillating. Care should be taken that the counterpoise wire is heavily insulated from ground. A poorly insulated or partially grounded counterpoise will increase the antenna resistance and may prevent the tube from oscillating. The resistance of the antenna and lead-in wires should be kept as low as possible.

Parts List

In ordering this set or parts of this set, specification must be made by names and type numbers as listed below, exactly. The designation printed in bold-face type *only* will be used in requisitioning, making property returns, purchasing, etc.

In ordering *complete* sets, it is not necessary to itemize the parts; simply specify, "2 Sets, Radio Telegraph Transmitting, Type SCR-69." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment, Type PE-8."

The Type SCR-69 set is not complete unless it includes all of the items listed below:

SET, RADIO TELEGRAPH TRANSMITTING, TYPE SCR-69

EQUIPMENT, TYPE PE-8; Power

- **2 Batteries, Type BB-1;** Edison storage; 7 cells, 10 volts, 37.5 amp-hr.; 1 in use, 1 spare.

2 **Batteries, Type BB-2;** Edison storage; 3 cells, 4 volts, 75 amp-hr.; 1 in use, 1 spare.

1 **Dynamotor, Type DM-1;** Westinghouse; 10-300 volts, 50 watts.

Equipment, Type RT-6; Transmitting.

1 **Set Box, Type BC-34;** Radio telegraph transmitting; complete with carrying strap.

5 **Tubes, Type VT-12;** vacuum; 1 in use, 4 spare.

Equipment, Type A-6; Antenna; (old type SCR-53 set).

3 **Mast Sections, Type MS-1;** without tubes.

12 **Mast Sections, Type MS-2;** with tubes.

3 **Caps, Mast, Type MP-5.**

3 **Insulators, Type IN-1;** hard rubber, with hooks.

9 **Reels, Type RL-3;** hand.

1 **Antenna, Type AN-5;** two lengths of braided antenna cord 150 ft. long, and one length of lead-in wire 40 ft. long, all carried on three hand reels.

9 **Guys, Type GY-3;** No. 5 sash cord, each 36 ft. long, with metal tent slide and hook; a set of three guys to be carried on each of three hand reels.

1 **Counterpoise, Type CP-4;** two lengths of wire 150 ft. long, and one lead-in wire 40 ft. long, all joined together at their intersection; to be carried on three hand reels.

3 **Hammers, Type HM-1.**

9 **Stakes, Type GP-2;** guy.

3 **Cords, No. 5 Sash; Pieces, 3 ft. Long**

1 **Chest, Type BC-35;** carrying; used for packing antenna equipment for transportation.

FOR OFFICIAL USE ONLY

TWO-WAY T. P. S. SET

Type SCR-76

(Confidential)

Radio Pamphlet

No. 15

Signal Corps, U. S. Army

8-10-18

Two-Way T.P.S. Set
Type SCR-76

TWO-WAY T. P. S. SET, TYPE SCR-76

The type SCR-76 set is a transmitting and receiving set for ground telegraph work (T. P. S. or earth induction), and is therefore to be used at stations where two-way communication is necessary. It is practically an assembly of the type SCR-71 T. P. S. buzzer and the type SCR-72 amplifier (with some important changes in design) into a single unit to facilitate the installation and use of the two when both are required at one location. The set comprises an adjustable frequency power buzzer, a telegraph key for sending, and a two-stage vacuum tube low frequency amplifier for receiving. The power required to operate the buzzer and to light the filaments of the vacuum tubes is derived from a 10-volt storage battery.

Principles of Operation

The principle of operation of the SCR-76 set is illustrated in the wiring diagram given herewith, Fig. 1. In general it consists of generating by induction, high potential current of audio frequency, which is caused to flow through the ground between two ground terminals separated by about 500 ft. In flowing through the ground, the lines of current spread out in all directions so that some of them may be intercepted at considerable distances by a suitable receiving device similarly connected to the ground and sensitive enough to respond to the extremely small currents thus received by conduction through the earth. Then by breaking up the pulsating emf. impressed on the ground into dots and dashes, it is possible to read the signals at the receiving station.

In the two-way T. P. S. set, the same ground connections and the same 10-volt storage battery are used for both sending and receiving, this being accomplished by means of a double pole double throw "Transmit-Receive" switch mounted on the panel of the set. With the switch in the "Transmit" position, the local circuit from the storage battery through the sending key and the primary of the power buzzer is completed and the base line wires are connected directly to the secondary or high potential winding. When the sending key is closed, the vibrator interrupter makes and breaks the current through the primary winding at a frequency which is controlled by means of small

weights screwed to the vibrating armature. The followi
frequencies are possible:

Large weight out ....630 cycles per second.
Large weight in ....700 cycles per second.
Two small weights out ..830 cycles per second.
One small weight out ...980 cycles per second.
One small weight in ....1150 cycles per second.
No weights ....1380 cycles per second.

The pulsating primary current resulting from the action the buzzer, induces an alternating emf. of high potential the secondary winding.

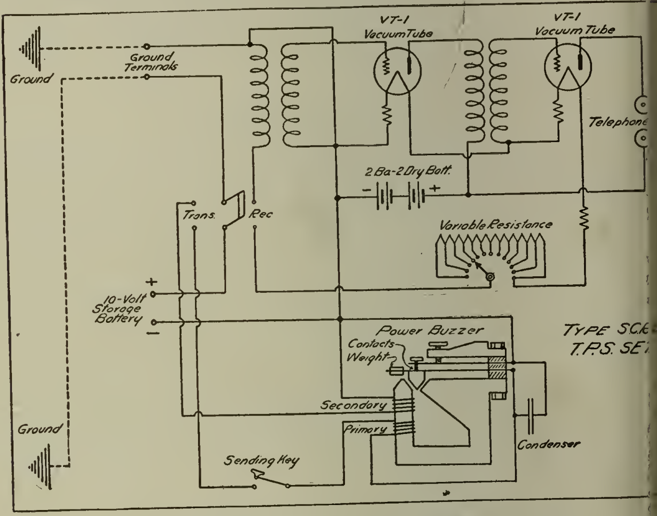


Fig. 1—Schematic Circuit Diagram of Two-Way T.P.S. Set.

The power buzzer is a double winding, closed magnetic circ buzzer interrupter, of practically the same construction the SCR-71 T.P.S. buzzer. As in the SCR-71 buzzer, a conde is connected across the vibrator contact points to reduce spark and improve operation. For every change of freque the screw on top of the buzzer should be adjusted to giv good clear note, and then locked in position. The adjustn should be made as tight as possible and still give a clear n as the current input into the ground will then be a maximu

For good operation of the buzzer, the vibrator contact po must be clean, and the surfaces even and parallel. A some time, these contact points may become pitted and require cleaning and truing up. It is best not to use the file furnished with the set, but to remove the contacts from the vibrator,

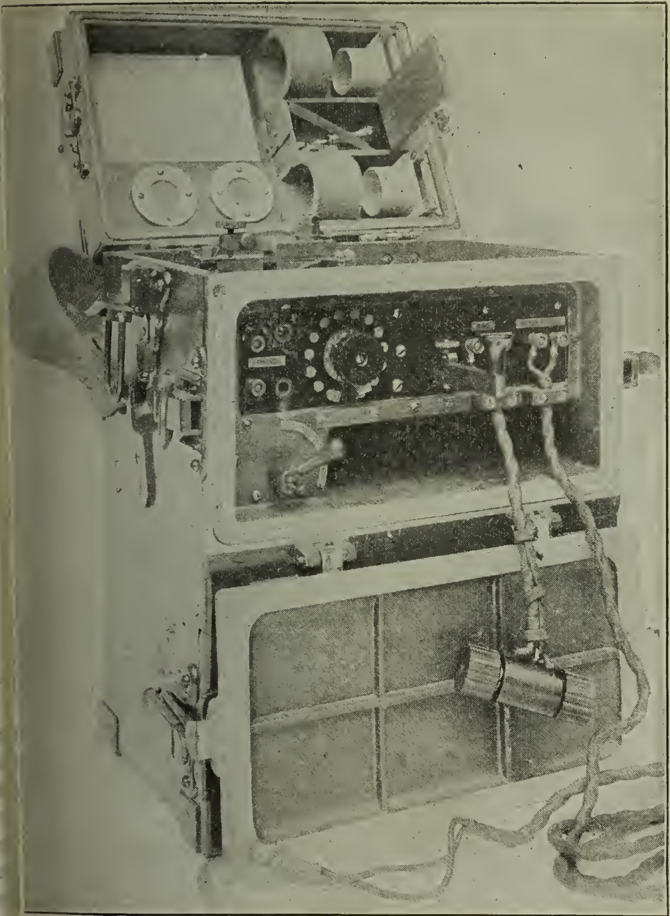


Fig. 2—Buzzer in Top Compartment and the Operating Panel on the Side.

ıd rub them gently on a piece of emery cloth laid on a flat rface. Only in exceptional cases will it be found necessary

to use the file or to replace the contact points with the spa
ones furnished with the set.

With the switch closed in the "Receive" position, the ba
and 10-volt battery are connected to the amplifier. This is
low frequency, two stage amplifier, using two type VT-1 thre
electrode vacuum tubes connected for cascade amplification b

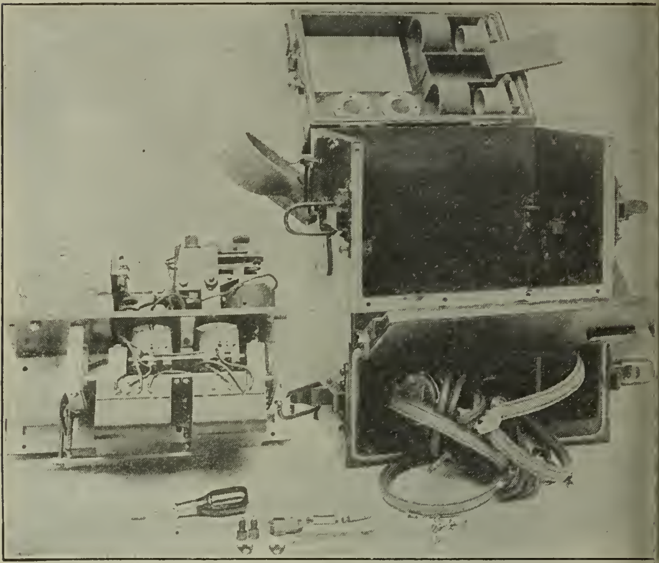


Fig. 3—Radio Apparatus Removed from Set Box.

means of two iron core transformers. Jacks and binding pos
for connecting telephone receivers are provided in the pla
circuit of the last tube. The filaments of the two tubes are co
nected in series to the 10-volt storage battery. Three fix
resistances having a total value of 3.9 ohms, and a 6-oh
resistance variable in 12 steps, are in series with the filame
circuit. The variable resistance is operated by means of
dial switch on the operating panel of the set, and is cut entire
out of the circuit on the last point to the right, this bei
the position for maximum amplification. To reduce the degr
of amplification, the rheostat is turned to the left to inse
resistance in the filament circuit. This decreases the filame
temperature and reduces the electron emission in the tube

and hence the degree of amplification. A plate potential of about 45 volts is obtained for both tubes by means of two type BA-2 dry batteries connected in series. When the battery voltage has run down to 34 volts, (17 volts each) the batteries should be replaced.

When it is necessary to replace the dry batteries of the amplifier circuit, particular care must be taken to see that they are connected in with the correct polarity. This is essential for the operation of the vacuum tubes. It is also necessary that both vacuum tubes be in good condition, since the amplifier cannot operate on one tube only, with the other one broken, burned out, or out of the circuit. If the amplifier does not work properly, this may be due to a poor telephone connection, or to a wrong connection of either the storage or the dry batteries, or to the failure of one of the tubes.

When the set is not in use, the Transmit-Receive switch should be in the "Off" position as this will avoid any possibility of unnecessarily running down the storage battery.

Mounting of the Set

The set is mounted in a rugged wooden case having the overall dimensions, 15¼ in. x 12⅞ in. x 8½ in. This case is provided with three doors or covers, one at the top and two on the front side, which close against rubber gaskets and are held tightly by strong toggle latches, Fig. 2 and Fig. 3. This construction makes the set fairly waterproof, especially if care is taken to keep the rubber gaskets clean and free from dust or mud before clamping the doors shut.

The upper cover gives access to the power buzzer, the tubes in use, and the dry batteries in use. Two spare vacuum tubes, spare parts for the buzzer, the vibrator weights and tools are mounted in the top of the cover. This cover should be open only while adjusting the buzzer or replacing tubes or batteries. It should be kept closed during operation, particularly in rainy weather.

The upper side-cover is of metal and hinges downward. It encloses the operating panel of the set. On this are mounted the telegraph sending key, the filament rheostat, the "Transmit-Receive" switch, two telephone jacks and two emergency telephone binding posts, two binding posts for the line wires, and two binding posts for connecting the 10-volt storage battery.

The telegraph sending key may be folded back against the panel so that it will not protrude beyond the face of the box and thus will allow the cover to close.

Two twisted pair cords are also permanently attached to panel binding posts. One of these is provided with lugs for making connection to an Edison storage battery, and the other is connected to a special double terminal block by means of which connection to the two base line wires is effected. When not in use, these two cords are folded in the pocket provided underneath the operating panel which may be clearly seen in Fig. 2. If a French made storage battery is used instead of an Edison battery, the connection lugs are to be replaced by special terminals provided for the purpose, and normally kept in the top cover box compartment of the set. A rubber curtain is provided with the set to protect the operating panel while using the set in rainy weather.

The bottom compartment of the box, which is normally closed by a wooden cover hinging upward, contains two P-11 telephone head sets and two spare BA-2 dry batteries, Fig. 3.

It may be necessary to take the set apart for repair or inspection. This may be done by opening the top cover and the metal side door and unscrewing the six screws which fasten the panel frame work to the set box. The entire set will then come out of the box as a unit.

Opening a Station

To open a station, the base line, approximately 500 ft. long is established in accord with the rules laid down below. The set box is then laid horizontally on its back, the bottom door opened, the telephone head receivers removed, and the door carefully clamped shut. This is done in order to keep the set clean and waterproof. The box is then set upright and the metal side door opened. The battery wires are connected to the 10-vol storage battery terminals, due regard being given to the polarity The two base line wires are connected to the special connector In order to remove any mechanical strain from the electrical connections on the connector, the line wires are tied together with a piece of cord about 8 in. from their free ends and the cord is tied to the small metal ring at the center of the connector All these inter-connections between set parts are shown in Fig. 4

The telephones are plugged in the telephone jack, or connected to the telephone binding posts. By moving the switch to "Re

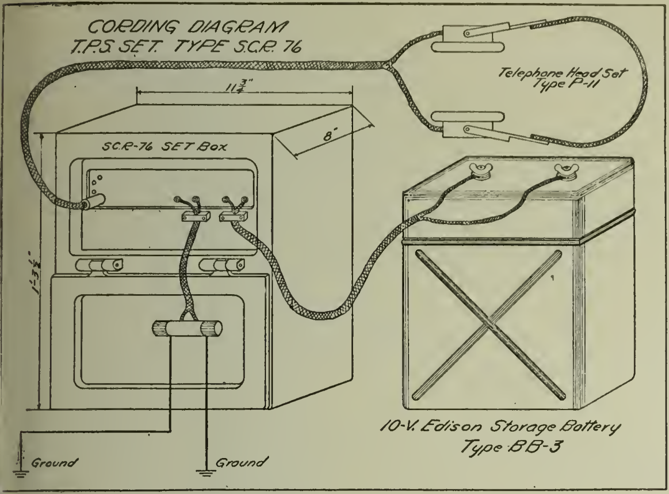


Fig. 4—Cording Diagram of T.P.S. Set, Type SCR-76.

ceive" and setting the filament rheostat to the desired value (generally to "Maximum"), the set is ready for receiving signals. If it is desired to send a message, the switch is thrown to "Transmit", the telegraph key straightened out and the buzzer adjusted to give a clear note of the desired frequency. This is done, after opening the top cover, by placing the proper weight on the vibrator armature and adjusting the set screw of the buzzer. The cover is then closed and the set is ready for operation.

How to Lay Out the Base Lines

When laying out the base lines of various stations communicating with each other, it is very important to follow the general rule of arranging them so that the imaginary straight line joining the centers of the base lines of the stations will make equal angles with the two base lines, the angles considered being taken on the same side of that imaginary line and between the base lines. The best position is that in which the two base lines are parallel to each other and the line joining their centers makes right angles with them. This arrangement is indicated in the first drawing of Fig. 5. The other two drawings show the application of the above rule by two different methods to the case of one station communicating with two others.

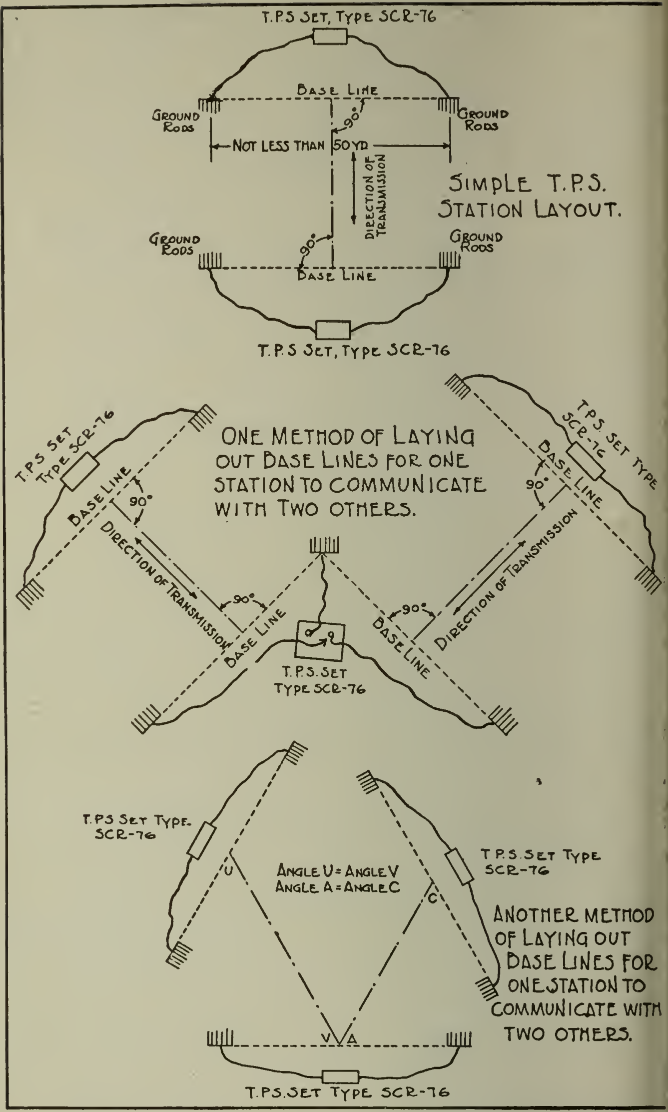


Fig. 5—Methods of Laying Out Simple T.P.S. Station, and One Station to Communicate with Two Others.

If one station is to communicate with a number of different stations, best results are obtained by providing at that one station a number of base lines, laid out radially around the station in positions at right angles, respectively, to the lines joining that base line to each of the other station base lines. A selector switch then enables the connection of the central station to any desired base line.

The installation of such a central station may be made in a number of different ways. Two methods are illustrated in Fig. 6. By the method shown in the upper drawing, any one of the four outer ground terminals may be used with the local ground to make four different base lines, these covering closely almost any direction. By the method shown in the lower drawing, the two switches will usually be placed to make A and A, or B and B, etc., the ends of the base line in use. However the terminals D and B on opposite switches might be used as the pair of ground terminals if they were laid out the proper distance apart. This gives an idea of the various combinations possible.

The first method is preferable, it being easier to install and operate. There are only five grounds to establish, and one half of the selector switch only is used. In the second method, both sides of the switch are used and there are eight grounds to establish.

When a station having a single base line is to communicate with a central station having the choice of a number of base lines, the single station will establish its base perpendicularly to the line joining the two stations. The central station then selects the one of its bases which is nearest perpendicular to the line joining the two stations.

The best method for laying out the base lines is to use a compass, by means of which the direction of the bases of the various stations can be determined accurately. A number of types of compasses are in use, which makes it impossible to give definite rules as to their use in this connection.

Another important consideration is the method of grounding the far ends of the base line wires. Twelve ground rods are furnished with the set. At least four rods should be driven into the ground in a straight line at each end of the base, and at a distance apart of not less than 2 ft. They should be driven at least 1 ft. into the ground. It is well to moisten the ground around the rods after they have been driven in.

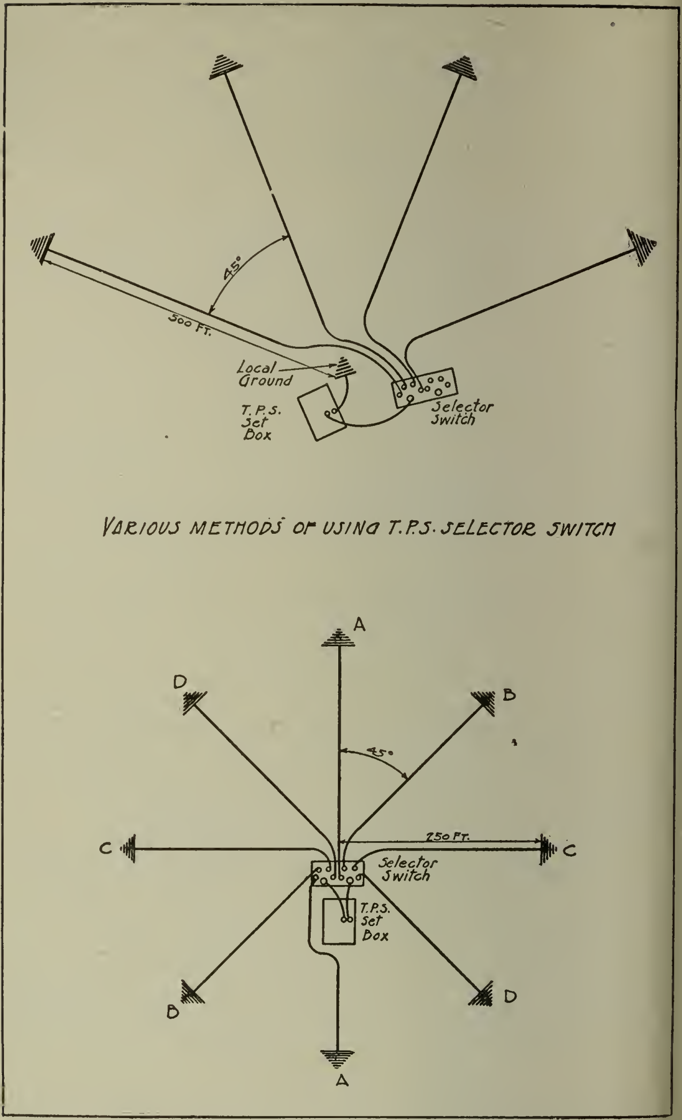


Fig. 6—Methods of Laying Out Central T.P.S. Stations.

For more complete details on the theory of ground telegraphy, and the methods of laying out ground stations, see Radio

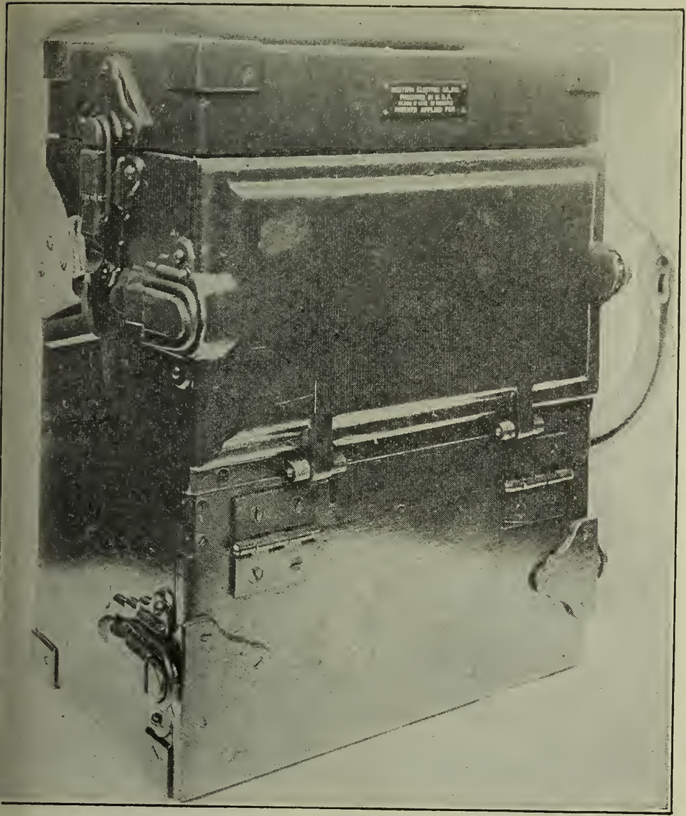


Fig. 7—Type SCR-76 Set Box Closed Up and Waterproof.

Pamplet No. 10. For details of the listening-in service and the means of coping with interference, see Radio Pamphlet No. 18.

Comparison of SCR-76 with SCR-71 and SCR-72 Combination

The advantages of the SCR-76 set over the former practice of utilizing the SCR-71 buzzer and SCR-72 amplifier are given as follows:

1. The set is more convenient to set up, as there is no switch to connect, thereby avoiding the numerous short interconnecting wires. Generally, all connections are easier to make.

2. The radio apparatus is easier to transport, as it is contained in a single box which is not an excessive load for one man. The total weight of the two sets SCR-71 and SCR-72 is somewhat greater than that of the SCR-76 box.

3. A great advantage is that there is only one storage battery required for the set, the 4-volt filament battery of the former set being entirely eliminated.

4. Space for spare vacuum tubes and dry batteries is provided within the set, while they had to be carried in separate boxes with the old set.

The following disadvantages may be pointed out:

1. If the set is used at stations where one-way communication only is required, the SCR-76 set provides superfluous material and equipment.

2. The amplifier of the SCR-76 set cannot be used for radio frequency amplification purposes. If it is desired to use it in connection with radio signals, it must be connected in the audio frequency circuits of the receiving set.

Parts List of the Two-Way T.P.S. Set, Type SCR-76

Power Equipment, Type PE-13.

2 Storage Batteries, type BB-3. (1 in use, 1 spare).

Ground Equipment, Type GD-3.

12 Ground Rods, type GP-4; size 22½ in. x ⅝ in.; weight 5 lb. 14 oz.

2 Wire Carriers, type DR-3; for breast reel; size 9 in. x 9½ in.

1 Breast Reel, type RL-6; size 10 in. x 12 in. x 2 in.

1,000 ft. Wire, type W-4, in two 500-ft. lengths, each wound on wire carrier, type DR-3; net weight 20 lb.; modified B & S No. 16 gage.

1 Carrying Bag, type BG-3 for wire, ground stakes, etc.

60 ft. Wire, type W-5; 16 strands of No. 30 B & S soft copper braided, in two 30-ft. lengths, each wound in 3-in. coil.

T. P. S. Equipment, Type RE-3.

1 T.P.S. Set Box, type BC-21; size 15½ in. x 11¾ in. x 8 in. weight 32 lb.

1 Large Weight for vibrator, type WT-2.

2 Small Weights for vibrator, type WT-3.
2 Spare Upper Contacts for vibrator, type CN-1.
2 Spare Lower Contacts for vibrator, type CN-2.
1 Wrench for changing vibrator weights, type TL-6.
1 Air Gap Gauge for vibrator, type TL-7.
1 Contact File for vibrator, type TL-5.
2 Telephone Head Sets, type P-11; total weight 2 lb. 4 oz.
4 Dry Batteries, type BA-2 (2 in use, 2 spare); weight 3 lb. 8 oz.
4 Vacuum Tubes, type VT-1 (2 in use, 2 spare).
1 Selector switch, type SW-16.
1 Compass, type I-1.
1 Roll Friction Tape, ¾-in., Spec. 569-B.
1 Pair Pliers, type TL-19; Universal.
1 Voltmeter, type I-2; with leads; 8 to 24 volts, d.c.
1 Screwdriver, type TL-2.
1 Sheet Emery Cloth, 11 in. x 8 in.
1 Carrying Bag, type BG-13; size 9½ in. x 7½ in. x 1 in.

CARRYING UNITS.

All of the above parts are included in five carrying units, as follows:

1. Set Box, type BC-21, 15½ in. x 11¾ in. x 8 in.; weight 39 lb., including telephone head sets, dry batteries, vacuum tubes, etc.

2. Carrying Bag, containing 12 ground rods, 2 spools of wire and 2 coils of wire.

3. Storage Battery, type BB-3, 10 volts; 11 in. x 10½ in. x 7 in.; weight 45 lb.

4. Carrying Bag, containing compass, voltmeter, tape, screwdriver, pliers, emery cloth, selector switch, also breast reel if desired.

5. Breast Reel, type RL-6, 10 in. x 12 in. x 2 in., when not included in unit 4 above.

Prepared in the
Office of the Chief Signal Officer
Training and Instruction Division
Washington

SETS
UNDAMPED WAVE RADIO TELEGRAPH

TYPES SCR-79-A AND SCR-99

Radio Communication Pamphlet No. 17

PREPARED IN THE OFFICE OF
THE CHIEF SIGNAL OFFICER

November, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

WAR DEPARTMENT

Document No. 1084

Office of The Adjutant General

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WAR DEPARTMENT,
WASHINGTON, *November 18, 1921.*

The following publication, entitled "Sets, Undamped Wave Radio Telegraph, Types SCR–79–A and SCR–99," Radio Communication Pamphlet No. 17, 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.

TABLE OF CONTENTS.

SCR-79-A CARRYING CHEST - SHOWING METHOD OF PACKING

SETS UNDAMPED WAVE RADIO TELEGRAPH, TYPES SCR–79–A and SCR–99.

SECTION I.

PURPOSE OF SETS.

1. Purpose of sets—Ranges.—The radio telegraph sets, Types SCR–79–A and SCR–99, are vacuum-tube sets designed for transmitting undamped wave signals and for receiving either damped or undamped signals. Both sets use in the transmitter two tubes in parallel whose circuits are inductively coupled to the oscillating circuit of the antenna, and in the receiver inductively coupled circuits with a vacuum-tube detector and a 2-stage audio-frequency amplifier. When used with the prescribed antenna, the SCR–79–A set has a continuous range of wave lengths for transmitting and receiving of from 500 to 1,100 meters. Its transmitter delivers about 10 watts to the antenna, and with this power two similar sets can communicate over a distance of about 20 miles. The SCR–99 set is very similar to the 79–A except that it is somewhat more powerful, has a range of wave lengths of from 900 to 1,900 meters, and two similar sets can communicate over a distance of about 60 miles. Both sets are intended for use at command posts or at headquarters that are equipped with ample motor or wagon transport. Frontispiece shows a 79–A set in its carrying chest.

SECTION II.

DESCRIPTION OF SETS.

2. **Equipments comprising the sets.**—Each set is comprised of three equipments as follows: Antenna, radio, and power. These equipments are alike in both sets except where noted below.

3. **Antenna equipment, Type A–9–A.**—The same antenna equipment is used with the SCR–79–A and SCR–99 sets. The essential component parts are the antenna, masts, counterpoise, ground mats, guys, and stakes. The antenna itself is a "V" with a 60-degree opening, 20 feet high, 100 feet long on each side, and with a 25-foot lead-in wire. Under some conditions, such as a limited space or for short-distance work, an inverted "L" may be used. This should be 20 feet high, 100 feet long, and with a 25-foot lead-in wire. The "V" antenna is supported on three masts, 20 feet high, each with two guys. The antenna wire is a bare stranded wire, and the lead-in is a lightly insulated wire or lamp cord. One end of both legs of the antenna wire forms the point of the "V" and to this is joined the lead-in wire. The two outer ends of the antenna and the point of the "V" are provided with strain insulators which have a snap or harness hook for fastening them to the tops of the masts. These insulators are made of an insulating material known as phenol fiber which has been thoroughly varnished and baked so as to secure high insulation. The antenna, lead-in, etc., are wound on two hand reels for convenience in storing away in transportation. The masts are of spruce and in three sections, each about 6¾ feet long, all sections being interchangeable. Each section is fitted at one end with a spike and at the other end with a steel tube that is tapered slightly to take the spike of the next section, and is pierced with three holes to take the snap hooks of the antenna insulators and guy ropes. The mast sections are carried in a carrying roll which has both a handle and a shoulder strap of nonelastic webbing. The guys are of No. 5 sash cord, 40 feet long, provided at one end with a snap or harness hook, for fastening in the holes in the steel tube of the topmast section and at the other end with a tent slide for adjusting the tension on the guy after it has been passed around the ground stake. In storing away they are wound on the same type of hand reels as the antenna. The ground stakes are of galvanized pipe, 18 inches long, and are provided with a binding post that makes it possible to use them as a ground rod if desired.

The counterpoise consists of two lengths of 150 feet of heavily insulated wire which is laid out on the ground in a "V" shape with a 60-degree opening under the antenna. In storing away they are wound on two hand reels. As an alternative for the counterpoise, three ground mats, which are of a fine copper gauze, each 13 feet long and 3 feet wide, are furnished. These have wood strips at both ends to keep the mats flat and are provided with binding posts at both ends for convenience in making quick connections. The mats are generally rolled up for transportation and carried in the roll with the mast sections. The antenna and counterpoise wires, guys, stakes, hammer, etc., are carried in a carrying bag. The essential electrical constants of the "V" antenna are approximately: Inductance, 0.04 millihenry; capacity, 0.0004 microfarad; fundamental wave length, 240 meters; and average resistance, 50 ohms. Additional information about antennas and their theory in general can be found in Signal Corps Radio Communication Pamphlet No. 2, entitled "Antenna Systems."

4. Power equipment, Type PE–7.—*a. Battery equipment.*—The same power equipment is used with the SCR–79–A and SCR–99 sets. The essential component parts are the batteries and the dynamotor with its case. The battery furnishes current for the filaments of the transmitting and receiving vacuum tubes and for the dynamotor. It is a lead storage battery of a nonspill type; of 12 volts and 90 ampere-hour capacity, consisting of 3 units, each unit being a BB–14 battery of 4 volts. These units are connected in series by two extension cords. The connections should be made as follows: The positive or red binding post terminal of the first battery should be left free to be connected later to the operating chest (set box) by an extension cord; the negative or black binding post terminal of this battery should be connected to the positive or red terminal of the second battery; the negative or black terminal of this battery should be connected to the positive or red terminal of the third battery; and the negative or black terminal of this battery should be left free to be connected later to the operating chest (set box). If for any reason the polarity or color of the terminals can not be told, they may be identified in the BB–14 battery as follows: If the battery box is so placed that the cover opens away from the operator, the right-hand terminal in the box is positive and the left-hand is negative. The battery boxes can also be connected in series with battery cords and plugs by means of the sockets on each unit box. Both ends of the cord are provided with plugs which can fit in the socket (receptacles) only in one way, and thus no mistake can be made in the series connections. The polarity of the two receptacle terminals can be identified by the same rule as the binding posts. If neither set of battery cords is available, the necessary connections can be made as described above by any heavy wire. The connection between the battery and the operating chest (set box) is made with an extension cord. At the battery end the cord is provided with heavy lugs stamped "Plus" and "Minus." The junction of the cord and its lug is covered with rubber tubing. At the chest end it has red and

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black wires, respectively, for plus and minus, that are to be connected to the binding posts on the operating chest (set box) marked, respectively, "Plus 12 V" and "Minus 12 V."

Each battery unit holds two cells in series, in hard rubber or celluloid jars, contained in a wood carrying case. If the jar is of celluloid, the wood case has two peepholes for noting the height of the electrolyte. The over-all dimensions of the two kinds of batteries (rubber and celluloid jars) differ slightly, but as an average each unit is $7\frac{1}{2}$ by $8\frac{1}{2}$ inches by 14 inches high, weighs about 37 pounds, and is provided with a battery carrying strap. Three 12-volt batteries (9 BB–14 units) are provided with the set. These should be assigned as follows: One in use with the set; one spare, fully charged with set and ready for immediate use; and the other under charge at the charging plant. Brief instructions by the manufacturer for the care of the battery are contained on a card in the cover of the battery box. Additional instructions on the use and maintenance of storage batteries will be found in Signal Corps Training Pamphlet No. 8, entitled "Storage Batteries."

4 *b. The dynamotor, Type DM–1.*—The dynamotor, type DM–1, is a combined motor and generator that, together with certain accessories, is contained in a cast aluminum alloy case. With the motor running light—that is, with no generator load—it takes a current of about 4 amperes at 10 or 12 volts from the storage battery. At full load the motor takes about 10 amperes at 10 or 12 volts, and the generator delivers about one-sixth ampere (167 milliamperes) at 300 to 350 volts to the plate circuit of the vacuum tubes of the transmitter. The motor input is therefore about 120 watts, the generator output about 50 watts, and the over-all efficiency is between 40 and 50 per cent. The machine is a converter from a low to a high direct-current voltage. It has separate motor and generator armature windings and commutators mounted on the same shaft, revolving in a single common magnetic field. The speed of the machine is 2,550 R. P. M. (revolutions per minute). The motor end is marked but can still further be identified by the heavier wires at the brushes. Generator ends are marked on the end shield. The necessary wiring from the motor and generator is brought up onto a bakelite panel that carries a fuse block, with 15-ampere fuse wire, a switch in the motor leads, extension cords, oiling holes, etc. Spare fuse wire is wound on a small spool in the cover of the box. On the panel the motor terminals are marked "10 Volts," "Plus," and "Minus." An extension cord is provided to connect them to the binding posts on the operating chest (set box) marked, respectively, "Plus 10 V" and "Minus 10 V." The generator terminals are marked "300 Volts," "Plus," and "Minus." An extension cord is provided to

connect them to the binding posts on the operating chest (set box) marked, respectively, "Plus 300 V" and "Minus 300 V." In both cords the red wire is positive and the black is negative. Both cords are permanently fastened to the dynamotor terminals and are to be stored away on top of the panel. The polarity of the dynamotor terminals is marked on the panel, but in both cases they can be identified by noting that with the cover of the case opened away from the operator the right-hand post of each pair is positive. The dynamotor is secured in place in the lower part of its carrying case by two heavy machine screws through the bottom. The approximate over-all dimensions are 7 by 11 inches by 9 inches high, its weight is about 24 pounds, and it is provided with a carrying strap.

5. Radio equipment for SCR–79–A and SCR–99.—The radio equipment of these sets is mounted in an operating chest (set box) shown in figure 1.

The radio equipment of the SCR–79–A, RE–5–A, is mounted in the operating chest (set box), Type BC–32–A, and the radio equipment of the 99, RE–7, is mounted in the operating chest (set box), Type BC–45. These operating chests, together with auxiliary equipment, are all carried in a carrying chest, Type BC–43. Although the operating chests are removable from their carrying chests, in general they should be left inside. The auxiliary parts carried in the operating chest are the telephones, key, wavemeter, voltmeter, clock, various extension cords, tools, and spare parts, including tubes. The dynamotor is also carried in this chest. There follows a more detailed description of the principal parts of the radio apparatus and also a description of the panel clock carried in the chest.

5 *a. Transmitter.*—The transmitting set in the SCR–79–A and SCR–99 is practically the same except for the range of wave lengths. It consists of vacuum-tube oscillating circuits with fixed inductive coupling between the tube and the antenna circuits. The transmitter inductances have been so designated that with standard antenna the correct couplings are automatically secured over the entire range of wave length when the inductances corresponding to a given wave length are in use. The wave length is determined by the electrical constants of the antenna circuit, and *not* by those of the *tube circuit*, being adjustable by a variable inductance L_3 and a variable condenser C_5 in the antenna circuit. When the key is closed power at about 350 direct-current volts from the dynamotor is supplied to the plate circuits of the tubes and the antenna circuit immediately starts oscillating. Thus the energy is radiated only when the key is pressed and there is no "back wave" as in some arc transmitters. The current in the transmitting-tube filaments is adjustable by a rheostat.

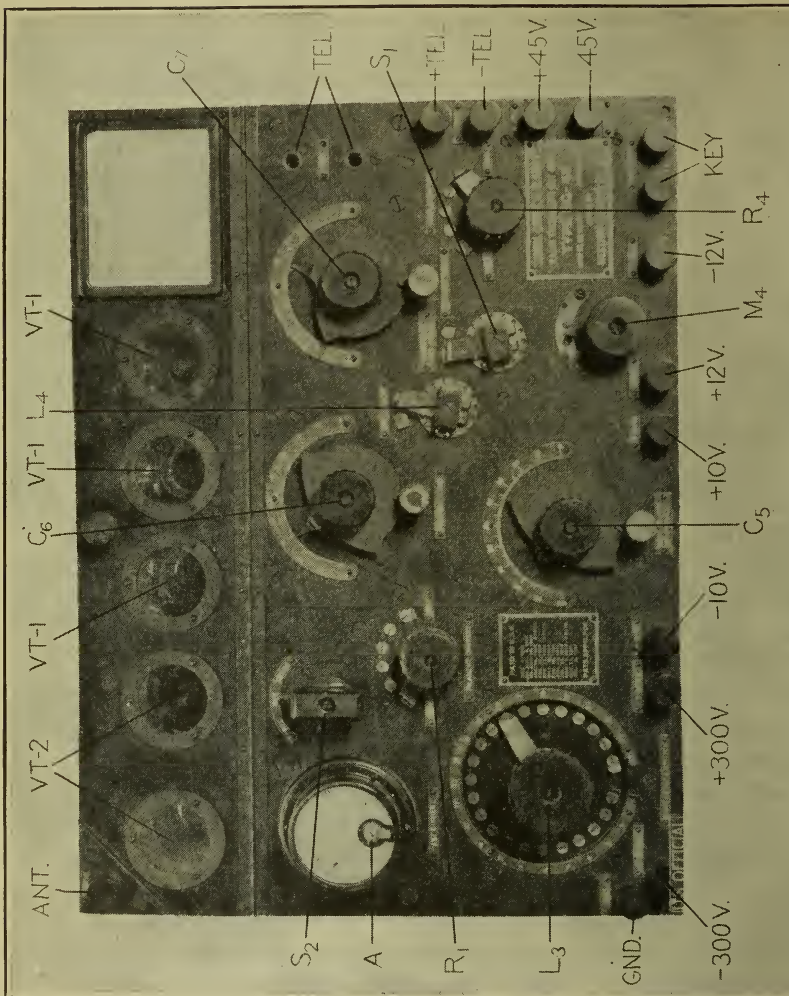
ANT.
VT-2
VT-1
C_6
VT-1
L_4
VT-1
C_7
TEL
S_1
+TEL
-TEL
+45V.
-45V.
KEY
R_4
-12V.
M_4
+12V.
+10V.
C_5
-10V.
+300V.
-300V.
GND.
L_3
R_1
A
S_2

FIG. 1.

Each figure in this pamphlet has the identical parts marked the same.

In Figure 1 the controls bear the same legend as the actual parts. The legend is as follows:

A	Antenna ammeter.
ANT	Antenna binding post.
C_1	High-frequency by-pass condenser across dynamotor leads.
C_2	Grid leak condenser for VT–2 tubes.
C_3	Plate coil shunting condenser.
C_4	Ground circuit condenser.
C_5	Transmitter antenna tuning condenser.
C_6	Receiver antenna tuning condenser.
C_7	Receiver secondary tuning condenser.
C_8	High-frequency by-pass condenser across the primary of the first intervalve transformer.
C_9	Audio-frequency by-pass condenser across the resistance in the detector tube plate circuit.
Fil. Bat.	12-volt storage battery for heating filaments of VT–1 and VT–2 tubes.
GND	Ground binding post.
H. P. Bat.	45-volt high potential battery for plate circuits of VT–1 tubes.
L_1	Grid coil for VT–2 tubes.
L_2	Plate coil for VT–2 tubes.
L_3	Transmitter antenna tuning inductance.
L_4	Receiver antenna tuning inductance.
L_5	Reaction or "feed-back" coil.
L_6	Receiver secondary circuit coil.
M_1	Fixed coupling between VT–2 grid coil, L_1, and antenna coil, L_3.
M_2	Fixed coupling between VT–2 plate coil, L_2, and antenna coil, L_3.
M_3	Fixed coupling between reaction coil, L_5, and primary receiving coil, L_6.
M_4	Variable coupling between primary and secondary receiving circuits.
R_1	Variable filament resistance for VT–2 tubes.
R_2	Grid leak resistance for VT–2 tubes.
R_3	Series filament resistance for VT–1 tubes.
R_4	Shunt resistance across primary of first intervalve transformer for variations in amplification.
R_5	High resistance in detector tube plate circuit for adjustment to best detecting point on characteristic curve.
R_6	Series filament resistance for VT–2 tubes.
RFC	Radio frequency choke coils in dynamotor leads.
S_1	Switch to change from spark to tube reception, and vice versa.
S_2	Switch to change from transmitting to receiving, and vice versa.
T_1	Intervalve iron core transformer between detector tube and first amplifying tube.
T_2	Intervalve iron core transformer between first and second amplifying tubes.
TEL	High impedance telephone receivers.
VT–1	Receiving vacuum tubes for detector and audio-frequency amplifiers.
VT–2	Transmitting vacuum tubes for developing oscillations in transmitting antenna.

5 *b*. *Receiver*.—The receiver set in the SCR–79–A and SCR–99 is practically the same except for the range of wave lengths. It is an inductively coupled set with a vacuum-tube detector and a 2-stage audio-frequency amplifier, arranged for both damped wave and undamped wave reception. In the antenna circuit an inductance, L_4, with two taps, one for short waves, "SW," and the other for long waves, "LW," is connected in series with a variable condenser C_6 to change from short wave to long wave. In the secondary circuit a fixed inductance and a variable condenser (C_7) are connected in series to form a local resonant circuit with leads from its terminals to the detector. A "feed-back" or "reaction" coil can be put into circuit by the 2-point switch S_1, depending on whether undamped or damped signals are to be received. The coupling between the primary and secondary circuits is controlled by a two-position switch (M_4). In some cases the full amplification given by the tubes is not desired and it may be reduced by the switch R_4, which connects resistance shunts across the primary circuit of the first amplifier transformer. There is no adjustment for the filament current of the receiver tubes. Figures 2 and 3 show interior views of the set.

5 *c*. *Vacuum tubes*.—Two types of 3-electrode vacuum tubes are furnished with each set; one, Type VT–2, for the transmitter, and the other, Type VT–1, for the receiver. The transmitter type, VT–2, is spherical, and the receiver type, VT–1, cylindrical; and in some cases the type number is also marked on the base or on the glass. The bases and sockets for the two types are identical except for the position of a pin in the base and a slot in the socket, which are so arranged that only the right tube can be put in the right socket. The VT–2 filament uses about 1.35 amperes at about 7 volts, and as two tubes are connected in parallel, the total current is 2.7 amperes. If the 12 volts of the standard battery were applied directly to the filaments, too much current would flow and hence a small fixed resistance R_6 of about 1.8 ohms, is connected in series in one lead to each filament, and in addition, for fine adjustment and to compensate for a drop in the voltage as the battery runs down, there is inserted in series in one battery lead another small resistance that is variable by a 6-point dial switch, R_1. In transmitting, the 12-volt battery furnishes the current for the filaments as well as that for running the dynamotor with its generator load of plate currents. The receiving tubes (VT–1) must be burned only at a dull reddish-yellow heat, as in the case of the VT–2 tubes, otherwise their normal life of 500 hours will be seriously shortened. The VT–1 filament uses about 1.1 amperes at about 3.6 volts, and in order to be able to use the 12-volt standard battery the filaments of the three tubes are connected in series and in addition there is a small fixed resistance R_3 of about 1.05 ohms, in the negative lead to each filament. There is no variable resistance in

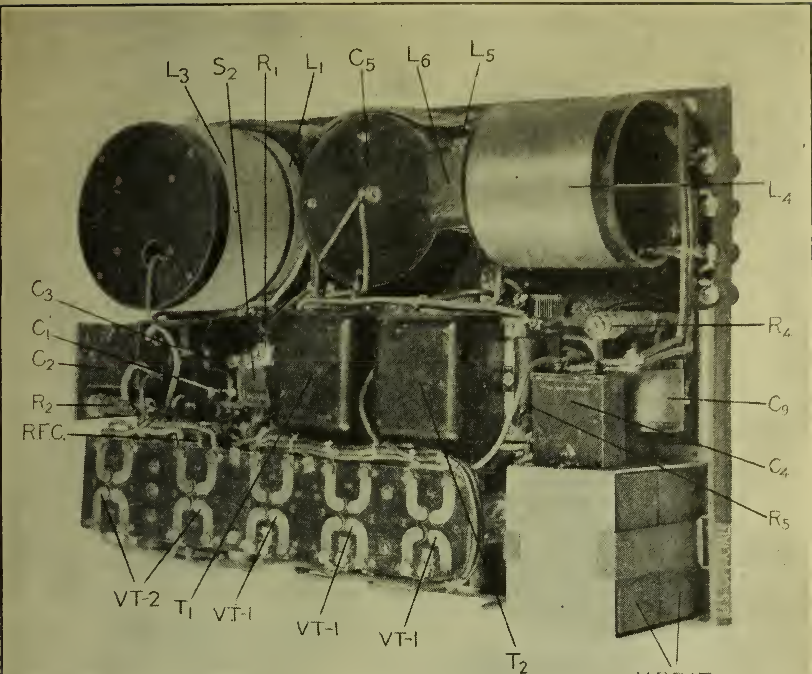
L3
S2
R1
L1
C5
L6
L5
L4
C3
C1
C2
R2
R.F.C.
R4
C9
C4
R5
VT-2
T1
VT-1
VT-1
VT-1
T2
H.P.BAT.

FIG. 2.

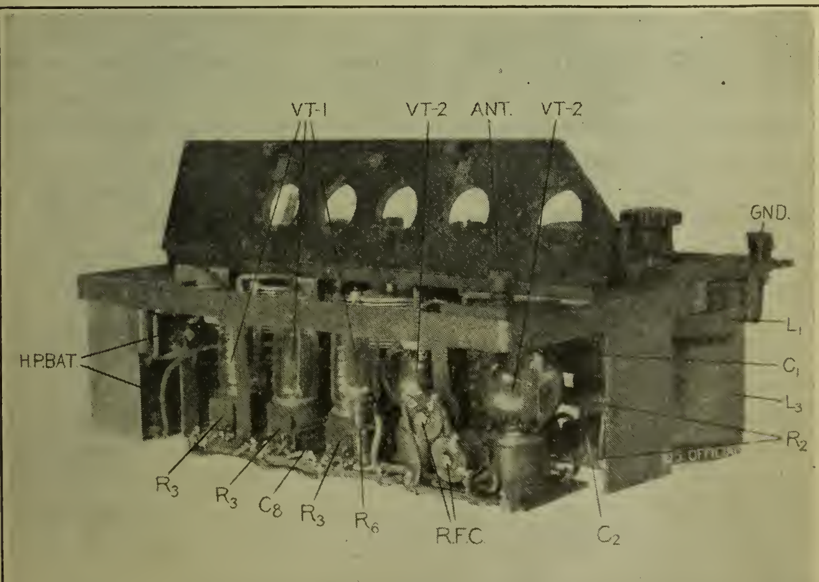
VT-1
VT-2
ANT.
VT-2
GND.
H.P.BAT.
L1
C1
L3
R2
R3
R3
C8
R3
R6
R.F.C.
C2

FIG. 3.

circuit. The plate circuit of each receiving tube takes only a small current, less than a milliampere (0.001 ampere), which is supplied by the high potential battery.

5 *d. Key.*—This is a Morse key, provided with heavy contacts of silver. On account of its high conductivity for heat, etc., this metal has the property of quenching an arc and hence tends to reduce the sparking in much the same way that the spark in a quenched gap is quenched. It is connected in series in one lead in the 300-volt generator circuit of the dynamotor and thus directly controls the supply of direct-current power to the plate circuit of the transmitting tubes. A brass plate is provided on the inside of the cover of the carrying chest for mounting the key when the cover is used as an operator's table, and the 1½-foot extension cord should be used to connect the binding posts of the key to the "KEY" binding posts on the operating chest (set box).

5 *e. Antenna ammeter.*—The ammeter used is of the thermocouple type and is connected directly in series with the antenna when it is used for transmitting. The ammeter used in the SCR–99 set is designed to read a greater current than that used in the SCR–79–A set and is graduated from 0 to 1. Although there is an adjustment for setting the ammeter needle to its zero position, this should not be used, as in the field it is not necessary to know the absolute current in the antenna. The ammeter is used to show the relative strength of current in the antenna and to show that the set is oscillating properly. If the set does not oscillate, there will be no antenna current.

5 *f. Voltmeter.*—This meter is a 2-scale direct-current instrument with scales 0 to 10, and 0 to 50 volts, and is provided for the measurement of the battery voltage. The positive terminal is the tip of the flexible lead which is connected to the binding post on the top of the meter. The negative terminal is the brass point on the bottom of the case. The meter normally reads on the 50-volt scale, but by pressing on the push button on the back of the base the reading is transferred to the 10-volt scale. There is no adjustment for any zero error of the needle, as such accuracy is not needed in field service.

5 *g. Wave-length switch.*—This is a 23-point dial switch, L_3, for making large step adjustments in antenna inductances of the transmitting circuits. Exact adjustment of wave lengths is made by the shunt condenser, C_5. In using the switch, care must be taken *not* to allow the switch point to rest on two contacts, as this would short-circuit turns in the antenna coil, cause losses therein, and possibly burn out the windings. It will be noted, however, that the switch is provided with a ratchet that *should* prevent the point from bridging two contacts.

5 *h. Table of wave lengths.*—A table for recording the receiver wave lengths in meters and the position of the secondary circuit condenser in degrees is provided in the upper right corner of the panel of the

operating chest (set box). The method of obtaining this data is given under "Wavemeter," paragraph 5 *k*, and by its use it is possible to pick up very easily a station sending on a known wave length.

5 *i. Amplification switch.*—This is a 5-point switch for the control of the amplification of the receiver signals, from the full amplification of two stages at "Max." to slightly more than one stage at "Min." The variation in amplification is obtained by shunting the primary or input winding of the first intervalve audio-frequency transformer by a variable resistance, R_4. At "Max." the resistance is cut out of circuit so that all the audio-frequency current from the plate circuit of the detector tube is allowed to pass through the windings; at "Min." a *low* resistance is shunted across the windings so that most of the current is diverted from them and the resulting amplification is much reduced; and at immediate steps the amplification is somewhere between these stages.

5 *j. Receiver-transmitter switch.*—This switch, S_2, is a 3-throw, 2-pole switch with positions marked "Rec.," "Off," and "Trans." In the "Trans." position the circuits are connected as shown in figures 4 and 5, whereby the VT–2 filaments are lighted, and if the switch on the dynamotor panel is closed, the dynamotor is started and the circuits are ready for adjustment. It is to be noted that there is no motor starting resistance or box in circuit, but this is not necessary, as the motor is only a fraction of a horsepower in size and the starting current is not large. Whenever the dynamotor is to be stopped, it should be done by throwing the switch to the "Off" position rather than to open the switch on the dynamotor panel. The VT–2 filament current is adjusted to its correct value when the dynamotor is running; if its switch is now opened and the load of the dynamotor taken off the battery, the voltage across the battery will rise. This rise in voltage may so increase the filament current as to burn out the filament or seriously injure its life by the rush of excessive current. In the "Rec." position the circuits are connected as shown in figures 4 and 6. The VT–1 filaments are lighted, and the circuits are ready for adjustment. In the "Off" position the antenna and ground wires are simply disconnected from the rest of the circuits but the antenna is *not* grounded direct to the ground, as is sometimes the case in such a switch. For this reason when the set is not in use the antenna and ground wires should be disconnected from the set and the antenna put to ground. The complete circuits of the sets are shown in figure 4.

5 *k. Wavemeter.*—Wavemeter, Type SCR–95, is furnished for use with the SCR–79–A set and Type SCR–111 for use with the SCR–99 set. Each has the same range of wave lengths as its set, i. e., 500–1,100 meters, or 900–1,900 meters, and can be used to measure both transmitter and receiver signals. They are of the type that uses for the essential elements of its resonant circuit a fixed (mica) condenser as the capacity, in series with a variometer as the inductance,

COMPLETE CIRCUIT

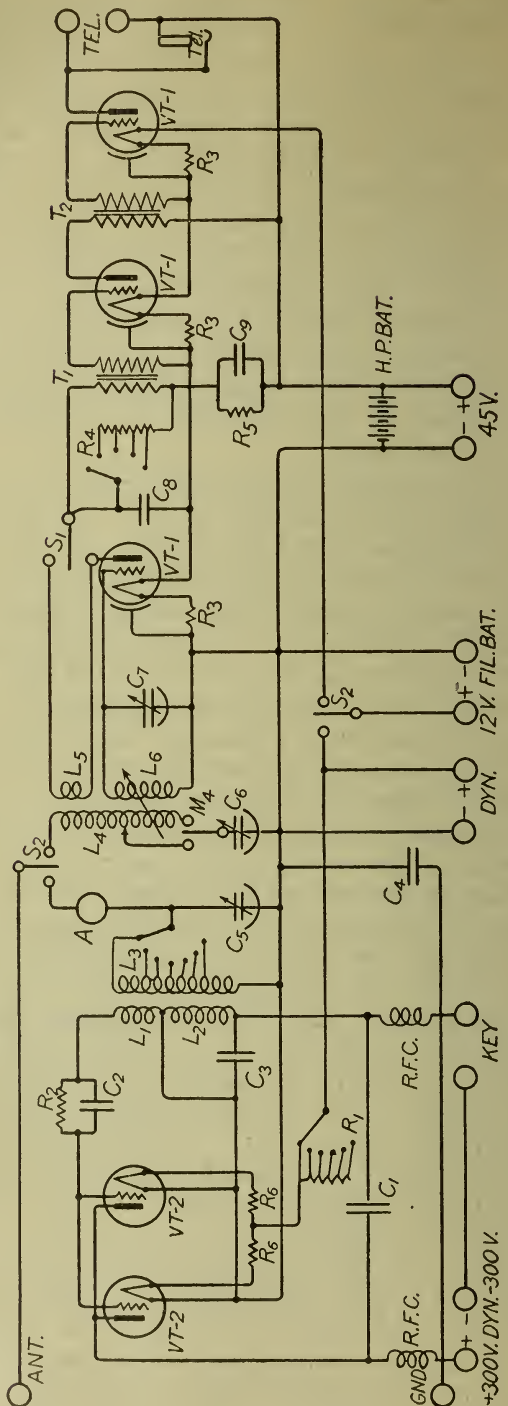

FIG. 4.

and a miniature (flashlight) lamp, Type LM–4, as the means of indicating resonance. One dry cell, Type BA–4, of 1.5 volts, about 3 inches long and 1¼ inches in diameter, is provided for lighting the filament of the lamp, also for operating a buzzer. The wavemeter has one scale for direct reading of wave length and another one of degrees. There is a 3-point switch which, when on contact C, puts the lamp into circuit; on B puts the buzzer into circuit for receiver signals; and on A disconnects the battery. Although the battery is disconnected when the switch is on the A contact, yet the meter is operative for strong transmitter signals, as its circuit is still complete. A small, adjustable carbon rheostat is placed in the lamp circuit to keep the filament burning at a dull red where it is most sensitive in showing small changes in current caused by the reception of signals. The front of the box is hinged so as to provide access to the inside of the meter for replacing the battery, adjusting the buzzer, etc. When the meter is held with the scale horizontal, the plane of the fixed variometer coil is vertical and parallel with the rear of the box. It is often necessary to take note of the position of this coil in obtaining coupling with the circuit under measurement. Brief instructions for the use of the meter are contained on a card inside the front cover of the box, as follows: "To measure wave length, set switch on 'C' and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial. To set receiver for given wave length, set switch on 'B,' adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above and tune receiver until buzzer is heard loudest in phones. Caution: Replace battery when it fails to operate buzzer or lamp. When meter is not in use, leave switch on 'A' only." For further information concerning wavemeter, see Radio Communication Pamphlet No. 21 or 28. See also paragraph 11, this pamphlet.

5 *l. Clock.*—The clock is an 8-day Waltham automobile clock that is mounted flush with its panel. To wind or set the clock, press in on the knurled metal frame carrying the plate-glass front and turn it counterclockwise until the clock springs out from its panel. This will generally occur when the "1" or "2" hour mark is at the top. It is then held by a universal joint that permits access to the key that lies in a slot on the top of the clock. To wind, raise the key and turn it clockwise. To set the clock, pull up on the key until a sharp click is heard, in which case the key is engaged with the gears that will now turn the hands. After setting, be sure to push the key down until the sharp click is again heard. After winding or setting the hands, put the key back flat in its slot and return the

clock to its panel by inserting it with the "1" or "2" hour mark at the top and turning clockwise until the "12" hour mark is at the top. There is no adjustment provided for "faster" or "slower" regulation. Under ordinary circumstances the clock should never be removed from the panel, but when necessary this can be done by unscrewing the narrow ring at the back of the clock, which is prevented from working loose by a heavy spring washer.

Section III.

SETTING UP AND OPERATION OF SETS.

6. Setting up the antenna.—The antenna can be installed for either of two purposes: (1) general use and (2) directional use. For the former the orientation of the wire is not important, but for the latter the point of the "V" should be directed toward the other station.

Stretch out the antenna wires on the ground with an opening of about 60 degrees. Couple three mast sections together for each mast and lay them on the ground alongside the wire and in the same straight line with it. Attach the antenna insulators to the tops of the three masts by means of the snap hooks and also attach two guys to each mast. Drive two ground stakes near each mast about 20 feet beyond the end of the wire so that the guys will lie at an angle of about 45 degrees with the line of the wire. Having raised the mast at the point of the V, raise the other mast tops gradually by using a light strain on the guys and, keeping the bottom ends of the masts on the ground, move them toward the points where they are to be when the mast is in the vertical position. Pass the guys around the ground stakes and take up the slack with the tent slides. If necessary, straighten up the masts and tighten the guys so that the antenna wires are nearly horizontal. Care should be taken in raising the masts to keep them in the prolongation of the antenna wires, as then there will be little or no stress tending to bend the masts.

7. Installing the counterpoise.—For general use the two counterpoise wires should be laid out on the ground under the antenna with the point of the "V" at the "GND" binding post of the operating chest (set box). If four counterpoise wires are available they should be laid out as two "Vs" with the points together, one under the antenna and the other with its free ends opening out toward the other station.

For directional use the two wires should be laid out as a "V" with the point at the "GND" post as before and with the free ends opening out toward the other station.

8. **Installing the ground mat.**—As an alternative for the counterpoise, three ground mats are furnished that should be connected to the "GND" post of the operating chest. These mats should be buried under a few inches of earth, which should be well packed down so as to get good contact with all the wires. Under some circumstances the spare ground stakes should be used as an additional ground, and the other ground wires or plates connected to the chest. The ground connection should preferably be made where it is wet, but in each case use whichever apparatus will give the largest reading on the antenna ammeter.

9. **Installing the operating chest.**—Set up the operating chest on a dry place under the point of the "V" of the antenna. Before making any connection to the chest be sure that the switch, S_2, is in the "Off" position, and that the high potential battery, 2 units Type BA–2, in series, is in its compartment. If there is no battery, an external battery of 45 volts may be connected to the binding posts marked "Plus 45 V" and "Minus 45 V," being sure that the positive or red-wire terminal is connected to the upper and positive post and the negative or black wire terminal to the lower and negative post. These connections must be correctly made, as otherwise the receiver will be inoperative. If the standard high potential battery is available, it is preferable to install it in place as follows: Take out the right-hand VT–1 tube so as to give free access to the battery compartment. Put one BA–2 battery in place with the line of its terminals vertical and to the left, connecting them to the Fahnestock clips on the small panel by passing the lead wires behind the panel; put the other battery similarly in place except for passing the leads in front of the panel; the positive or red-wire terminal of each battery must be connected to the clips on the red part of the panel and the negative or black-wire terminals to the clips on the black part of the panel; if these connections are correctly made the two batteries will be in series, with the positive terminal connected to the plate circuit of the last tube through the telephone receivers and with the negative terminal to the ground.

Connect the antenna and ground wires respectively to the two binding posts marked "ANT" and "GND." Make the other connections to the binding posts as shown by their name plates on the chest, taking care that the polarity is correct in the case of both sets of dynamotor terminals and of the storage battery. (See par. 4.) It is specially necessary that the high potential side of the dynamotor be correctly connected, as otherwise the transmitter will be inoperative. Be sure to connect the battery leads first to the chest and then to the battery, as otherwise the battery may be short-circuited by the other terminals of the cord being in contact. If the telephone is not provided with the standard plug, connections can be made by the telephone cord to the posts marked "TEL," making sure that the green tracer wire is connected to the "Plus" post and the red tracer wire to the "Negative" post. If for any reason the two wires can not be identified, the correct polarity of the connections must be found by trial, using faint signals which may be generated by the wavemeter with the set. *Close the switch* on the dynamotor panel and then turn the switch S_2 to "REC." or "TRANS." as desired. The set is now ready for tuning either the receiver or transmitter.

10. **How to receive.**—Turn the switch "S_2" to the "Rec." position and the three VT–1 filaments should light; if they do not, there is either a bad battery contact or one or more broken or burnt-out filaments. Examine the battery connections and the filaments and correct the difficulty. In a few cases the filament pins in the base of the tube may not make good contact with the springs of the socket, but generally this can be remedied simply by taking the tubes out and putting them back in the sockets. It must be remembered that the three filaments are in series in the battery circuit and that one break in the circuit will prevent all filaments from lighting. If signals are to be received from another SCR–79–A or 99 set or from any undamped wave source, set the switch "S_1" on the "Het." position and the switch "R_4" on the "Min." position. If the wave length is known, set the secondary receiver condenser handle, "C_7," at the reading corresponding to this wave length as shown in the "Wave-length table" in the upper right-hand corner of the panel of the operating chest (set box). Set the switch "L_4" on the short-wave position, "SW," or on the long-wave position, "LW," depending upon whether the signal is at the short-wave or long-wave end of the scale of wave lengths for the given set. Set the switch "M_4" on the "Min," position. This adjusts the coupling between the primary and secondary circuit to the best average value for the reception of undamped signals. Vary the primary receiving condenser, "C_6," slowly over its scale until the signals are heard. As the tuning with undamped signals is much sharper than with damped signals, the tuning must be accurately done in order to pick up signals—in many cases a change of 1 or 2 degrees on a condenser scale will completely cut out the signals. After the signals are picked up, adjust the primary and secondary condensers, "C_6" and "C_7," until the loudest signals are heard at the best note for the operator. If necessary, increase the amplification by moving the switch "R_4" toward the "Max." end of the scale.

If spark signals or damped wave signals are to be received, set the switch "S_1" at the "Spark" position and the switch "M_4" on the

"Max." position (sometimes "Min." position is preferable). If the wave length is known, set the secondary receiving condenser, "C_7," at the given wave length as shown on the table; set the switch "L_4" in the short or long wave position, depending upon the wave length to be received; and vary the primary receiving condenser, "C_6," until the signals are heard. Adjust both condensers and the amplification if necessary.

If the wave length of the undamped or damped wave signals is unknown, then they can be picked up only by trial, somewhat as follows: First, set the switch "L_4" at, say, the long-wave position; the primary condenser, "C_6," near the 100-degree end of its scale; and vary the secondary condenser, "C_7," slowly over its scale, until the signals are picked up. If no signals are heard, set the primary condenser near 80 degrees on its scale and vary the secondary condenser as before. Proceed in this way by repeated trials until the signals are found.

11. **How to transmit.**—Close the switch on the dynamotor panel. Set the switch "S_2" in the "Trans." position. The filaments of the two VT–2 tubes should light and the dynamotor start. If only one filament lights it is certain that either there is a bad contact in the socket of the other or that its filament is burnt out. Under these conditions the set is operative, but it is working only at half power and consequently its range of operation and signal strength will be reduced. Close the sending key, which should immediately set the antenna circuit into oscillation and give a reading on the antenna ammeter "A." The wave length of the transmitter is determined by the constants of the antenna and can be adjusted to any given values within its range by means of the variable inductance "L_3" and variable condenser "C_5." In order to measure the wave length in use, the wavemeter must be used as follows: Set the button switch on contact "C" and with a screw driver adjust the screw at the "Lamp resistance" until the indicator lamp shows a dull red glow. Close the telegraph key and bring the meter near the lower left corner of the panel of the operating chest (set box) with the back of the wavemeter box parallel with the panel, thereby coupling the wavemeter coil with the variable inductance "L_3" in the antenna circuit. Vary the wavemeter handle slowly over its scale until the lamp shows its brightest glow. The wave length in meters can then be read directly from the wavemeter scale. In order to radiate a predetermined wave length, set the wavemeter at that wave length, close the telegraph key, bring the wavemeter near the lower left corner of the panel as before, and vary switch "L_3" of the transmitting set until contact is made which gives the brightest glow in the lamp. Then adjust condenser "C_5" until a still brighter glow is attained, and clamp in this position. The inductance adjustment is

in large steps and the condenser gives a continuous, fine adjustment for exact tuning of wave length to that of the wavemeter. The radiated wave length is then the same as that of the wavemeter setting and the set is ready for transmitting. Set the button switch of the wavemeter back on contact "A" so as to cut the battery out of circuit.

Under some conditions the antenna ammeter may not show a reading when the key is pressed. This generally indicates that the filaments of the VT–2 tubes are not hot enough and that there are no oscillations being developed. The current through them should be slightly increased by turning the switch "R_1" from the minimum position toward the maximum position until the ammeter indicates that there are oscillations, and that these are always developed with the closing of the key.

Under average field conditions the SCR–79–A set should give an antenna current of about 0.4 of an ampere and the SCR–99 set more than 0.5.

Section IV.

CARE OF SETS.

12. Handling and storage.—A careful handling is due any radio set, as the apparatus is very compact and there are a large number of connections inside the operating chest (set box). Careless, rough handling may dislodge the apparatus and will surely weaken or entirely break some connections. The set should not be permitted to become wet if it is possible to prevent it. If, for any reason, the set does become wet, either from exposure to rain or a long spell of damp weather, it should be carefully dried out but not exposed to any direct heat, as from a stove or radiator. The sets should be stored in a dry place that is free from dust.

13. The telephones.—The telephone receivers, Type P–11, must be carefully handled, special care being taken not to injure the diaphragm. If the diaphragm is bent or dented it may touch the pole pieces of the magnet and the magnetic attraction may be so strong that it will be held there with the result that the telephone becomes "dead." In order to obtain the correct clearance between the diaphragm and the poles it has been found necessary to grind the latter *after the assembly* of the telephone, as otherwise the standard parts can not be assembled with sufficient accuracy. For this reason the telephones should never be taken apart, as it is certain that the adjustments will be disturbed. If it becomes necessary to replace the cords the connections to the plug and to the receivers should be made so that the steady current from the plate battery will cause the magnetic flux in the receivers to be in the same direction as the flux of the permanent magnet; otherwise the magnet will be partially demagnetized and the efficiency of the telephones reduced. The following facts will enable one to make the correct connections: The spring of the telephone jack in the operating chest is positive with respect to its sleeve, and hence when the telephone is plugged in its tip will be positive and its sleeve negative. The telephone magnets are so wound that when the diaphragm is uppermost and the terminals are toward the operator, the right-hand terminal is positive. The cords have a colored thread or tracer running through them so as to give a color scheme to identify the various wires—as green, white, and red; the green tracer cord should always be connected to the tip. It then becomes the positive wire and should be connected to the right-hand terminal of one of the receivers; the white cord should be connected to the left terminal of the same receiver and to the right-hand terminal of the other receiver; and the red cord should be connected to the left terminal of this receiver and to the sleeve of the plug. In putting the telephones away into their compartment, the following standard practice should be followed in order to protect the diaphragm and the terminals: Place the two receivers with the faces of the caps parallel and together so that all access to the diaphragm is closed; and then bind them in this position by winding the telephone cord around the outside of the headband, beginning close to the cap.

14. Don'ts.—Don't fail to oil the dynamo after each two hours operation, with a few drops of oil.

Don't use too much oil on the dynamotor, as it will leak out on the commutator and cause sparking and other troubles.

Don't fail to keep the panel of the dynamotor clean, especially between the 300-volt leads.

Don't fail to have the control switch on the operating chest (set box) on the "Off" position before pulling the dynamotor switch.

Don't fail to see that the dynamotor switch is closed before placing the control switch on the operating chest (set box) in the "Transmit" position.

Don't use higher potentials than are supplied by the batteries furnished with the set.

Don't fail to check all the connections you have made before trying to operate the set, either for sending or receiving.

Don't fail to inspect connections of the high-volt battery occasionally and to renew it when they are defective.

Don't fail to store all spare parts so they can not shift in transportation.

SECTION V.

PRINCIPLES EMBODIED IN THE SETS.

15. Transmitter.—The transmitting circuit shown in simplified form in figure 5 is a modification of one of the fundamental oscillation circuits. The antenna circuit consisting of the antenna, the inductance L_3 shunted by small variable air condenser C_5, the condenser C_4, and the ground is the circuit which determines the frequency of oscillations of the set. In the valve circuits proper the inductance L_1 is the grid coil and serves as a reactance or feed-back coil, being coupled

TRANSMITTING CIRCUIT – SIMPLIFIED

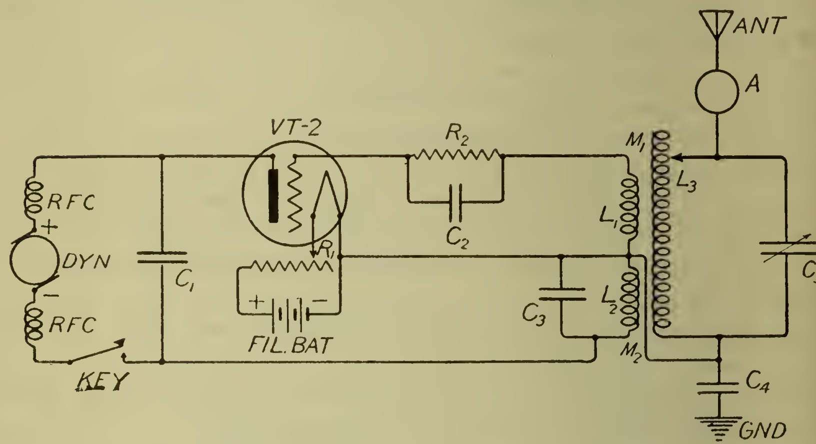

FIG. 5.

to the antenna coil L_3. The plate coil L_2 is the driving coil and is also coupled with the antenna coil L_3.

The high potential voltage, approximately 350 volts, is supplied by the dynamotor to the vacuum tubes. The key used in telegraphing is connected directly in series with the dynamotor. In order to protect the operator from possible shocks, the whole apparatus, including the generator side of the dynamotor, is carefully insulated from the ground. It is for this purpose that the large condenser C_4 is inserted in the antenna ground lead. The condenser C_3, which shunts the plate coil, has a capacity of 450 microfarads and aids in giving steady and uniform oscillations at all wave lengths. The design of the coils L_1, L_2, and L_3 and their relation to one another is such that the required changes in coupling are automatically secured in approximately proper proportions that correspond with the wave-length changes produced by manipulation of the wave-length switch, which changes the number of turns in series in the inductance L_3. The design of these coils, together with the condenser C_3, makes a separate coupling adjustment unnecessary, thus simplifying the operation of the set. The resistance R_2 and its by-pass condenser C_2 in the grid circuit are of such value to insure a negative voltage on the grid during oscillations and at the same time to put upon the grid, when there are no oscillations taking place in the tube, a potential which will permit oscillations to be readily started. The small variable air condenser C_5 shunted across the antenna inductance L_3 permits more exact changes in the wave length of the antenna to be made than is secured by the taps on the antenna inductance. It also, together with the connection from the tube circuit to the antenna circuit, insures the starting of oscillations when the key is closed. It is to be noted that the connection between the tube circuits and antenna circuits gives a direct coupling in addition to the inductive coupling between them.

The detail of operation is as follows: With the key open there are no oscillations occurring in the set, the plate being at a high positive potential and the grid having a negative potential with respect to the filament, being connected with the negative side of the filament battery. Closing the key disturbs the conditions as set forth above, as it throws a negative potential on the filament and because of the resistance R_2 a still higher negative potential on the grid. There is therefore a surge of current in the plate circuit which passes through the plate coil L_2 and starts oscillations in the antenna circuit. The antenna circuit induces oscillations in the grid coil L_1, which affects the grid potential, and thus the oscillations are built up. The tube circuits are connected to the antenna circuit so that if a surge of current through L_2 should fail to start oscillations the sudden application of the high negative potential to the antenna circuit will upset its stabilized condition and start oscillations therein. This will cause the tube to oscillate as noted above.

The condenser C_1 furnishes a path for the oscillations so that they will not pass through the dynamotor. They are compelled to take this path because the dynamotor has in series with its leads radio frequency chokes which prevent the passage of high frequency oscillations. The radio frequency choke coils, RFC, together with the by-pass condenser C_1, serve also to smooth out the commutator ripples that may be present in the dynamotor. The radio frequency choke coils have an inductance each of 3 millihenries and a resistance of 6.9 ohms. The inductance reactance of each coil then at frequency of 158,000 (corresponding to 1,900 meters) is nearly 3,000 ohms. Their reactance to the commutator ripples which at the usual speed would occur at about a rate of 1,785 per second is 34 ohms, approximately.[1]

16. **Receiver.**—The primary circuit of the receiver consists of the antenna, the inductance coil L_4 having two taps, a variable condenser C_6, together with a fixed condenser C_4 and the ground, all in series. The coupling between the primary circuit described above and the secondary circuit is variable in two steps marked "Minimum" and "Maximum," on the control handle. The "Min." gives a 2 per cent coupling while the "Max." gives a 6 per cent coupling. The secondary consists of an inductance L_6 shunted by a variable air condenser C_7, across which is placed the grid and filament of the detector tube. The two other VT–1 tubes are used as low-frequency amplifiers, they being connected by intervalve transformers. The simplified circuits are shown in figure 6. It is to be noted that the

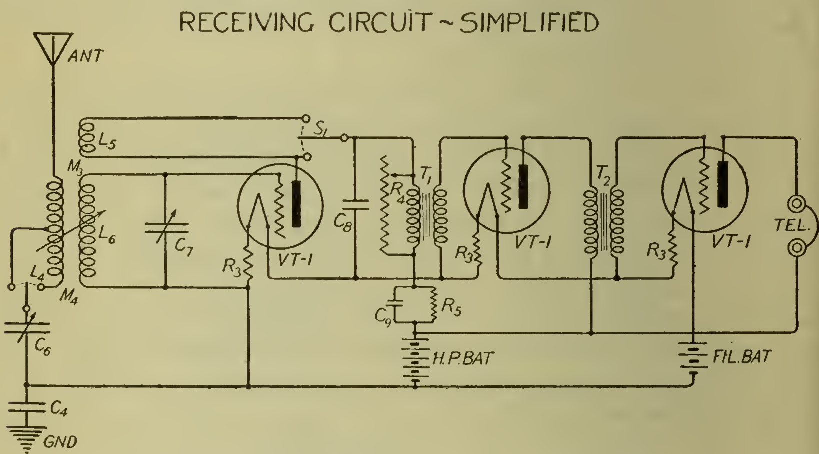

FIG. 6.

primary of the transformers between the detector and the first amplifying tube is shunted by a variable resistance. Variation of this resistance changes the amount of current passing through the primary of the transformer and hence is a control of the amount of amplification given by the set. This is found convenient especially in cutting down the amplification for the purpose of avoiding interference.

The detector vacuum tube operates on the bend of its characteristic curve, the resistance R_5, together with the resistance R_3, insuring the proper relative potentials of the filament, grid, and plate for it to act as a detector. The resistance R_5 is shunted by the by-pass

[1] The transmitting circuits employed in the SCR–79–A and 99 sets are fully discussed in treatises on vacuum tubes as applied to radio telegraphy. For a full mathematical discussion, see chapter 8, particularly section 89, of "Thermionic Vacuum Tube" by Van Der Bijl.

condenser C_9 to permit free passage of oscillations. A tickler coil L_5 permanently coupled with the secondary inductance L_6 causes the detector tube to oscillate when thrown in circuit, thus making the first tube an autodyne. These oscillations, whose frequency is determined by the characteristics of the secondary circuits, L_6 and C_7, produce with the incoming oscillations a beat note which is used in receiving undamped waves.

The purity of the autodyne note so produced depends upon the constancy of the frequency in both the receiver and transmitter. As the frequency depends in part upon the capacity in the circuit, it is evident that the capacity must be allowed to vary only as desired for tuning of the circuits and adjusting the pitch of the note in the receiver. If no precautions are taken, the approach of the operator's hand, or even its contact on the insulating handle of the receiving detector, may so change its capacity as to cause the autodyne note to become inaudible. This trouble has been avoided in these sets by connecting the moving plate of the transmitting wave-length adjustment, the receiving primary and receiving secondary condenser plates and their metal parts together, so as to form a shield. The approach of the operator's hand, therefore, does not have any appreciable effect on the autodyne note.

Section VI.

PARTS LIST OF SETS.

17. **Equipments in 79–A set.**—The SCR–79–A comprises the following equipment:

One equipment, Type PE–7.
One equipment, Type RE–5–A.
One equipment, Type A–9–A.

18. **Equipments in 99 set.**—The SCR–99 comprises the following equipment:

One equipment, Type PE–7.
One equipment, Type RE–7.
One equipment, Type A–9–A.

19. **Parts comprising above equipments.**—These equipments are made up of parts as noted below:

Equipment, Type PE–7:
- Battery, Type BB–14 (9).
- Box, type BC–25 or BC–25–A (1).
- Dynamotor, Type DM–1 (1).

Equipment, Type A–9–A:
- Antenna, Type AN–8 (2).
- Bag, Type BG–12 (2).
- Cord, sash, No. 5, olive drab (300 feet).
- Guy, Type GY–4 (8).
- Hammer, 2-face, 2-pound (1).
- Insulator, Type IN–10 (4).
- Mast section, Type MS–14 (12) 9 in use; 3 spare.
- Mat, Type MT–5 (3).
- Pliers, combination, 6-inch (1 pair).
- Reel, Type RL–3 (8).
- Roll, Type M–15 (1).
- Stake, Type GP–8 (12).
- Tape, friction (1 roll).
- Wire, Type W–4 (50 feet).
- Wire, Type W–6 (300 feet).
- Wire, Type W–24 (750 feet).

Equipment, Type RE–5–A:
- Battery, Type BA–2 (4) 2 in use; 2 spare.
- Battery, Type BA–4 (4) 1 in use; 3 spare.
- Chest, Type BC–43 (1).
- Clock, Type I–15 (1).
- Cord, Type CD–15 (3).
- Cord, Type CD–38 (5).
- Cord, Type CD–47 (2).
- Cord, Type CD–48 (2).
- Cord, Type CD–49 (2).
- Head set, Type P–11 (2).
- Key, Type J–12 (1).
- Lamp, Type LM–4 (4) (for wavemeter), 1 in use; 3 spare.
- Pliers, combination, 6-inch (1 pair).
- Screw driver, 2½-inch blade (1).
- Set box (operating chest), Type BC–32–A (1).
- Set box (wavemeter), Type BC–40 (1).
- Tape, friction (½ pound).
- Tube, Type VT–1 (6) 3 in use; 3 spare.
- Tube, Type VT–2 (4) 2 in use; 2 spare.
- Voltmeter, Type I–10 (1).
- Wire, Type W–7 (2 pounds).
- Radio Communication Pamphlet No. 17 (1).

Equipment, Type RE–7:
- Battery, Type BA–2 (4) 2 in use; 2 spare.
- Battery, Type BA–4 (4) 1 in use; 3 spare.
- Chest, Type BC–43 (1).
- Clock, Type I–15 (1).

Equipment, Type RE–7—Continued.

Cord, Type CD–15 (3).
Cord, Type CD–38 (5).
Cord, Type CD–47 (2).
Cord, Type CD–48 (2).
Cord, Type CD–49 (2).
Head set, Type P–11 (2).
Key, Type J–12 (1).
Lamp, Type LM–4 (4) (for wavemeter), 1 in use; 3 spare.
Pliers, combination, 6-inch (1 pair).
Screw driver, 2½-inch blade (1).
Set box (operating chest), Type BC–45 (1).
Set box (wavemeter), Type BC–49 (1).
Tape, friction (½ pound).
Tube, Type VT–VT–1 (6) 3 in use; 3 spare.
Tube, Type VT–2 (4) 2 in use; 2 spare.
Voltmeter, Type I–10 (1).
Wire, Type W–7 (2 pounds).

SIGNAL CORPS PAMPHLETS.

(Corrected to November 1, 1921.)

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 (Types SCR–65 and 65–A).
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. No. 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).
21. Theory and Use of Wavemeters (Types SCR–60; SCR–61).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A).
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. No. 1077).
26. Sets, U. W. Radio Telegraph, Types SCR–127 and SCR–130 (W. D. D. No. 1056).
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921) (W. D. D. No. 1069).

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and Type EE–2–A and Monocord Switchboard Operator's Set, Type EE–64 (W. D. D. No. 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 (W. D. D. No. 1020).
10. Wire Axis Installation and Maintenance Within the Division (W. D. D. No. 1068).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21) (W. D. D. No. 1055).
4. Visual Signaling.
5. The Homing Pigeon, Care and Training (W. D. D. No. 1000).
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).
3. Directions for Using the Two-Way T. P. S. Set (Type SCR–76).

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Two-Way T. P. S. Set
Type SCR-76-A

▽

Communication

RADIO PAMPHLET No. 19

April 20, 1919

Signal Corps, U. S. Army

PRO PATRIA VIGILANS

Washington : Government Printing Office : 1919

Two-Way T. P. S. Set.

Type SCR–76–A.

THE TYPE SCR–76–A SET is a transmitting and receiving set for ground telegraph work (t. p. s. or earth induction), and is therefore to be used at stations where two-way communication is necessary. It is practically an assembly of the type SCR–71 t. p. s. buzzer and the type SCR–72 amplifier (with some important changes in design) into a single unit to facilitate the installation and use of the two when both are required at one location. The set comprises an adjustable frequency power buzzer, a telegraph key for sending, and a two-stage vacuum tube low frequency amplifier for receiving. The power required to operate the buzzer and to light the filaments of the vacuum tubes is derived from a 10-volt storage battery. Provision is made for operating the buzzer from a 20-volt battery should extreme conditions demand a higher output than is possible with the use of a 10-volt battery.

Principles and Description.

The principle of operation of the type SCR–76–A set is illustrated in the wiring diagram given herewith, Fig. 1. In general it consists of generating by induction, high potential current of audio frequency, which is caused to flow through the ground between two ground terminals separated by about 500 ft. In flowing through the ground the lines of current spread out in all directions, so that some of them may be intercepted at considerable distances by a suitable receiving device similarly connected to the ground and sensitive enough to respond to the extremely small currents thus received by conduction through the earth. Then by breaking up the pulsating emf. impressed on the ground into dots and dashes, it is possible to read the signals at the receiving station.

In the two-way t. p. s. set, the same ground connections and the same 10-volt storage battery are used for both sending and receiving, this being accomplished by means of a double pole double throw "Transmit-Receive" switch mounted on the panel of the set.

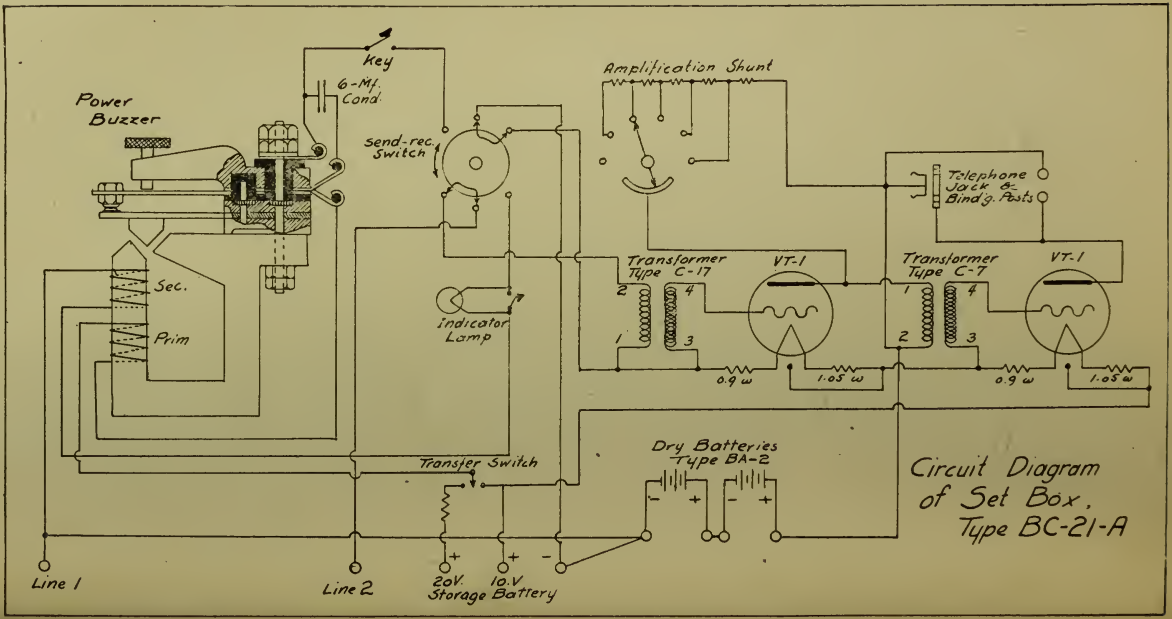


FIG. 1.—Schematic Circuit Diagram of Set Box Type BC-21-A Which Forms a Part of Set Type SCR-76-A.

With the switch in the "Transmit" position, the local circuit from the storage battery through the sending key and the primary of the power buzzer is completed and the base line wires are connected directly to the secondary or high potential winding. When the sending key is closed, the vibrator interrupter makes and breaks the current through the primary winding at a frequency which is controlled by means of small weights screwed to the vibrating armature. Six different frequencies are possible, as listed under a later paragraph (par. 9 of "Method of Operating"). The pulsating primary current resulting from the action of the buzzer induces an alternating emf. of high potential in the secondary winding.

The power buzzer is a double winding, closed magnetic circuit, buzzer interrupter, of practically the same construction as the SCR–71 t. p. s. buzzer. As in the SCR–71 buzzer, a condenser is connected across the vibrator contact points to reduce the spark and improve operation. For every change of frequency, the screw on top of the buzzer should be adjusted to give a good clear note, and then locked in position. The adjustment should be made as light as possible and still give a clear note, as the current into the ground will then be a maximum.

The proper setting of the vibrator adjustment may be obtained by depressing the "Line Lamp" switch on the face of the panel and holding down the key with the "Send-Receive" switch in the "Send" position. The vibrator screw should then be adjusted until the line lamp glows at maximum brilliancy.

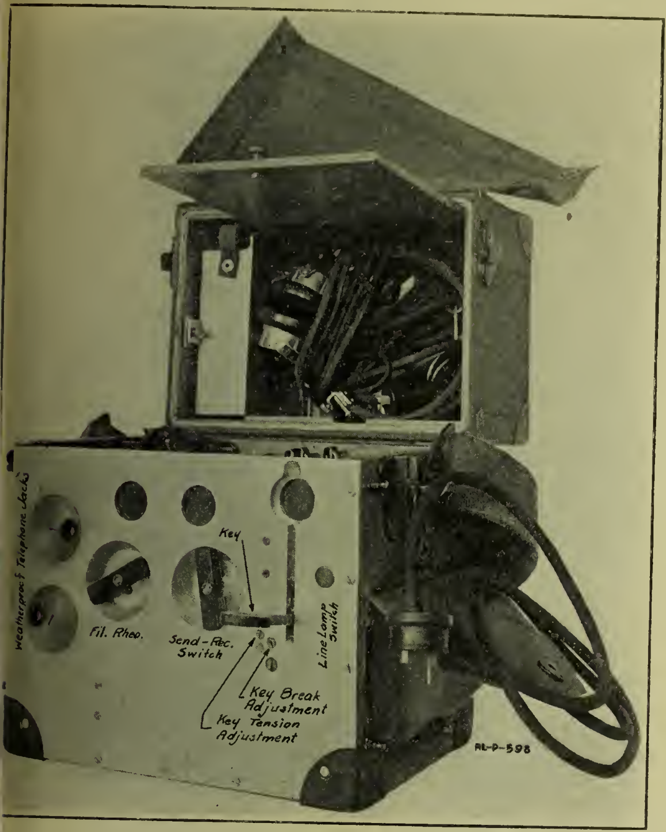
When it is desirable to operate the buzzer at 20 volts input, an additional 10-volt storage battery is required. This second battery is connected in series with the first battery without disconnecting the leads used for 10-volt operation (these are necessary for lighting the filaments for receiving), and the positive terminal is connected to the third (rear) binding post on the right side of the set. The transfer switch, located inside the set box on the back of the box is thrown to the right.

CAUTION.—Under no condition should 20 volts be applied to the forward battery binding posts, since this would result in burning out the tube filaments when the "Send-Receive" switch is turned to "Receive."

For good operation of the buzzer, the vibrator contact points must be clean, and the surfaces even and parallel. After some time, these contact points may become pitted and require cleaning and truing up. It is best not to use the file furnished with the set, but to remov the contacts from the vibrator and rub them gently on a piece emery cloth laid on a flat surface. Only in exceptional cases wi it be found necessary to use the file or to replace the contact poin with the spare ones furnished with the set.

Fig. 2.—Set Box Type BC-21-A as it Appears Closed Up Ready for Transportat

With the switch closed in the "Receive" position, the base and volt battery are connected to the amplifier. This is a low frequen two-stage amplifier, using two type VT-1 three-electrode vacu tubes connected for cascade amplification by means of two iron c transformers. Jacks and binding posts for connecting telephone ceivres are provided in the plate circuit of the last tube. The f ments of the two tubes are connected in series to the 10-volt storage battery. Four fixed resistances having a total value of 3.9 ohms are in series with the filament circuit. These resistances are so con-



G. 3.—Set Box Type BC-21-A Opened to Show Upper Compartment for the Head Sets. This is Normally Closed While Operating and the Panel Exposed by Fastening the Canvas Flap Up.

cted as to allow the substitution of VT-11 or VT-21 tubes for the [-1 tubes normally furnished with the set, without changing the ernal connections of the set. There is no variable resistance in series with the filament circuit. Variation of amplification is ob tained by shunting the primary of the second transformer with resistance. A switch marked "Amplification" is provided on th face of the panel for this purpose. A plate potential of about 4

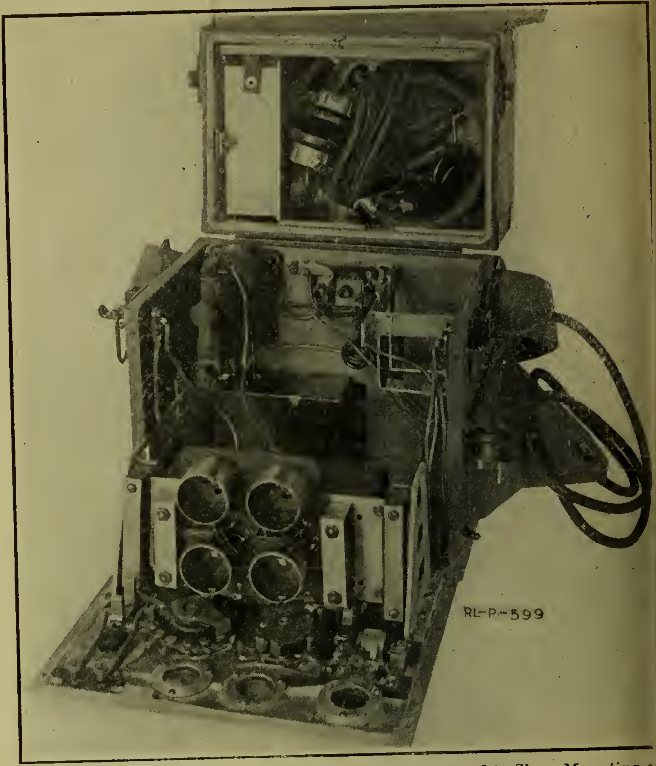
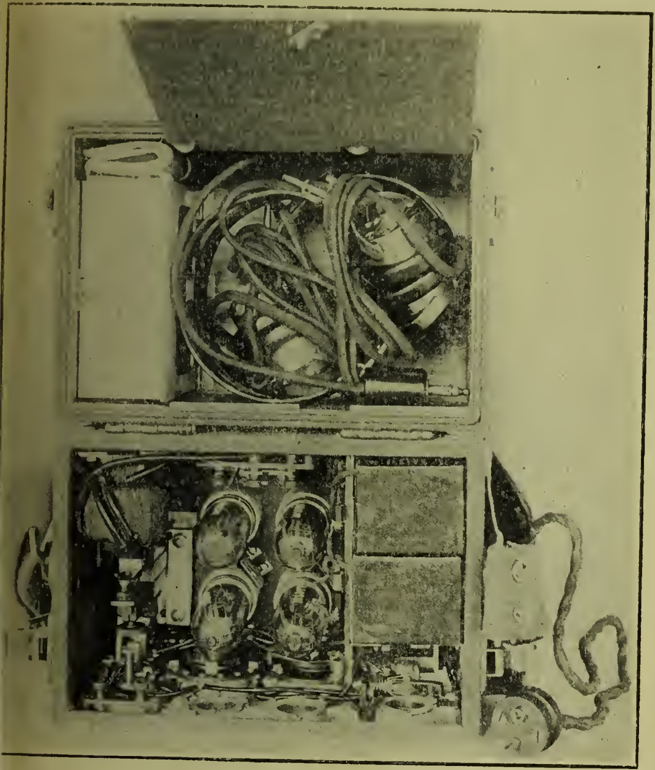


FIG. 4.—Panel of Set Box Type BC-21-A Opened Forward to Show Mounting o Various Apparatus. Note Transfer Switch or Strap on the Back (Top Center) of the Box.

volts is obtained for both tubes by means of two type BA-2 d batteries connected in series. When the battery voltage has ru down to 34 volts (17 volts each) the batteries should be replaced.

When it is necessary to replace the dry batteries of the amplifi circuit, particular care must be taken to see that they are connect in with the correct polarity. This is essential for the operation of the vacuum tubes. It is also necessary that both vacuum tubes be in good condition, since the amplifier can not operate on one tube only, with the other one broken, burned out, or out of the circuit. If the amplifier does not work properly, this may be due to a poor



'IG. 5.—Looking Down on the Top of Set Box Type BC-21-A with Top Compartment Opened.

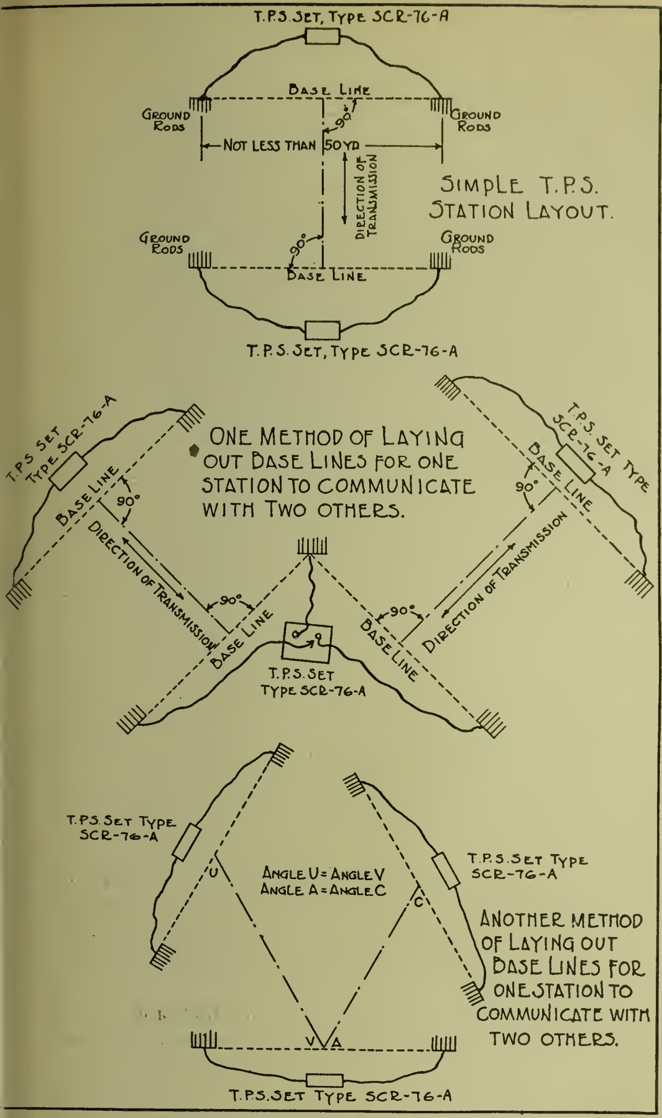
ephone connection, or to a wrong connection of either the stor- e or the dry batteries, or to the failure of one of the tubes. When the set is not in use, the transmit-receive switch should be the "Off" position, as this will avoid any possibility of unneces- ily running down the storage battery.

Mounting of the Set.—The set is mounted in a rugged canvas covered wooden case, having the overall dimensions of $12\frac{1}{2}$ in. x $10\frac{1}{4}$ in. x $7\frac{5}{8}$ in. This case is provided with one lid which closes against a rubber gasket and is held tightly by two strong toggle latches. The panel is protected by a canvas cover which buckles over the face of the set. This construction makes the set fairly waterproof, especially if care is taken to keep the rubber gaskets clean and free from dirt or mud before clamping the lid shut.

The lid carries two Headsets, Type P–11, two Batteries, Type BA–2, and a tool roll containing tools, vibrator weights, and spare parts for the buzzer. The two spare vacuum tubes are carried on the same tube base mounting that carries the operating tubes. Two spare line lamps are carried in sockets located below the transfer switch. The battery cord for standard 10-volt operation of the set is permanently connected to the battery binding posts and is carried in the pocket on the outside of the set. This cord is provided with a standard plug for making battery connection.

Opening a Station.—To open a station, the base line, approximately 500 ft. long, is established in accord with the rules laid down below, and connected to the line binding posts on the left hand end of the set. The battery cord is removed from the pocket and connected to the battery. The canvas cover over the panel is then unbuckled and catches released so that the lid may be thrown back. The telephones are then removed from the lid and inserted in the telephone jack. The lid should now be closed to protect the set. This operation is of especial importance, particularly during bad weather. By moving the switch to "Receive" and setting the "Amplification" switch to "Max," the set is ready for receiving signals. If it is desired to send a message, the switch is thrown to "Send" and the key is revolved down in the operating position. Should the buzzer require adjusting, it will be necessary to open the lid. This is also necessary in the case of changing tubes or "B" batteries, but under all other conditions the lid should remain closed.

How to Lay Out the Base Lines.—When laying out the base lines of various stations communicating with each other, it is very important to follow the general rule of arranging them so that the imaginary straight line joining the centers of the base lines of the stations will make equal angles with the two base lines, the angles considered being taken on the same side of that imaginary line and between the base lines. The best position is that in which the two base lines are parallel to each other and the line joining their centers makes right angles with them. This arrangement is indicated in the first drawing of Fig. 6. The other two drawings show the applica-



G. 6.—Methods of Laying Out a Simple T. P. S. Station, and One Station to Communicate with Two Others.

tion of the above rule by two different methods to the case of one station communicating with two others.

If one station is to communicate with a number of different stations, best results are obtained by providing at that one station a number of base lines, laid out radially around the station in positions at right angles, respectively, to the lines joining that base line to each of the other station base lines. A selector switch then enables the connection of the central station to any desired base line.

The installation of such a central station may be made in a number of different ways. Two methods are illustrated in Fig. 7, making use of Switch Type SW–16. By the method shown in the upper drawing, any one of the four outer ground terminals may be used with the local ground to make four different base lines, these covering closely almost any direction. By the method shown in the lower drawing, the two switches will usually be placed to make A and A or B and B, etc., the ends of the base line in use. However, the terminals D and B on opposite switches might be used as the pair of ground terminals if they were laid out the proper distance apart This gives an idea of the various combinations possible.

The first method is preferable, it being easier to install and operate There are only five grounds to establish, and one-half of the selector switch only is used. In the second method, both sides of the switch are used and there are eight grounds to establish.

When a station having a single line is to communicate with a central station having the choice of a number of base lines, the single station will establish its base perpendicularly to the line joining the two stations. The central station then selects the one of its bases which is nearest perpendicular to the line joining the two stations.

The best method for laying out the base lines is to use a compass by means of which the direction of the bases of the various stations can be determined accurately. A number of types of compasses are in use, which makes it impossible to give definite rules as to their use in this connection.

Another important consideration is the method of grounding the far ends of the base line wires. Twelve ground rods are furnished with the set. At least four rods should be driven into the ground in a straight line at each end of the base, and at a distance apart of not less than 2 ft. They should be driven at least 1 ft. into the ground It is well to moisten the ground around the rods after they have been driven in.

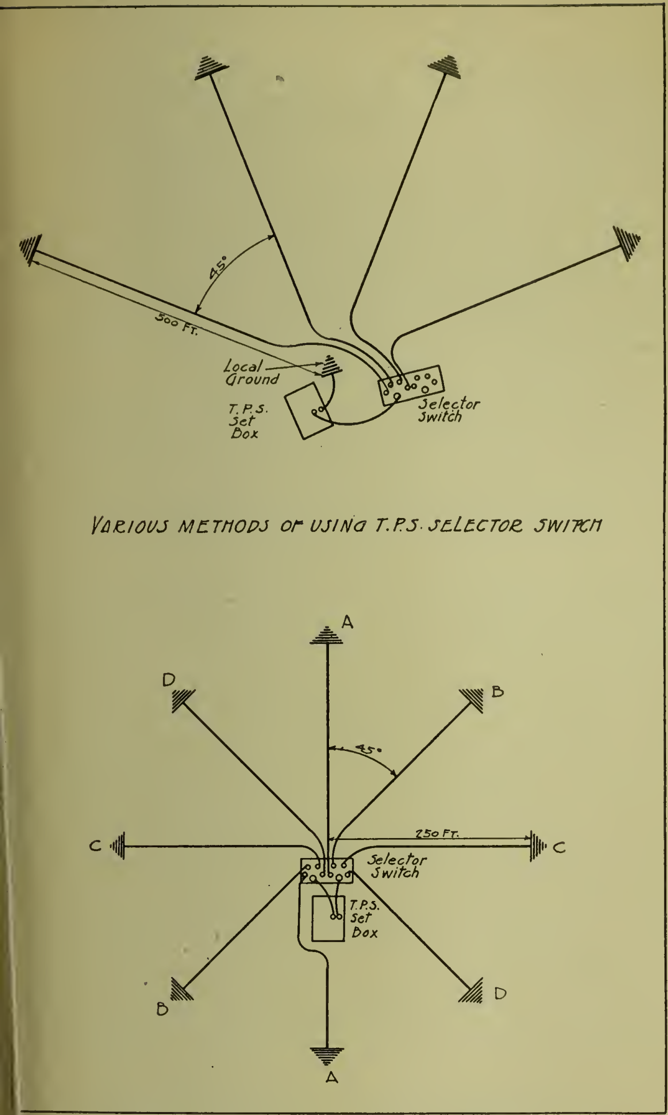


FIG. 7.—Methods of Laying Out Central T.P.S. Station.

Special care should be taken to use only line wires having perfect insulation for connecting the ground rods to the set box. These line wires may be buried in the ground if desired in order to protect them somewhat from shell fire. This, however, may increase the difficulties in case it is necessary to repair the wire after it has been cut by a shell. Inspect the line wires frequently to see that they are in good condition. If splices have to be made, insulate them carefully. Never use lead covered cable for these wires.

In order to make ground connections of low resistance, it is often useful to bury tin cans, shell cartridges, pieces of pipe, etc., in addition to the ground rods, or in place of them in cases of emergency. All these metallic masses should be carefully interconnected and connected to the line.

For more complete details on the theory of ground telegraphy and the methods of laying out ground stations, see Radio Pamphlet No. 10. For details of the listening-in service and the means of coping with interference, see Radio Pamphlet No. 18.

Method of Setting Up and Operating.

Installation of the Grounds.—After the direction of the base line has been determined, a ground connection is made at each end of the base, the grounds being separated by a distance of approximately 500 ft.

1. The base line wire is run out from the set box by means of the breast reel, on which is wound 500 ft. of wire. One end of the wire is connected to the set box, as explained below. At the other end drive four to six ground stakes as deep as possible into the ground, in a straight line coinciding with the line of the base, and with at least 2 ft. separation between adjacent stakes. All the stakes are connected together by means of a wire which is then spliced to the line wire.

2. Near the set box, drive another group of four to six stakes into the ground and interconnect them similarly. This ground is connected to the other line wire from the set box. If possible, moisten the ground around each ground connection by pouring some water over the ground stakes after they have been driven in.

Connecting up the Set.—While the base line is being established, the set box can be connected up in the following manner:

3. Connect the free ends of the base line wires to the two binding posts on the left hand side of the set box.

4. Open the canvas pocket on the right hand side of the box and connect the 10-volt storage battery to the terminals in that pocket, using the battery plug or ordinary connection wires. If under exceptional circumstances it is desired to increase the range, 20 volts may be used for energizing the buzzer. In this case, connect one 10-volt battery between the "0" and "10 V" binding posts, with the positive pole of the battery to the "10 V" binding post, and connect another 10-volt battery to the "10 V" and "20 V" binding posts, with the positive pole of the battery to the "20 V" binding post.

5. Unbutton the front curtain covering the operating panel of the box and open the cover of the box to remove the telephone receivers. At the same time, check up that the two vacuum tubes in use are in good shape. These are the two tubes which are mounted directly in back of the operating panel of the box. Also check up that the two dry batteries are connected up with the proper polarity.

6. See that the line lamp is in good condition. This is the small lamp mounted in back of the opening in the front panel, which is ordinarily covered by the telegraph key when the latter is folded flush with the panel.

7. Three small binding posts are mounted inside the box, on the rear wall, above the spare line bulbs, and a strap fastened to the center post may be made to connect across either pair. If 20 volts are to be used for energizing the buzzer, connect the metal strap between the two right hand binding posts. If a 10-volt battery only is to be used, connect the strap between the two left hand binding posts.

Adjustments for Transmitting.—8. Place the right hand switch of the operating panel in the "Send" position.

9. Open the top of the box and by means of the special wrench to be found in this cover, fasten the desired weight to the power buzzer armature, according to the frequency at which it is desired to transmit. The following frequencies may be obtained by attaching the weight indicated:

	Cycles per second.
Large weight out	630
Large weight in	700
2 small weights out	830
1 small weight out	980
1 small weight in	1150
No weights	1380

10. Unlock the buzzer adjusting screw. Straighten out the telegraph sending key and depress it so that the buzzer will vibrate. Hold the key down and adjust the buzzer adjusting screw until a good clear note is obtained, then lock the screw in this position. As the current input into the ground is greater, the tighter the adjustment, the screw should be turned in as far as possible and retain a clear tone. If the tone is ragged, it is very difficult to eliminate interference at the receiving station.

11. Close the top cover. The set is now in operating condition for transmitting.

12. In order to test whether the base line wires are in good condition, and whether the proper current is flowing into the ground, depress the small black push button at the right of the key, and observe that the small line bulb is glowing. If it fails to light or glow, the base line must be broken or the buzzer is poorly adjusted.

13. The gap and tension of the sending key may be adjusted by means of the two screws located on the panel at the left of the stem of the key, the upper screw being the gap adjustment, the lower screw being the tension adjustment.

Adjustments for Receiving. 14.—Place the right hand switch of the operating panel in the "Receive" position.

15. Observe that both vacuum tubes are glowing by looking through the mica covered openings in the operating panel.

16. Open the cover of the box, check up the polarity of the dry batteries, and close the cover again.

17. Insert the telephone receiver plug into one of the jacks.

18. In order to vary the intensity of the received signals, such as for minimizing interference, operate the "Amplification" switch of the panel (left hand switch marked "Filament Rheostat" in Fig. 3).

19. While waiting for signals, check up frequently that the filaments of both vacuum tubes are glowing, as an assurance that the set is in operating condition and that nothing is being missed.

Precautions.

When the set is not in use, the transmit-receive switch must be placed in the "Off" position, so that there will be no possibility of running down batteries unnecessarily.

Always keep the set box dry and waterproof. Keep the rubber gaskets on the cover clean so that they will keep moisture out of the box. In case of rain, cover the operating panel of the set with the canvas curtain furnished for this purpose.

Do not operate the set on run down batteries. Check up the voltage of the storage battery (10 volts) and of each dry battery separately (20 volts) by means of the voltmeter furnished with the set. The lower limit of working voltage for the dry batteries is 17.5 volts per battery.

It is impossible to operate the set for receiving messages with only one vacuum tube inserted, or with one tube broken or burned out. Two good tubes in place are essential. At least two spare tubes should be kept on hand at all times. This will be a sufficient supply to take care of the requirements between times of getting new supplies from the depot.

Take note that the contact points on the buzzer vibrator are clean and not pitted or burned. If they require cleaning or truing up, remove them by means of the wrench, and gently rub them against some emery cloth on a plane surface. Do not use the file unless absolutely necessary. Replace the contacts carefully, with their surfaces in plane contact. Be sure to place the upper contact on the upper armature and the lower one on the lower armature. Do not interchange them.

Keep the connection leads as dry as possible. Frequently inspect the base line wires, as they may be broken by shell fire and this makes communication impossible.

While sending, another check on the condition of the line wires is obtained by means of the small line lamp, as explained in the operating instructions. Care should be taken that this lamp does not remain in the circuit while sending messages, and that the push button springs back in position when not used, short circuiting the lamp filament.

It is important to check up the connection of the three binding posts on the back wall inside the set box, and see that the position of the connection strap is correct for the storage batteries being used with the set.

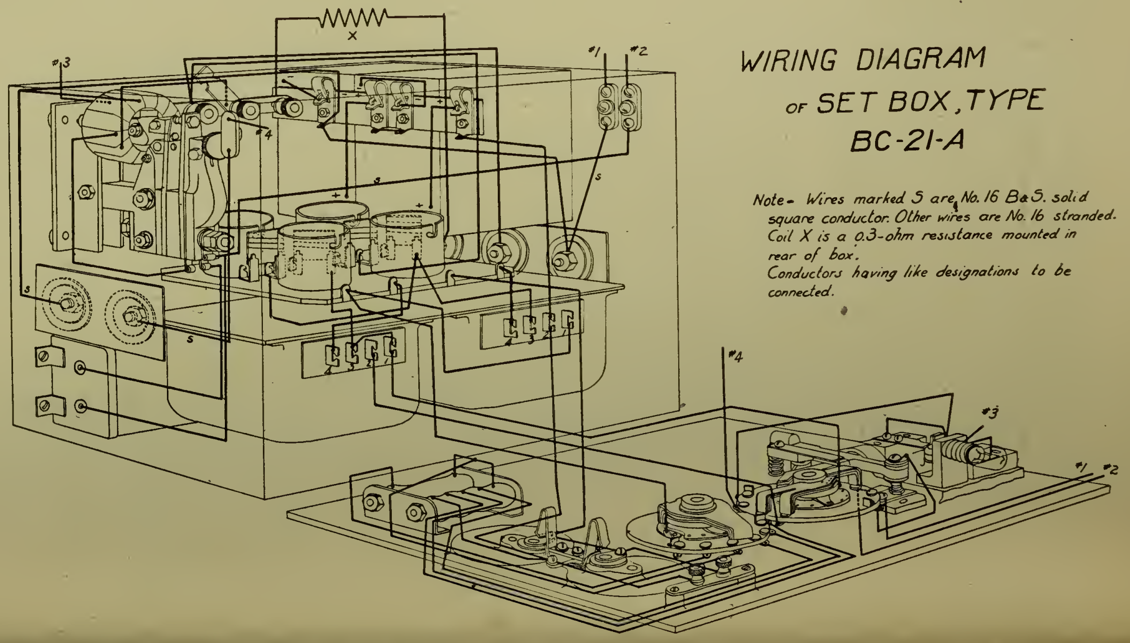
Comparison of SCR-76-A with SCR-71 and SCR-72 Combination.

The advantages of the SCR–76–A set over the former practice of utilizing the SCR–71 buzzer and SCR–72 amplifier are given as follows:

1. The set is more convenient to set up, as there is no switch to connect, thereby avoiding the numerous short interconnecting wires. Generally, all connections are easier to make.

WIRING DIAGRAM
OF SET BOX, TYPE
BC-21-A

Note – Wires marked S are No. 16 B&S. solid square conductor. Other wires are No. 16 stranded.
Coil X is a 0.3-ohm resistance mounted in rear of box.
Conductors having like designations to be connected.



2. The radio apparatus is easier to transport, as it is contained in a single box which is not an excessive load for one man. The total weight of the two sets SCR–71 and SCR–72 is somewhat greater than that of the SCR–76–A.

3. A great advantage is that there is only one storage battery required for the set, the 4-volt filament battery of the former set being entirely eliminated.

4. Space for spare vacuum tubes and dry batteries is provided within the set, while they had to be carried in separate boxes with the old sets.

The following disadvantages may be pointed out:

1. If the set is used at stations where one-way communication only is required, the SCR–76–A set provides superfluous material and equipment.

2. The amplifier of the SCR–76–A set cannot be used for radio frequency amplification purposes. If it is desired to use it in connection with radio signals, it must be connected in the audio frequency circuits of the receiving set.

PARTS LIST.

In ordering this set or parts of this set, specification must be made by names and type numbers as listed below, exactly. The designation printed in bold face type *only* will be used in requisitioning, making property returns, etc.

In ordering *complete* sets it is not necessary to itemize the parts; simply specify, "1 Set, Two-Way T.P.S., Type SCR–76–A." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment Type RE–3–A."

The type SCR–76–A set is not complete unless it includes all of the items listed below.

Set, Two-Way T.P.S Type SCR-76-A.

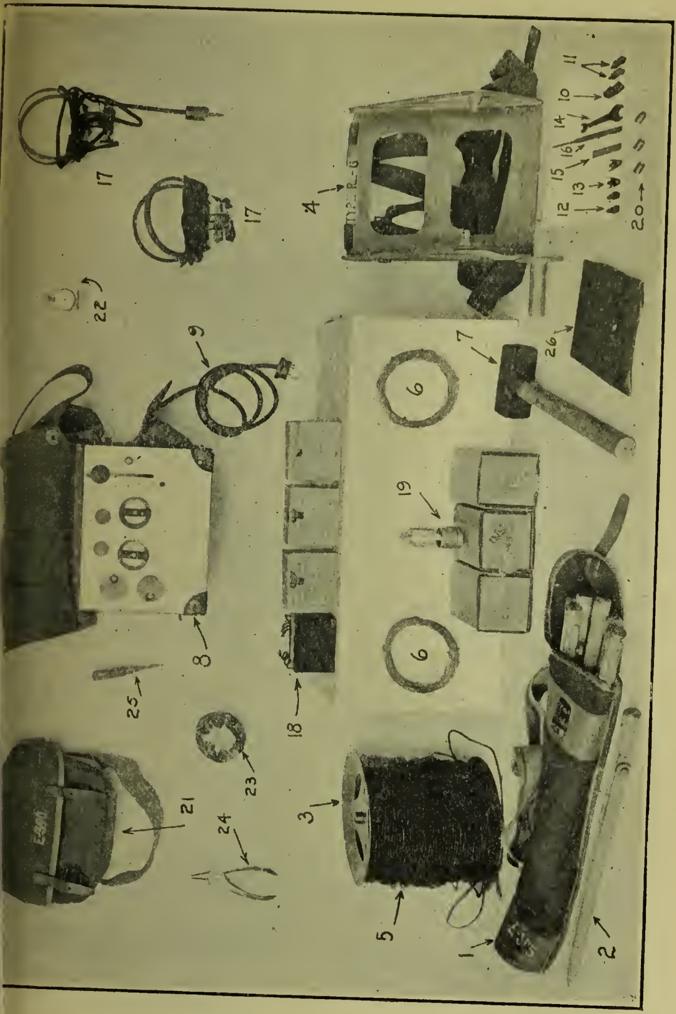
Equipment Type PE–11: power:

3 **Batteries, Type BB–23**; storage; lead; 10-volt, 20 amp-hr.; acid for electrolyte to be supplied separately in carboys; 1 in use, 2 spare.

(Or, as an alternative, not for overseas use, **Equipment Type PE–13**; power, comprising 2 **Batteries, Type BB–3**; storage; Edison; 10-volt, 8-cell, 25-amp-hr.; with electrolyte in separate containers; 1 in use, 1 spare.)

Equipment Type GD-3-A; ground:	★
1 Bag Type BG-8; carrying	(1)
12 Stakes Type GP-6; ground	(2)
2 Drums Type DR-3; for breast reel	(3)
1 Reel Type RL-6; breast	(4)
1000 ft. Wire Type W-4; two 500-ft. lengths, each wound on drum	(5)
60 ft. Wire Type W-5; two 30-ft. lengths, each wound in 3-in. coil	(6)
1 Hammer Type HM-1	(7)
Equipment Type RE-3-A; t.p.s.	
1 Set Box Type BC-21-A; two-way t.p.s	(8)
1 Cord Type CD-61; extension; set box to battery	(9)
1 Tool Roll Type BG-20	(Not shown.)
1 Weight Type WT-2; large; for vibrator	(10)
2 Weights Type WT-3; small; for vibrator	(11)
2 Contacts Type CN-1; upper; for vibrator; spare	(12)
2 Contacts Type CN-2; lower; for vibrator; spare	(13)
1 Wrench Type TL-6; for changing vibrator weights	(14)
1 Gage Type TL-7; air gap; for vibrator	(15)
1 File Type TL-5; for vibrator contacts	(16)
2 Head Sets Type P-11; telephone	(17)
4 Batteries Type BA-2; dry; 2 in use, 2 spare	(18)
4 Tubes Type VT-1; vacuum; receiving; 2 in use, 2 spare.	(19)
3 Lamps Type LM-6; current indicating; 1 in use, 2 spare	(20)
1 Bag Type BG-13; carrying	(21)
1 Switch Type SW-16; selector	(Not shown.)
1 Compass Type I-1; "cebynite" or equivalent	(22)
½ lb. Tape friction; ¾ in	(23)
1 Pliers Type TL-19; pair combination	(24)
1 Voltmeter Type I-10; 0-10/0-50 volts; with lead	(Not shown.)
1 Screwdriver Type TL-2	(25)
1 Sheet *Emery Cloth, No. 4-0;* approx. 11 in. x 8 in	(26)

* Figures in parenthesis in the right hand column refer to the corresponding parts in the illustration on the opposite page.



Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

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Airplane
Radio Telephone Sets

▽

Communication

RADIO PAMPHLET No. 20

Second Edition Revised to May 21, 1919

Signal Corps, U. S. Army

PRO PATRIA VIGILANS

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Airplane
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RADIO PAMPHLET No. 20

Second Edition Revised to May 21, 1919

Signal Corps, U. S. Army

Washington : Government Printing Office : 1919

Engin. Lib.

Airplane Radio Telephone Sets

Type SCR–68

Type SCR–68–A

Type SCR–114

Type SCR–116

Airplane Radio Receiving Sets

Type SCR–59

Type SCR–59–A

Type SCR–75

Type SCR–115

TABLE OF CONTENTS

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR–68–A

THE TYPE SCR–68 and SCR–68–A sets are airplane radio telephone transmitting and receiving sets designed primarily for interplane communication work between airplanes in squadron formation, these sets being used by the commanders of squadrons. The other planes of the squadron are usually equipped with the type SCR–59 receiving set. The set may also be used for two-way communication with ground stations equipped with the type SCR–67 or SCR–67–A sets. The type SCR–68 and SCR–68–A sets have an approximate wave length range of 215 to 450 meters. A detailed study will be made here of the type SCR–68–A set, which is the more recent model, and the differences with the type SCR–68 will be pointed out in a later section.

The set comprises a special constant voltage generator, which furnishes the power for transmitting and for heating the receiving vacuum tube filaments; a filter box; a radio set box; an interphone set box for permitting telephone communication between the pilot and the observer; two head sets and telephone transmitters; and the required connecting cords.

The Transmitting Circuit

A complete circuit diagram of the set is given in Fig. 1. The set box is equipped with a multi-pole double throw "Transmit-Receive" switch, which connects either the transmitting or receiving circuit. For the purpose of facilitating explanation, these circuits are treated separately.

A schematic diagram of the circuits in use when the switch is in the "Transmit" position is given in Fig. 2. This circuit comprises a type VT–2 three-electrode vacuum tube connected up as an oscillator to generate undamped high frequency oscillations in the antenna circuit. The plate circuit of this tube is energized by a 275-volt direct current generator, the terminal voltage of which is kept constant by means of special devices described in a later paragraph. In series with this plate circuit is a jack J_2, which permits the insertion of an ammeter for reading the plate current, an iron core choke

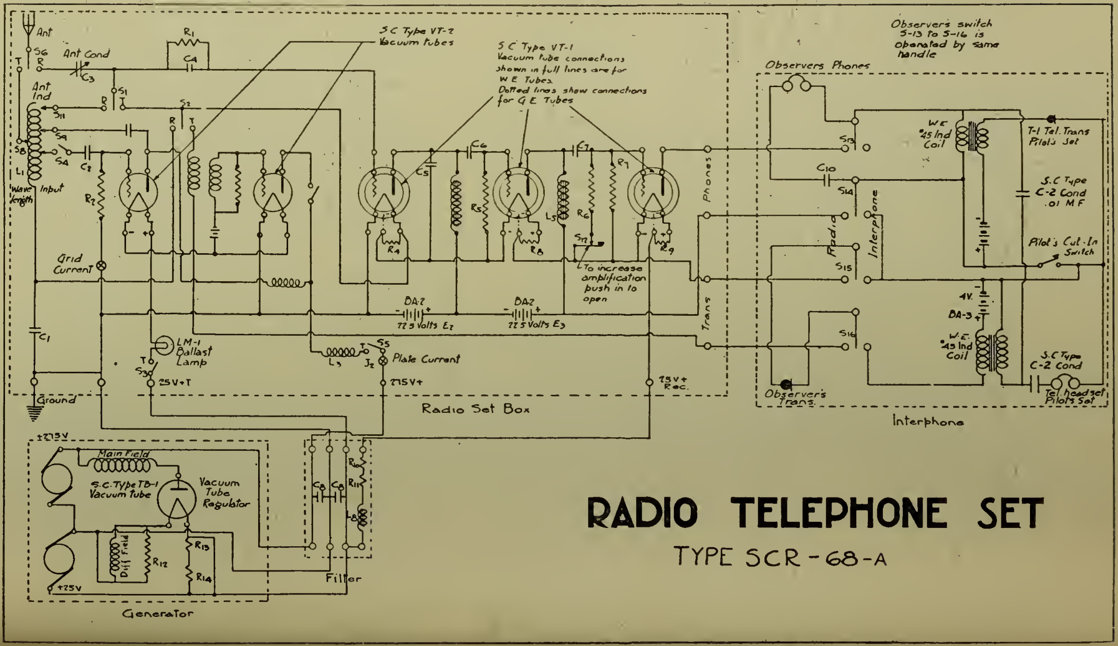


FIG. 1.—Complete Schematic Circuit Diagram of the Radio Telephone Set Type SCR-68-A.

coil L_3 which tends to keep the current from the generator constant, and a radio frequency choke coil to prevent the high frequency alternating current generated by the tube from flowing outside the radio circuits.

The filament of the oscillator tube is in series with that of a modulator tube, the function of which will be explained later, and is heated by the current from a 25-volt direct current generator,

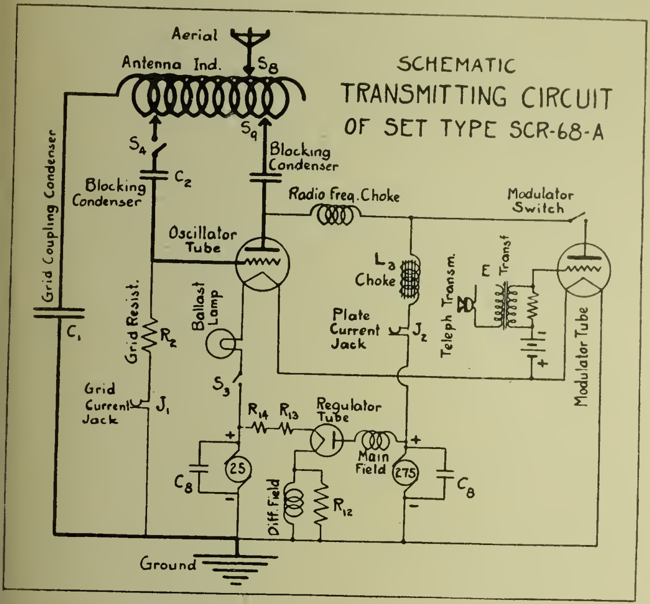


FIG. 2.—Schematic Diagram of the Transmitting Circuit of Set Type SCR-68-A.

mounted on the same shaft and having the same fields as the 275-volt generator.

The grid circuit of the oscillator tube comprises a high resistance R_2 and a jack J_1 which permits the insertion of a milliammeter for reading the grid current. The function of the grid resistance is to obtain a negative potential on the grid when the tube is oscillated.

The grid and plate circuits are coupled electrostatically by means of a fixed condenser C_1 connected between the grid and the filament, and the condenser formed by the antenna and counterpoise in the plate circuit. An antenna inductance, which forms the inductance of the oscillatory circuit, is connected directly between the plate and the grid. A blocking condenser is inserted in each of the plate and grid radio circuits in order to prevent any possible short circuiting of the direct current circuits. The wave length, grid and plate couplings may be changed by connecting the aerial, grid and plate wires to different points of the antenna inductance.

A second three-electrode vacuum tube (the modulator) is connected with its plate circuit in parallel with that of the oscillator tube, that is, between the negative terminal of the 275-volt generator armature and a point between the iron core choke coil and the radio frequency choke. The grid of this modulator tube is connected to the filament through a 20-volt dry battery, type BA–2, and the secondary of an "input" transformer. This gives the grid of the modulator tube a constant negative potential. The primary of the input transformer is connected in series with a telephone transmitter type T–3 described below, and a source of continuous potential which is the voltage drop across the filament of one receiving tube and two resistances of the receiving tube filament circuit.

With the circuits as described above and shown in Fig. 2, it may be seen that the constant current of the 275-volt generator divides between the plate circuits of the oscillator and modulator tubes. The amplitude of the alternating current generated by the oscillator tube in the antenna circuit, and therefore of the waves radiated by the latter, is directly proportional to the amount of direct current flowing in the plate circuit of that tube. On the other hand, the potential of the grid of the modulator tube controls the amount of current which may flow through the modulator tube. And since, due to the iron core choke coil L_3, the sum of the plate currents in the two tubes is constant, any variation in the amount of current allowed to flow through the modulator tube is accompanied by a corresponding variation (in opposite direction) of the current supplied to the plate circuit of the oscillator tube, and therefore, in the amplitude of the oscillations generated by the latter tube.

The principle underlying the transmission of speech by means of this set is therefore the following. When no speech is impressed on the telephone transmitter, the potential of the modulator tube grid remains constant, and there is no variation in the plate currents of the two tubes. The oscillations in the antenna circuit are then of constant amplitude, as shown in Fig. 3. When one talks into the telephone transmitter, a pulsating current is made to flow in the primary of the input transformer, resulting from the action of the transmitter, which impresses on the grid of the modulator tube an alternating or varying potential following the modulations of the voice. These variations of potential produce corresponding variations in the current allowed to flow in the plate circuit of the modulator tube, and therefore in the plate current of the oscillator tube, and finally, in the amplitude of the oscillations in the antenna circuit. The result is that the waves radiated by the set, instead of being of constant amplitude, have an envelope reproducing the pulsations of current in the telephone transmitter circuit. In

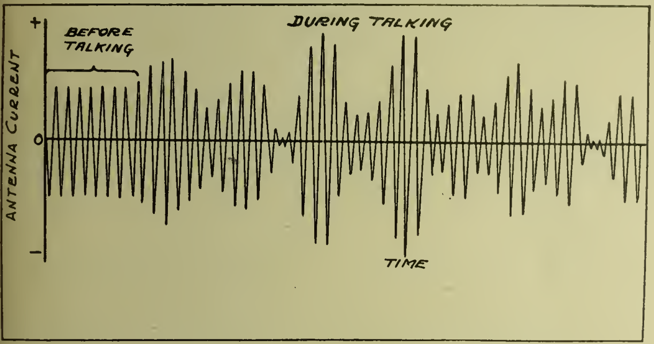
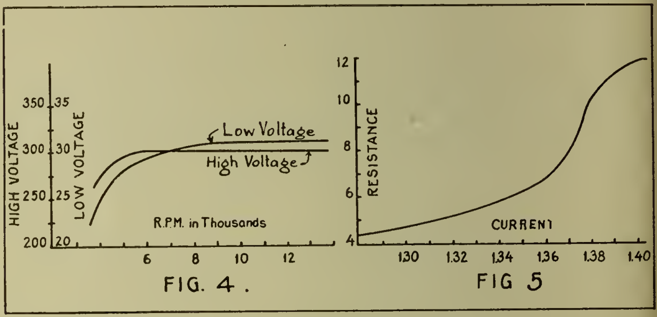


FIG. 3.—Effect of Voice Modulation upon the Amplitude of the Waves in the Antenna Circuit.

other words, the waves are modulated to the speech. For a more thorough explanation of modulation and voice transmission by radio, see Radio Pamphlets Nos. 1 and 40.

Some essential requirements must be fulfilled for giving a satisfactory operation of the set, and with the conditions encountered in airplane work these requirements necessitate the use of special regulating devices. The generator furnishing the power to the plate and filament circuits is a fan driven generator mounted on the strut of the landing gear of the airplane. It is enclosed in a streamline case, and driven by a special regulating airfan, the purpose of which is to keep the speed of the generator constant for varying airplane and wind speeds. This airfan, type FA–7, is made of metal and its two blades may be rotated around their longitudinal axis so that the pitch of the airfan will automatically change when the speed of the airfan through the air changes. The twist of the airfan blades is counterbalanced by a set of springs and weights inside the airfan hub. The operation of this airfan maintains a constant generator speed of about 4000 r. p. m. for airplane speeds of from 50 to 200 m. p. h.

An additional means of keeping the generator voltage constant is provided in the peculiar method of exciting the generator. It is self-excited and has a main and differential field winding, the fluxes of which are opposed. The main field winding is connected in series with a special two-electrode type TB–1 vacuum tube, the filament circuit of which comprises the differential winding. This is shown in Fig. 2. The operation of this device is then as follows



FIGS. 4 and 5.

If the generator speed should tend to increase, the generated voltage would increase, which consequently would increase the current in the main field winding and in the regulator tube filament in series with it. It would also increase the plate voltage on the tubes, and therefore the plate current. The latter current, flowing through the differential field winding, would increase the flux in the latter and counteract that of the main field, and thus prevent any further rise of the generator voltage. In case the generator should be driven at a speed below normal, the effect would be exactly opposite, and the generator voltage would be thus kept constant despite the small variations in speed which are not entirely corrected by the regulating airfan. The combined effect of the several regulating devices is shown in Fig. 4.

In order to reduce the pulsations in the output current of the two armatures of the generator resulting from commutation, a condenser C_8 is shunted across each. These condensers are located in the filter box, and serve as a by-pass for the commutation pulses. Without this precaution, these pulsations, especially those on the 275-volt armature, would produce a steady hum in the telephone receivers, due to a modulation of the wave resulting from them.

An additional precaution in maintaining constant the current in the filament circuit is taken by the use of a "ballast lamp." This lamp, which is located in the radio set box, is connected in series with the filament circuit. It has an iron filament and is filled with hydrogen. The resistance of this lamp is a function of

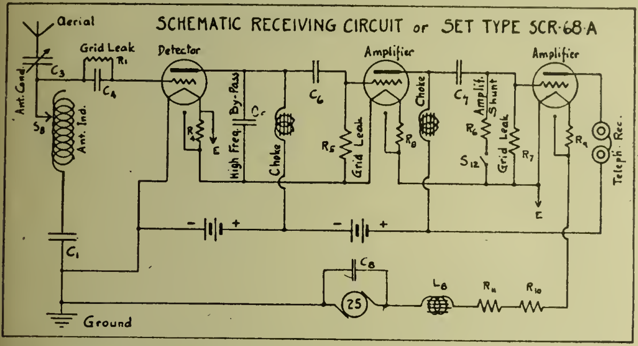


FIG. 6.—Schematic Diagram of the Receiving Circuit of Set Type SCR-68-A.

the current flowing through it, as shown by the characteristic curve of Fig. 5. The operation of this lamp may be understood when it is noted that an increase of filament current would increase the ballast lamp filament resistance, which would therefore tend to prevent the current from increasing (and vice versa), thus aiding to keep the current constant.

The Receiving Circuit

The type SCR-68-A set has a receiving circuit which is connected for operation when the switch on the radio set box is closed in the "Receive" position. It may be used for the purpose of receiving a conversation sent out by another set using the transmitting circuit described above or a similar one. A schematic diagram of this receiving circuit is given in Fig. 6. It may be seen that the circuit comprises a type VT–1 three-electrode vacuum tube used as a detector, and two similar tubes used as audio frequency amplifiers, the coupling between successive tubes being by means of iron core choke coils. The antenna circuit comprises a variable air condenser C_3 used for tuning, an antenna inductance, a large blocking condenser C_1, and the antenna-counterpoise condenser. The antenna inductance and blocking condenser are connected between the grid and filament of the detector tube, there being also a grid condenser and leak resistance in series with the grid. The plate circuit of the detector tube is energized by a type BA–2 dry battery, in series with

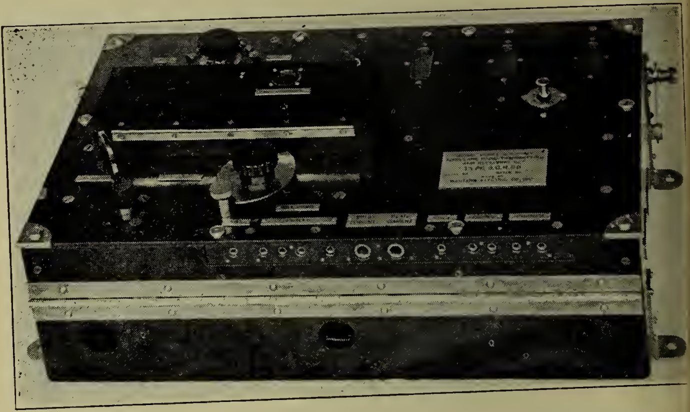


Fig. 7.—Operating Panel of Set Box Type BC–11 Used in Set Type SCR–68, Showing Jacks Along the Bottom Edge.

which is an iron core choke coil. Shunting the battery and chok is a condenser C_5, which by-passes the high frequency oscillation while the audio frequency pulsations which are the envelope of th incoming waves produce pulsations in the plate current of th detector tube. In flowing through the choke coil, these pulsatio induce a high counter-emf. across the latter, which is impresse upon the grid of the first amplifier tube through the condenser C

The potential variations of the grid of the first amplifier tube a thus similar to those of the grid of the detector tube, but are of great amplitude. The resulting variations in the plate current of the fi amplifier tube are therefore amplifications of those of the pla current of the detector tube. The amplifier tube operates at plate voltage of about 40 volts, obtained by means of two type BA–2 dry batteries in series. Connected between the grid and filament of the first amplifier tube is a high resistance R_5 through which the charges on the grid may leak off to the filament, thus preventing the accumulation of a charge on the grid as it is being transferred from the detector tube to the amplifier tube.

The first amplifier tube is coupled to the second amplifier tube in the same way the detector tube is coupled to the first amplifier. The plate circuit of the second amplifier tube, however, instead

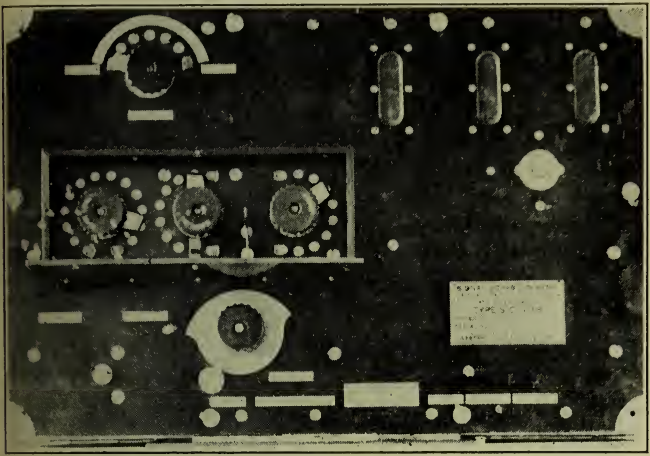


FIG. 8.—Operating Panel of Set Box Type BC–11 Used in Set Type SCR–68, Showing the "Wave Length," "Coupling" and "Input" Switches in the Small Covered Panel.

of comprising a choke coil, comprises the telephone head sets of the observer and pilot, which are connected to it through the circuits of the interphone set box in a manner described in a later paragraph. A resistance R_6 is shunted between the grid and filament of the last amplifier tube and may be connected by means of a push button switch when it is desired to reduce the amount of amplification.

The filaments of the three receiving vacuum tubes are connected in series and are energized by the 25-volt armature of the generator. In series with each filament is a small resistance of about one ohm, which, for certain types of tubes, is short circuited automatically, as indicated in Fig. 1. The filament circuit also comprises an iron core choke coil L_8 located in the filter box and the function of which is to assist in maintaining the filament current constant.

Set, Airplane Interphone, Type SCR-57-A

The telephone head set and transmitter of the radio operator may be connected directly to the radio set box of the type SCR–68–A

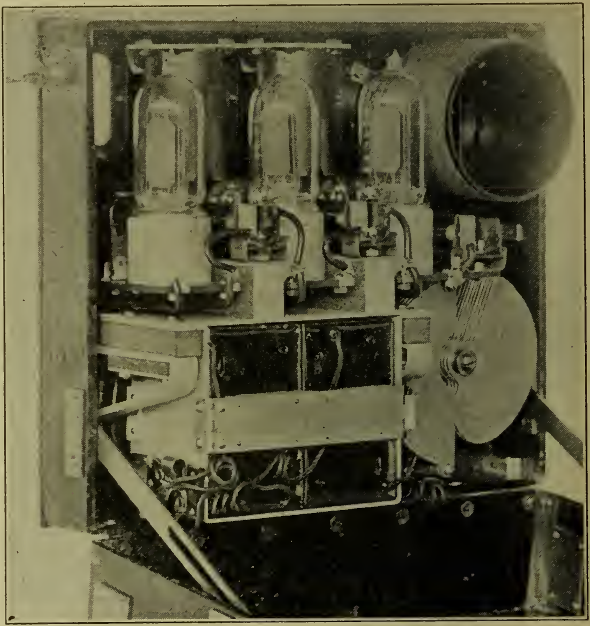


FIG. 9.—Mounting of Apparatus in Set Box Type BC–11 Used in Set Type SCR–68.

set. However, it is of advantage that both the observer and the pilot should be able to receive signals and to converse with each other. This is done by means of the interphone set type SCR–57–A, which differs from the type SCR–57 in some points as explained at the end of this paragraph. A circuit diagram of the set is shown in Fig. 1 and two photographs in Fig. 10.

With the four-pole double throw switch closed to the right in the "Interphone" position, the pilot and observer are entirely disconnected from the radio set, and are connected to each other by an ordinary telephone circuit. They may talk back and forth without any additional operation. A special feature of the set is the "side tone" circuit, which comprises a condenser the purpose of which is to shunt some of the telephone current from the transmitter circuit back into the telephone receiver circuit of the person talking. This circuit is used in order to enable the operator to hear his own voice and know how loud he is talking and whether the circuit is in working condition. Without this provision, he would not hear himself talk on account of the sound proof helmet he wears.

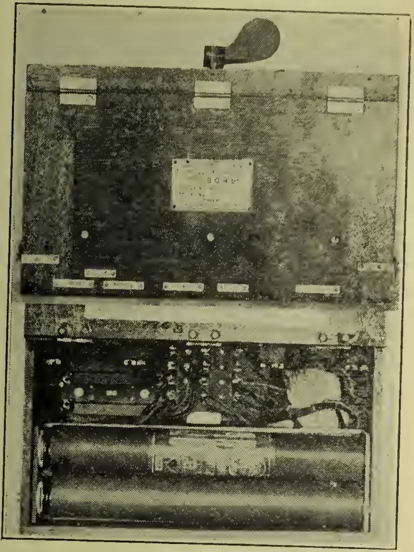


FIG. 10.—Set Box Type BC-10 Used in the Interphone Set Type SCR-57, Lower View Showing the Mounting of Batteries and Radio-Interphone Switch Within the Box.

With the switch closed to the left in the "Radio" position, the observer's telephone receivers are directly connected to the radio receiving circuit, and his telephone transmitter is directly connected to the transmitter terminals at the radio set box. The observer's telephone transmitter is however disconnected from the interphone circuit so that the observer cannot talk to the pilot. The pilot's circuits are disconnected, but by closing the "cut-in switch," he can receive radio signals and talk to the observer.

The operation of the set is then as follows. When the observer and pilot want to talk back and forth to each other, the observer closes the interphone-radio switch to "Interphone." When the observer desires to receive or send radio signals, this switch is closed to "Radio." If, now, the pilot desires to talk to the observer, he must first close his cut-in switch, and if he does not hear any incoming radio conversation, he may speak to the observer without interrupting him in the reception of a message. If he hears an incoming radio conversation, he should wait for the end of the message. If the observer desires to answer the pilot, he must close the interphone radio switch to "Interphone." This, however, disconnects him from the radio set so he should not leave the switch in this position longer than necessary or he may miss some incoming radio signals.

Other Parts of The Set

Fan Driven Generator.—The characteristics of the fan driven generator supplying the current for heating the filaments of the transmitting and receiving vacuum tubes and for supplying power

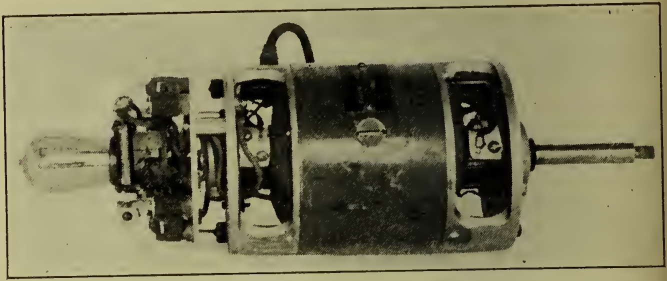


FIG. 11.—Generator Type GN-1 with the Housing and Airfan Removed.

to the plate circuits of the transmitting vacuum tubes were partly described in the discussion of the transmitting circuit. The generator is a self-excited unit having one main field, one differential field, and two armatures wound on the same core. It is enclosed in a streamline case, including also the regulator tube, the function of which was explained in a previous paragraph. See Fig. 11. Due to the regulating action of the airfan type FA-7 and of the regulator tube, the generator will work satisfactory between speeds of 4000 to 14000 r. p. m. The regulation will be entirely satisfactory provided the brushes are correctly adjusted. This adjustment is made in the following manner:

The high voltage brushes which are at the front end of the generator are locked exactly on the no-load electrical neutral point, and the low voltage brushes which are at the rear end of the generator are moved enough forward of the no-load electrical neutral point to obtain the flat voltage characteristic curve shown in Fig. 4.

As may be seen from the circuit diagram of Fig. 1, three resistances labeled R_{12}, R_{13}, and R_{14}, are mounted inside the generator casing. They are respectively of 100, 1.5 and 1.5 ohms resistance. They are mounted around the regulator tube socket in a triangle. The 100-ohm resistance is connected across the main field winding and helps to prevent hunting. The other two resistance units are not connected in any circuit when the generator leaves the factory. They are to be used for voltage adjustment as explained in the following paragraph.

It was explained above that the voltage regulation is dependent on the current through the filament of the regulator tube. This current is determined by the voltage generated by the low voltage armature and by the resistance o the filament circuit, which includes the main field winding. If this resistance decreases for any reason, the voltage required for supplying sufficient filament current to produce regulation will be less and it will be attained at a lower generator speed. Therefore, both high and low voltages will have values below those required by the set. This occurs at high altitudes and during cold weather, the field windings being kept cooler, and having therefore less resistance. To compensate for this effect, one or both of the 1.5-ohm units may be connected in series with the main field winding to obtain the correct resistance. Connecting one of the units increases the low voltage by about two volts and the high voltage by about twenty volts.

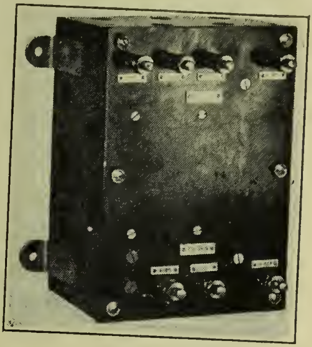


Fig. 12.—Filter Type FL-1 Used in Set Type SCR-68.

While the generator may be safely used on airplanes producing a wind speed of from 50 to 200 miles per hour if equipped with a type FA-7 regulating airfan, it should not be used outside the limits of from 60 to 160 miles per hour when using the airfan type FA-3.

Filter Box.—The filter box contains two condensers, labelled C_8, Fig. 1, one choke coil L_8, and two resistances R_{10} and R_{11}. It is a wooden box with a bakelite panel and binding posts, weighing 6 lb. and measuring 8⅜ in. x 3$\frac{7}{16}$ in. x 6 in., Fig. 12. The function of these units has been previously discussed.

Radio Set Box.—The radio set box contains the circuits shown in Fig. 1, and is illustrated by the photographs given herewith. It weighs about 17 lb. and measures 16½ in. x 4¾ in. x 11 in.

Installation of the Set.

The plan of installation of the type SCR–68 or SCR–68–A sets as given here is only of a very general character, since definite and

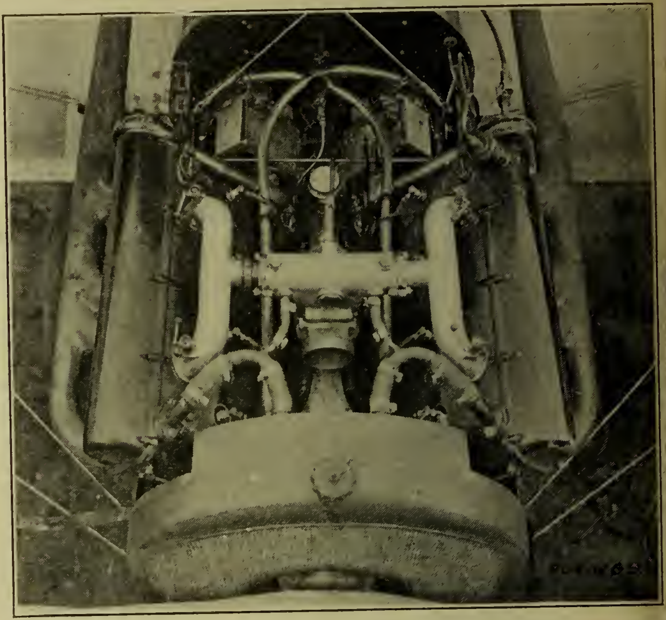


FIG. 13.—Engine Ignition Circuits Encased in Copper Tubing and Magnetos Al Encased as a Shield Against Interference with the Radio Set.

special instructions will have to be given for each kind of airplan on which the set is to be used. Before attempting to install an radio apparatus on an airplane, a thorough knowledge of the con tents of Radio Pamphlet No. 30 should be had.

As a special precaution against interference, no wires should b near and parallel to those of the switch operated by the pilot in con trolling the ignition system, for the magneto is a source of particula annoyance to the radio set. As a further remedy against magneto interference, it is well to shield the entire magneto system. This may be done by means of metallic covers for all the high-tension wires and the magnetos. The best practice is that of using solid metallic tubing for enclosing the high tension ignition wires and

G. 14.—Method of Mounting the Generator of Set Type SCR–68 on the Landing Gear Strut.

en connecting the tubing and the magneto covers to the frame of e airplane motor. An installation of this kind is shown in Fig. 13. The generator should be mounted in the slip stream, a good loca- n being slightly above the middle of the right hand vertical strut the landing gear, Fig. 14. When this position is not available, e to a lighting or heating generator occupying this strut, as is the se with the De Haviland airplane, the left hand strut must be

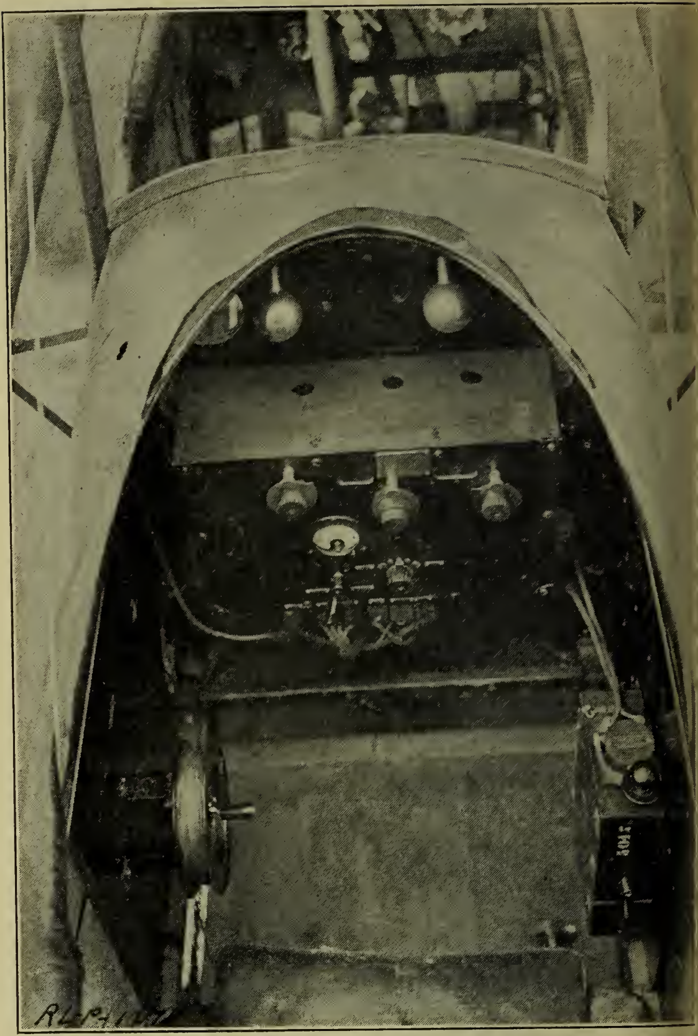


FIG. 15.—General View of the Mounting of Set Type SCR-80 in the Observer's Cockpit. The Mounting of this Set is Practically Identical with that of the Set Type SCR-68-A.

used. The generator base is bolted to a mounting made of iron, aluminum or wood (Mountings Type FT-7 or FT-8) which is clamped to the strut.

The airfan driving the generator may be the wooden fan type FA-3 or the regulating fan type FA-7. The fan type FA-3 is held in place by a nut screwed on the end of the generator shaft which presses against the aluminum hub of the fan, forcing it against a collar on the shaft and thus preventing the fan from rotating independently of the shaft. To replace fan type FA-3 by a type FA-7, remove the fan and generator front casing; then put on the casing supplied with the airfan type FA-7, using the screws taken out of the old casing. The nut which held the wooden fan is not to be used, as the type FA-7 fan is itself screwed on the shaft and then clamped in place.

A variable speed fan should be twisted about its longitudinal axis before each flight, to determine that the governor is functioning properly. The fan must be tightly fastened on the shaft or it may vibrate loose. A light oil should frequently be used to lubricate the bearings and gears of the fan and generator shaft. To properly oil the type FA-7 airfan, remove it from the shaft and oil the cone bearing and ball bearing of each blade as well as the gears at the bottom of the shaft bore.

The filter box is usually screwed to the fusilage floor, under the orward seat, or placed in the cockpit under the dash. In the De Haviland it is necessary to mount the filter box on the left side of he cockpit.

The radio set box should be mounted where its operating panel will be in easy reach of the operator so that he may readily use the arious switches mounted thereon. It should be supported so that ibration will be reduced to a minimum, and whenever possible, so hat the panel may be readily swung open from bottom hinges without interference.

When possible the interphone set box should be located near the dio set box and placed so that the switch is within easy reach of he operator, and with the jacks in a position which will allow the ugs to be readily inserted. The box may be mounted on the side the cockpit without unbalancing the airplane.

The pilot's interphone extension cord, type CD-6, should be run ong the longitudinal member supporting the seat, and the pilot ould have the interphone jack within easy reach so that the transmitter and receiver plugs may be inserted conveniently. The pilot's cut-in switch should be installed in a readily accessible position. The cord type CD–62 is provided with the SCR–68–A set to care for the necessity in certain installations to mount the interphone box and the transmitter and receiver jacks in different locations and some distance apart.

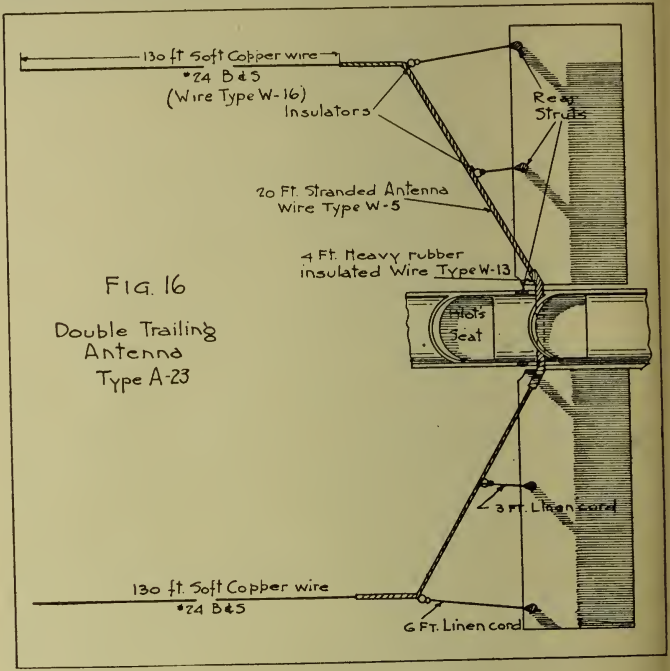


FIG. 16.

If a trailing antenna is to be used, the antenna reel should be mounted on the left hand inside of the fusilage on a wooden mounting fastened between the upper longeron and the seat support. The fairlead should be installed in the floor so that the wire will be guided directly in line with the reel.

The single trailing antenna type A–21 which is used for straightaway flying comprises a 4-ft. length of cord made fast to the reel at one end and tied at the other end to a 290-ft. length of antenna wire, which at its free end is spliced to a 10-ft. length of hemp center phosphor bronze wire having a lead fish weight on the end.

For airplanes flying in squadron formation, it is necessary to use a double trailing antenna so that there will be less restriction of the movements of the machine. This antenna is illustrated in Fig. 16. The counterpoise, as in the case of a single wire trailing antenna, consists of the metal parts and wires of the airplane itself.

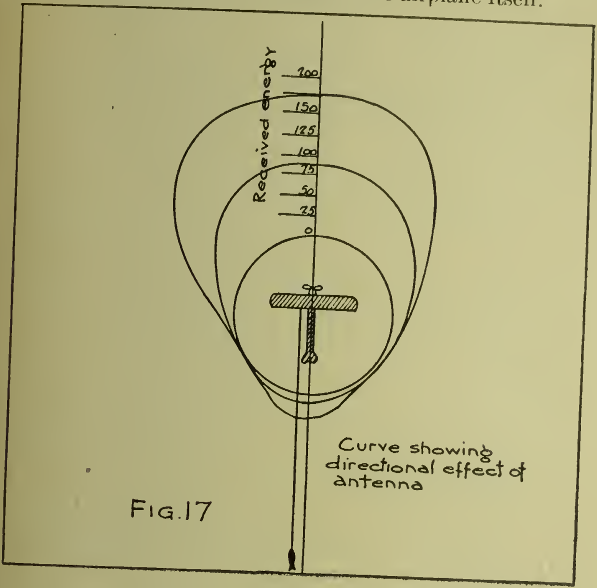


FIG. 17.

Both of these antennae have a general directive effect about as hown on Fig. 17. Transmission and reception is best when the irplane is flying toward the station with which communication is eing carried on.

All the stay wires of the airplane should be carefully bonded and lectrically connected to the motor and other important metal parts f the airplane to form the counterpoise. This is a very important art of the installation work, and the thoroughness with which it is one not only improves the operation of the set but insures against angerous sparks between metal parts resulting from the high oltage.

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The various units of the type SCR-68 set having been installed as explained above, they should be interconnected by means of the extension cords furnished with the set and in the manner shown in the cording diagram of Fig. 18.

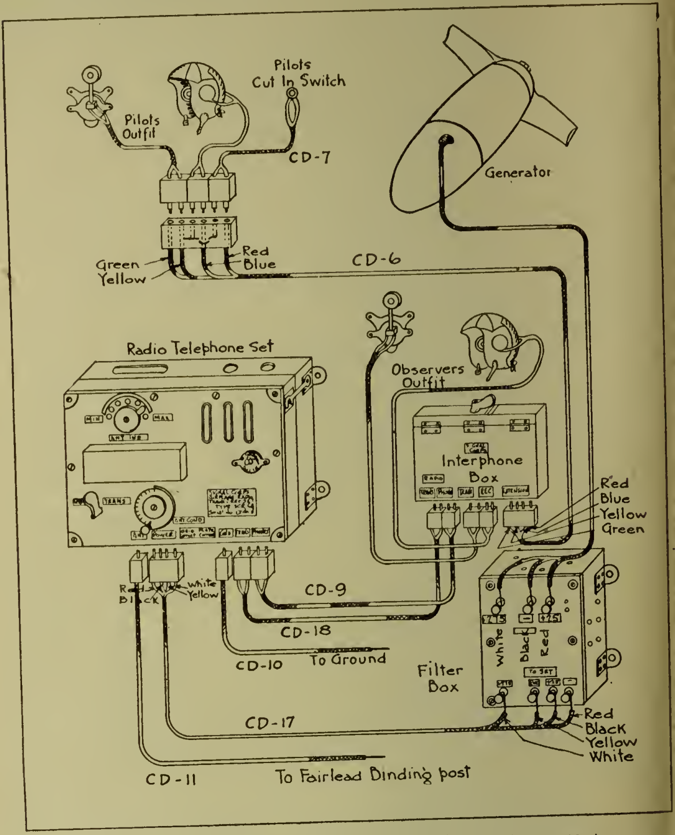

FIG. 18.—Cording Diagram of Sets Type SCR-68 and SCR-68-A.

Calibration of Set Type SCR-68-A

The set having been properly installed and connected as explained in previous paragraphs, it is necessary to tune it for transmitting and receiving at a given wave length. While the operatio of tuning may be done in the air during flight, it is better practice to calibrate the set on the ground and record the settings of the various switches for a number of different wave lengths within the range of the set. It is then possible, by referring to this record chart, to rapidly tune the set to any desired wave length. This calibration must be repeated every time the set is installed in a different airplane, or whenever a new antenna is used having different characteristics. The method of calibrating the set on the ground is as follows:

The calibration of the set on the ground is made with a phantom antenna adjusted to have the same effective resistance and capacitance as the actual antenna to be used with the set. The first thing to do is then to determine the constants of the actual antenna to be used. These may be readily measured, but this process is not described here. The antennae generally used are the type A–21 or type A–23. The former is a 300-ft. single wire trailing antenna, while the latter is a double trailing antenna, as shown in Fig. 16. The constants of these two antennae are given in the curves of Fig. 19 for different wave lengths. The natural wave length of the single wire trailing antenna is given in Fig. 20 for various lengths of wire.

A phantom antenna well suited for this purpose of calibration is the type A–50. The following meters will also be required:

1 Voltmeter Type I–5, range 0–50 volts.
1 Voltmeter Type I–6, range 0–500 volts.
1 Ammeter Type I–7, range 0–150 mililamp.
1 Ammeter Type I–9, hot wire, 0–0.5 amp.
1 Wavemeter Type SCR–60–C

The method of calibrating the set is then given in the following paragraph, the various operations being performed in the order given.

Calibrating the Transmitting Circuit.—

1. Remove the airfan from the generator and couple the generator shaft to a motor which will drive it at any desired speed between 4000 and 6000 r. p. m. Also remove the streamline casing of the generator.

2. With the "Transmit-Receive" switch of the radio set box on "Receive" to protect the operator from high voltage on the antenna and in the transmitting circuit, drive the generator at several speeds between 4000 and 6000 r. p. m. and measure the voltage at the

brushes. This should be between 275 and 300 volts on the high voltage side, and from 25 to 29 volts on the low side. If the voltage is much above 310 volts on the high side, inspect the connections and brushes. If these are in good condition, change the regulator tube and repeat the test.

3. Disconnect the real antenna by removing from the radio set box the "Antenna" and "Ground" plugs.

4. Substitute for the real antenna, the phantom antenna type A–50, after the latter has been properly set to have the same constants as the real antenna, as given in the curves of Fig. 19. The settings should be those corresponding to the average wave length of the set, that is, about 400 meters. In order to be connected to the "Ground" and "Antenna" jacks of the radio set box, the wires coming from the phantom antenna terminals should be equipped with plugs type PL–12.

5. Insert the telephone transmitter and receiver plugs in the proper jacks of the interphone set box.

6. Throw the "Interphone-Radio" switch of the interphone set box to the position "Radio."

7. Throw the "Transmit-Receive" switch of the radio set box to "Transmit."

8. Turn the "Input" and "Coupling" dial switches in the small covered panel of the radio set box all the way to the left and right, respectively, which corresponds to their maximum settings. The settings of the "Wave Length" switch are made for adjusting the wave length, the longer waves being obtained when the switch is turned to the right. In order to calibrate the set over the entire range, the various steps given below should be repeated for each position of the wave length switch.

9. Connect the milliammeter to the "Plate Current" jack of the radio set box.

10. Open the modulator switch. This is the small knife switch between the "Input" and "Coupling" dial switches.

11. Throw the "Transmit-Receive" switch on the radio set box to the "Transmit" position.

12. Observing the oscillator plate current on the milliammeter, adjust the coupling switch so that the reading will be as near as possible to 40 milliamp. This current should be maintained between 30 and 50 milliamp. It should be noted that increasing the coupling (turning the coupling switch to the right) decreases the plate current.

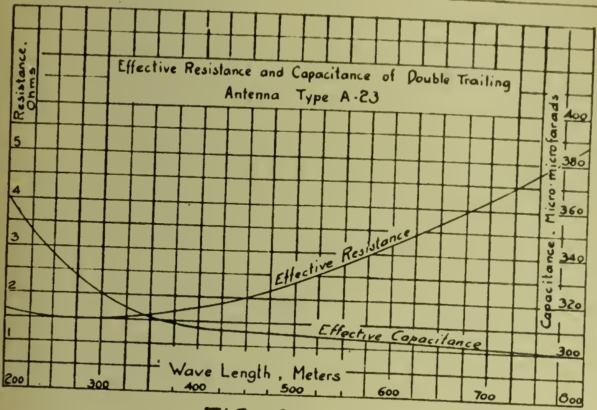
Effective Resistance and Capacitance of Double Trailing Antenna Type A-23
Resistance. Ohms
Capacitance. Micro-microfarads
Effective Resistance
Effective Capacitance
Wave Length, Meters

FIG. 19

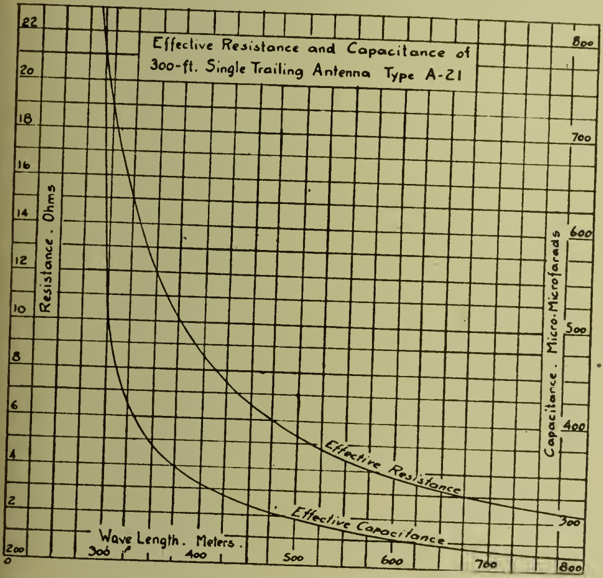
Effective Resistance and Capacitance of 300-ft. Single Trailing Antenna Type A-21
Resistance. Ohms
Capacitance. Micro-Microfarads
Effective Resistance
Effective Capacitance
Wave Length. Meters.

FIG. 19.

13. Set the "Transmit-Receive" switch to "Receive."
14. Close the modulator switch.
15. Set the "Transmit-Receive" switch to "Receive." The plate current should be between 60 and 80 milliamp., generally about 70. If greater than 80 milliamp., the modulator tube is defective and should be replaced.
16. Connect the milliammeter to the grid current jack. Adjust the "Input" switch so that the grid current, as read on the milliammeter, will be between 2 and 6 milliamp., and so that the radia-

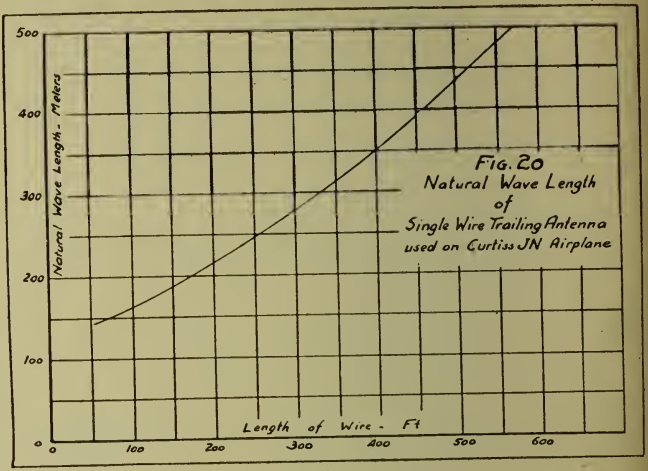

Fig. 20.

tion is a maximum as indicated by the hot wire ammeter on the phantom antenna.
17. Measure the emitted wave length by means of the wavemeter, placing the latter near the upper left hand corner of the radio set box.
18. Record the wave length, and the settings of the input, coupling and wave length switches.
19. Repeat the procedure for all positions of the wave length switch.

Calibrating the Receiving Circuit.—

1. Follow steps 1, 2, 3, 4, 5 and 6 above.
2. Set the "Antenna Condenser" (the handle to the right of the transmit-receive switch) approximately to its middle position.

3. Place the wavemeter at some distance from the radio set box, and set its buzzer into action.

4. For each position of the "Antenna Inductance" switch, adjust the wavemeter until the maximum signals are received in the telephone receivers connected to the radio set through the interphone set box.

5. Record the wave length giving maximum signals for each setting of the antenna receiving inductance. This calibration is only approximate, as will be seen from the method of operating the set in the air.

Operating the Set

Preflight Inspection and Tests.—Before each flight, the set should be thoroughly inspected and tested to insure proper operation during the flight. This should be done in the following manner:

1. Test the generator as explained in paragraphs 1 and 2, page 27.
2. Replace the airfan on the generator shaft, tightening it securely.
3. Ascertain that the following conditions are met:
   - No loose or broken connection.
   - No worn insulation.
   - Plugs inserted in their proper jacks.
   - Good condition of the airfan.
   - Secure mounting of airfan, generator, radio set box, interphone set box, filter box.
   - Required number of vacuum tubes in the set box.
   - Vacuum tubes free from imperfections.
   - Batteries connected with the proper polarity.
   - Proper insulation of antenna, and proper length of antenna wire as gauged by the eye.
   - Fish weight attached to antenna, if A–21 is used.
   - Receive-Transmit switch on "Receive."

4. Set the various switches in accordance with the calibration chart obtained as explained above, so that the set will be tuned to transmit and receive at the desired wave length.

5. Test the interphone box by talking to the pilot through the telephone transmitter with the switch on "Interphone." Then replace the interphone switch to the "Radio" position.

6. The set being then ready and the switches on "Radio" and "Receive," the operator should hear a certain amount of magneto noise in the receivers, while the pilot is testing out the airplane engine. Also, when the engine is brought to full speed, the generator

will be driven by the wind of the propeller, and the receiving tube filaments of the radio set box should glow a dull red.

Operating the Set in the Air.—No additional adjustments are required for transmitting if the set has been properly tuned on the ground. If a type A–21 antenna is used, it should be unreeled when the airplane has reached an altitude of about 500 meters. When receiving, some slight readjustments may be made by means of the "Antenna Condenser" handle. Until the first signals are heard, the amplification push button switch on the radio set box should be pushed in. If then the incoming signals are too strong, it should be pulled out. If the receiving circuit has not been calibrated on the ground, tuning may be done by varying the antenna condenser for each position of the antenna inductance switch, with the amplification push button pushed in until the signals are heard loudest. The operation then consists merely in throwing the switch on the interphone set box to "Radio," and the switch on the radio set box to "Transmit" or "Receive," as desired. When not transmitting or talking to the pilot, the observer should always have these switches on "Radio" and "Receive," in order to be sure of not missing any radio signals which may happen to come in.

Receiving and transmitting with the type SCR–68–A set presents no special difficulties when simple rules are remembered. A list of these, emphasizing the principal points of operation, is given below:

(1) Do not forget to inspect the set before each flight.

(2) Do not forget to plug in the telephone transmitter and telephone receiver plugs.

(3) Do not forget to throw the "Receive-Transmit" switch on "Transmit" and the "Interphone-Radio" switch on "Radio" while talking.

(4) Do not talk rapidly.

(5) Do not have the telephone transmitter away from the mouth while transmitting.

(6) Do not "cup" the hands over the telephone transmitter.

(7) Do not shout into the telephone transmitter.

(8) Do not forget to leave the "Receive-Transmit" on "Receive" when not using the set.

(9) Do not become impatient if you do not hear incoming signals immediately.

(10) Do not expect satisfactory operation over more than five miles range.

(11) Do not forget to put the "Interphone-Radio" switch on "Radio" after talking over the interphone.

(12) Do not touch any uninsulated parts of the set while the switch is on "Transmit."

(13) Do not tinker with the set.

(14) Do not forget to note any cause as to failure of the set to operate.

(15) Do not fail to study the instructions thoroughly.

Troubles and Remedies

In the following outline of troubles encountered with type SCR-68-A sets, no endeavor is made to arrange them in the order of their importance, the reason being that it is easily ascertained to just what extent such troubles may affect the operation and what can be done in case of emergency.

Generator.—

Mounting.—Trouble may be experienced with the generator mounting if it is not firmly fastened to the strut, thus allowing considerable vibration which may cause the generator base to become loosened from the mounting and possibly to break the base.

Leads.—If the lead from the generator to the filter box has been run along the innerside of the strut, the insulation may become oil-soaked and deteriorate to such an extent as to cause a short circuit. To avoid this the lead should always be fastened on the outerside of the strut—the side farthest from the engine.

Brushes and Their Mountings.—It is very important to inspect the condition of the brushes and their mountings. In the type GN-2 generator there are two kinds of brushes used, one a composition of carbon and copper for the low voltage side and the other, a high resistance carbon for the high voltage side. These should obviously not be interchanged. In the type GN-1 generator only one type of brush is used, thus obviating any trouble due to interchange of brushes. Sometimes the brush holders of the type GN-2 generator become quite hot and then unsoldered, in which event it is necessary to re-solder them. Furthermore, the pig-tails on the brushes may also become loose and thus necessitate the renewal of the brushes. Trouble from these sources has been eliminated in the design and construction of the type GN–1 generator. In case the brush pressure becomes too low on any type of generator, it is advisable to insert new brushes, as this is an indication that the brushes have become worn down.

Bearings.—The generator usually runs at a high speed, requiring that the bearings be in good condition and well oiled at all times.

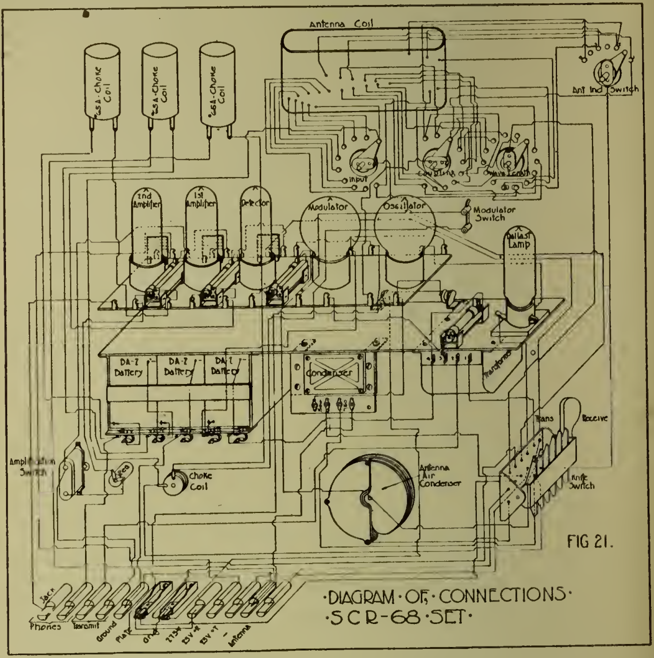

FIG. 21.—Actual Wiring Connections Within Set Box Type BC–11 Used in Set Type SCR–68.

Commutators.—Dirty, scratched and burned commutators, and also low brush pressure will cause very much noise when transmitting, which "comes in" as interference, and may even make it impossible to understand what is being said. These same conditions may also produce noise in the telephone receivers of the transmitting set itself.

Field.—Due to overheating, the terminals of the differential field of the generator may become unsoldered on the regulator tube mounting, causing very high voltage with the subsequent burning out of the regulator tube. In warm weather the resistance of the differential field is greater than in cold weather and consequently the voltage regulation may be somewhat higher, but this will probably not cause any trouble.

Armature.—It may happen that the generator armature rubs slightly against the pole faces which is an indication that the bearings have become worn.

Hunting.—Some of the first type GN–2 generators manufactured have a copper shield on the differential pole which may cause hunting, but this can be remedied by the removal of the shield. The 100 ohm resistance in parallel with the main field is used to prevent hunting; therefore, an open circuit in the shunt resistance would be a source of hunting.

Excessive Voltage.—In the operation of the set the plate voltage should not attain a value much over 310 volts. If this occurs, it is probably caused by the regulator tube, or by the generator brushes being incorrectly set.

Filament.—Due to imperfections in the construction of some of the tubes, the filament and plate sometimes short circuit. Incorrect adjustment of the generator brushes may produce an excessive voltage across the filament and result in its burning out.

Vibration.—Vibration of a tube may result in the filament making an intermittent contact with the plate thus producing an effect in the transmitting circuit similar to that caused by generator hunting.

Tube Mounting.—Wear by vibration and deterioration of the sponge rubber upon which the tube mounting is held, may cause too much play in the mounting and thus loosen the tube leads.

Airfan.—

Pitch.—The airfan is a very important part of the generator. If the pitch of the airfan is too small, the generator and regulator tube are overloaded and if too large the generator may at times run too slowly to produce the proper voltage. Fixed blade airfans must not be used on airplanes traveling at higher speeds than that for which the airfans are designed, because the airfan may break and the result may be serious injury to the airplane and its occupants.

Injury.—When the airplane "lands" or "takes off," the rush of air created by its propeller may cause pebbles to be thrown against the generator airfan. A type FA-3 fan may become marred and at times damaged seriously enough to prevent its being used.

Mounting.—The airfan should be securely fastened to the shaft of the generator. Since no key is provided to keep the airfan from turning on the shaft, the transmission of power from it to the shaft depends entirely upon friction, and therefore, if only loosely installed, slipping will take place and little or no voltage be delivered from the generator.

Filter Box.—This part of the set will give very little or no trouble, the only probable source being the danger of connections becoming loose and short circuiting each other. These should therefore be securely made.

Radio Set Box.—The type SCR-68 set has many possible sources of trouble but only those that may be commonly experienced are enumerated here.

Ballast Lamp.—While operating the set, if it is noticed that the filaments of the receiving tubes are not lighted, and it is known that power is being delivered to the set, the probable cause of trouble is a broken or burned out filament in the ballast lamp.

Blocking.—Blocking is the failure of the modulator tube to properly modulate. It manifests itself by a noise in the telephone receivers and an intermittent or complete cessation of the transmitted speech. When intermittent, it acts just as though the "Receive-Transmit" switch were thrown alternately from "Receive" to "Transmit," thus causing the receiving set to obtain only part of the incoming message. If the operator is experiencing a very severe case of blocking he will be unable to hear himself in the telephone receivers while talking and unable to cause his message to be received. The oscillator and modulator tubes should be interchanged periodically after about ten hours of use, for any tube will eventually develop blocking if used continuously in the modulator circuit. Blocking is a result of the characteristic of the modulator, of too high plate voltage or too low filament current. The interchanging of the modulator and oscillator tubes may remedy this trouble or it may be necessary to discard the tube and replace it.

Paralysis.—Paralysis is the stoppage of plate current due to an abnormal accumulation of negative charge on the grid. It manifests itself by an intermittent or complete cessation of incoming sound when receiving, and sometimes can be remedied by the interchanging of receiving tubes. Or it may be necessary to discard the tube and replace it. Paralysis of the oscillator tube can be detected by putting an ammeter in the antenna circuit and observing the intermittent or complete absence of antenna current. Lowering the grid current or throwing the "Receive-Transmit" switch to "Receive" may remedy paralysis of the oscillator.

Noise in Receivers.—Noise in the telephone receivers may be due to various causes such as poor or worn out dry batteries in the receiving circuit, poor grid leak resistances, loose connections, poor tube contacts, noisy tubes or trouble on the low voltage side of the generator.

Failure to Oscillate.—Failure to obtain a grid current or of the set to oscillate may be caused either by a burned out tube or an open circuit in the antenna or counterpoise. This, however, does not happen very frequently if the tubes are inspected before each flight, and also the connections to antenna and counterpoise. Paralysis of a tube will prevent it from oscillating to a greater or less extent. The paragraph of this section entitled "Paralysis" as relating to the oscillation tube, should be referred to.

Faulty Tubes.—Faulty regulator, transmitting and receiving tubes or ballast lamp will cause the most frequent trouble and the only method of avoiding this is to ascertain by inspection and tests that no such tubes or lamps are in use.

Tube Sockets.—The tube sockets sometimes cause difficulties either by being too tight or too loose. In the latter case any vibration of the set will tend to injure the tubes, whereas tight fitting sockets only prevent the tubes from being readily inserted and removed.

Jacks and Plugs.—Unless properly adjusted the plugs may give some trouble by becoming loose, but this can be avoided by proper maintenance of plugs and jacks.

Batteries Type BA–2.—The type BA–2 batteries which are used in this set must be carefully inspected and tested because if their voltage falls below 17 volts they will not give satisfactory operation and may fail completely at any moment. The ammeter should not be used to test these batteries as it results in practically short circuiting them and thus materially decreasing their life. It has sometimes been found that the terminals of the batteries are incorrectly marked. Therefore, whenever these batteries are installed, a test should be made to ascertain their correct polarity.

Indistinct Speech.—Indistinct transmission of speech may be produced by the operator having the telephone transmitter too far from his lips, by his speaking inarticularly or in too weak or too strong a voice. The paragraphs of this section entitled "Blocking" and that part of "Paralysis" relating to the oscillator tube should be referred to.

Shocks.—Frequent shocks may be experienced by the operator making adjustments unless the "Receive-Transmit" switch is on "Receive." A particularly severe shock may be obtained from the antenna which should of course not be touched while transmitting.

Vibration.—Vibration of the airplane may cause the screws of the set to become loose and the mortised joints to open. It is therefore advisable to inspect the set rather closely for this trouble, particularly after a set has been in operation some time.

Interphone Set Box.—

Batteries.—The equipment of the interphone set box is important, if communication between pilot and observer is to be maintained. The type BA–3 batteries used with the type SCR–57 set should be placed in the interphone set box in the correct position, so that they may make proper contact. Their voltage should be frequently checked and they should be replaced when it is less than 3.5 volts. The 6-volt storage battery, type BB–7, used with the type SCR–59 set should be recharged when its voltage is less then 5 volts.

Switches.—In operating the "Interphone-Radio" switch, it should be thrown to its extreme positions for otherwise poor communication will result. The pilot's cut-in switch should be frequently inspected. If the observer continually leaves the switch on "Interphone," some pilots may complain of the additional noise in their receivers. To prevent this, always leave the switch on "Radio" except when talking to the pilot.

Helmets and Telephone Transmitters.—Each pilot and observer should have his own helmet which should be most carefully adjusted to fit the individual wearer and not loaned to others. The telephone receivers should come directly over the ear canals and exert sufficient pressure to exclude most of the extraneous noises. The telephone transmitter should be so adjusted that its wearer can use it without causing him to bend his head when transmitting.

Antenna.—

Length.—After the antenna has been used, it becomes frayed and consequently weakens so that sections of it are apt to be broken off during flight. The antenna must at all times be kept of proper length.

Fish.—Little trouble will be experienced from the loss of the fish weight if it is attached to phosphor bronze wire and the splice is made securely and so that it will not catch in the fairlead.

Reel.—In the use of the single trailing antenna, the reeling up of the last few feet should be done slowly so that the fish will not whip around with danger of damage to the fuselage. The vibration of the airplane may cause the antenna to unreel, due generally to the spring which holds the pawl being too weak, or the pawl and ratchet being worn. The wearing of the pawl and ratchet can be greatly minimized by releasing the catch while reeling in.

Short Circuits.—Great care should be taken that the antenna and counterpoise do not become short circuited, for if this happens with the type SCR–68 set while the Transmit-Receive switch is on "Transit," it may result in the burning out of coil L_3 in Fig. 1 or 2. In case a fire is started, pull out all the plugs and use the Pyrene extinguisher and do it quick. If necessary, the pilot should be notified to prepare to land.

Trouble Charts

The following chart has been prepared to assist in tracing various troubles which occur with this set. The first column indicates how the trouble manifests itself to the operator, while the other columns show what part of the set probably causes the trouble. It is then merely a process of elimination of possible troubles in order to determine which particular one is the cause. The more familiar one is with the set, the easier this is to do.

- Noise in the Receivers.
  - Detector circuit
    - Connections
      - Loose
      - Poor spring contacts in tube socket
    - Detector tube
      - Loose or broken supports
      - Faulty tube
    - Loose contact at type BA-2 batteries
    - Grid leak
      - Faulty grid leak resistance
      - Broken down grid condenser
  - Amplifier circuit
    - Connections
      - Loose
      - Poor spring contacts in tube sockets
    - Loose contact at type BA-2 batteries
    - Faulty grid leak resistances, especially first amplifier
    - Amplifier tubes
      - Noisy tubes
      - Loose or broken supports
      - Faulty tubes
  - Generator
    - Sparking commutators
      - Incorrect adjustment of brushes
      - Incorrect type o brushes used
      - Insufficient brush pressure
    - Shorted commutator bars
    - Chattering of brushes
    - Connections — Loose, especially at at terminals.
  - Filter box
    - Shorted or open condensers
    - Connectors — Loose, especially at terminals
  - Telephone receiver circuit
    - Loose contacts in interphone radio switch
    - Poor plug contacts
    - Telephone cord
      - Poor cord
      - Loose connections

- Indistinct Speech or No Speech When Using Interphone.
  - Interphone batteries.
    - Low voltage
    - Poor contacts
    - Incorrect position
  - Switches
    - Poor contacts in Transmit-Receive switch
    - Poor contacts in Interphone-Radio switch
    - Failure of pilots cut-in switch
  - Leads and connections
    - Loose plug connections
    - Poor cords
    - Loose wiring connections
  - Poor telephone transmitter
  - Poor telephone receivers
  - Poor fitting helmet

- **Failure to Hear One's Self While Transmitting**
  - Tubes
    - Plate circuit
      - Open circuit
      - Spring contact in base of tube socket loose
    - Lack of grid current
      - Open grid circuit
      - Faulty telephone transformer
      - Faulty telephone transmitter
      - Broken receiving tube
      - Not enough resistance in receiving tube circuit
    - Poor contacts in tube socket
    - Burned out filament
    - Faulty tube filament
- **Filament of Receiving Tubes too Bright**
  - Open circuit in differential field of generator
  - Poor regulator tube
  - High voltage brush contact broken
  - Propeller pitch too low
- **Signals too Loud in Receivers When Transmitting**
  - Improper adjustment of set
- **Failure of Receiving Tubes to Light**
  - Connections
    - Poor tube socket contacts
    - Open in filter box
    - Open in filament circuit
  - Tubes
    - Open in filament
    - Burned out filament
  - Generator
    - Regulator tube
      - Break in filament
      - Filament and plate shorted
    - Open circuits
      - Main field
      - Armature
- **Failure to Receive Signals**
  - Grid leak resistances
    - Open
    - Shorted
    - High resistance
  - Tubes
    - Burned or broken filaments
    - Broken tubes
    - Faulty tubes
  - Antenna and counterpoise
    - Open circuit in antenna or ground
    - Grounded antenna
    - Poor connections
  - Condensers
    - Shorted antenna condenser
    - Shorted input condenser
    - Shorted or open grid condensers
  - Connections
    - Open circuits
    - Loose switch contacts
    - Loose
    - Poor tube socket contacts
  - Telephone receivers
    - Open circuit
    - Shorted
    - Loose diaphragms
    - Improper adjustment of helmet
  - Interphone
    - Poor switch contact
    - Incorrect placing of cord connection to radio set
  - Dry batteries
    - Low voltage
    - Incorrect connections
- **Failure of Signal Loudness to Increase When Amplification Switch is Pushed in**
  - Second amplifier tube faulty
  - Amplification switch not functioning properly
  - Shunt resistance has open circuit
  - Incoming waves too great in amplitude
  - Incorrect connections of shunt resistance and amplification switch

- Varying Strength of Signal in Receivers when Transmitting
  - Generator .... Hunting
    - Open in 100-ohm resistance
  - Regulator tube..... Filament of tube moving with respect to plate
    - Poor tube
    - Loose filament support
    - No filament support

- Blocking—Modulator Tube
  - Faulty tube........
    - Characteristic abnormal
    - Loose connections
  - High plate voltage..
    - Regulator tube.....
      - Open plate circuit
      - Poor tube
    - Generator..........
      - Open differential field
      - Incorrect setting of brushes
  - Low filament current
    - Faulty regulator tube
    - High resistance ballast lamp
    - Generator..........
      - Poor brush contact
      - Incorrect brushes
      - Incorrect brush adjustment
      - Poor brushes
  - Low voltage type BA-2 battery

- *Failure to Oscillate
  - Low plate voltage..
    - Regulator tube.....
      - Short circuited tube
      - Poor tube
    - Generator..........
      - Open circuit
      - Poor brushes
  - Improper adjustment of set.......
    - Low plate current.
    - No grid current.
  - Failure of oscillator tube to light.....
    - Open in filament circuit
    - Burned out filament
    - Ballast lamp broken
  - Antenna circuit....
    - Open circuit
    - Leaky insulation
    - Grounded antenna
  - Low filament current in oscillation tube.............
    - Faulty regulator tube
    - High resistance ballast lamp
    - Generator..........
      - Poor brush contact
      - Incorrect brushes
      - Incorrect brush adjustment
      - Poor brushes

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR–68

The type SCR–68 set is an earlier model of the airplane radio telephone and is now superseded by the type SCR–68–A described in the previous pages. The method of operation is identically the same as given above for the type SCR–68–A. The main differences from the type SCR–68–A set are the following:

A wooden airfan, type FA–3, is provided instead of the regulating airfan, type FA–7. The set may therefore not be used on airplanes having a speed of less than 60 or more than 160 miles per hour.

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*Existence of this condition can only be determined by a radio frequency ammeter in the antenna circuit or a milliammeter in the grid circuit.

The plate blocking condenser shown in Figs. 1 and 2 is not provided in the set box of the type SCR–68 set. It was added in the newer set in order to prevent the possibility of short circuiting the 275-volt generator armature by accidentally grounding the antenna. This protects the set and the operator as well.

The interphone set used with the type SCR–68 set is the type SCR–57, now superseded by the type SCR–57–A. The latter was described as a part of the type SCR–68–A set. The older type is not provided with the side tone circuit and therefore the observer or pilot does not hear his own voice when speaking in the telephone transmitter when the switch on the interphone set box is on "Interphone." This has the disadvantage that the person talking does not know how loud he is speaking.

The telephone transmitter used with the type SCR–68 set is the type T–1, of which the type T–3 used with the type SCR–68–A set is an improvement. These differ but little, the former having an aluminum face plate perforated with numerous pin holes, while the latter has an insulating face plate having only three pin holes.

These differences do not affect materially the performance and operation of the sets, and what has been said about the type SCR–68–A set heretofore, as to method of operation, etc., applies also to the older type SCR–68 sets, a number of which are in use.

SETS, AIRPLANE RADIO TELEPHONE, TYPE SCR–114 AND SCR–116

The type SCR–114 set is essentially the same as the type SCR–68–A, with the main difference that no interphone set is provided. The type SCR–116 set is the same as the type SCR–68–A, except that the five-station interphone set, type SCR–89, is used instead of the two-station type SCR–57–A set.

SET, AIRPLANE RADIO RECEIVING, TYPE SCR–59

The type SCR–59 set is an airplane set for receiving damped or modulated wave radio signals. It is primarily intended for the reception of signals sent by a radio telephone set. The circuit is essentially the same as the receiving circuit of the type SCR–68–A set, except that the vacuum tube filaments are in parallel and derive their energy from a 4-voltage storage battery instead of a fan driven generator.

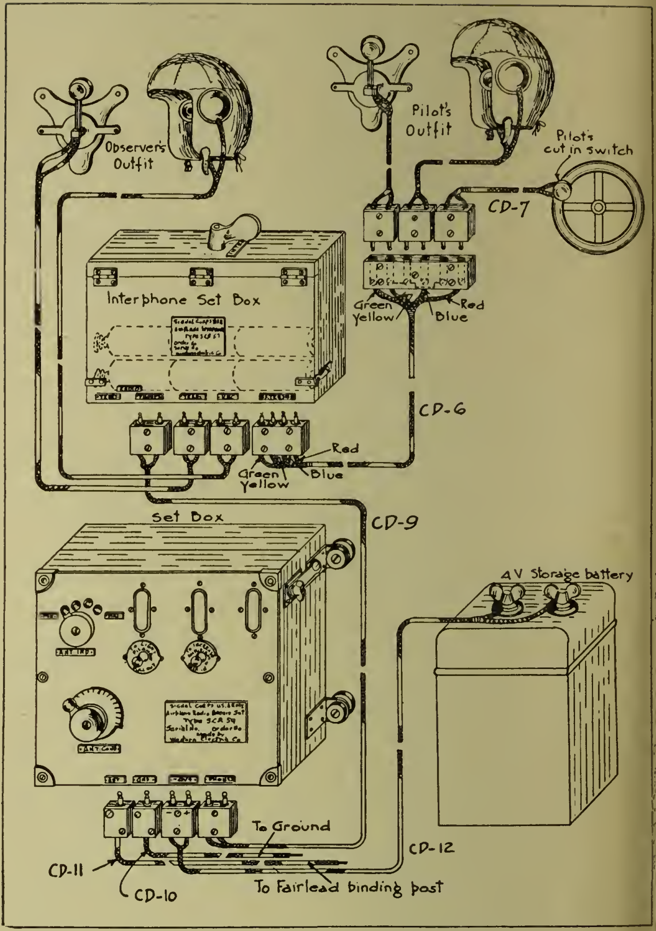

FIG. 22.—Cording Diagram of Sets Type SCR-59, SCR-59-A and SCR-75.

The theory of the circuit being the same as for the SCR–68–A set is therefore not repeated here. The method of using the set is very nearly the same as for the type SCR–68–A and is briefly summarized below.

Installing the Set.—In the installation of the set on an airplane, the general principles given above for the type SCR–68 set should be followed. There is no generator or filter box to install with this set. The various units of the set should be interconnected by means of the extension cords furnished, as shown in Fig. 22.

Preflight Inspection.—Before each flight, a careful inspection of the set should be made to insure satisfactory operation. Inspect the insulation of the connecting wires and check that all connections

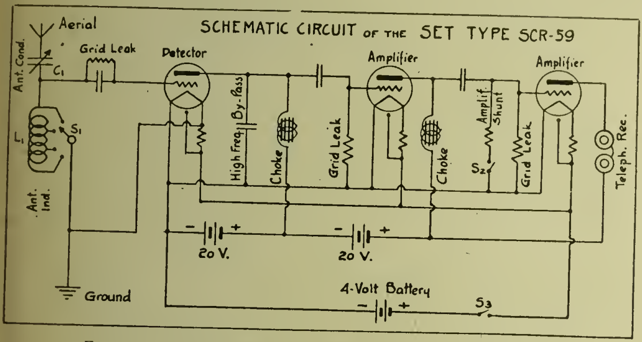

FIG. 23.—Schematic Circuit Diagram of Set Type SCR–59.

are correct and tight. Check that the interphone set is in operating condition by throwing the interphone-radio switch to "Interphone" and talking to the pilot through the telephone transmitter. Check the storage battery voltage and polarity.

See that the radio set box contains three type VT–1 vacuum tubes in good condition, and two type BA–2 dry batteries properly connected and of a voltage greater than 17.5 volts each.

See that the filament of *all three* vacuum tubes are glowing when the filament push button switch (left hand push button on the radio set box) is pulled out.

The final test showing that the set is in operating condition is made while the pilot is testing out the airplane engine on the ground. The radio operator should throw the interphone switch to "Radio," pull out the filament switch and push in the amplification switch.

He should then hear the magneto hum in his telephone receiver for all positions of the antenna inductance and condenser handles

Calibrating the Set.—If the wave length to be received is know in advance, the set may be tuned on the ground in the followin manner:

1. Remove the "Ground" and "Antenna" plugs from the radi set box and connect in their place the two terminals of a phanto antenna having the same constants as the real antenna. Se page 28.

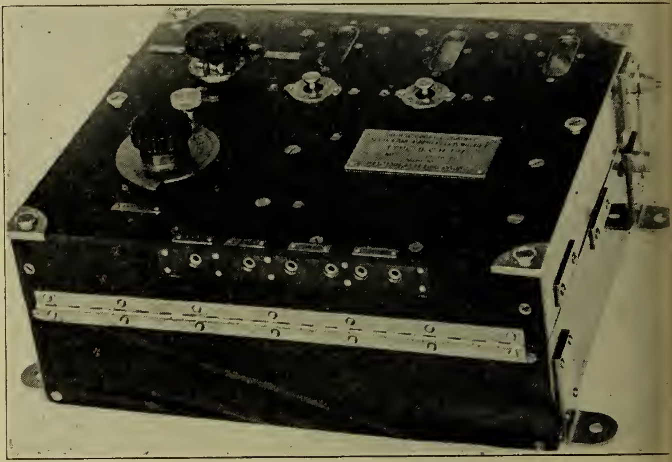

FIG. 24.—Operating Panel of Set Box Type BC–12 used in Set Type SCR–59.

2. Place a wave meter, type SCR–60–C, near the set box and le it emit some known wave length, excited by means of the buzzer.

3. Throw the interphone switch to "Radio," pull out the filamen switch on the radio set box to light the filaments, and push in th amplification switch.

4. Set the "Antenna Inductance" switch of the radio set box i each of its various positions successively, varying the "Antenn Condenser" over its entire range for each of these positions unti maximum response is heard in the telephone receiver. If the not is too strong for accurate tuning, pull out the amplification switc to reduce the amplification.

5. Record the setting of the inductance and condenser handles and the wave length. Repeat the operation for a number of wave lengths within the range of the set, in order to obtain a complete record chart.

6. Cut off the filament current by pushing in the filament switch.

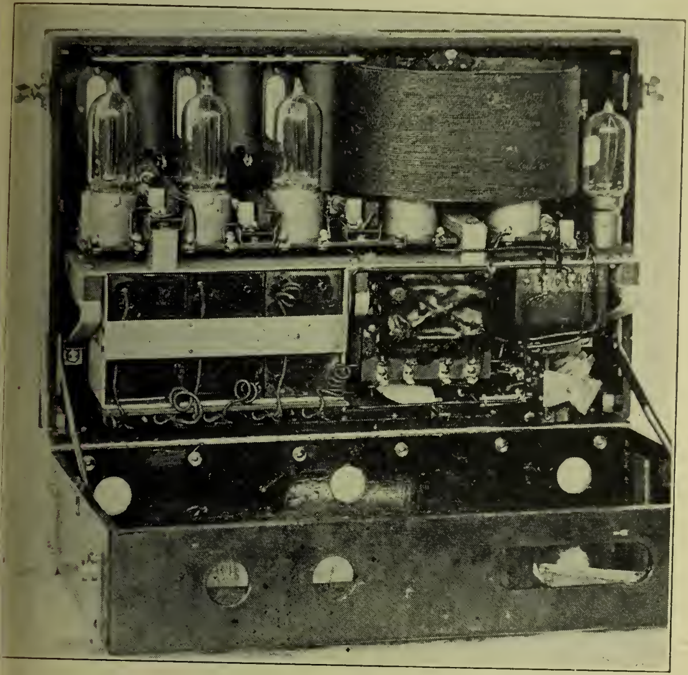

FIG. 25.—Mounting of Apparatus on the Panel of Set Box Type BC–12.

7. Remove the phantom antenna and re-connect the real antenna and ground.

8. The set is now tuned and only minor adjustments of the antenna condenser will be required in the air to perfect the tuning.

Tuning in the Air.—If the set has been previously tuned on the ground, proceed as follows. If the set has not been tuned on the ground, proceed as per paragraph 9 below.

1. Reel out the antenna when the airplane has reached a sufficient height.

2. Throw the interphone switch to "Radio."

3. Pull out the filament switch..

4. Push in the amplification switch.

5. Set the antenna inductance and condenser in accord with the calibration chart for the wave length to be received.

6. Upon receiving the signals, adjust slightly the condenser to see if the tuning is improved.

7. If the amplification is too great, reduce it by pulling out the amplification switch.

8. Do not forget after having used the interphone set, to replace the switch to "Radio" in order to be always in a position to receive any signals which may come in.

9. If the set has not been tuned on the ground, proceed as above, but replacing paragraphs 2, 3, 4, 5, 6, and 7 by paragraphs 3 and 4 of the instructions for calibrating the set on the ground.

Trouble.—All that has been said for the type SCR–68–A set concerning trouble when receiving may be applied to this set.

SETS, AIRPLANE RADIO RECEIVING, TYPE SCR–59–A AND SCR–115

The type SCR–59–A set differs from the type SCR–59 in that the type SCR–57–A interphone set is used instead of the type SCR–57 and that the single wire trailing antenna is replaced by a double trailing antenna.

The type SCR–115 set comprises no interphone set, but is otherwise the same as the type SCR–59–A set.

SET, AIRPLANE RADIO RECEIVING, TYPE SCR–75

The type SCR–75 set is an airplane set for the reception of dampe[d] or modulated wave signals, and especially suited for the receptio[n] of radio telephone signals. The only difference of the circuit [of] this set from that of the type SCR–59 set is that the detector tub[e] instead of being directly connected to the antenna circuit, is couple[d] to the latter through a secondary tuned circuit. This secondar[y] circuit may be cut out by means of a switch, the circuit of the se[t] being then identical with that of the type SCR–59. The purpo[se] of this double tuning is to afford greater selectivity by sharper tu[n]ing. The type SCR–75 set should therefore be used when it impossible with the type SCR–59 set to eliminate interference from neighboring sets.

The theory of the set is not materially different from that of the sets described previously in this pamphlet, and may easily be understood from the circuit diagram.

Installing the Set.—The method of installing the set on an airplane is the same as for installing a type SCR–59 set. The cording diagram, Fig. 22 for the type SCR-59 set also applies to the type SCR–75 set.

Preflight Inspection.—All that has been said under this heading for the type SCR–59 set may be applied to the type SCR–75 set.

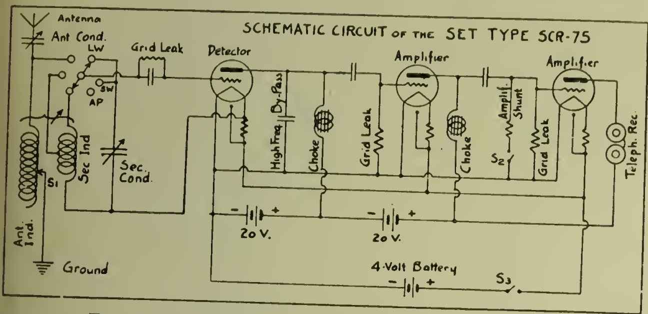

FIG. 26.—Schematic Circuit Diagram of Set Type SCR–75.

Calibrating the Set.—The calibration of the set on the ground after it has been installed on the airplane comprises the calibration of the primary or antenna circuit, and that of the secondary circuit. While the calibration of the primary circuit must be repeated whenever a new antenna is used having different constants, the calibration of the secondary is made once for all. The method is as follows:

1. Remove the ground and antenna plugs from the radio set box and connect in their place the two terminals of a phantom antenna having the same constants as the real antenna.

2. Place a wavemeter, type SCR–60–C, near the set box and let it emit a known wave length, excited by means of the buzzer.

3. Throw the interphone switch to "Radio," pull out the filament switch on the radio set box, and push in the amplification switch.

4. Set the three-position switch in the upper left hand corner of the radio set box operating panel in the position marked "AP" (aperiodic). This disconnects the secondary tuned circuit and permits the calibration of the primary (antenna) circuit.

5. For each position of the "Antenna Inductance" switch, vary the "Antenna Condenser" over its entire range, until maximum response is obtained in the telephone. If the amplification is too high and prevents accurate tuning, reduce it by pulling out the amplification switch.

6. Record the wave length, and settings of the antenna condenser and antenna inductance switches and repeat the operation for

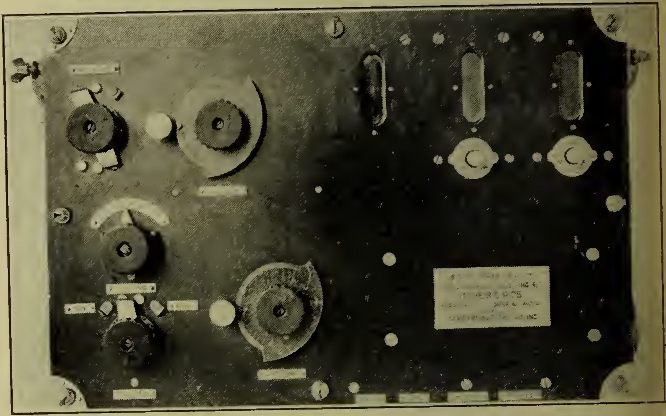

FIG. 27.—Operating Panel of Set Box Type BC-20 used in Set Type SCR-75.

various values of wave length, in order to obtain a calibration char covering the entire range of the set. This will complete the cali bration of the primary circuit.

7. Set the "Coupling" handle in the zero position and push in th amplification switch.

8. The wavemeter being placed near the radio set box and emittin a known wave length, tune the set by placing the three-positio switch in the position "SW" and "LW" successively, varying th "Secondary Condenser" over its entire range for each position o the three-position switch, until maximum response is obtained i the telephone receivers. If the amplification is too great and pre

vents accurate tuning, reduce it by pulling out the amplification switch.

9. Record the wave length and settings of the "LW-SW" and "Secondary Condenser" switches and repeat the operation for different wave lengths to cover the entire range of the set.

10. The calibration being complete, push in the filament switch.

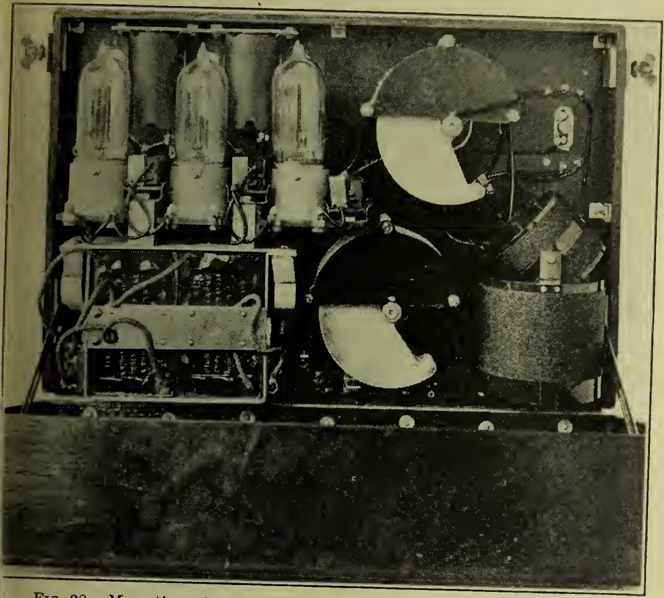

FIG. 28.—Mounting of Apparatus on the Panel of Set Box Type BC-20.

11. Disconnect the phantom antenna and re-connect the real tenna and ground.

Tuning the Set in the Air.—

1. Reel out the antenna when the airplane has reached a sufficient ight.

2. Push in the amplification switch.

3. Pull out the filament switch.

4. Throw the interphone switch to "Radio."

5. If the wave length to be received is unknown, proceed as pe paragraphs 10 to 14 below. If the wave length is known in advance proceed as follows:

6. Set the "Coupling" switch to "90."

5. Set the "LW–SW" switch, the "Antenna Condenser," "Sec ondary Condenser" and "Antenna Inductance" switches in accor with the calibration chart.

8. If the signals come in too loud or if too much interference i experienced, reduce the coupling and pull out the amplificatio switch.

9. Try slight readjustments of the two condensers to see if th tuning can be improved.

If the set has not been calibrated on the ground or if the wav length to be received is unknown, proceed as follows:

10. Set the three-position switch to "AP."

11. For each position of the antenna inductance switch, vary th antenna condenser over its entire range until the signals are hear loudest.

12. Reduce the coupling by turning the coupling handle towar the right until the incoming signals are barely heard.

13. For each of the LW and SW positions of the three-positic switch, vary the secondary condenser over its entire range until th signals are heard loudest.

14. If the signals are too loud or if there is too much interferenc reduce the coupling and pull out the amplification switch.

Troubles.—Most of the troubles experienced with this set are the same nature as for the type SCR–59 set, to which reference here made. An additional source of trouble may be the breakir off, due to wear, of the flexible wires connecting the secondary ir ductance coil.

PARTS LISTS.

In ordering any of these sets or parts of these sets, specification mu be made by names and type numbers as listed below, exactly. Tl designation printed in bold face type *only*, will be used in requis tioning, making property returns, etc.

In ordering complete sets, it is not necessary to itemize the part simply specify, for example, "Set, Airplane Radio Receiving, Tyl SCR–59." If all the parts listed under a group heading are desire it is not necessary to itemize the parts; simply specify, for exampl "1 Equipment Type PE–14."

Any of the sets is not complete unless it includes all of the iten listed in the component parts table, below.

SET, AIRPLANE RADIO RECEIVING, TYPE SCR-59.

1 Equipment Type PE-14
- 3 Batteries Type BB-4

1 Equipment Type RC-2
- 1 Set Box Type BC-12
- 1 Cord Type CD-10; for connecting BC-12 to ground
- 1 Cord Type CD-11; for connecting BC-12 to fairlead
- 1 Cord Type CD-12; for connecting BC-12 to battery
- 8 Tubes Type VT-1; 3 in use, 5 spare
- 8 Batteries Type BA-2; 2 in use, 6 spare
- 1 Set Box Type BC-10
- 2 Head Sets Type HS-1
- 2 Transmitters Type T-1
- 1 Cord Type CD-9; for connecting BC-12 to BC-10
- 1 Cord Type CD-6; for connecting BC-10 to pilot's jack
- 1 Cord Type CD-7; for connecting BC-10 to pilot's cut-in switch
- 20 Batteries Type BA-3; 2 in use, 18 spare

1 Equipment Type A-21
- 1 Reel Type RL-2
- 2 Drums Type DR-2
- 3000 ft. Wire Type W-5
- 10 Weights Type WT-1; 1 in use, 9 spare
- 2 Fairleads Type F-1; Type F-2 when Type F-1 is not available; 1 in use, 1 spare
- 20 ft. Twine Type TW-2; approx. 2 ft. in use

SET, AIRPLANE RADIO RECEIVING, TYPE SCR-59-A

Equipment Type PE-14
- 3 Batteries Type BB-4

Equipment Type RC-2-A
- 1 Set Box Type BC-12
- 1 Cord Type CD-10; for connecting BC-12 to ground
- 1 Cord Type CD-11; for connecting BC-12 to antenna
- 1 Cord Type CD-12; for connecting BC-12 to battery
- 8 Tubes Type VT-1; 3 in use, 5 spare
- 8 Batteries Type BA-2; 2 in use, 6 spare
- 1 Set Box Type BC-10-A
- 2 Head Sets Type HS-2
- 2 Transmitters Type T-3

1 **Equipment Type RC-2-A**—Continued.
- 1 **Cord Type CD-6**; for connecting BC-10-A to pilot's jack
- 1 **Cord Type CD-62**; for connecting BC-10-A to observer's jack
- 1 **Cord Type CD-7**; for connecting cut-in switch to pilot's jack
- 1 **Cord Type CD-9**; for connecting BC-12 to BC-10-A
- 20 **Batteries Type BA-3**; 2 in use, 18 spare

1 **Equipment Type A-23**
- 1 **Antenna Type AN-6**
- 780 ft. **Wire Type W-16**; in six 130-ft. lengths, wound on 6 spools, spare
- 4 **Insulators Type IN-8**
- 40 ft. **Cord Type RP-6**; in two 20-ft lengths
- 1/4 lb. **Tape Type TL-83**

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR-68

1 **Equipment Type PE-1**
- 2 **Airfans Type FA-3**; 1 in use, 1 spare
- 1 **Generator Type GN-1** or **Type GN-2**
- 5 **Tubes Type TB-1**; 1 in use, 4 spare
- 1 **Cord Type CD-19**
- 1 **Filter Type FL-1**

1 **Equipment Type RE-1**
- 1 **Set Box Type BC-11**
- 8 **Tubes Type VT-2**; 2 in use, 6 spare
- 8 **Tubes Type VT-1**; 3 in use, 5 spare
- 3 **Lamps Type LM-1**; 1 in use, 2 spare
- 12 **Batteries Type BA-2**; 3 in use, 9 spare
- 1 **Cord Type CD-10**
- 1 **Cord Type CD-11**
- 1 **Cord Type CD-17**
- 1 **Cord Type CD-9**
- 1 **Cord Type CD-18**
- 1 **Set Box Type BC-10**
- 2 **Head Sets Type HS-1**
- 2 **Transmitters Type T-1**
- 1 **Cord Type CD-6**
- 1 **Cord Type CD-7**
- 20 **Batteries Type BA-3**; 2 in use, 18 spare

1 Equipment Type A-21

- 1 Reel Type RL-2
- 2 Drums Type DR-2
- 3000 ft. Wire Type W-5
- 10 Weights Type WT-1; 1 in use, 9 spare
- 2 Fairleads Type F-1; Type F-2 when Type F-1 is not available 1 in use, 1 spare
- 20 ft. Twine Type TW-2; approx. 2 ft. in use

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR-68-A

1 Equipment Type PE-1-A

- 2 Airfans Type FA-7; if not available, Airfan Type FA-3
- 1 Generator Type GN-1-A or Type GN-2-A
- 5 Tubes Type TB-1
- 1 Cord Type CD-19
- 1 Filter Type FL-1-A

1 Equipment Type RE-1-A

- 1 Set Box Type BC-11-A
- 8 Tubes Type VT-2; 2 in use, 6 spare
- 8 Tubes Type VT-1; 3 in use, 5 spare
- 3 Lamps Type LM-1; 1 in use, 2 spare
- 12 Batteries Type BA-2; 3 in use, 9 spare
- 1 Cord Type CD-10
- 1 Cord Type CD-11
- 1 Cord Type CD-17
- 1 Cord Type CD-9
- 1 Cord Type CD-18
- 1 Set Box Type BC-10-A
- 2 Head Sets Type HS-2
- 2 Transmitters Type T-3
- 1 Cord Type CD-6
- 1 Cord Type CD-62
- 1 Cord Type CD-7
- 20 Batteries Type BA-3; 2 in use, 18 spare

1 Equipment Type A-23

- 1 Antenna Type AN-6
- 780 ft. Wire Type W-16; in six 130-ft. lengths, wound on 6 spools, spare
- 4 Insulators Type IN-8
- 40 ft. Cord Type RP-6; in two 20-ft. lengths
- 1/4 lb. Tape Type TL-83

SET, AIRPLANE RADIO RECEIVING, TYPE SCR-75

1 Equipment Type PE-14
   3 Batteries Type BB-4
1 Equipment Type RC-4
   1 Set Box Type BC-20
   1 Cord Type CD-10
   1 Cord Type CD-11
   1 Cord Type CD-12
   8 Tubes Type VT-1; 3 in use, 5 spare
   8 Batteries Type BA-2; 2 in use, 6 spare
   1 Cord Type CD-9
   1 Set Box Type BC-10
   2 Head Sets Type HS-1
   2 Transmitters Type T-1
   1 Cord Type CD-6
   1 Cord Type CD-7
   20 Batteries Type BA-3; 2 in use, 18 spare
1 Equipment Type A-23
   1 Antenna Type AN-6
   780 ft. Wire Type W-16; in six 130-ft. lengths, wound on 6 spools; spare
   4 Insulators Type IN-8
   40 ft. Cord Type RP-6; in two 20-ft. lengths
   1/4 lb. Tape Type TL-83

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR-114

1 Equipment Type PE-1-A
   2 Airfans Type FA-7; if not available, Airfan Type FA-3
   1 Generator Type GN-1-A or Type GN-2-A
   5 Tubes Type TB-1
   1 Cord Type CD-19
   1 Filter Type FL-1-A
1 Equipment Type RE-11
   1 Set Box Type BC-11-A
   8 Tubes Type VT-1
   8 Tubes Type VT-2
   3 Lamps Type LM-1
   12 Batteries Type BA-2
   1 Cord Type CD-10

1 Equipment Type RE-11—Continued.
- 1 Cord Type CD-11
- 1 Cord Type CD-17
- 1 Head Set Type HS-2
- 1 Transmitter Type T-3

1 Equipment Type A-23
- 1 Antenna Type AN-6
- 780 ft. Wire Type W-16; in six 130-ft. lengths, wound on 6 spools; spare
- 4 Insulators Type IN-8
- 40 ft. Cord Type RP-6; in two 20-ft. lengths
- 1/4 lb. Tape Type TL-83

SET, AIRPLANE RADIO RECEIVING, TYPE SCR-115

1 Equipment Type PE-20
- 2 Airfans Type FA-7; if not available, Airfans Type FA-3
- 1 Generator Type GN-1-A or Type GN-2-A
- 5 Tubes Type TB-1
- 1 Cord Type CD-19
- 1 Filter Type FL-1-A
- 3 Batteries Type BB-7

1 Equipment Type RC-9
- 1 Set Box Type BC-12
- 1 Cord Type CD-10
- 1 Cord Type CD-11
- 1 Cord Type CD-12
- 8 Tubes Type VT-1
- 8 Batteries Type BA-2
- 1Head Set Type HS-2

1 Equipment Type A-23
- 1 Antenna Type AN-6
- 780 ft. Wire Type W-16; in six 130-ft. lengths, wound on 6 spools, spare
- 4 Insulators Type IN-8
- 40 ft. Cord Type RP-6; in two 20-ft. lengths
- 1-4 lb. Tape Type TL-83

SET, AIRPLANE RADIO TELEPHONE, TYPE SCR-116

1 Equipment Type PE-20
  - 2 Airfans Type FA-7; if not available, Airfans Type FA-3
  - 1 Generator Type GN-1-A, or Type GN-2-A
  - 5 Tubes Type TB-1
  - 1 Cord Type CD-19
  - 1 Filter Type FL-1-A
  - 3 Batteries Type BB-7

1 Equipment Type RE-14
  - 1 Set Box Type BC-11-A
  - 8 Tubes Type VT-1
  - 8 Tubes Type VT-2
  - 3 Lamps Type LM-1
  - 12 Batteries Type BA-2
  - 1 Cord Type CD-10
  - 1 Cord Type CD-17
  - 1 Interphone Circuit Type BC-56
  - 5 Transmitters Type T-3
  - 5 Head Sets Type HS-2
  - 1 Cord Type CD-9
  - 1 Cord Type CD-18
  - 1 Cord Type CD-11

1 Equipment Type A-23
  - 1 Antenna Type AN-6
  - 780 ft. Wire Type W-16; in six 130-ft. lengths, wound on 6 spools, spare
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  - 1-4 lb. Tape Type TL-83

1 Equipment Type A-24
  - 1 Reel Type RL-2
  - 2 Drums Type DR-2
  - 3,000 ft. Wire Type W-5
  - 50 Weights Type WT-5
  - 2 Fairleads Type F-5
  - 20 ft. Cord Type RP-6

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

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Theory and Use of Wavemeters

Radio Pamphlet
No. 21

Signal Corps, U. S. Army
5-21-18

THEORY AND USE OF WAVEMETERS

Various Methods of Using the Wavemeter as a Measuring Device—Description of SCR-60 and SCR-61 Wavemeters

The wavemeter is a piece of apparatus by means of which t is possible either to measure the length of electromagnetic aves generated by some outside source, or to emit waves of known length. It may therefore be used to measure the nductance of a coil, the capacitance of a condenser, or the ecrement of electromagnetic waves. It is thus a calibration nstrument which finds use in both the field and the laboraory.

The principles upon which all wavemeters operate are the ame. A general circuit diagram which might apply to any avemeter is shown in Fig. 1. It consists of an oscillating ircuit containing a condenser C and an inductance coil L, aving a low ohmic resistance. By varying the capacitance n this oscillating circuit, its natural frequency can be brought nto resonance with another oscillating circuit. When used s a measuring instrument, some sensitive device A is inerted in shunt or in series in the circuit, to indicate the oltage across the condenser or the current in the coil. In ractice, this sensitive device may be a telephone receiver nd a detector, a neon tube, a hot wire ammeter, or a galvanmeter and thermo-couple. When the wavemeter is used as a enerator of waves of known length, the device A is replaced y a buzzer and battery which excite damped oscillations in e wavemeter resonance circuit, at an audible wave train equency.

The method of adjustment most commonly employed in sing a wavemeter is to vary the natural period of the circuit y changing the capacitance of the meter and keeping the nductance constant. This affords a continuous variation of ave lengths between the limits of 0 and $2\pi\sqrt{LC}$. The conenser is therefore usually an air condenser, the capacitance

of which may be varied from 0 to a certain maximum b
means of a handle on the operating panel. To this handl
is attached a pointer which moves over graduated scale

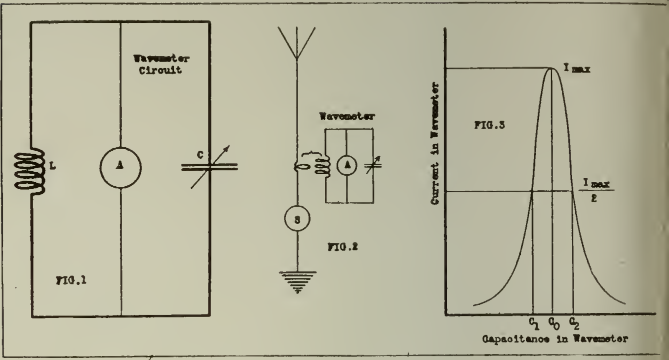

Fig. 1. General Wavemeter Circuit—Fig. 2. Use of Wavemeter
Fig. 3. Typical Resonance Curve.

reading directly in wave lengths or in conventional numbe
corresponding to calibration curves. Several inductance coi
having different numbers of turns are usually provided wi
a set, any one of which may be connected in the circuit. Tl
apparatus may thus be made to cover a very wide range
wave lengths with reasonable accuracy.

Using the Wavemeter as a Measuring Instrument

To use a wavemeter for measuring the length of the wav
sent out or received by a radio set S, Fig. 2, it is coupled
this set as loosely as its operation will permit so that the
will be no appreciable reaction between the two circuits. T
coupling is made inductively to the inductance coil of t
wavemeter. The capacitance of the wavemeter condenser
then changed until a maximum indication is observed on t
instrument A—maximum loudness of sound in the telepho
maximum brightness in the neon tube, maximum reading
the galvanometer, etc. At that time, the wavemeter circu
will be in resonance with the waves to be measured, and t
length of waves will be indicated by the reading on the co
denser dial scale.

Using the Wavemeter as a Generator

The wavemeter is used as a generator of electric oscillations when it is desired to calibrate another resonant circuit. It can be made to oscillate at any desired frequency by choosing the proper setting of the wavemeter condenser. For each setting of the wavemeter, the circuit to be calibrated is then tuned to the waves generated by the wavemeter, this establishing a calibration point for which the adjustments of the set under test are noted as corresponding to that specific wave length. This operation is repeated for various settings of the wavemeter condenser to obtain the desired number of calibration points.

Measuring Inductance and Capacitance

A rapid method of measuring the inductance of a coil or the capacitance of a condenser is to connect the coil or the condenser to a standard condenser or coil, respectively, of known constants, to make an oscillating circuit. This is then made to oscillate by means of a buzzer and its natural period is found by means of the wavemeter. Having determined the period, and knowing one of the constants, either L or C, of the circuit under test, the other constant C or L is easily computed by means of the formula

$$\lambda \text{ (wave length)} = 1884 \sqrt{LC}$$

where L is expressed in microhenrys, C in microfarads and λ in meters.

Measuring Decrement

If an oscillatory circuit of constant wave length is made to act upon a wavemeter circuit, the wave length of which is varied by changing the value of its capacitance, a so-called resonance curve may be plotted, showing the variation of wavemeter current with the natural frequency of the current in the wavemeter circuit. Such a curve will show a maxi-

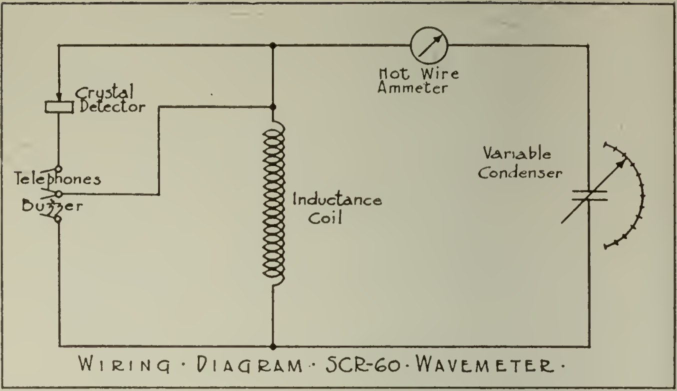

Fig. 4. Schematic Circuit Diagram of the SCR-60 Wavemeter.

mum current at that wavemeter frequency which is equal to the frequency of the circuit under test. The sharpness of the peak of this curve depends on the decrements d_1 and d_2 of the two circuits.

Instead of plotting current against frequency, current may be plotted against the corresponding condenser capacitance of the wavemeter, which is proportional to the frequency. If C_0, Fig. 3, represents the capacitance value of the condenser at resonance, and C_1 and C_2 the two values corresponding to current equal to one-half the resonance current, it can be shown that

$$d_1 + d_2 = \frac{\pi}{2} . \frac{C_2 - C_1}{C_0},$$

or approximately that

$$d_1 + d_2 = \pi \frac{C_0 - C_1}{C_0}, \text{ or}$$

$$d_2 = \pi \frac{C_0 - C_1}{C_0} - d_1.$$

If the decrement d_1 of the wavemeter circuit is known, and C_1 and C_2 determined, it is possible to find the decrement, d_2, of the circuit under test.

As the decrement of a circuit is a function of its resistance, it is important that the adjustment of the wavemeter should not change its resistance. This is one of the reasons why the condenser is made variable rather than the inductance, since cutting turns of the inductance in or out of the circuit would change the resistance as well as the wave length.

SCR-60 Wavemeter

The SCR-60 wavemeter is a very simple set designed primarily for use with the SCR-67, SCR-68, SCR-79 and other radio apparatus, particularly airplane sets, in tuning them to emit the desired wave length. It is also extensively used for calibrating newly set up receiving stations. The wavemeter contains a single inductance coil and a variable condenser and hot wire ammeter in the local oscillating circuit, Fig. 4. In calibrating a set, the wavemeter is placed on the set box, or near it, and the condenser handle moved around until the maximum current reading is observed in the ammeter. The reading on the condenser scale then indicates the wave length of the set under calibration.

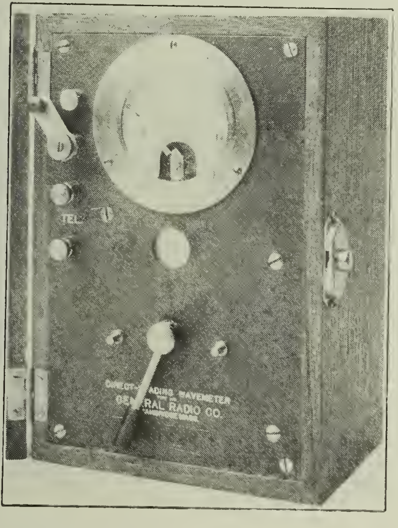

Fig. 5. Operating Panel of the SCR-60 Wavemeter.

The SCR-60 set is designed to measure wave lengths ranging from 200 to 700 meters. The SCR-60-A set is an identical wavemeter, except that the constants are changed to give a range of from 300 to 1000 meters. The SCR-60-B wavemeter is a similar set but is equipped with connectors for changing the constants of the wavemeter circuit to secure two ranges of measurement. One scale reads from 50 to 200 meters and the other from 200 to 700 meters. All three of the SCR-60 sets are equipped with crystal detectors, and with binding posts for connecting in telephones and a buzzer when it is desired to use these.

SCR-61 Field Type Wavemeter

A wiring diagram of the SCR-61 wavemeter, which is designed for ground work, is shown in Fig. 6. Three inductance coils are provided with the set and when any one of these is in use, it is clamped in the cover of the case containing the set, the clamp forming the electrical connection. The circuit from the coil in use to the remainder of the wavemeter circuit in the box, is made through the hinges of the cover. The condenser is varied by means of a handle which moves over scales reading directly in meters, there being a separate scale to correspond with each inductance coil. Each induction coil is designated by a letter stamped in the wood case, and a corresponding letter is printed on the dial opposite each scale. A telephone jack in series with a crystal detector is connected unilaterally when

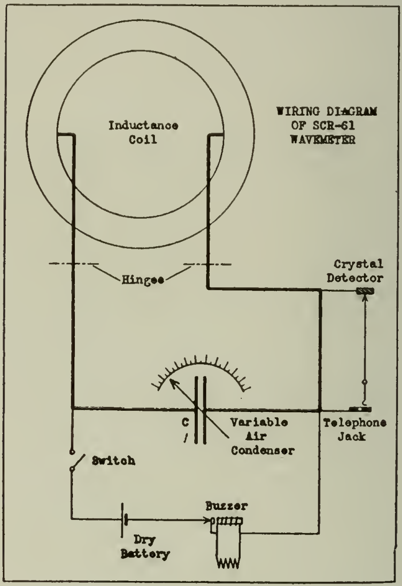

Fig. 6. Schematic Circuit Diagram of the SCR-61 Wavemeter.

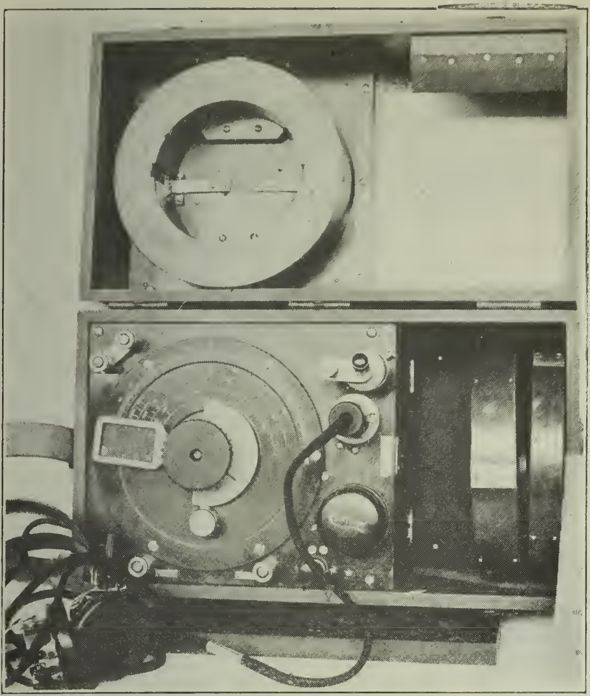

Fig. 7. Operating Panel of the SCR-61 Wavemeter and the Three Inductance Coils.

using the wavemeter for calibrating purposes. When using the set as a wave generator, the buzzer circuit through the wavemeter inductance coil is closed by a small switch to produce the necessary oscillations. The range of the set is from 150 to 2400 meters. It is intended for field use and is provided with a carrying strap.

GROUND RADIO TELEPHONE SETS

(Types SCR-67 and SCR-67-A)

RADIO COMMUNICATION PAMPHLET No. 22

PREPARED IN THE OFFICE OF THE CHIEF SIGNAL OFFICER

(REPRINT)

December, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

War Department

Document No. 1091

Office of The Adjutant General

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WAR DEPARTMENT,
WASHINGTON, *December 5, 1921.*

The following publication, entitled "Ground Radio Telephone Sets (Types SCR-67 and SCR-67-A)," Radio Communication Pamphlet No. 22, 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.

GROUND RADIO TELEPHONE SETS.

(Types SCR-67 and SCR-67-A.)

The type SCR–67 set is a two-way radio telephone set for use on the ground in communicating with a similar set, or with the airplane radio telephone sets types SCR–59, SCR–68, and other or similar sets. The type SCR–67–A set is an improvement of the type SCR–67 set, and differs from the latter in minor details only, which do not affect the method of operation, or the explanation of the theory of the circuits. The circuits given here are those of the type SCR–67–A set, and the points in which the circuits of the type SCR–67 set differ are noted in the text and indicated in the drawings, the type SCR–67 constants and other variations being indicated in parentheses and dotted lines in figure 2, except for the wiring of the three-position power switch.

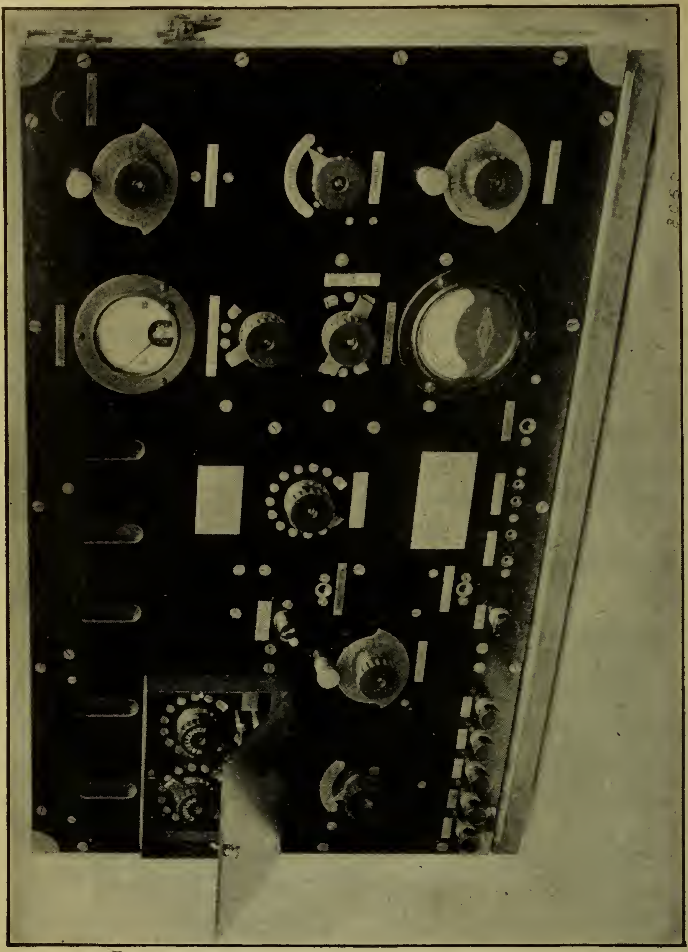
The average working range of either set when used with one of the airplane sets mentioned above, is 2 to 3 miles. This range depends to a considerable extent on the adjustments of the set, the type antenna used, and on the quality and distinctness of the operator's voice. When communicating with a ground set, the range may be as great as 5 to 7 miles.

The range of wave lengths is from 250 to 450 meters when transmitting, and from 200 to 700 or 800 meters when receiving and making use of a suitable antenna. Some antenna constructions are given in a later paragraph.

THEORY UNDERLYING THE OPERATION OF THE SET.

The complete theory of radio telephony is not taken up in this pamphlet. For this, reference is made to Radio Communication Pamphlets Nos. 1, 20, and 40. The principle of transmission involves the generation of undamped oscillations of a frequency greater than that of audible vibrations in the antenna circuit, and the varying of the amplitude of these oscillations proportionally to the voice modulations to be transmitted. These modulated high frequency oscillations, when rectified in the receiving circuit, produce in the telephone receivers a current of amplitude varying proportionally to the voice modulations at the transmitting station, and therefore reproduce the speech. The process will be better understood after the description of the circuits has been given.

A complete circuit diagram of the type SCR–67–A set is given in figure 1. By operating the three-position switch, marked on the panel "Off," "12–V on," "Power on," the set may be used either for receiving alone or for receiving and transmitting. For the latter position of the switch the transmitting circuit is connected by depressing a control push button, while the receiving circuit is con-



Operating panel on set box, Type BC–13 used in set, Type SCR–67.

nected when the push button is released. These two circuits are analyzed separately in the following paragraphs.

Theory of the transmitting circuit.—The circuit in use when transmitting is shown schematically in figure 2. The same letters and names are used as in figure 1, so that reference may be made to both diagrams if desired.

Undamped oscillations are generated by a type VT–2 three-electrode vacuum tube. The filament of this tube is heated by the current of a 12-volt storage battery. In series with the latter is a rheostat for regulating the current, and an ammeter. The negative side of the circuit is connected to ground.

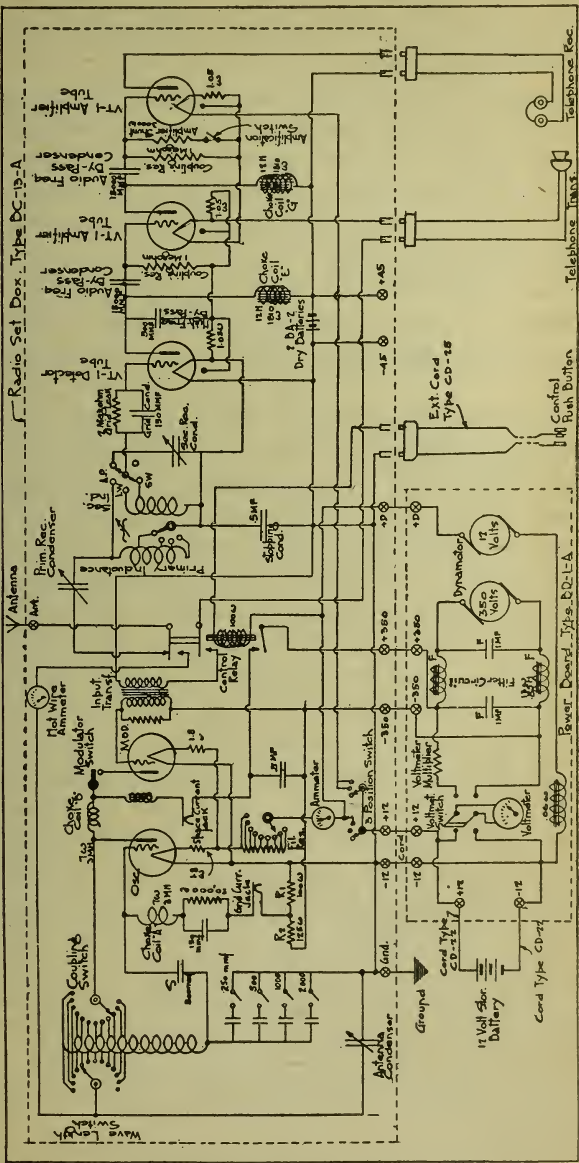


FIG. 1.—Complete schematic circuit diagram of the SCR–67–A.

A constant positive potential of about 350 volts is applied to the plate of the tube by means of a type DM–2 dynamotor, the low-voltage side of which is run by the same 12-volt battery that furnishes the filament-heating current. In series with the plate circuit is a short-circuiting jack in which a plug connected to a milliammeter may be inserted to read the space current in the tube. The function of the choke coils marked " B " and " D," and that of resistances R_1, R_2, and R_3 will be explained later. A filter circuit, comprising two coils and two condensers F, is connected across the 350-volt terminals of the dynamotor for the purpose of minimizing the pulsations of current resulting from commutation.

A constant negative potential is impressed upon the grid of the oscillator tube, which is the voltage drop across a 100-ohm resistance connected between the filament and the grid. In series with this resistance is a 20,000-ohm resistance and a choke coil marked "A." The latter prevents any high frequency oscillations from flowing through this grid circuit. The 20,000-ohm resistance is shunted by a condenser, and it provides the proper negative potential when the tube is oscillating. A short-circuiting jack is also in series with the circuit. This permits the insertion of a plug for connecting in a milliammeter.

In the type SCR–67 set, resistance R_1 is 130 ohms instead of 100 ohms, and 10,000 ohms are used instead of 20,000 for the high resistance. The choke coil A and condenser C are also omitted.

The grid and plate circuits just described are coupled so that the tube will generate oscillations. The oscillatory circuit comprises a grid coupling condenser, the antenna, and the transmitting inductance coil. The grid coupling is effected through a fixed condenser S in series with any one or all of four fixed condensers in parallel, which may be connected as required by closing the small knife switches in the covered panel. This condenser S also serves as a stopping condenser in preventing the 350-volt direct current plate potential from being applied to the grid through the transmitting inductance. The plate coupling is made through the antenna and the transmitting inductance. The latter is connected at one end between the condenser S and the four parallel grid coupling condensers. At the other end of the coil are 12 taps, connected to two 12-point dial switches, marked " Coupling " and " Wave length," to which the plate and aerial are connected, respectively. The operation of the plate dial switch alters the plate coupling, while that of the aerial dial switch changes the transmitted wave length. A variable air condenser, marked "Antenna condenser " in figure 2, shunts the antenna and gives a continuous variation of wave length between any two consecutive taps of the wave length switch.

It may thus be seen from the above description how the direct current generated by the dynamotor is transformed by the oscillator tube into a high frequency undamped alternating current in the antenna circuit, which continually radiates energy into space. The amplitude of these oscillations is proportional to the amount of current furnished by the dynamotor and flowing in the oscillator tube from the plate to the filament. A method of varying the amplitude of the oscillations is to vary the amount of direct current furnished to the tube. This is done in the type SCR–67 and SCR–67–A sets by means of a second three-electrode tube, called the modulator tube. The plate circuit of this tube shunts the plate circuit of the oscillator tube, as may best be seen from figure 2. The current generated in the 350-volt armature of the dynamotor will thus divide between

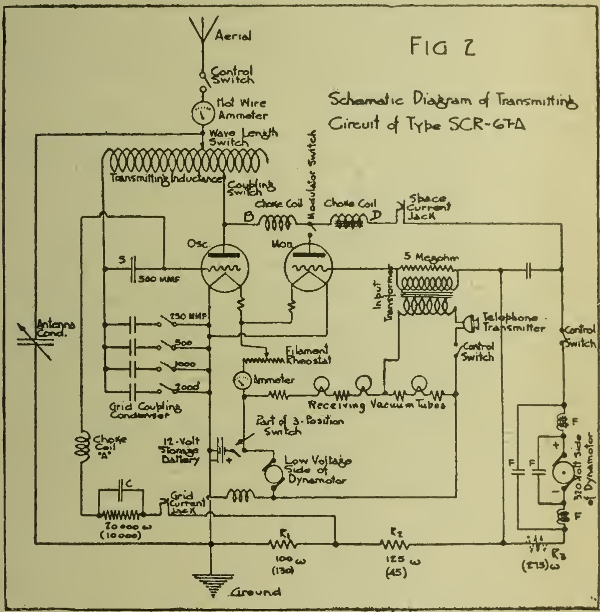


FIG. 2.—Schematic diagram of the transmitting circuit of the SCR–67–A.

the oscillator and the modulator tube in inverse proportion to their impedances.

In order to modulate the amplitude of the oscillations generated by the tube, the impedance of the modulator tube is varied by impressing upon the grid of this tube a potential the frequency and amplitude of which are determined by the strength and pitch of the voice. This is accomplished by connecting the secondary winding of a transformer, called the input transformer, between the grid and the negative side of the filament of the modulator tube. The grid circuit also comprises resistances R_1 and R_2, which give to the grid a negative potential derived from the drop across these two resistances due to the current flowing through them. This grid potential is of such value as to make the tube operate on the point of its characteristic curve which is most suitable for modulation.

The primary circuit of the input transformer comprises a telephone transmitter. The current flowing in that circuit is obtained by connecting the circuit across the filament of one of the receiving tubes and two 1-ohm resistances. In case of the type SCR–67 set, the filament of the first amplifier tube is used, while for the type SCR–67–A set the detector tube is used instead.

The entire transmitting circuit having now been described, its theory of operation may be explained as follows:

The circuit will be ready for operation when the main switch, push button control switches, modulator switch, and the required grid coupling condenser switches are closed. The three-position switch will complete the filament heating circuit and the low voltage dynamotor circuit. The three control switches are closed by pressing the control push button.

By suitable adjustment of the wave length switch, plate coupling, grid coupling, and antenna condenser, the oscillator tube is made to generate undamped oscillations. This adjustment is made, in accordance with the rules given in a later paragraph, for the greatest antenna current with as small a plate and grid current as possible.

By closing the modulator switch, the plate circuit of the modulator tube is connected in parallel with that of the oscillator tube, so that the current from the dynamotor, instead of all flowing through the oscillator tube, will divide between the oscillator and modulator tubes. By talking into the telephone transmitter, an alternating emf. is induced in the secondary of the input transformer, and therefore on the grid of the modulator tube. This emf. is proportional to the voice modulations, and the impedance of the modulator tube is varied accordingly. The result is that a correspondingly greater or lesser part of the total constant current generated by the dynamotor will be shunted off the oscillator tube, by the modulator tube, and the amplitude of the oscillations is thus modulated. It is evident that the operation of this scheme will be satisfactory only if the current fed by the dynamotor is kept constant. This is insured by the presence of an iron core choke coil D in the plate circuit of the two tubes. A 0.5-megohm resistance is shunted around the input transformer secondary for improving its operation. The actual method of operating the transmitting circuit is explained under a separate heading.

Theory of the receiving circuit.—The circuits in use when receiving are shown schematically in figure 3. Reference may also be made to figure 1, where the same letters and designations are used. The primary (antenna) circuit comprises the aerial, a variable air condenser, an inductance coil variable in four steps, a large stopping condenser, and the ground. The stopping condenser does not stop the incoming high frequency oscillations, but prevents a short circuit in the filament circuit of the tubes. Inductively coupled to this circuit is the secondary oscillatory circuit, comprising a variable air condenser and an inductance coil variable in two steps, the entire coil being used when receiving long waves, and only half the coil being used for short waves. The secondary circuit may be entirely disconnected when the dial switch is placed in the aperiodic position, "AP." In this case, the detector tube is directly connected to the antenna circuit. This position cuts out the secondary tuned circuit and is used when searching for signals of unknown wave length.

The detector tube is a type VT–1 three-electrode tube having its filament and grid connected across the receiving inductance. A grid condenser shunted by a 2-megohm leak resistance is connected in series with the grid. The filament of this tube is in series with the filaments of the amplifier tubes, and is heated by the current from

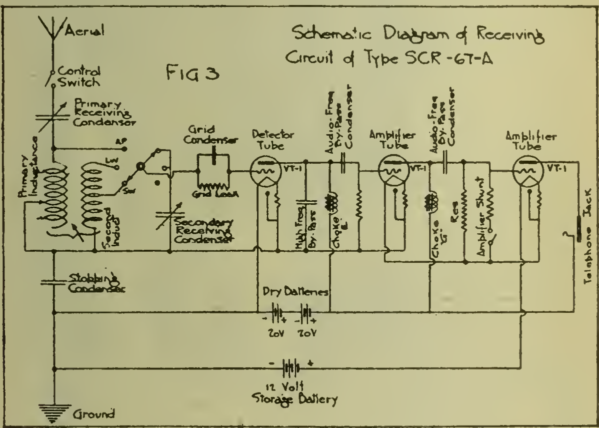


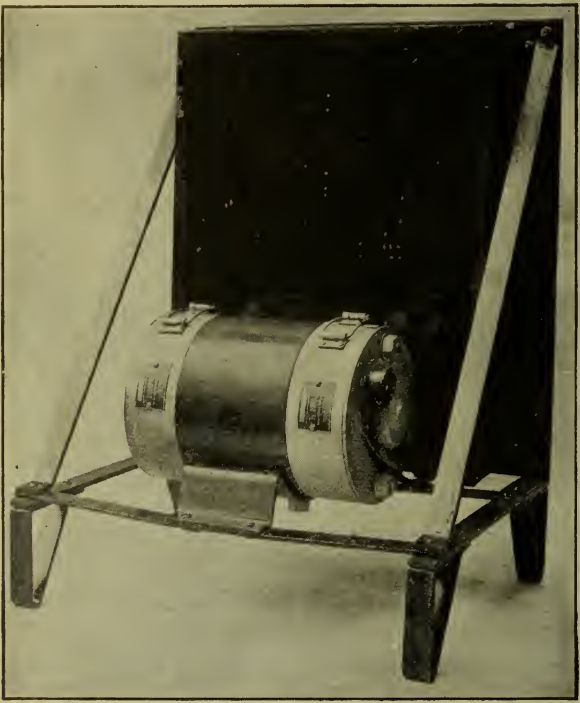
FIG. 3.—Schematic diagram of the receiving circuit of the SCR–67–A.

the 12-volt storage battery. The plate current of the detector tube is furnished by a 40-volt battery, made up of two type BA–2 dry batteries in series. In the case of the type SCR–67 set, one 20-volt BA–2 battery only is used for the detector tube. The high frequency currents are by-passed from the plate to the filament by a fixed condenser, while the audio frequency currents, in flowing through the choke coil E, induce in the latter a high alternating emf. This emf. is transferred through the grid stopping condenser to the grid of the first amplifier tube, correspondingly varying the plate current of that tube. The latter variations are therefore amplified repetitions of the detector tube plate current audio frequency variations. The charges induced on the grid of the first amplifier tube leak off to the filament through a 1-megohm resistance.

A similar scheme is used for coupling the first and second amplifier tubes. Both amplifiers work at a plate voltage of about 40 volts derived from the same battery that is used for the detector tube.

In the type SCR–67 set this plate potential is obtained by means of a second type BA–2 battery in series with the one used for the detector tube. Telephone receivers are plugged in the plate circuit of the last tube, and the degree of amplification may be reduced by closing the "Amplifier" switch, which connects a low resistance across the input circuit of the last amplifier tube, thus reducing the intensity of the sound in the telephones.

Summary of differences between the type SCR–67 and SCR–67–A sets.—The main differences between the type SCR–67 and SCR–67–A sets are the following: The choke coil A and condenser C, figure 2, do not exist in the type SCR–67 set. The grid resistance is 10,000



Rear of power board, showing dynamotor Type DM–2.

ohms in the type SCR–67 set and 20,000 ohms in the type SCR–67–A set. Resistances R_1 and R_2 are 130 and 45 ohms, respectively, in the SCR–67, and 100 and 125 ohms in SCR–67–A. Resistance R_3 exists in the type SCR–67 set only. The connections of the three-position switch are quite different. When in the middle position, all five tubes light with SCR–67, while the receiving tubes only are on in the SCR–67–A set. These differences may be noted in figures 5 and 6 at the end of the pamphlet.

COMPONENT PARTS OF THE SET.

The apparatus making up the set comprises the radio set box, type BC–13 or BC–13–A, which contains the radio circuits and operating switches; the power board, in back of which is mounted the dynamotor and dynamotor filter circuit, and which also has a voltmeter for reading the storage battery voltage and the voltage generated by the dynamotor; the 12-volt storage battery; the telephone head set and transmitter; the control push button; and the connecting cords. The set box measures 23¾ by 15¼ by 6¼ inches over all. The power board measures 17⅜ by 13¼ by 10¼ inches. The various parts of the set are interconnected, as shown in the cording diagram, figure 4. Heavy wire should be used to connect the storage battery to the power board in order to reduce the resistance losses. This is an important point which affects the radiation to an appreciable extent.

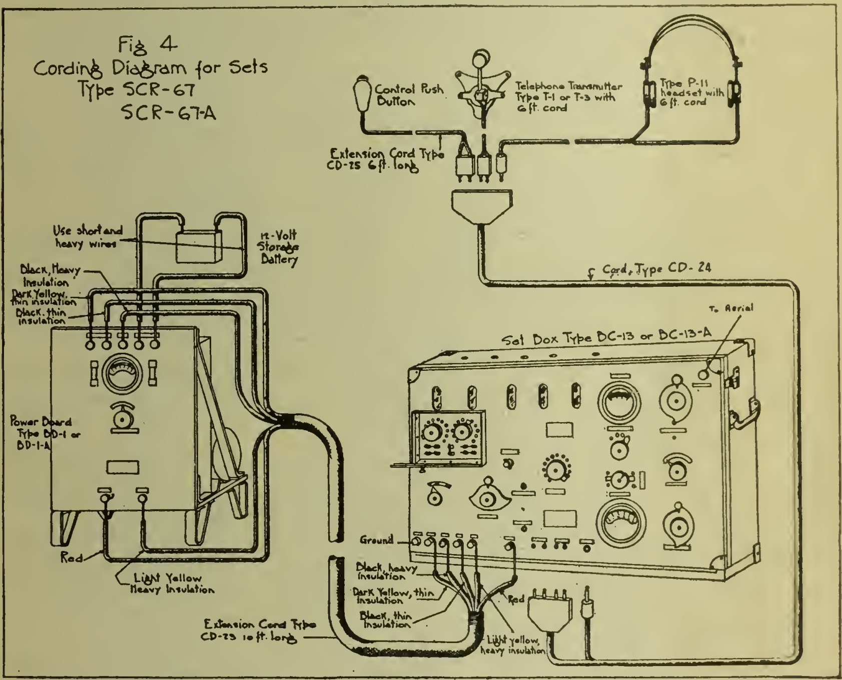


FIG. 4.—Cording diagram for sets, SCR–67 and SCR–67–A.

METHOD OF OPERATION.

Various types of antennae may be used with the ground telephone sets. Two factors which are of great importance in setting up the antenna are its resistance and natural wave length. The resistance should be as low as possible, preferably less than 20 ohms. The natural wave length must be shorter than the shortest wave length to be used for transmitting. The following types of antenna construction are suggested:

(*a*) An umbrella type antenna, 40 feet high, with six 50-foot aerial wires and six 90-foot insulated counterpoise wires. The aerials are held in proper position by means of guy ropes 75 feet long. The natural wave length is 250 meters.

(*b*) A "V" antenna, 24 feet high, 100 feet long on each side, using two 100-foot insulated counterpoise wires or two buried ground mats. The natural wave length is about 250 meters.

(*c*) An inverted "L" antenna, 20 feet high, 100 feet long, with an insulated counterpoise wire 100 feet long. This has a natural wave length of 200 meters.

(*d*) An inverted "L" antenna, 20 feet high, 150 feet long, with an insulated counterpoise wire 150 feet long. This antenna has a natural wave length of 325 meters, and is recommended for use when working at wave lengths greater than this value.

Transmitting.—The set having been fully connected up as per cording diagram, figure 4, and using a suitable antenna, the method of operation is as follows:

It is well to calibrate the set in advance for a number of wave lengths, with the set connected to the antenna to be used. The method of calibrating the transmitting circuit, or of operating the latter when not previously calibrated, is given below.

1. Open the radio set box, and see that two type VT–2 tubes and three type VT–1 tubes are inserted in their proper sockets. The VT–2 tubes are at the left, the VT–1 tubes at the right of the box, as one faces the operating panel.

2. By means of a voltmeter, check the voltage and polarity of the dry batteries. The voltmeter should read not less than 36 volts, and should in general read 40 to 45 volts.

3. Close the set box and throw the voltmeter switch on the power board to "12" volts and check the storage battery voltage. This should be at least 12 volts, and may be 14 volts without damage to the apparatus. A voltage of 13 or 14 volts will, in fact, improve the operation of the set, but the latter limit should never be exceeded. After checking the voltage, throw the switch to "Off."

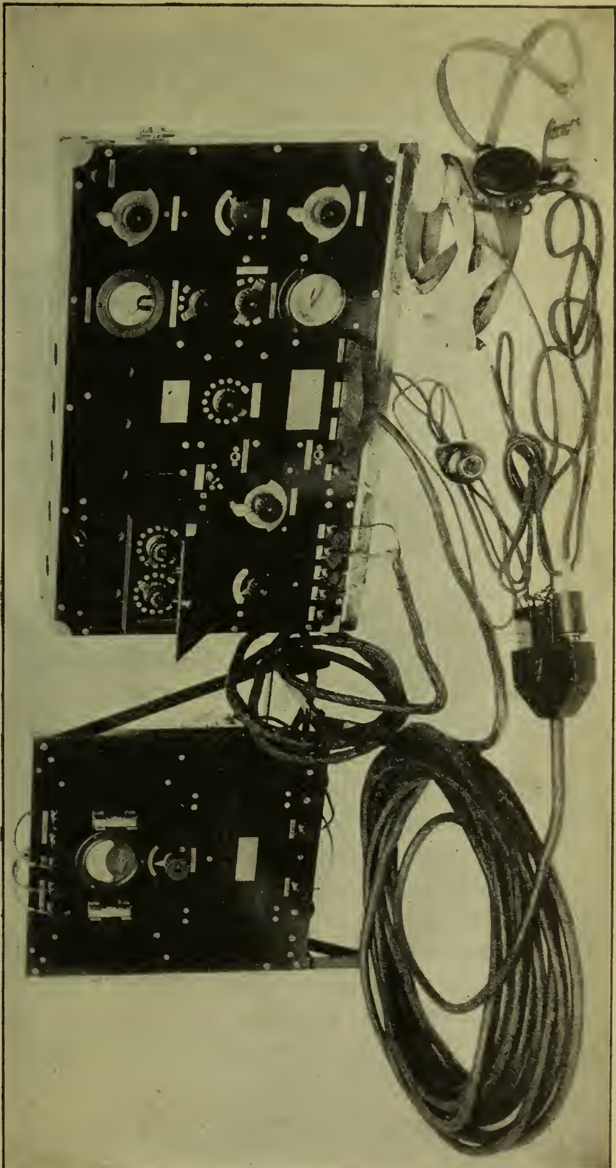
4. Place a type SCR–60–C or SCR–61 wavemeter near the left hand end of the radio set box and set it to the desired wave length. If the type SCR–61 wavemeter is used, insert type P–11 telephone receivers in the wavemeter jack, start the buzzer and adjust the crystal detector. Keep the buzzer running while adjusting the radio set. If the type SCR–60–C wavemeter is used, operate similarly, or better, simply read the galvanometer, without using the buzzer or telephone receivers.

5. Turn the filament current switch of the radio set box all the way to the left, to the position "Minimum."

6. Insert the milliammeter plugs in the jacks marked "Grid current" and "Space current." Two type I–7 ammeters may be used, with an extension cord type CD–57.

7. Open the modulator switch. This is the small vertical knife switch in the center of the covered panel.

8. Throw the three-position power switch all the way to the right, in the position marked "Power on." This should light the filaments of all five vacuum tubes, should give a reading on the filament current ammeter, and should start the dynamotor.



Set box and power board, showing extension cords used when it is desired to remove the dynamotor from close proximity to the set box to reduce the noise.

9. Adjust the filament current so that the filament current ammeter will indicate 2.6 to 2.7 amp.

10. Press the control push button. This will connect the control relay, figure 1, across the 12-volt storage battery, which in turn will close the three contacts, corresponding to the control switches of figure 2. The plate current should be about 50 milliamp. if the oscillator tube is working properly.

11. Connect the 750 or the 1,000 micro-mfd. grid coupling condenser, by closing the corresponding knife switch in the covered panel, and set the 12-point "Coupling" dial switch so that the tube will oscillate, as indicated by a reading on the antenna ammeter.

12. Adjust then, in rotation and in the order mentioned, the "Wave length" switch, antenna transmitting condenser ("Cond. trans."), and "Coupling" switch until maximum response is obtained on the wavemeter. Also try various combinations of the four grid condenser switches, so that the grid current will be between 2 and 7 milliamp. The greater the wave length, the greater the grid condenser to be used.

13. Readjust the wave length switch and antenna condenser to perfect the tuning.

14. Readjust several times, in the order mentioned, the plate "Coupling" dial switch, grid coupling knife switches, and antenna transmitting condenser to secure that adjustment which will give, at the desired wave length, greatest radiation and smallest grid and plate current possible.

15. If the grid current is too high, increase the grid condenser. If the plate current is too high, increase the plate coupling. With a suitable antenna, the radiation should be from 0.3 to 0.6 amp.

16. Close the modulator switch in the covered panel. The plate current will be 60 to 70 milliamp. In no case should it exceed 80 milliamp.

17. The set is now ready for transmitting. Remove the wavemeter and the grid and plate milliammeters. When talking, speak in an even tone of voice, not too high nor loud, and with the lips close to the transmitter. It is essential that the push button be kept closed while transmitting.

18. An idea of the settings of the various switches may be obtained from the calibration chart given below. This chart was obtained with a type SCR–67 set, using an inverted "L" antenna having a natural wave length of about 200 meters. Such an antenna is not very well suited for use with this set.

Wave length.	Antenna switch point.	Coupling switch point.	Antenna trans-mitting condenser.	Grid coupling condenser.
235	1	12	100	500
250	2	12	100	750
300	5	12	70	1000
350	8	11	80	1000
400	11	11	26	1000
450	12	10	100	1000

CAUTION.—Do not touch the modulator and grid condenser switches with bare hands while the power is on.

Receiving.—The receiving circuit may be calibrated, after the set has been connected to the antenna, by means of a wavemeter which is set to a number of wave lengths, the set being tuned in as explained below, and the settings of the various switches recorded. If not calibrated in advance, or if the wave length to be received is unknown, the procedure is as follows:

1. Follow the instructions given in paragraphs 1, 2, 3, and 5 of the previous section.

2. Close the three-position power switch of the radio set box in the middle position, marked "12 volts." This should light the filaments of the three receiving tubes. The circuits in use are shown in figure 3. The antenna control switch, figure 2, is closed and it is not necessary to close the push button. If it is desired to transmit and receive, set the three-position switch to "Power on." When transmitting, press the push button; when receiving, release the push button. In case of the type SCR-67 set, all five vacuum tubes will light simultaneously when the power switch is in the "12-volt" or "Power on" position.

3. Set the three-point dial switch located above the filament current ammeter in the position "AP."

4. Adjust the receiving "Primary inductance" and the "Primary receiving condenser" until the signals are heard loudest.

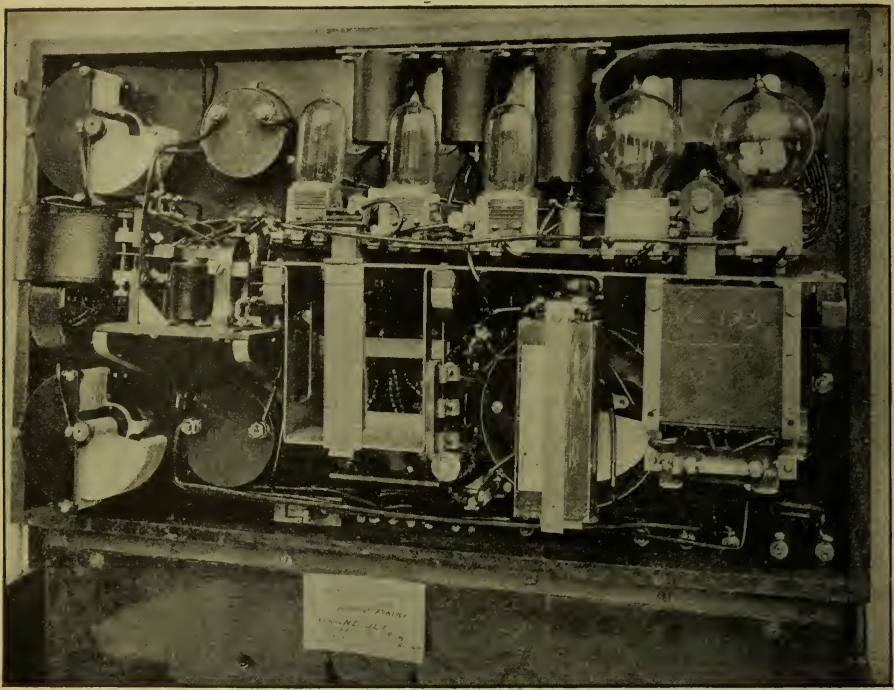
5. Set the three-point dial switch to "LW" or "SW," and adjust the secondary receiving condenser for loudest signals, using maximum coupling if required.

6. If the signals are too loud, set the "Amplifier" key to "Minimum." If they are not loud enough, set it to "Maximum." Also, reduce the coupling for protection against interference.

POSSIBLE SOURCES OF TROUBLE.

Frequently, the set does not operate satisfactorily on account of incomplete adjustment of the transmitting circuit. In making adjustments, each setting affects all the others, and it is therefore necessary to go over all adjustments in the same order until proper conditions are obtained. Once the set is adjusted, it will therefore save time to record the settings and corresponding wave length. These settings will of course change if the antenna is changed.

With a set properly adjusted, the results are still dependent on the voice of the operator. The speech should be clear, rather slow and in an even, moderate tone, and with the lips close to the telephone transmitter.



Mounting of apparatus on the back of panel on set box, Type BC–13.

In general, it may be said that the set is operating properly when, with the switch on "Power on" and the control push button closed, and the amplification switch on "Minimum," the operator hears himself distinctly in the telephone receiver while talking in the transmitter in a low tone of voice. The explanation of this test is that the modulated oscillations of the transmitting circuit induce currents in the receiving inductance. The test is therefore a check on the working condition of the circuits, but may not be considered as a conclusive proof that the circuits are perfectly adjusted.

Some of the troubles which may be encountered in operating the set are mentioned below. The wiring diagrams of figures 5 and 6 may be helpful when tracing the circuits in the set box.

NOISE IN RECEIVER.

(*a*) Worn-out dry batteries. Voltage should not be less than 17.5 volts per battery.

(*b*) Noisy leak resistances.

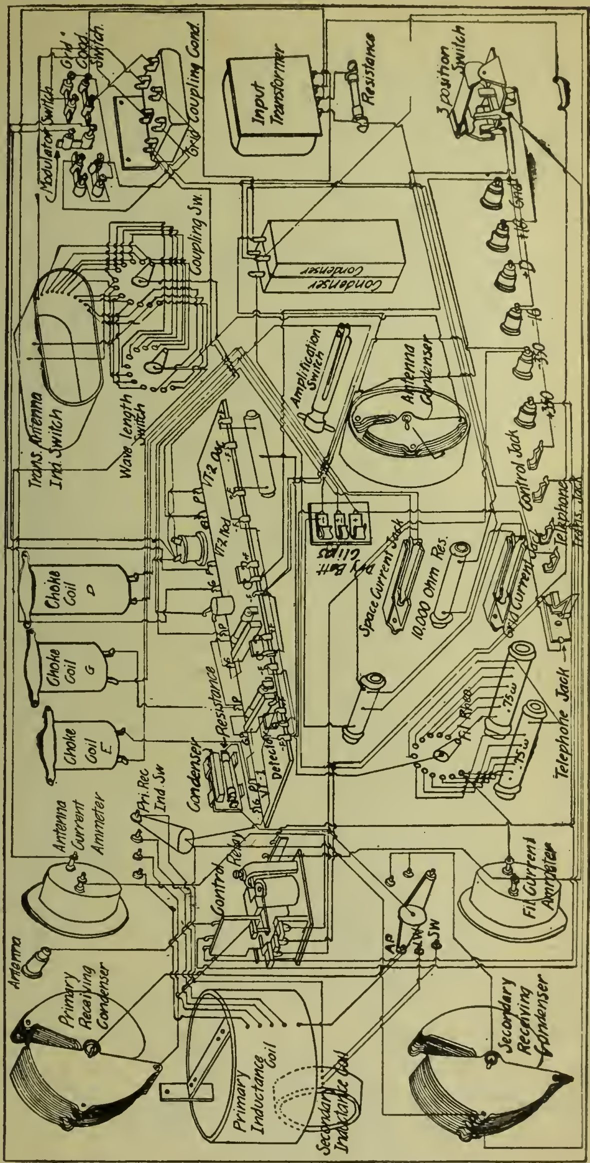


FIG. 5.—Actual wiring connections within the set box Type BC-13.

(*c*) Loose connections in plate, filament, or grid circuits. Inspect soldered connections, especially of long wires which may vibrate loose. Inspect connection clips of grid leak and telephone jack.

(*d*) Poor contact between vacuum tube and spring contacts in socket.

(*e*) Broken-down grid leak condenser. Remove condenser and test for click, using telephones.

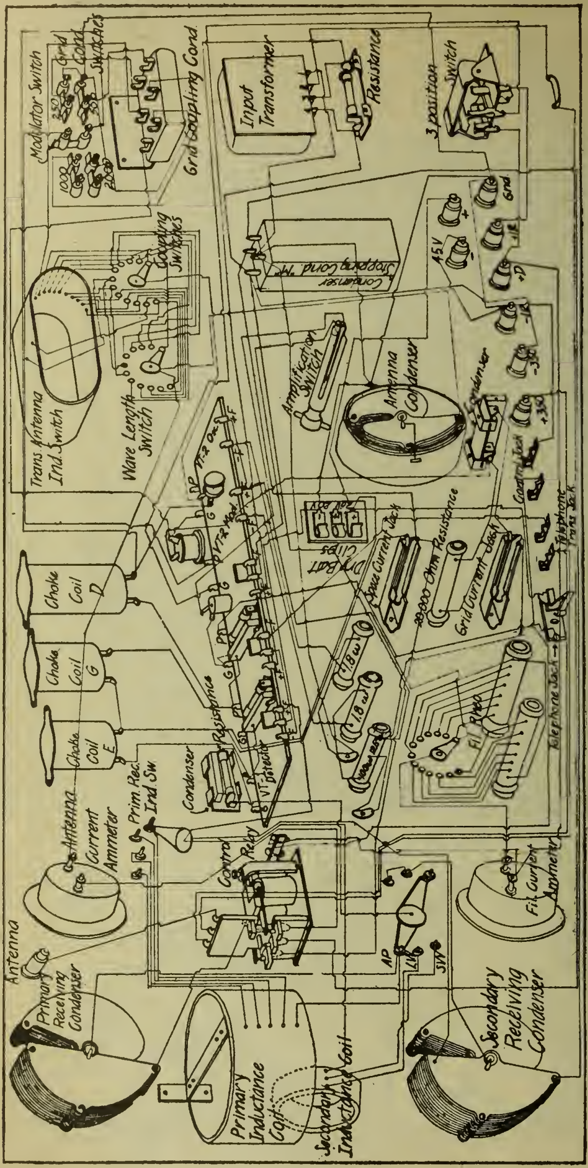


FIG. 6.—Actual wiring connections within the set box Type BC-13-A.

(*f*) Noisy detector vacuum tube.

(*g*) Sparking at dynamotor commutator, due to poor brushes or dirty commutator.

FAILURE TO RECEIVE.

(*a*) Tap on the detector tube. If a loud ringing noise is heard, the trouble is probably in the antenna primary and secondary circuits. If no noise is heard, the trouble is probably between the detector and telephones.

(*b*) Failure of filaments to light; due to broken filament in one of the receiver tubes (VT–1) or open in filament circuit. May also be due to broken-down antenna stopping condenser.

(*c*) Blocking of detector tube; due to too high resistance grid leak or open in grid circuit. Examine grid leak connecting clips.

(*d*) Receiving condenser short circuited, due to buckled plates; or antenna stopping condenser broken down.

FAILURE OF AMPLIFIER.

(*a*) Amplifier resistances may be burned out, or short-circuited, or the connections may be broken.

(*b*) Condenser terminals grounded to metal frame.

(*c*) Loose connections. Condenser terminal connections broken off.

FAILURE TO OSCILLATE.

(*a*) Failure to have any plate current with modulator switch open may be due to a failure to impress the plate voltage on the tube. Test direct current plate circuit for an open by shunting the plate and filament terminals of the tube socket with a buzzer or receiver. Test dynamotor voltage on power board. The milliammeter circuit may be open. Inspect plate current jack and plug. The contacts on the control relay may not operate properly. Too small a plate current may be due to too small a filament current.

(*b*) Failure to have any grid current may be due to a burned-out grid resistance. Test the latter by clicking through with the telephones. It may also be due to a burn-out or open in the R_2 and R_3 resistance (fig. 2), to an imperfect grid current jack, or burned-out ammeter.

(*c*) Oscillator tube filament may not light due to an open in the filament circuit.

(*d*) No reading on antenna ammeter may be due to an open in the antenna circuit. Ammeter may be burned out, or antenna inductance coil may be open. Test by buzzer. Antenna condenser may be shorted. Antenna switches may be faulty.

(*e*) Test grid coupling condenser by buzzer.

(*f*) Circuit may not be adjusted properly.

(*g*) Antenna insulator may leak, or antenna may be grounded.

OVERHEATING OF OSCILLATOR TUBE.

(*a*) Too much plate voltage.

(*b*) Improper adjustment of circuit.

(*c*) Lack of grid current or excessive grid current due to improper adjustment of circuit.

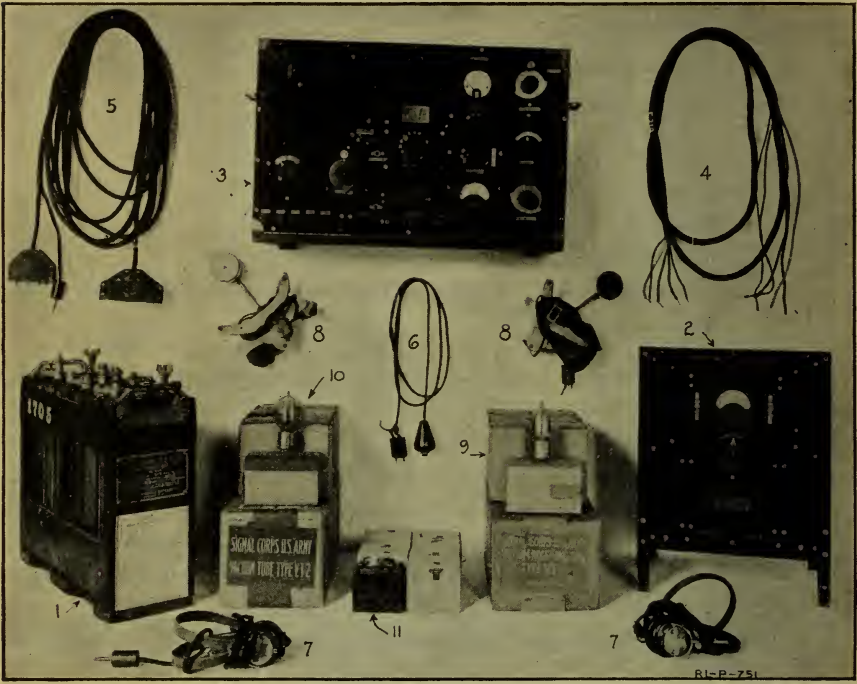
(*d*) Faulty tube.

FAILURE TO MODULATE.

(*a*) Receiving tube filaments may not light.

(*b*) Control relay contacts may not work.

(*c*) Open in modulator plate circuit. Modulator knife switch should be closed. If the latter is open, plate current ammeter should



Component parts of the set.

read 40 to 50 milliamp. When closed, space current should be 60 to 70 milliamp.

(*d*) Iron core choke coil may be short-circuited.

(*e*) Faulty or burned out input transformer.

(*f*) Short circuit on input transformer secondary.

(*g*) Open circuit between transformer and grid of modulator tube.

(*h*) Faulty telephone transmitter.

(*i*) Faulty tube.

(*j*) Blocking of modulator may be due to too high or too low a plate current, or to improper resistances in plate circuit. A tendency of the tube to block will be evidenced by a high and unsteady reading on the plate current ammeter when blowing or whistling on the telephone transmitter. Blocking of the modulator is also evidenced by the fact that when the operator talks into the transmitter while sending, he hears his speech interruptedly. A remedy, if the tube is not faulty, is to interchange the oscillator and modulator tubes.

PARTS LIST.

In ordering this set or parts of this set specification must be made by names and type numbers as listed below exactly. The designation printed in bold face type *only* will be used in requisitioning, making property returns, etc.

In ordering complete sets it is not necessary to itemize the parts; simply specify "Set, Radio Telephone, Type SCR–67." If all the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment Type PE–2."

The set is not complete unless it includes all of the items listed in the component parts table below:

SET, RADIO TELEPHONE, TYPE SCR–67.

1 **Equipment Type PE–2**; power.
- 4 **Batteries Type BB–5**; 2 in use, 2 spare.
- 1 **Powerboard Type BD–1.**
- 1 **Cord Type CD–22.**

1 **Equipment Type RE–2**; radio.
- 1 **Set Box Type BC–13.**
- 1 **Cord Type CD–23**; powerboard to set box.
- 1 **Cord Type CD–24.**
- 1 **Cord Type CD–25.**
- 2 **Head Sets Type P–11**; 1 in use, 1 spare.
- 1 **Radio Communication Pamphlet No. 22.**
- 2 **Transmitters Type T–1**; 1 in use, 1 spare.
- 16 **Tubes Type VT–1**; 3 in use, 13 spare.
- 16 **Tubes Type VT–2**; 2 in use, 14 spare.
- 8 **Batteries Type BA–2**; 2 in use, 6 spare.

1 **Equipment Type A–9**; antenna.
- 6 **Insulators Type IN–5.**
- 6 **Insulators Type IN–7.**
- 6 **Couplers Type FT–2.**
- 3 **Mats Type MT–3.**
- 750 ft. **Wire Type W–1.**
- 2 **Reels Type RL–3.**
- 300 ft. **Wire Type W–6.**

6 Mast Sections Type MS–5.
2 Bags Type BG–14.
12 Stakes Type GP–3.
1 Bag Type BG–8.
50 ft. Wire Type W–4.
1 Hammer Type HM–1.
½ lb. Marlin Type RP–2.
300 ft. Cord Type RP–3.

SET, RADIO TELEPHONE, TYPE SCR–67–A.

1 Equipment Type PE–2–A; power		*
	6 Batteries Type BB–5 or Type BB–14	(1)
	1 Powerboard Type BD–1–A	(2)
	1 Cord Type CD–48.	
	2 Cords Type CD–38; 1 in use, 1 spare.	
1 Equipment Type RE–2–A; radio.		
	1 Set Box Type BC–13–A	(3)
	1 Cord Type CD–23; powerboard to set box	(4)
	1 Cord Type CD–25; set box to operator's cut-in switch	(5)
	1 Cord Type CD–24; set box to operator's jack	(6)
	2 Head Sets Type P–11; 1 in use, 1 spare	(7)
	1 Radio Communication Pamphlet No. 22.	
	2 Transmitters Type T–3; 1 in use, 1 spare	(8)
	16 Tubes Type VT–1; 3 in use, 13 spare	(9)
	16 Tubes Type VT–2; 2 in use, 14 spare	(10)
	8 Batteries Type BA–2; 2 in use, 6 spare	(11)
1 Equipment Type A–9; antenna.		
	6 Insulators Type IN–5.	
	6 Insulators Type IN–7.	
	6 Couplers Type FT–2.	
	3 Mats Type MT–3.	
	750 ft. Wire Type W–1.	
	2 Reels Type RL–3.	
	300 ft. Wire Type W–6.	
	6 Mast Sections Type MS–5.	
	2 Bags Type BG–14.	
	12 Stakes Type GP–3.	
	1 Bag Type BG–8.	
	50 ft. Wire Type W–4.	
	1 Hammer Type HM–1.	
	½ lb. Marlin Type RP–2.	
	300 ft. Cord Type RP–3.	

*Numbers in parentheses at the right refer to the corresponding part in the illustration on page 18.

SIGNAL CORPS PAMPHLETS.

(Corrected to February 1, 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 (Types SCR–65 and 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.)
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 Type 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. (W. D. D. 1020.) (2d edition.)
10. Wire Axis Installation and Maintenance Within the Division. (W. D. D. 1068.)

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21). (W. D. D. 1055.)
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).

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CONFIDENTIAL! For Official Use Only

U.W. Airplane Radio Telegraph Set Type SCR-80

RADIO PAMPHLET No. 23

April 14, 1919

Signal Corps, U. S. Army

Washington Government Printing Office . 1919

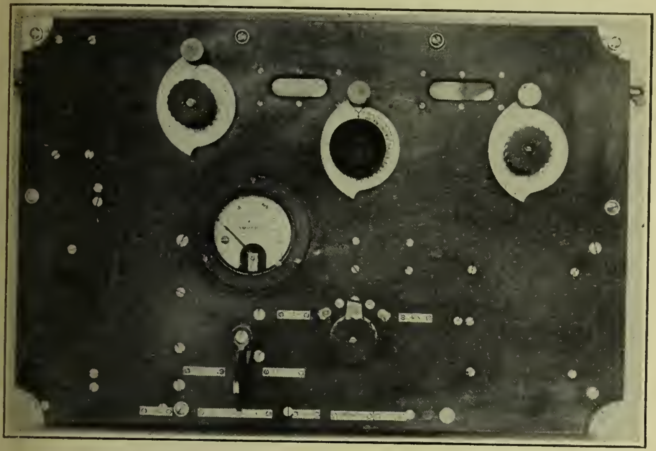
U.W. AIRPLANE RADIO TELEGRAPH SET

TYPE SCR-80

113948—19——1

THE TYPE SCR–80 SET is a transmitting and receiving undamped wave airplane radio telegraph set, having a wave length range of from 550 to 750 meters. It may be used with a single wire trailing antenna about 300 ft. long, or with a two-wire antenna, such as the type A–23, which gives the same range of wave lengths.

This set is primarily intended for long range fire control work in conjunction with the type SCR–79 ground set. However, it may



'perating Panel of Set Box Type BC–52 Used in Set Type SCR–80, as it Appears Set Vertically in Front of the Observer.

e used for intercommunication with other airplanes similarly quipped. When communicating with a type SCR–79 set, the 'pe SCR–80 set has a range of about 20 miles. This distance will ary with the type of antenna used and may be as great as 40 miles. his is an exceptionally long range for an airplane set.

An advantage of this set is that it is practically interchangeable ith the type SCR–68 set, as it uses the same double voltage, fan 'iven generator, the same filter box and interphone box. The set 'x itself may be mounted on a bracket differing but little from that used for the set box of the type SCR-68 set. The principal difference in the installation is that one or more telegraph sending keys are used on the set box instead of telephone transmitters.

The set is rugged and compact and is very simple to operate, there being only one adjustment of the transmitting circuit and two ad justments of the receiving circuit.

General Description and Principle of Operation.

A complete schematic circuit diagram of the set is given in Fig. 1 which illustrates the principle of operation of the set. A five-pole double-throw "Transmit-Receive" switch is provided on the se box, which effects all the necessary changes in the connections c the set box when transmitting or receiving.

Switch in "Transmit" Position.—With the switch in th "Transmit" position, the circuits in use are equivalent to thos shown in Fig. 2. The two type VT-2 three-electrode vacuum tube used for the generation of the oscillations are connected with the filaments in series, and the filament heating circuit, which com prises also a ballast lamp, is connected across the 25-volt termina of the fan driven generator.

The ballast lamp has a filament the resistance of which varies wit the current flowing through it, and it functions to minimize th variations of the filament current resulting from the slight variatio of generator potential. These potential variations are due to sligh changes in the speed of the generator and to the action of comm tation. They are reduced and smoothed out by the condenser F which is located in the filter box, and acts jointly with the balla lamp to deliver a constant current to the transmitting tube filamen

The grids and plates of the two tubes are connected in parall so that the arrangement is equivalent to one single tube of larg size. A continuous positive potential of 275 volts, generated the 275-volt armature of the fan driven generator, is applied to t plates when the telegraph key is closed. This location of the k in the plate circuit insures a very positive action of the tubes, sin there is thus no plate current when the key is open, which preve any accumulation of negative charge on the grid, and hence any l in the starting of the oscillations when the key is closed is avoide In order to smooth out small variations of plate potential, such ıose resulting from commutation, a condenser F_2 is connected ross the 275-volt terminals of the generator. This condenser, ke the condenser F_1, is located in the filter box.

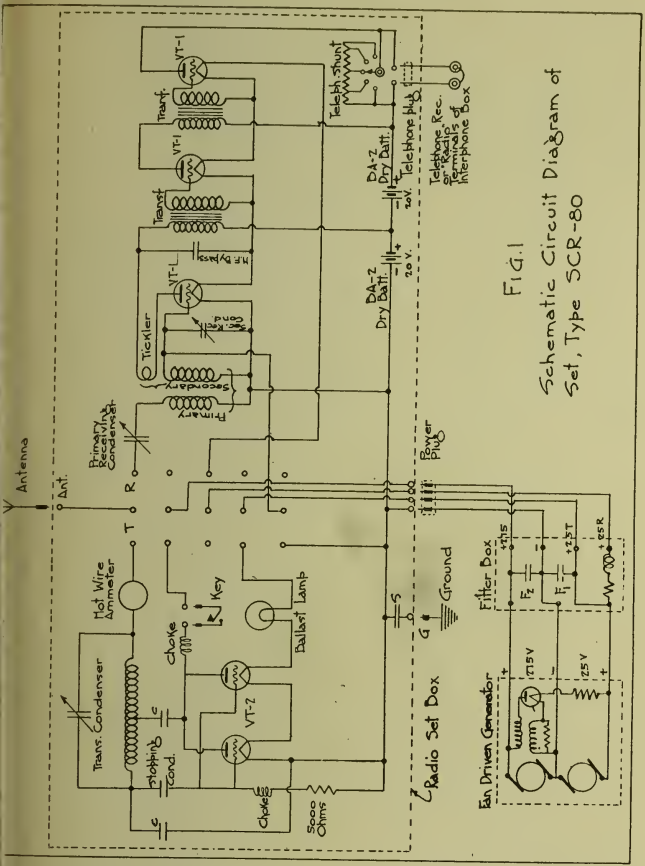


FIG. 1
Schematic Circuit Diagram of Set, Type SCR-80

\ continuous negative potential is impressed upon the grid, ich is derived from the potential drop resulting from the grid rent flowing through a 5000-ohm grid resistance connected-between the grid and the filament. A choke coil is inserted in eac of these d.c. grid and plate potential circuits in order to preve the high frequency oscillations generated by the tubes from ente ing these circuits.

The plate and grid circuits just described are coupled electr statically through the medium of two fixed mica condensers mark C, Fig. 2. The oscillatory circuit in which undamped oscillatio are generated comprises the inductance coil L, the radiati antenna-ground condenser and the variable "Transmitting Co denser" in parallel with it. A hot wire ammeter in series wi

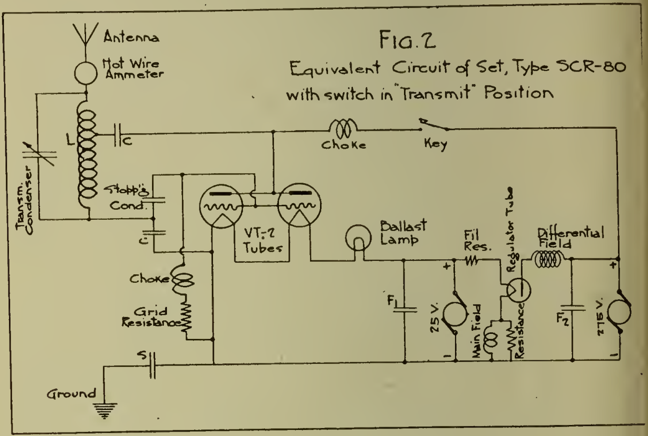


FIG. 2
Equivalent Circuit of Set, Type SCR-80 with switch in "Transmit" Position

the antenna indicates the radiation, and provides a method checking that the vacuum tubes are in an oscillating conditi It should be noted that the condenser S in the ground wire preve any possible outside short circuit of the generator. As may seen from the above, the only adjustment provided in the circ is that of the transmitting condenser. This is sufficient to co the entire wave length range of the set.

Switch in "Receive" Position.—Since the signals to be receiv by the set are undamped wave signals, the heterodyne method used for their reception. With the switch in the "Receive" pc tion, the circuits in use are equivalent to those of Fig. 3. T incoming signals first energize the primary circuit, which compri the antenna, primary tuning condenser, primary inductance, stopping condenser S, and ground (counterpoise). Inductively coupled to the primary inductance is the secondary oscillatory circuit, comprising a secondary inductance coil and a variable secondary condenser. No provision is made to vary the coupling of the primary and secondary coils since this is not necessary for satisfactory operation, and reduces the number of adjustments. A peculiar feature of the secondary condenser is the micrometer adjustment which makes possible a fine adjustment of the secondary

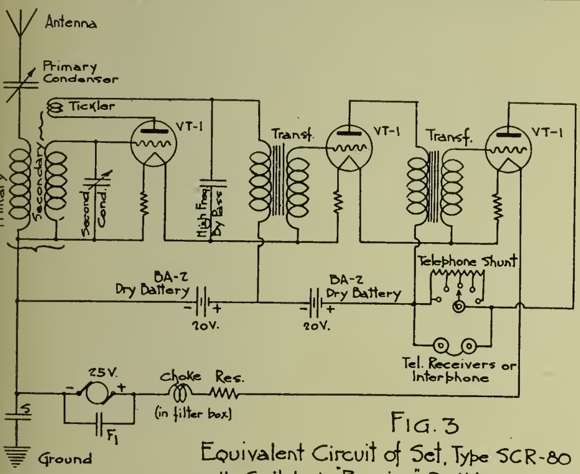
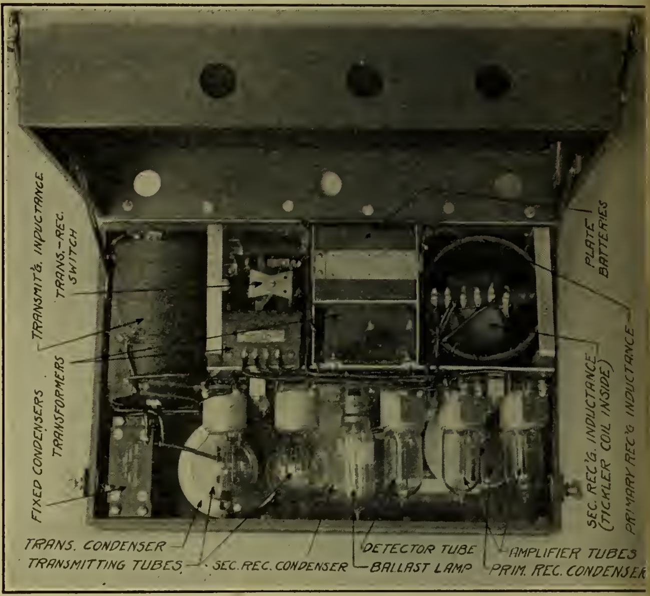


FIG. 3
Equivalent Circuit of Set, Type SCR-80 with Switch in "Receive" Position

circuit. This is made necessary by the use of the heterodyne method of reception. The secondary condenser is operated by means of an insulating handle which rotates all the movable plates but one. This one plate is operated separately by means of a smaller handle mounted on the same shaft.

The secondary oscillatory circuit is connected between the grid and the negative side of the filament of a type VT–1 vacuum tube used as a detector. The plate current for this tube is furnished by a 20-volt, type BA–2 dry battery. The plate circuit comprises a tickler coil, permanently coupled to the secondary inductance, and

the primary winding of an iron core transformer which couples tl
detector tube circuit to the first amplifier tube. Shunting th
transformer winding and dry battery is a fixed mica condenser whi



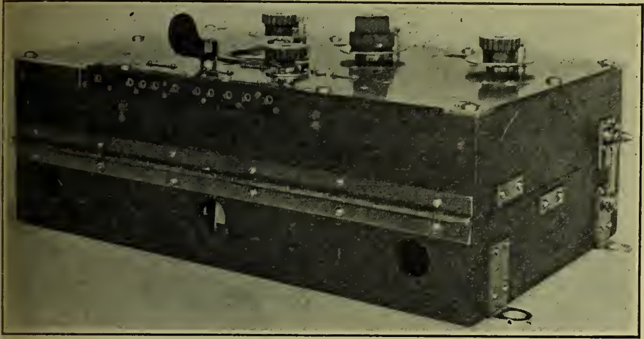
View of Set Box Type BC–52 Interior, as it Opens Before the Observer Wh
the Set Box is Mounted in the Airplane Cockpit.

serves as a by-pass for the locally generated high frequency oscill
tions.

The remainder of the receiving circuit is a two-stage casca
amplifier using type VT–1 vacuum tubes, with a plate potenti
of 40 volts on each one of these tubes, and iron core transforme
coupling them. Telephone receivers are inserted in the plate ci
cuit of the last tube. These are shunted by a resistance variable
five steps, which is used to vary the proportion of the signal curre
flowing through the receivers and thus permits the elimination
weak interfering sounds.

All three filaments are connected in series, the heating current)eing furnished by the 25-volt side of the fan driven generator. n series with the latter is a choke coil and resistance, which are ocated in the filter box and which serve to reduce the commutation)ulses which were not by-passed by the condenser F_1. This con-lenser shunts the generator terminals and smooths out the commu-ation pulses of the generator. In series with each filament is a -ohm resistance the voltage drop across which supplies to the grid f each tube the proper negative potential.

It will be noted, Fig. 1, that the secondary receiving condenser ; short circuited when the switch is in the "Transmit" position.



)ttom View of Set Box Type BC-52 Showing Connecting Jacks and Elevation of Operating Handles.

ıis arrangement is made in order to prevent excessive currents)m being induced in the secondary receiving inductance coil by e oscillations taking place in the transmitting inductance while nding.

Description of Generator.—The fan driven generator, type N-1-A or GN-2-A, used with this set is the same as that used with e type SCR-68-A airplane radio telephone set. It has two arma-re windings, giving 25 and 275 volts, respectively, when the gen-ıtor is run at rated speed. Since it is very important for the satis-:tory operation of the set that the terminal voltage of the gener-)r remain constant, a regulating fan, type FA-7, is used. This ı has a variable pitch which adjusts itself automatically for varying wind velocities, so that it will rotate at a constant speed within wide limits of wind (or airplane) velocities. When no regulating fan is available, a type FA–3 wooden airfan may be used, which, however, is likely to give less satisfactory operation under conditions of varying wind velocity. In addition to the regulating action of the variable pitch airfan, the voltage output of the generator is also controlled through the use of a main and a differential field winding, the fluxes of which are opposed in effect. There is also a special two-electrode regulating tube inserted in series with the differential field. The complete connections are illustrated in Fig. 1. The action of this device may be explained as follows:

When the generator is driven at a higher speed than normal, the generated voltage has a tendency to increase, which consequently increases the current in the main field winding and in the regulator tube filament in series with it. It also increases the plate voltage on this tube, and therefore the plate current. The latter current flowing through the differential field winding, increases the flux in the latter, which counteracts that of the main field, and thus prevents any further rise of the generator voltage. In case the generator is driven at a speed below normal, the phenomena occur in exactly the opposite manner. By means of this arrangement, the output voltages of the generator are maintained fairly constant under the conditions encountered in practice.

Filter Box.—With the operation of the generator regulated by means of the variable pitch airfan, the regulator tube, and differential field, there remains the pulsating terminal voltage of the generator resulting from commutation to be eliminated. The result of such a pulsating current is a steady hum in the telephone receivers. This noise is minimized by the use of a filter box, which is of the same type as that used with the type SCR–68–A set. It consists of two condensers, shunting the 25-volt and 275-volt terminals of the generator, and a reactance coil and resistance connected in series in the filament circuit of the receiving tubes.

Interphone.—While the type SCR–80 set is essentially a radio telegraph set, it is of great importance in connection with its use that the pilot and observer should be able to talk to each other during the flight. Also, while the observer is the only one to use the sending key, it is of advantage that both the pilot and observer receive the incoming signals, so that the pilot will not talk to the observer while the latter is receiving a message. This double function is accomplished by the interphone which is connected to the radio set box in place of the telephone receiver, as shown in Figs. 1 and 4. The set used is the Set, Airplane Interphone, Type SCR–57–A, for which a circuit diagram is shown in Fig. 5. This set is also used on airplane radio telephone sets, such as the type SCR–68–A. It has two radio telephone transmitter terminals, which are not used when the interphone set is used with the telegraph set type SCR–80.

The method of functioning of the interphone may readily be understood from the circuit diagram. When the four-pole double-throw switch is closed in the position "Interphone," the contacts marked "I" in the diagram are closed. The pilot and observer are

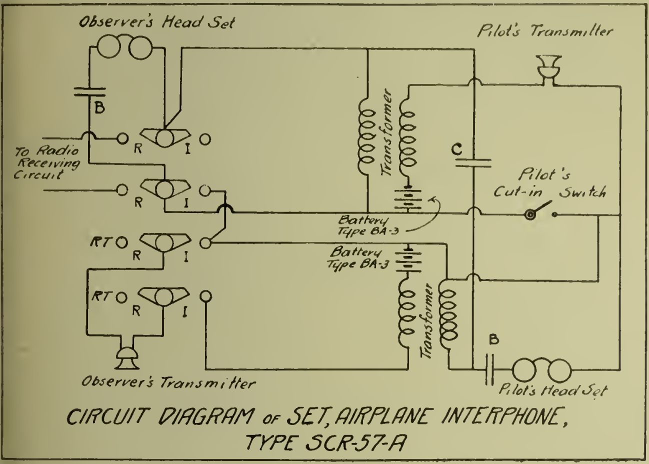


Fig. 5.—Circuit Diagram of the Interphone Set Used With Set Type SCR–80.

then entirely disconnected from the radio set, and are connected to each other by an ordinary telephone circuit. They may talk back and forth without any additional operation. A special feature of the set is the "side tone" circuit, which comprises the condenser C, and the purpose of which is to shunt some of the telephone current from the transmitter circuit back into the telephone receiver circuit of the person talking, so that he may hear his own voice and know how loud he is talking and whether or not the circuit is working.

When the switch on the interphone set box is closed to "Radio," the observer's telephone receivers are directly connected to the radio telegraph receiving circuit, and the observer receives incoming radio signals in the ordinary manner. The observer's telephon transmitter is entirely disconnected, so that he can not talk to th pilot. The pilot's circuits are disconnected, but by closing hi cut-in switch he can receive the radio signals and talk to the observe The operation is then as follows:

When the observer and pilot want to talk back and forth to eac other, the observer closes the interphone-radio switch to "Inter phone." When the observer desires to receive radio signals, thi switch is closed to "Radio." If, now, the pilot desires to talk to th observer, he must first close his cut-in switch, and if he does no hear any radio signals, he may speak to the observer without inter rupting him in the reception of a radio message. If he hears incomin radio signals, he should wait for the end of the message. If th observer desires to answer the pilot, he must close the interphone radio switch to "Interphone." This, however, disconnects hin from the radio set, so he should not leave the switch in this positio longer than is necessary or he may miss some incoming radio signals

Method of Installing the Set.

All of the apparatus described above is grouped in a number o units, as indicated schematically by the dotted lines, Fig. 1. Thes units comprise the fan driven generator, generally mounted on th right hand strut in the landing gear; the filter box, which may b installed on the floor inside the fuselage; the radio set box, preferabl mounted as for the SCR–68 in front of the observer; and the inter phone set box, which is conveniently mounted on the right hand sid of the observer's cockpit. The antenna reel can then be mounted o his left hand side. When one telegraph key is used, it is mounte on the right hand side of the observer. When two keys are used such as in the De Haviland DH–4 two-seated machine, one i mounted in front and the other in back of the observer. Thes suggestions for the installation of the set are, of course, of a genera character, and the actual location of the apparatus will differ in th various types of airplanes. The usual precautions of good insulation neat wiring, balancing of the load, etc., must be observed.

The interconnection of the various units should be made with th extension cords provided and in accord with the cording diagran given in Fig. 4. Care should be taken to see that all connections an plugs are tight, since a loose connection or broken cord will preven satisfactory operation of the set.

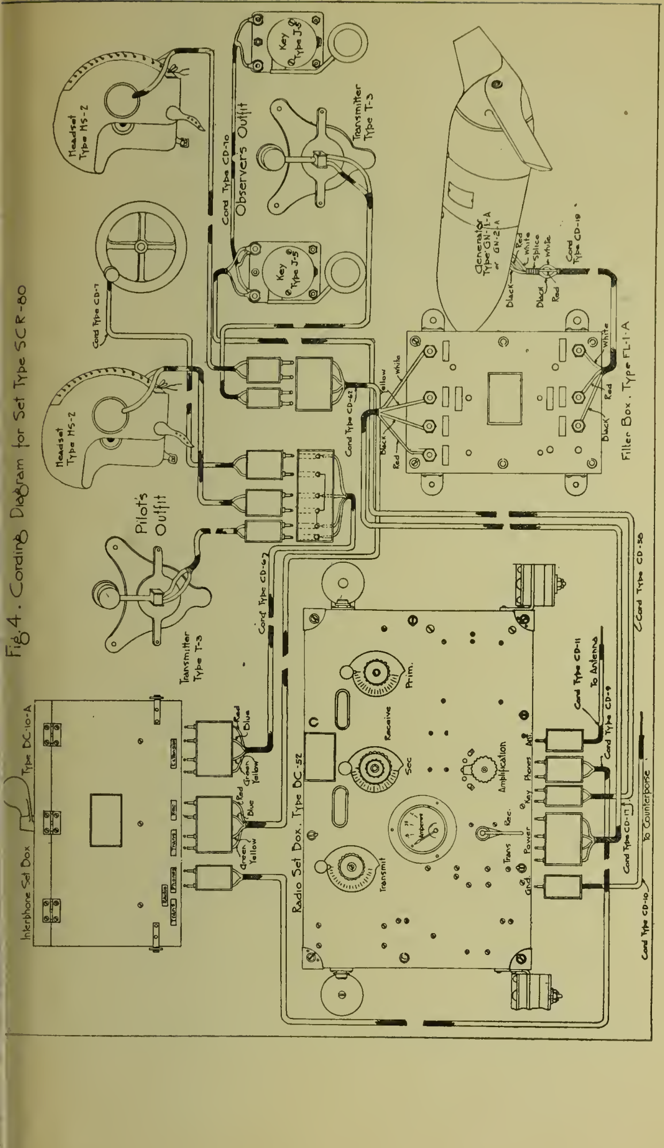


Fig. 4. Cording Diagram for Set Type SCR-80

Method of Calibrating the Set.

In general, an airplane will always use an antenna of the sam length, so that it will be found of advantage to calibrate the trans mitting circuit of the set for this antenna. This is done in order tha the setting of the transmitting condenser will be known for an value of wave length it is desired to use. It is also well to calibrat the secondary receiving circuit of the set, so that it may be adjuste in advance to receive any predetermined wave length. The cali bration of this latter circuit will not change, even if the set is use with an antenna having different characteristics. The calibratio

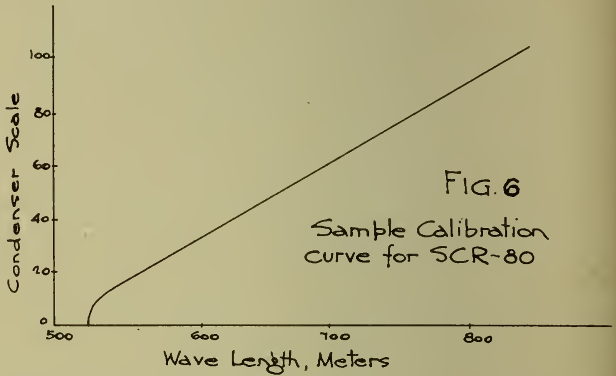


FIG. 6
Sample Calibration curve for SCR-80

may be made in a laboratory before installing the set on the airplane This is of especial advantage when a number of sets are to be tested For calibrating a set on an airplane, the method of procedure is a follows.

(a) **Calibrating the Transmitting Circuit.**—With the set in good working condition and fully installed on the airplane an connected up, the generator airfan is removed from the generator The generator shaft is then coupled to a small motor which is use to drive the generator at the standard speed. The "Antenna and "Ground" plugs are first removed from their jacks in the radi set box, and a phantom antenna, type A–50, connected in place o the real antenna. The phantom antenna is set to correspond t the constants of the real antenna. If no phantom antenna is available, a condenser may be used having the same capacitance (about 300 micro-mfd.) as the real antenna. This is, however, not as good practice, since the calibration will not be quite so accurate. In all cases, whether the phantom antenna, type A-50, or an improvised phantom antenna is used, the connecting wires should be equipped with plugs, type PL-12, so they will fit the "Antenna" and "Ground" jacks of the radio set box.

The "Transmit-Receive" switch is thrown to the "Transmit" position, and the set excited by running the generator at its rated speed. The telegraph sending key is closed and the wave length emitted by the set is measured by means of a type SCR-95 wavemeter for a number of positions of the transmitting condenser covering its entire range. A curve is then plotted, similar to that shown in Fig. 6, from which the transmitting condenser setting may be found for any value of wave length within the limits of the set. Maximum coupling between the type SCR-95 wavemeter and the type SCR-80 set radio circuits may be obtained, if required, by placing the side of the wavemeter box marked "Plane of Coil" in front of the lower left hand side of the operating panel of the type SCR-80 radio set. Complete instructions regarding the use of this wavemeter are given in Radio Pamphlet No. 21, second edition.

(b) **Calibrating the Receiving Circuit.**—To calibrate the receiving circuit, the set is first connected to a phantom antenna and the generator is driven by a small motor, as explained in the preceding paragraph. The "Transmit-Receive" switch is then closed to the "Receive" position, and the wavemeter is successively made to emit a number of wave lengths covering the entire range of the set. For each wave length, the secondary receiving condenser is adjusted to give maximum response in the telephone receivers. This calibration is made with the primary receiving condenser set on "0" and then with that condenser set at "100," and a curve is plotted similar to that of Fig. 6, giving the secondary condenser setting for receiving any desired wave length within the range of the set. The points will, in most cases, be on either side of the calibration curve, which should therefore be an average curve for the readings obtained.

The calibration of the receiving circuit, as explained above, will have to be made only once, as the set is put into use the first time.

The calibration of the transmitting circuit will have to be repeated every time a new antenna is used having different electrical constants.

Method of Operating the Set.

The following tests should be made on the ground prior to each flight, for the purpose of ascertaining that the set is in good working condition.

1. Remove the airfan from the generator shaft, and couple the generator to a motor, which will be used to run it at rated speed.

2. Remove the "Power" plug from the corresponding jack in the radio set box, and start the generator.

3. By means of a voltmeter, check the voltage between the "Power" plug terminals. The voltmeter readings should be 25 and 275 volts, respectively.

4. By means of a voltmeter, check the voltage of the type BA-2 dry batteries in the set box. This should not be less than 18 volts. Note that the batteries are connected with the correct polarity.

5. Connect a phantom antenna in place of the real antenna and ground, insert the "Power" plug into its jack in the radio set box, and close the "Transmit-Receive" switch in the "Transmit" position.

6. The two type VT-2 transmitting tube filaments should now glow a dull red, and the hot wire ammeter on the operating panel should read from about 0.9 to 0.6 amp. when the transmitting condenser is turned from the "0" to the "100" position.

7. Close the "Transmit-Receive" switch to "Receive," and the interphone switch to "Radio." The three type VT-1 tube filaments should now glow a dull red, and the characteristic commutation hum should be heard in the telephone receivers, for all positions of the primary and secondary receiving condensers.

8. Turn the telephone shunt switch over its entire range, and note that there occurs a gradual change in the intensity of the commutation hum.

9. Check the oscillating condition of the detector tube for various positions of the receiving condensers. This is done by opening the set box, and touching the grid terminal (upper terminal of the secondary condenser) with a wet finger, when a click should be heard in the telephone receivers.

10. The generator is now stopped, and the airfan replaced and ocked tight to the shaft, so that it will not work loose or vibrate luring the flight. The airfan blades should be twisted around mce or twice, to see that they rotate properly. Oil the bearings lightly if required.

11. The set having been found in good working condition, the hantom antenna is removed, and the real antenna and ground are lugged in. The transmitting condenser is then set to the proper osition, as given by the calibration curve of the transmitting circuit, or the wave length at which it is desired to transmit. The secndary receiving condenser is also set at the predetermined wave ength to receive the signals from the ground set. This latter setting s only approximate and will have to be adjusted while in flight, s explained below.

12. The set is now ready for the flight. After the airplane has eached a sufficient height, the antenna is reeled out, if such a type e used, and the "Transmit-Receive" switch is closed in the "Transnit" position. Upon closing the telegraph sending key, the hot wire mmeter should read from 0.9 to 0.6 amp. It is well to check up hat the waves emitted are of the desired length. This may be lone by closing the key and using the type SCR–95 wavemeter, vhich can be readily taken up in the airplane on account of its mall size. On account of the rather large current passing through he key, it is best to have a large opening of the key, in order to revent possible arcing between the key contact points.

13. For receiving, the "Transmit-Receive" switch is closed in he "Receive" position, and the interphone switch placed in the 'Radio" position. The secondary receiving condenser having een set on the ground at approximately the correct position for the ignals to be received, it is not disturbed at first. The primary eceiving condenser setting is varied over its range until a position s found at which the signals are heard. If the signals are not eceived after the entire range of the primary condenser has been ried, the setting of the secondary condenser should be altered lightly either way, and the operation repeated. It is well when ying within 5 to 10 miles of the sending station to set the telephone unt switch on the middle tap. For finer adjustment of the set, e secondary condenser micrometer adjustment may be used, pecially when receiving weak signals, such as when flying at a reat distance.

Possible Sources of Trouble.

Among the possible sources of trouble with this set, the following may be mentioned:

Switch on "Receive."—Failure to receive signals with the set properly tuned may be due to a failure of the detector tube to oscillate. The test for oscillating condition is given in Par. 9 above.

If signals are not received and the commutation hum is not heard, the dry battery may be run down, or the filament of one of the three receiving tubes may be broken.

A crackling noise in the telephone receivers may be due to poor brushes on the generator, poor setting of the brushes, sparking at the commutator, or to poor dry batteries, or loose connections in the telephone cords or in the circuit. It may also be due to magneto interference. This last may be prevented effectively by shielding the magneto and magneto wires leading to the spark plugs of the airplane motor. A fairly satisfactory solution was found which involved the use of metallic covers for all the high tension wires and the magnetos. The most common practice made use of flexible copper clad cables for this purpose, but after considerable experimenting it was found that solid metallic tubing was preferable, it being possible to completely screen out the disturbances with this form of shielding.

Switch on "Transmit."—If the hot wire ammeter does not indicate any current, it may be due to a faulty transmitting condenser. This would usually be noticed in the preflight test on the ground. It may be the result of buckled and short circuited condenser plates.

A broken filament of improper plate voltage such as might result from a faulty regulator tube in the generator, will prevent operation of the set.

Generator trouble will frequently be found to be in the wiring and mounting of the regulator tube, in the brushes or commutators, or in the differential field circuit. An open in the latter will generally cause the burning out of the regulator tube filament or the three electrode tube filaments or even the highvoltage generator armature.

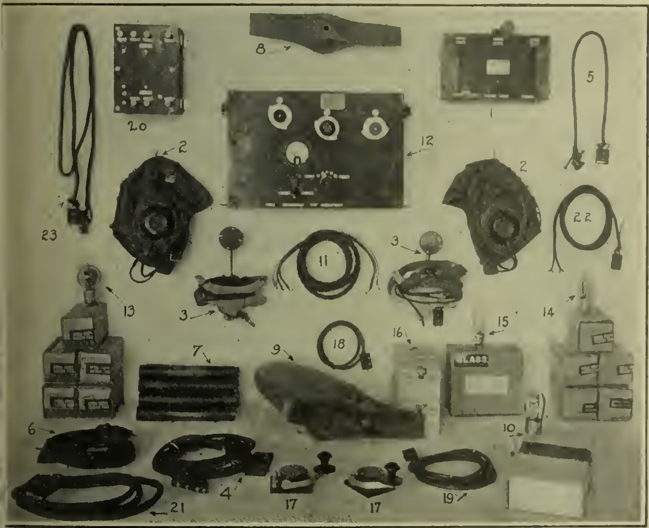
A frequent source of trouble will be due to loose connections at the filter box terminals. Breaking of the connection wires at those terminals usually results from the wires being run too tightly.

PARTS LIST.

In ordering this set or parts of this set, specification must be made by names and type numbers as listed below, exactly. The designations written in bold face type *only*, will be used in requisitioning, making property returns, etc.

In ordering *complete* sets, it is not necessary to itemize the parts; simply specify, "2 Sets, U. W. Airplane Radio Telegraph, Type SCR-80." If *all* the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment, Type PE-1-A."

The type SCR-80 set is not complete unless it includes all of the items listed below.



Set, U. W. Airplane Radio Telegraph, Type SCR-80.

	★
1 Set, Airplane Interphone, Type **SCR-57-A**:	
1 Set Box Type **BC-10-A**	(1)
2 Head Sets Type **HS-2**	(2)
2 Transmitters Type **T-3**	(3)
1 Cord Type **CD-6**; extension; 12 ft.; set box to pilot's jack	(4)
1 Cord Type **CD-7**; extension; push-button switch to pilot's jack	(5)
1 Cord Type **CD-62**; extension; 4 ft.; set box to observer's jack	(6)
20 Batteries Type **BA-3**; dry; 2 in use, 18 spare	(7)
1 Equipment Type **PE-1-A**; power:	
2 Airfans Type **FA-7**; regulating; or if not available, Airfan Type **FA-3**, wooden; 1 in use, 1 spare	(8†)
1 Generator Type **GN-1-A** or Type **GN-2-A**; wind-driven	(9)
5 Tubes Type **TB-1**; regulator; 1 in use, 4 spare	(10)
1 Cord Type **CD-19**; extension; generator to filter	(11)
1 Filter Type **FL-1-A**	(20)
1 Equipment Type **RE-9**; radio:	
1 Set Box Type **BC-52**; airplane radio telegraph	(12)
6 Tubes Type **VT-2**; vacuum; transmitting; 2 in use, 4 spare	(13)
6 Tubes Type **VT-1**; vacuum; receiving; 3 in use, 3 spare	(14)
3 Lamps Type **LM-1**; ballast; 1 in use, 2 spare	(15)
8 Batteries Type **BA-2**; dry; 2 in use, 6 spare	(16)
2 Keys Type **J-5**; flame proof	(17)
1 Cord Type **CD-10**; extension; BC-52 to ground	(18)
1 Cord Type **CD-11**; extension; BC-52 to antenna	(19)
1 Cord Type **CD-70**; extension; for connecting keys in parallel	(not shown
1 Cord Type **CD-17**; extension; BC-52 to filter	(21
1 Cord Type **CD-58**; extension; BC-52 to flame proof key	(22
1 Cord Type **CD-9**; extension; set box type BC-52 to set box type BC-10-A	(23

★The figures in parentheses in the right hand column refer to the correspondi[ng] part in the illustration on page 19.

†The airfan shown is the type FA-3, not regulating.

Equipment Type A–23; antenna:

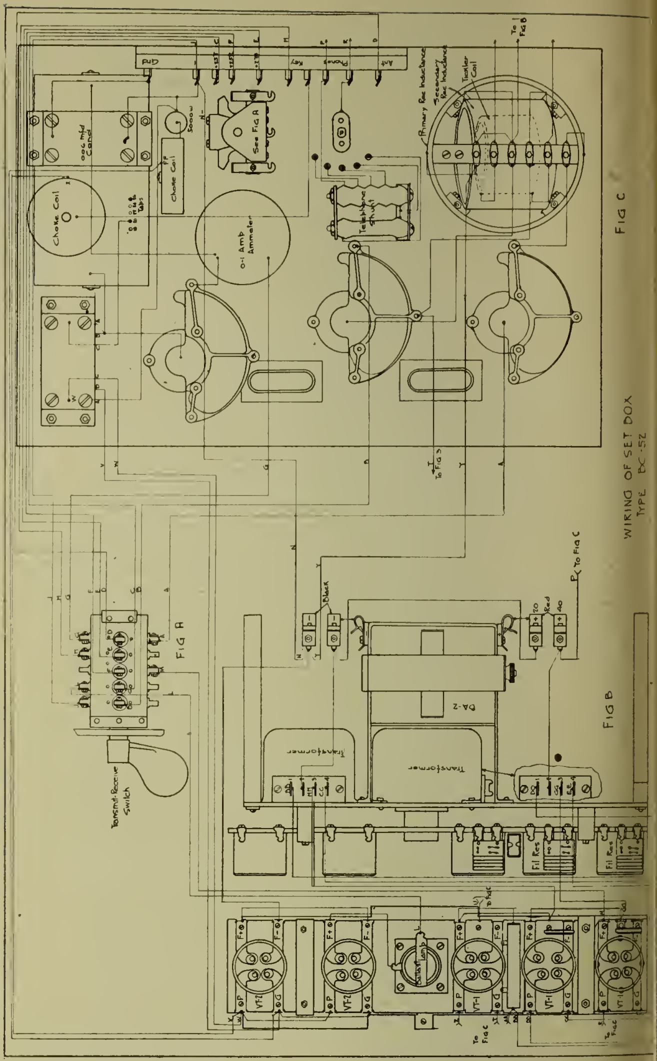
1 **Antenna Type AN–6.**

780 ft. **Wire Type W–16**; in six lengths of 130 ft. each; wound on six spools; for use on AN–6; spare.

4 **Insulators Type IN–8**; phenol fiber rod; 4 in. long.

¼ lb. **Tape Type TL–83.**

40 ft. **Cord Type RP–6**; impregnated linen; in two lengths of 20 ft. each.



WIRING OF SET BOX
TYPE BC-52

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

W. D. D. No. 1077

SET, RADIO TELEGRAPH

TYPE SCR-105

Radio Communication Pamphlet No. 25

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

September, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

WAR DEPARTMENT

Document No. 1077

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WAR DEPARTMENT,
WASHINGTON, *September 17, 1921.*

The following publication, entitled "Set, Radio Telegraph, Type SCR–105," Radio Communication Pamphlet No. 25, 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.

TABLE OF CONTENTS.

SET, RADIO TELEGRAPH, TYPE SCR-105.

GENERAL DESCRIPTION OF SET.

1. The SCR-105 is a transmitting and receiving quenched-spark radio set. It is designed to be used for communication between headquarters which are usually not more than 5 miles apart. It can maintain communication with a like set over a distance of 5 miles. If an amplifier is furnished with the receiving set, this distance is increased to 13 miles. The transmitting wave lengths are fixed at 150, 180, 210, 240, 270, and 300 meters. It can be tuned for the reception of damped waves and audio frequency modulated continuous waves at any wave length between 100 and 550 meters. The set is intended only for intermittent duty and should not be used for continuous sending. The equipment is so packed that the set may be carried by hand when necessary. There are three distinct equipments comprising the set; the power, the antenna, and the operating chest.

DESCRIPTION OF POWER EQUIPMENT.

2. Storage batteries Type BB-23 furnish the power. This battery is a 10-volt lead storage battery of a nonspill type of 20 ampere-hour capacity. There are five cells in individual celluloid jars, all being contained in a wood case with peepholes for showing when the battery acid is at the correct height. The battery complete weighs 26 pounds and is provided with a carrying strap. Its dimensions are 12¼ by 5 by 10 inches high. The three batteries are assigned as follows: One in use with the set; one spare, fully charged, with the set; and one at the charging point. (At the present time, however, only two batteries are being issued; one for use with the set and the other on charge.) A card containing the manufacturer's instructions accompanies each battery. Signal Corps Training Pamphlet No. 8 describes the care and charging of batteries.

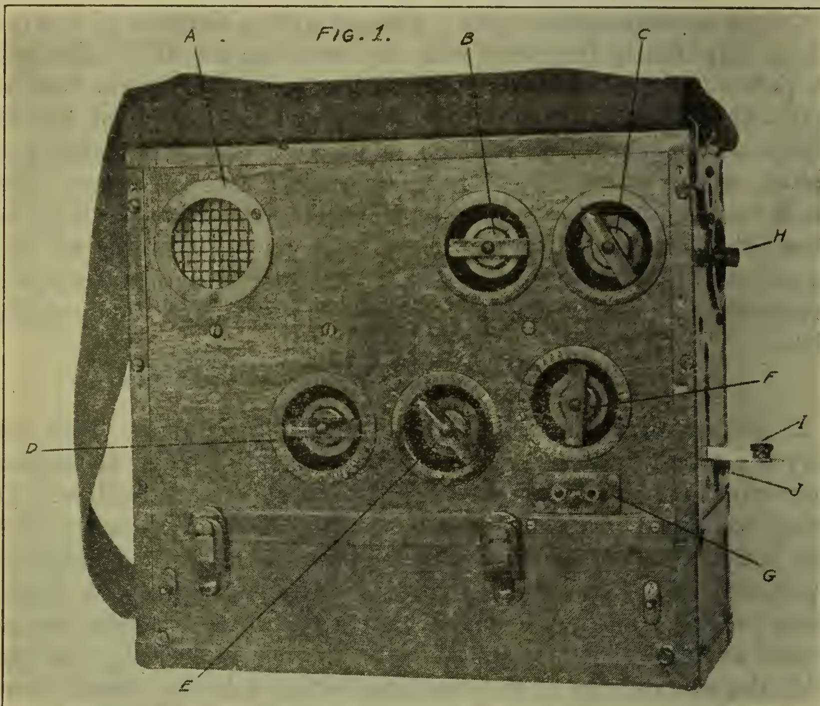
DESCRIPTION OF ANTENNA EQUIPMENT.

3. The antenna is a single wire inverted L 20 feet high, 75 feet long, and with a lead-in wire 25 feet long. It is supported by two bamboo masts, each with two guys. Each mast consists of two sections coupled together. The ground system is either a counterpoise or mats. There are two mats made of coarse copper-wire mesh, each being 9 by 1⅝ feet. The counterpoise consists of two heavily insu-

lated wires each 75 feet long. The essential electrical constants of the antenna are, approximately: Inductance, 0.037 millihenry; capacity, 0.000131 microfarad; fundamental wave length, 130 meters; resistance, 50 ohms.

DESCRIPTION OF OPERATING CHEST.

4. The radio equipment is contained in a chest which is shown in figures 1 and 2. Figure 1 shows the front and end view; figure 2 shows the top and other end. The chest weighs approximately 24



pounds, and has no projections when closed for transportation, and is furnished with a carrying strap. The dimensions are 15½ by 6 by 13 inches high. The chest is divided into two separate compartments. The lower compartment, hinged at the back and fastened at the front, contains the telephone receiver, cords, tools, and spare parts. The upper compartment, which is divided by a shelf, contains the necessary condensers, inductances, switches, etc., of the set. A canvas flap folds down over the front of the case in order to protect it. The top of the box is hinged so as to give ready access to the apparatus which is most liable to need adjustment. All transmitting and receiving adjustments can be made on the outside of the chest, except changing the transmitting wave length.

Transmitter.

5. The transmitter is a 50-watt quenched-spark set with an open type of gap energized from a 10-volt storage battery by a special buzzer transformer. The inductances of the primary and secondary of the oscillation transformer are conductively coupled and are vari-

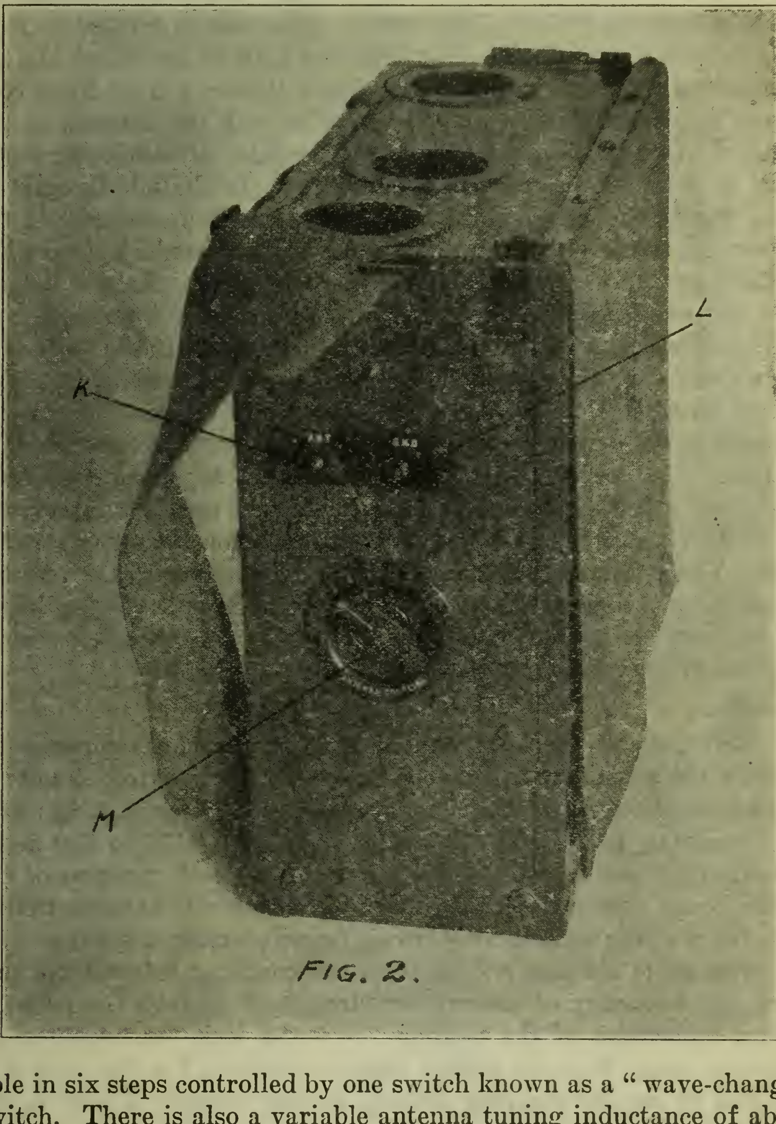


FIG. 2.

able in six steps controlled by one switch known as a "wave-change" switch. There is also a variable antenna tuning inductance of about 11½ turns in the secondary so that it can be exactly adjusted to resonance with the primary. A coupling switch controls the amount of inductance common to both the primary and secondary, and thus allows the coupling to be varied. The minimum coupling is at "1" and the maximum coupling is at "6" on the coupling handle scale. A Weston thermoammeter is in the antenna to ground circuit and indicates the antenna current.

Receiver.

6. The receiver is inductively coupled with variable coupling. It has three overlapping scales of wave length; 100 to 200 meters, 150 to 300 meters, and 275 to 550 meters. One control switch changes both the primary and secondary from one scale to the other. In the shortest scale of wave lengths the switch throws a fixed mica condenser and a variable inductance in series with the antenna in the primary, and at the same time throws a variable air condenser and a small inductance in series in the secondary. In the middle scale of wave lengths the switch throws only the variable inductance in the primary in series with the antenna, and in the secondary throws the variable condenser and more inductance in series. In the longest scale of wave lengths the switch throws the variable inductance and an added inductance in series with the antenna, and in the secondary throws the variable condenser and still more inductance in series. It is to be noted that exact tuning is accomplished by a variable inductance in the primary and by a variable condenser in the secondary circuits. The detector furnished with the set is galena (lead sulphide) but other similar crystal detectors can be used. It is mounted inside the chest, with a control for adjustment on the outside of the chest. The coupling between primary and secondary of the receiver is varied by means of the secondary inductance coil rotating inside the primary inductance coil. Figure 3 shows a schematic wiring diagram of the set.

Circuits.

7. Referring to figures 1 and 2, A is the antenna ammeter; B controls the secondary tuning condenser of the receiving circuit; C is the control switch with contacts providing for transmitting; testing; receiving 100 to 200 meter waves; receiving 150 to 300 meter waves; and receiving 275 to 550 meter waves; each position of the switch being appropriately marked; D controls the antenna tuning inductance of the transmitting circuit by which exact resonance with the primary is obtained; E controls the coupling between the primary and secondary of the receiver circuits; F controls the primary tuning inductance of the receiver; G is the jack for telephone or amplifier plug; H is the crystal detector control; I is the key; J is the jack to receive the plug leading to the battery; K and L are the terminals for the antenna and ground wires respectively; and M controls the coupling between the primary and secondary of the transmitter. Figures 5 and 6 are labeled similarly to figures 1 and 2. Figures 1 and 2 show the control handles; figures 5 and 6 show the actual apparatus.

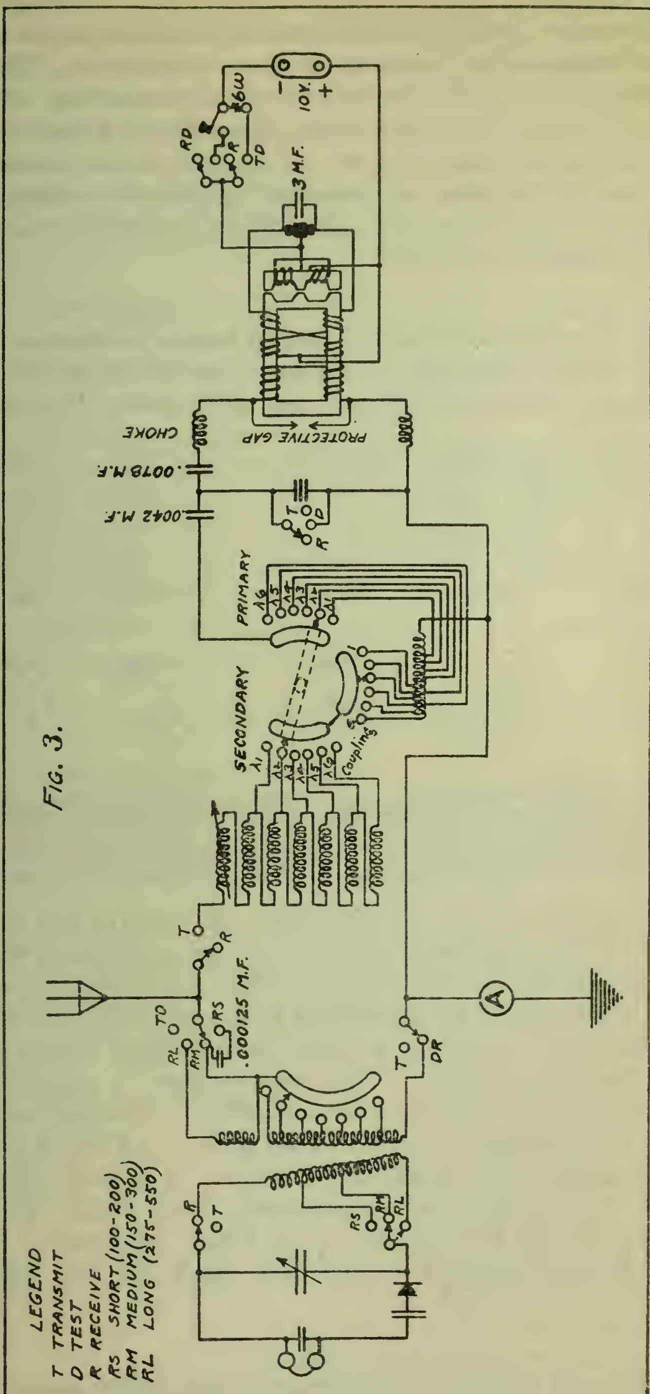

LEGEND
T TRANSMIT
D TEST
R RECEIVE
RS SHORT (100-200)
RM MEDIUM (150-300)
RL LONG (275-550)
.000125 M.F.
SECONDARY
Coupling
PRIMARY
.0042 M.F.
.0078 M.F.
CHOKE
PROTECTIVE GAP
3 M.F.
10 V.

FIG. 3.

Control Switch.

8. The control switch is a multicontact switch which makes connections between silver contacts as shown in figure 4. The arrows in the upper part of the diagram show the connections made when the switch is in the position shown immediately below each part. The legend on the diagram shows the purpose of each contact. The contacts and connections are protected against short-circuit by dirt or occasional drops of rain by a shield of xylonite, a noncombustible material resembling celluloid.

Buzzer.

9. The buzzer transformer is a special buzzer having two primary windings wound so as to give opposite magnetic effects when carrying current. It uses about 5 amperes at 10 volts. By means of a

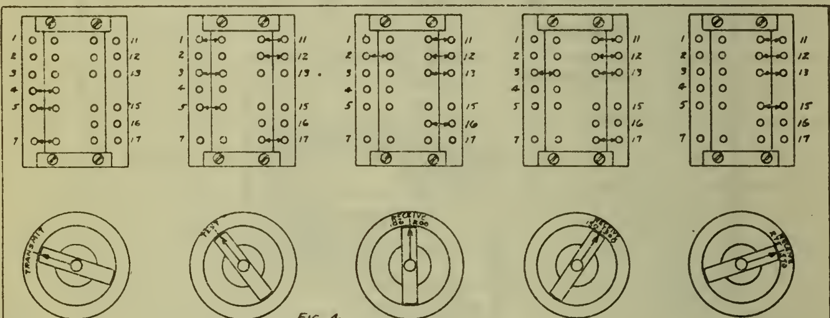


FIG. 4.

CONTACT NO	FUNCTION	CONTACT NO.	FUNCTION
1	SHORT CIRCUITS QUENCHED GAP TO PROTECT OPERATOR	11	CONNECTS GROUND TO RECEIVER PRIMARY (GROUND SIDE)
2	CONNECTS SHORT WAVE SECONDARY TAP TO RECEIVING CONDENSER	12	CONNECTS BEGINNING OF SECONDARY COIL TO RECEIVING CONDENSER
3	CONNECTS MEDIUM WAVE SECONDARY TAP TO RECEIVING CONDENSER	13	CONNECTS LONG WAVE SECONDARY TAP TO RECEIVING CONDENSER
4	CONNECTS BATTERY TO BUZZER THROUGH KEY	15	CONNECTS ANTENNA TO LONG WAVE PRIMARY RECEIVING TAP
5	CONNECTS BATTERY TO BUZZER THROUGH RESISTANCE	16	CONNECTS ANTENNA TO SHORT WAVE PRIMARY RECEIVING TAP
7	CONNECTS ANTENNA TO TRANSMITTING LOADING COILS	17	CONNECTS ANTENNA TO MEDIUM WAVE PRIMARY RECEIVING TAP

vibrator which makes contact first with one primary and then with the other, there is produced in the secondary a maximum voltage in one sense followed by a maximum voltage in the other sense. The vibrator is actuated by the magnetism produced by the primary windings attracting and repelling a double electromagnet having opposite ends of the same polarity. This electromagnet is supported on a spring and has the vibrator arm and contacts attached to it. The vibrator is adjustable by means of set screws and has a frequency of approximately 360 vibrations per second. The peak voltage produced in the secondary is approximately 2,000 volts. There is a safety gap (P, fig. 6) mounted on the buzzer transformer to avoid puncturing the insulation should the spark gap be improperly adjusted.

Key.

10. The key is shunted by a 6-ohm resistance which allows enough current to pass so that the vibrator of the buzzer transformer is

kept in motion in the intervals between dots and dashes. The key contacts are of silver, which has excellent spark-quenching properties. Because of the shunt resistance and the silver contacts, the key breaks the current practically without sparking. The tension of the key spring is adjustable within certain limits. It can be increased by turning the screw just below the bottom of the key in a clockwise direction. It can be decreased by turning the screw in the opposite direction.

Spark Gap.

11. The spark gap has three silver plates separated by mica gaskets or separators 5 mils (0.005 inch) thick and the sparking occurs uniformly around the edges of the plates. The open type of gap is used, as it permits the operator to view the gap in operation and detect any irregularity in the spark or failure of the gaskets, and has the additional advantage that a punctured gasket can be easily replaced in the field. The gap is protected against being accidentally short-circuited by particles of dirt or occasional drops of rain by a shield of xylonite. The plates and separators can be removed after unscrewing the thumb nut. A view of the operating chest with front panel removed is shown in figure 5. A part of the front panel appears at the right.

SETTING UP THE SCR-105.

Antenna and Ground Installation.

12. The 75-foot antenna wire should be stretched out on the ground with the 25-foot lead-in wire in either of two positions, depending upon the use to which the set is to be put: (1) For general use the antenna may lie in any direction and the lead-in may be at either end of the antenna, but (2) for directional work the antenna must be in line with the direction of the distant station with the lead-in nearest that station. The mast sections should be coupled together, using two couplers on each mast, so as to give two masts each with a length over all of 20 feet. Lay one mast at each end of the antenna, along the antenna wire, and with the tops of the masts at the ends of the wire. Screw the mast cap insulators into the masts and attach the antenna insulators and guys to the caps. Drive two ground stakes near each mast, one on each side of the line of the antenna wire, about 10 feet beyond the ends of the antenna and 40 feet apart; and attach the guys to the stakes. Next raise one mast into position, placing the foot of the mast so that the strain from its guys and the rest of the antenna on the ground will keep it nearly upright. Then raise the other mast in a similar way, placing it so that there is sufficient tension on the antenna wire to keep it nearly horizontal. If necessary, straighten up both masts, tighten

the guys, etc. If there is sufficient personnel, both masts can be raised at the same time and the guys tightened immediately after. In raising the antenna, handle the mast in such a way that the stress will be along the mast and not a bending one. For details in raising this antenna and for general information on antennas, see Radio Communication Pamphlet No. 2.

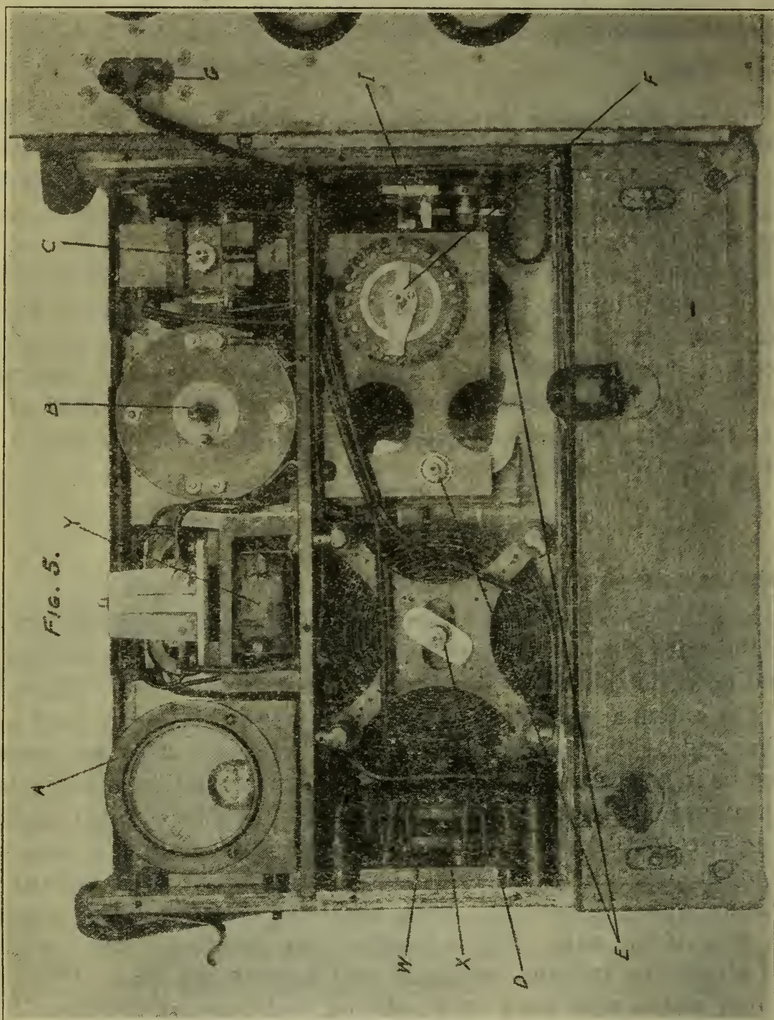


Fig. 5.

13. Whether the ground mats or the counterpoise is to be used depends upon the character of the ground, and the time available for installation. If it is possible to get a good ground, it is preferable to use the mats. The two mats should be connected in series and buried a few inches below the surface of the ground and the covering earth well tramped upon them. If the ground is dry or rocky or if the time available for installation does not permit of making

a good ground with the mats, the counterpoise should be used. When using the counterpoise, the two wires should be spread out at an angle of about 60° in such a manner that the antenna wire, if laid on the ground, would bisect the angle. The two counterpoise wires are connected electrically at the angle made by them.

14. Having decided which ground system to use, for general work (nondirectional) place the operating chest on a dry place underneath the antenna wire and if the ground mats are to be used put them also under the antenna and extend them away from the chest. If the counterpoise is used the angle of the wire should terminate near the operating chest, the wires being extended under the antenna and in the same general direction. For directional work the operating chest is placed outside the masts as far away as the lead-in wire will permit in the direction of the other station. Be sure that the lead-in wire does not touch the mast, as otherwise the antenna may be grounded thereby. The counterpoise is laid as described above, except that the wires should be extended away from the antenna. The mats should be buried beyond the operating chest. If additional counterpoise wires are available, they should be connected in parallel with the others. Similarly if other ground wires or plates are available they should be connected in parallel with the mats and in some cases the ground stakes may be used as additional ground connections. The better the ground connections or the greater the number of the counterpoise wires in general the sharper will be the tuning of both transmitter and receiver.

Necessary Connections.

15. Open the bottom compartment and remove the telephones and battery cords. Connect the antenna lead-in wire to the antenna binding post (K, fig. 2) and connect the mats or counterpoise to the ground binding post (L, fig. 2). Connect the battery cords to the proper terminals of the 10-volt battery and plug it in the battery jack (J, fig. 1), being sure to observe the proper polarity as marked on the jack and plug. Plug the telephone in the telephone jack (G, fig. 1). Pull down the key lever (I, fig. 1) until it snaps into place at right angles to the box. If no amplifier is to be used and the set has been properly adjusted, it is now ready to operate. If an amplifier is to be used, instructions for its use are contained in Radio Communication Pamphlet No. 9.

OPERATION OF THE SET.

To Transmit.

16. Raise the cover of the chest and move the wave-length lever (N, fig. 6) to the wave length desired. The upper edge of the slide *must be just below the white line* which is under the wave-length figure. This position must be exact, as otherwise the movable con-

tact will short-circuit turns on the primary coils (shown at W in fig. 5) and will not give the wave length desired. Set the control switch (C, fig. 1) in the "transmit" position. The buzzer should start vibrating although the key is not depressed, but there will be no spark at the spark gap (O, fig. 6). If the buzzer does not start vibrating, the set is not in adjustment. (See paragraphs 23 to 27, inclusive, on care and adjustment of the set.) Now set the antenna-coupling handle (M, fig. 2) to the maximum coupling for all wave lengths except 150, when it should be set one step lower than the maximum coupling. The coupling control is marked from "1" to "6"; the position at 1 gives the minimum coupling; that at 6 gives the maximum coupling. In setting the coupling be sure that the two index marks form a straight line. The coupling coil is shown at X in figure 5. Press the key and tune with antenna-tuning inductance (D, fig. 1) until the antenna ammeter shows the highest reading. Lower the antenna coupling one step and retune. Do this progressively until you are using the lowest possible antenna coupling that gives sufficient antenna current. The set is now ready for transmission. Under average field conditions the antenna current will be from 0.4 to 0.5 ampere and larger for the shorter wave lengths than for the longer ones.

To Receive.

17. Turn the control switch (C, fig. 1) to the "test" position. In this position a small current keeps the buzzer in vibration so as to serve as a testing buzzer for the detector. Adjust the detector by moving the detector adjustment (H, fig. 1) until a sensitive point has been found and the note of the buzzer is clearly heard in the telephone. In passing from transmitting to receiving, this test should also be made, as any previous adjustment is liable to have become disarranged. If the wave length to be received is known, the approximate setting of the tuning elements in the receiving circuits is shown in the following table:

CONTROL SWITCH SET AT "RECEIVE 150-300."

Wave length.	Ground mat.			Counterpoise.		
	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.
150	13	2	40	13	1	60
180	17	5	80	13	4	35
210	19	5	30	13	6	25
240	16	6	30	19	8	25

CONTROL SWITCH SET AT "RECEIVE 275-550."

Wave length.	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.
300	14	5	40	12	1	25

18. The above table is only approximate and will vary somewhat for each set. A table extending the wave lengths throughout their whole range should be made for each set. The table should be printed on a card and fastened to the inside cover of the operating chest. It saves much time in operating. It must be remembered that the table is only strictly accurate for the exact antenna used in compiling the table.

19. As soon as the signals are picked up, make slight adjustments of the tuning, coupling, detector, etc., until the loudest possible signals are obtained with the loosest possible coupling, that is, with the "receiver coupling" (E, fig. 1) as near the "minimum" as possible. Under these conditions any interference from other wave lengths will be reduced as much as possible with this set. The most important receiver adjustments are the sensitivity of the detector and the tuning of the secondary condenser. In a few cases the same wave length can be received with the "control switch" in two successive positions, near the end of the scale in the first position, and near the beginning of the scale in the second position. This is due to the overlapping of the scales and in many cases one adjustment is much better than the other.

20. If the wave length is unknown, signals may be found by trial somewhat as follows: Set the "control switch" (C, fig. 1) on the "275–550" meter range; the "receiver coupling" (E, fig. 1) at "maximum"; and the "secondary tuning condenser" (B, fig. 1) near the zero end of its scale. Tune with the "primary tuning inductance" (F, fig. 1) over its scale. If signals are not picked up, set the "control switch" on the "150–300" meter range and repeat. If necessary, repeat with the "control switch" on "100–200." When hunting for signals, make sure that the detector is kept in a sensitive condition by occasionally turning the "control switch" handle to the "test" position and then turning it back to its former scale position. As soon as the signals are heard, loosen the coupling, retune both circuits, etc., as stated in the previous paragraph.

Wave Length Measurements.

21. The transmitting and receiving wave lengths can be measured by a wave meter. Reference, Radio Communication No. 28. In measuring the wave lengths of the primary of the transmitter, that is without an antenna and ground connected to the set, the plane of the wave-meter coil should be parallel to the lower left end of the box near the antenna-coupling adjustment in order to couple with the primary coil. In measuring the wave lengths radiated by the set, the wave-meter coil may be brought near the antenna or if necessary parallel to the back of the box immediately behind the antenna-tuning-inductance adjustment in order to couple with the antenna

coils. The receiver wave lengths are measured by the usual methods. In every case, however, the usual precautions of loosely coupling the meter to the set must be observed so as to avoid any appreciable reaction between the two circuits.

Amplifier.

22. When an amplifier is used with the set in receiving, it is connected by a cord to the telephone jacks. The set itself contains a detector and should the amplifier also contain a detector, the latter one should not be used. The BC–101 amplifier, which will be most commonly used with the SCR–105, consists of a vacuum tube detector and a two-stage amplifier. A switch is provided on this amplifier which permits the detector being cut out of the circuit. It should be so cut out when used with the SCR–105 set. Radio Communication Pamphlet No. 9 will contain operating instructions for the BC–101 amplifier.

CARE AND ADJUSTMENT OF THE SET.

23. The operating chest should be kept dry and clean. Do not store it in a damp place, as it is impossible to make a set of this type waterproof. If it has been exposed to the rain it should be carefully wiped off and dried, but not exposed to direct heat. The battery cord is waterproof but the telephone cord is not. If the latter gets wet and short-circuits the telephones use another cord if available and in the meantime carefully dry out the wet cord, which will become operative again. If no other cord is available cut away very carefully the *outer* braid on the cord, making certain that the conductors are not injured and then separate them, thus removing the short-circuit. Do not subject the chest to unnecessary jars or rough treatment. The interior of the chest contains a great many parts packed in a small space and these are subject to derangement. The connection between the parts may also become loose if the chest is roughly handled. The detector crystal is mounted in a small casting of a low melting point alloy, known as Wood's metal. This is held by a screw in a post that is removable for convenience in renewing the crystals. Care must be taken to keep the sensitive surface dry and clean and not to scratch it in any way. The surface is sensitive only when it has been obtained from a *natural* fracture. Crystals should be separately wrapped in a paper wrapping and kept in the small box in the lower compartment. When not in use the key should always be folded into the end of the chest and the detector adjustment knob should always be pushed in flush with its plate.

Telephones.

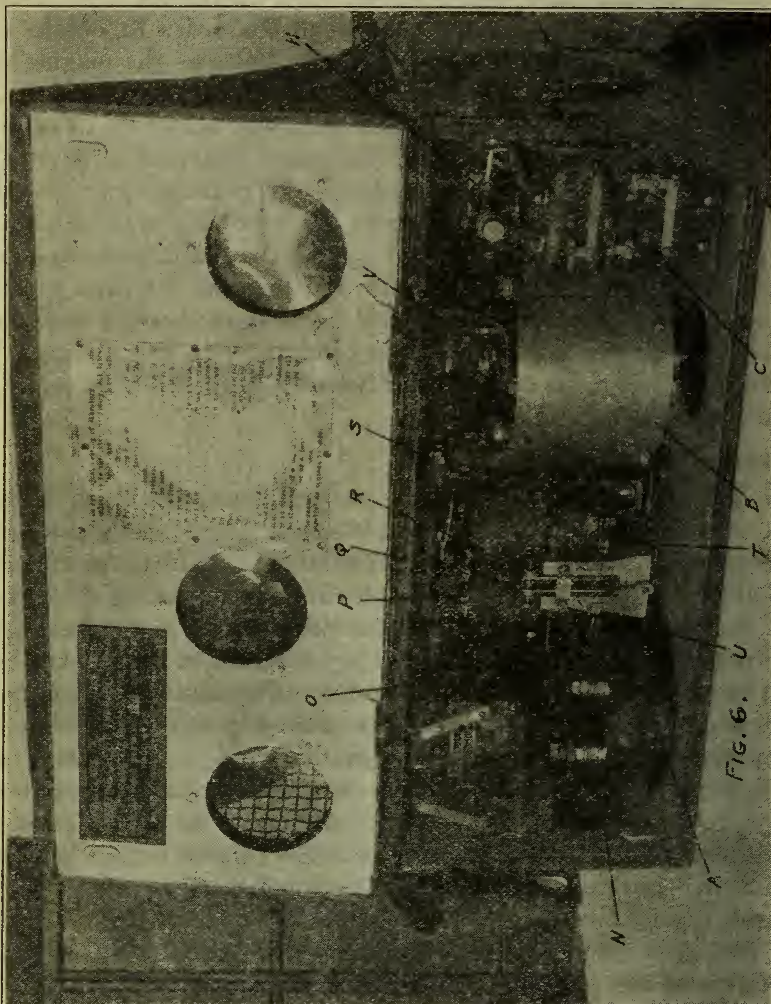
24. The telephone receivers must be carefully handled, special care being taken never to drop them and never to injure the diaphragm. If the latter is bent or dented the diaphragm may touch the pole pieces of the magnet and the magnetic attraction may be so strong that it will be held there, with the result that the telephone is "dead" although otherwise in perfect condition. In order to obtain the correct clearance under the diaphragm the poles of the magnet are ground *after assembly*, this being necessary as the standard parts can not otherwise be assembled with sufficient accuracy. For this reason the telephone should never be taken apart as it is certain that these adjustments will be disturbed. In putting away the telephones into the bottom compartment the following standard practice should be followed in order to protect the diaphragms and terminals: Place the two receivers with the faces of the caps parallel and together so that all access to the diaphragms through the openings in the caps is closed and then bind them in this position by winding the telephone cord around the outside of the headband, beginning close to the caps.

Buzzer Adjustments.

25. The adjustment of the buzzer requires patience and experience. Theoretically it is possible to adjust it so that there is no sparking at the contacts. Actually this is seldom attained, but it can be adjusted so that nearly sparkless operation obtains. In adjusting the buzzer it is well to do it under working conditions, i. e., in the field with the proper antenna and with the battery assigned to the set, but care must be taken not to cause interference to other stations. This interference can be avoided by using the loosest possible coupling between the antenna and primary circuits; that is, by setting the antenna coupling at 1. After the buzzer adjustment has been completed, be sure to return the antenna coupling to its correct position. In adjusting the vibrator, be sure that the control switch is in the "transmit" position, and then if it does not work when the key is pressed, *release the key instantly*, as otherwise the primary winding will be burnt out. With the vibrator working properly, it is the reactance of the primary winding that keeps the current down to its proper value, but with the vibrator stopped there is only a low resistance in circuit that will allow a very heavy direct current to flow. In transmitting, also, if the vibrator sticks, release the key instantly for the same reason.

26. The buzzer should vibrate when the "control switch" is in the "test" and also when it is in the "transmit" position, even when the key is not closed, but there should not be any spark at the spark gap under these conditions. When the key is pressed down the buzzer

should vibrate, and there should be a good spark at the spark gap. If it does not vibrate, do not under any circumstances add higher battery voltage. As shipped from the factory after inspection by the Signal Corps, the buzzer has been adjusted to give this operation. In general it will require very little adjustment when received.



27. Figure 6 is a view looking down into the set, showing the buzzer. The end of the vibrator with its double contacts is shown at Q. This vibrator is between two other fixed contacts symmetrically placed, one of which is labeled "R." The four contact tips are of platinum-iridium, which because of its hardness and the high temperature of its melting point makes the sparking much less than between other metals. The tips should have plane surfaces and be

parallel when contact is made. The play of the moving contacts should be about one one-hundredth of an inch. (The thickness of three sheets of this pamphlet is very nearly one one-hundredth of an inch.) After having been in service for some time, the contacts become roughened and should be cleaned. This is done with a fine file, which is a part of the equipment of the set carried in the lower compartment. The contacts should not be removed, but the locknuts loosened and the contacts unscrewed until the file can be introduced between them. It is seldom necessary to move these locknuts for any other purpose than cleaning. The two screws marked U in Figure 6 are for clamping the two adjustment screws with the black knobs marked S. The latter should never be turned without first loosening U, as otherwise their threads may be stripped. The black knobs are used in adjusting the opening between the fixed contacts, which must be such that the movable contact rests against one of the fixed contacts when no current is flowing, and so that the poles of the movable magnet, which is shown at T, Figure 6, do not hit the poles of the fixed magnet. If they do, the poles are liable to stick together. This condition will also prevent good contact at the vibrator points and will cause considerable sparking there. If a strip of paper can be passed between the poles when the buzzer is operating, the adjustment in this respect is good. If one of the poles hits, this can be remedied by *screwing* in the adjustment knob on the *opposite* side of the buzzer and *unscrewing* the knob on the *same* side until both pole tips are free.

Spark Gap.

28. The spark gap can be taken apart by unscrewing the thumb nut. When the sparking becomes localized at one or two points on the plate, unloosen the thumb nut and rotate each plate slightly on the mounting until the sparking is uniform again. If it is found impossible to get uniform sparking by this method, then the plates must be polished. This should be done by placing them face down on a sheet of fine emery or sand paper on a flat surface and rubbing them over the paper lightly, using a rotating motion. Great care must be taken not to polish only one part of the sparking surface, as this will decrease the thickness of the plate at this point, and hence may so increase the width of the gap that no sparks can pass. The thickness of each plate between its sparking surfaces is uniform to within less than half a thousandth of an inch. After polishing be sure that the particles of emery and metal dust are carefully cleaned off the plates, otherwise the emery may cut and puncture the mica gaskets. Care should be exercised in handling the gaskets in order to avoid cracking them. If a gasket fails replace it with a new one.

Cautions.

29. In handling and adjusting the set:

Don't subject it to rough usage. To do so will damage the instruments therein.

Don't try to adjust the ammeter. It is used to show comparative values of the antenna current and not exact values.

Don't use a closer coupling in transmitting than is absolutely necessary. The radiated wave will be very broad with a close coupling.

Don't connect more than 10 volts to the buzzer. A higher voltage will burn it out.

Don't expect the set to operate if the storage batteries are near discharge. It takes just 10 volts for the buzzer; less than 10 volts will not operate it.

Don't tinker with the buzzer adjustments when once properly adjusted. The buzzer is very easily thrown out of adjustment.

Don't hold the key down continuously for more than 10 seconds, and

Don't transmit continuously with the set, and

Don't fail to release the key instantly if the vibrator sticks. The buzzer will burn out if these three precautions are not observed.

Don't use a gasket in the spark gap thicker than the one provided. The voltage necessary to jump a longer gap will puncture the insulation and the transmitter note will be made rough or irregular.

Don't carry any parts in the upper compartment; use the bottom compartment.

Don't use a different antenna than the one prescribed. The variable inductance in the secondary of the transmitter is not great enough to permit any marked departure from the characteristics of the antenna prescribed.

Don't fail to study your set and to learn the causes of failure and their remedies. Learn also the appearance of the spark and the characteristic sound of the set when it is operating properly.

Don't fail to disconnect the battery when leaving the set for any purpose.

Don't fail to fasten both snap-catches on the bottom compartment when closing station.

THEORY.

Buzzer—Electric and Magnetic Circuits.

30. The buzzer transformer used in this set combines the principles of the induction coil and the resonance transformer. The moving part of the buzzer (the armature) is designed and adjusted to have a period of approximately 360 cycles per second. In order to insure sufficient pressure when contact is made, an electromagnet is used instead of a permanent magnet as it produces a stronger magnetic field.

This electromagnet is wound two ways upon its core from the center of the core, thus giving an electromagnet having both ends of the same polarity, with consequent poles in the middle of the core. This core is of steel and not laminated as the magnetic flux in it is nearly constant. There is a double primary in the transformer, one being wound so as to produce a magnetic flux opposite in direction to that of the other. The current passes through each primary successively as the armature successively makes one contact and then the other. The core of the transformer proper is built up of laminations of silicon steel with three projections, one near either end of the electromagnet and the third one near its consequent poles, which are along the axis of the vibrating system. When a current flows through a primary winding, a magnetic flux is established in the transformer core. Magnetic circuits resulting from the magnetic leakage from the projections pass through either end of the electromagnet and produce a torque on it. The electrical circuits are so connected and wound in the primary coils that the torque, produced by the magnetic flux established by the electric current passing through the circuit made by contact on one side, is such as to move the armature to the other contact. When the other contact is made, the resultant magnetic flux and therefore the resultant torque is changed in direction, thus pulling the armature back to make the first contact. There is only a single secondary winding which however is wound in sections, four on each leg of the core, thereby giving greater protection against high and sudden electromotive forces.

31. As a result of the action described in the previous paragraph, the magnetic flux made by the primary circuits and passing through the core of the transformer is periodically established in one direction, wiped out, and then established, with the same intensity, in the opposite direction. The electromotive force induced in the secondary therefore is symmetrical above and below the zero line. As a result of this symmetrical current induced in the secondary, and the precise and regular vibration of the armature giving regularly the corresponding changes in the induced current, the tone produced by the set in transmission is of good quality.

Vibrator.

32. In order to secure firm contact with a high rate of vibration, the armature was necessarily given a considerable mass, and a short distance of travel from contact to contact (about 0.01 inch). It is mounted on a tempered steel spring, silver plated, to prevent rusting, with an adjustable tension that is set at the time of assembly to give about 360 vibrations per second. The frequency of vibration of the armature is determined not only by the distribution of mass of the moving parts, its distance of travel between contact points, and its

method of suspension, but also by the constants of the electromagnetic circuits which actuate it. In this buzzer transformer, all parts are coordinated so as to give a frequency of approximately 360 vibrations per second.

Application of Resonance Transformer.

33. If no provision were made to diminish the arc resulting from self-induction, made at the breaking of the contacts, the arc would be considerable and would wear out the contact points in a short while, besides greatly reducing the efficiency of the apparatus.

34. To effect the reduction of this arc the primary and the secondary of the transformer are built so that their electrical constants are such as to give them the same natural (audio) frequency which is also the mechanical frequency of the vibrator. Thus the principle of the resonance transformer is used in the buzzer transformer. The design of the transformer involves the consideration of the electric and magnetic properties of each circuit separately, and the reflected value of one circuit as it appears in the other. Thus the capacity of the secondary condenser is reflected into the primary circuit in proportion to the inverse square of the ratio of transformation. With a ratio of primary to secondary of 1 to 175 the secondary series condensers of 0.0027-microfarad capacity appear in the primary increased 30,000 times or as 83 microfarads. The 3-microfarad condenser placed (shown at Y in fig. 5) across the contact points of the primary circuit is used to help establish the proper LC value of the primary. The leakage reactance of the magnetic circuit is an important factor in this consideration, as the magnetic leakage between the primary and secondary and from the projections of the core of the transformer is high.

35. Because of the resonance feature of the transformer the leads from the storage battery to the set box must not vary greatly in electrical length from those furnished with the set. Very long leads that are inclosed within an iron conduit should never be used on account of their high inductance. The leads from the battery are a part of the primary circuit of the transformer and any great change in their electrical length changes the LC value of this circuit and hence will throw it off the proper resonance point. Such conditions as described in this paragraph are, however, rarely met with in field service.

36. The action of the resonance transformer in reducing the arcing at the contact may be explained as follows: The time-voltage curve of electromotive force induced in the secondary lags behind the time-ampere curve of the inducing current in the primary. Thus when the primary current has reached its maximum value (i. e., sufficient to break the contact by its torque action) the electromotive

force in the secondary has not reached a value great enough to break down the quenched spark gap. At the instant the break is made in the primary there is released the energy of a large self-induction in the primary. The rising electromotive force of the secondary is not up to the final value that it attains because of its resonance and therefore keeps on mounting. The energy taken by this rising electromotive force is absorbed from the primary, thereby decreasing at the break the energy that would otherwise appear there and cause sparking. Also the electromotive force of the secondary rises higher because of this absorption of energy at the time of the break. It is the resonance feature of the transformer which causes the secondary electromotive force to rise higher at the primary break than it would do if it were an ordinary induction coil.

37. The condenser across the contacts also absorbs some of the energy of self-inductance. This condenser will then discharge with high frequency oscillation, thus dissipating the energy of the primary circuit and having the usual effect of quenching the arc.

38. The absorption of energy from the primary circuit and the quenching of the arc makes the arc a small one of short duration. When the electromotive force of the secondary reaches a value high enough to break down the quenched spark gap, the arc at the contacts of the buzzer has been extinguished and hence the circuit in the primary is not complete through the contacts and will not absorb appreciable energy from the current flowing in the secondary.

39. The constants of the circuits affecting resonance vary with the frequency of the alternations in the transformer. Thus the transformer works best on 360 cycles. If the current actuating the buzzer is entirely stopped, the buzzer comes to rest. The making of the circuit starts the buzzer which must pass from a zero frequency to the 360 frequency, and therefore the efficiency of the transformer during this time is very low. The transmission of dots and dashes involves many stoppings and startings of the current. Because of this fact, the key is shunted by a resistance of such a value that it

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NOTE.—It may be possible that the 3-microfarad condenser across the contacts of this set is charged by the battery to a higher potential than the battery furnished. A circuit that will oscillate on discharge will also oscillate on charge. The equation for charging a condenser is:

$$e_1 = e\left\{1 - \epsilon^{-\frac{r}{2L}t}\left(\cos\frac{q}{2L}t + \frac{r}{q}\sin\frac{q}{2L}t\right)\right\}$$

when $q = \sqrt{\frac{4L}{C} - r^2}$ and the other symbols are those as commonly used. Thus if the damping factor $\left(\frac{r}{2L}\right)$ is not large, the e_1 value will rise to greater than unity in the quadrants in which $\cos\frac{q}{2L}t$ is negative. The oscillating electromotive force damps down to the electromotive force of the charging battery. Because of the brief time in which contact is made, the circuit may be broken before the oscillating condenser electromotive force has been damped down to its steady value.

allows the passage of a current just of sufficient strength to actuate the buzzer at its proper frequency, but not strong enough to build up an electromotive force in the secondary which will break down the spark gap.

Choke Coils.

40. In order to protect the buzzer secondary windings from puncture by the radio frequency oscillations from the primary oscillating circuit, two heavily insulated choke coils of high inductance (0.35 henry) have been inserted in the leads of the buzzer secondary, one of which is shown at V in figure 6. The protection which such a coil can give by its inductance reactance (2 Π N L) is shown by the following: At a frequency of 1,000,000 cycles per second, corresponding to the 300-meter wave length, the reactance is 2,000,000 ohms. Thus each coil offers such a high impedance to the radio frequency oscillations as to reflect them back into the oscillating circuit and thus protect the buzzer windings. These same coils, however, offer only a slight impedance (800 ohms at 360 cycles) to the low-frequency current from the buzzer secondary that charges the oscillating circuit condenser.

Secondary Condensers.

41. In the schematic wiring diagram (fig. 3) it will be noticed that in the circuit of the buzzer secondary there are two condensers in series, one of 0.0078 microfarad, and the other of 0.0042 microfarad. The resultant capacity is 0.0027 microfarad, which had previously been found necessary for resonance at the buzzer frequency of 360 cycles per second, but too small for the capacity of the primary oscillating circuit. For this reason two larger capacities were used in series, one of 0.0042 microfarad as desired for the primary circuit and the other of 0.0078 microfarad, to give the correct resultant capacity as above. Both condensers are of mica, with sections in series to withstand the high potentials of the buzzer secondary circuit and the primary oscillating circuit, and they are sealed with a suitable wax to exclude the air and moisture.

Reception of Short Wave Lengths.

42. For the best reception of short wave lengths, that is with the control switch in the 100 to 200 position, it has been found necessary to short-circuit the turns needed for long waves. This is accomplished at contact 13 in figure 4 as noted in the legend giving the function of each contact. The purpose of the short circuit is to eliminate the so-called " dead-end " effect in which inactive turns absorb energy from the useful turns which would otherwise operate the detector.

Telephone Circuits.

43. In the schematic wiring diagram (fig. 3) it will be noticed that in the telephone circuit of the tuned secondary receiving circuit there is an extra condenser connected between the detector and telephones. This condenser is necessary however as will be seen from the following circumstances—if by mistake the 10-volt battery plug instead of the telephones is connected to the telephone jack, and if at the same time the detector arm or contact spring makes good connection with the detector post, then the 10-volt battery is applied directly to the windings of the secondary circuit. As a result either the windings will be burnt out or the battery will be run down. By the use however of a comparatively large condenser connected in series both the radio frequency currents and the audio frequency pulsating telephone currents will be permitted to flow freely, but the steady battery current will be completely stopped.

44. The telephones are wound with many turns of fine wire, and hence to a high resistance (2,500 ohms) as is necessary for use with crystal detectors. The windings are protected against high potentials by a small spark gap at their terminals. The *impedance* of the windings at the standard telephone testing frequency of 800 cycles per second, with the diaphragm clamped, is about 10,000 ohms. The *motional* impedance, however, will be different, particularly near the natural frequency of the diaphragm, which is between 700 and 1,000 cycles per second.

Efficiency.

45. The over-all efficiency of the set is about 20 per cent; that is, 20 per cent of the battery output is delivered to the antenna. Thus the battery output is 5 amperes at 10 volts or 50 watts; and the antenna input is 0.45 ampere in a 50-ohm circuit or 10 watts. The efficiency is therefore 20 per cent.

Parts List.

46. The SCR–105 set is complete only when it includes all of the items in the parts list given below. In ordering complete sets it is not necessary to itemize the parts but only to specify "1 set, radio telegraph, Type SCR–105." If all parts listed under a group heading, as "1 equipment, Type RE–12, radio," are desired, it is not necessary to itemize the parts but simply to specify the name of the equipment as given in the parts list. In ordering parts of the set use only the names and type numbers as given below. This list supersedes all others issued prior to the date of this pamphlet (November, 1921).

PARTS LIST OF SCR–105 SET.

[Arranged by equipment.]

1 Equipment, Type PE–11; power:
- 3 batteries Type BB–23—storage, lead; 10 volts, 20 ampere-hours; 1 in use, 2 spare.

1 Equipment, Type RE–12; radio:
- 2 contacts, Type CN–8—buzzer, movable contact; 1 in use, 1 spare.
- 4 contacts, Type CN–9—buzzer, fixed contacts; 2 in use, 2 spare.
- 2 contacts, Type CN–13—control switch, spring with silver contact; pairs with contact Type CN–14; 1 in use, 1 spare.
- 2 contacts, Type CN–14—control switch, bracket with silver contact; pairs with contact Type CN–13; 1 in use, 1 spare.
- 2 contacts, Type CN–15—key, screw with silver contact; pairs with contact Type CN–16; 1 in use, 1 spare.
- 2 contacts, Type CN–16—key, spring with silver contact; pairs with contact Type CN–15; 1 in use, 1 spare.
- 3 contacts, Type M–14—detector, spring contact; 1 in use, 2 spare.
- 1 cord, Type CD–95—10-volt leads, battery to operating chest.
- 1 cord, Type CD–96—amplifier leads from operating chest to amplifier.
- 4 crystals, type DC–1—detector, mounted galena; 1 in use, 3 spare.
- 1 file, 3½ inches, single cut, flat needle.
- 1 head set, Type P–11—used with amplifier.
- 1 head set, Type HS–11—used with operating chest.
- 1 operating chest, Type BC–53–A.
- 1 plier, pair, side cutting, 4-inch.
- 1 screw driver, 1½-inch blade, 1/8-inch tip.
- 6 separators, Type IN–9—mica, for quenched gap; 2 in use, 4 spare.
- 1 wrench, Type TL–100—buzzer contacts.

1 Equipment, Type A–16—antenna:
- 1 bag, Type BG–12—carrying counterpoise, stakes, etc.
- 250 feet cord, sash, 5/32-inch diameter—guy ropes.
- 2 counterpoise, Type CP–5—each 75 feet counterpoise wire.
- 6 couplers, Type FT–2—coupling mast sections; 4 in use, 2 spare.
- 6 fasteners, Type FT–9—for guy rope; 4 in use, 2 spare.
- 1 hammer, 2-pound, 2-face.
- 4 insulators, Type IN–5—for antenna; 2 in use, 2 spare.
- 3 insulators, Type IN–6 or IN–7—mast cap; 2 in use, 1 spare.
- 6 mast sections, Type MS–5—bamboo; 4 in use, 2 spare.
- 2 mats, Type MT–2—ground; connected in series.
- 3 pins, insulator, Type FT–3—for insulators IN–6 or IN–7; 2 in use, 1 spare.
- 1 pliers, pair, 6-inch combination.
- 7 reels, Type RL–3—2 for counterpoise; 1 for antenna; 2 for guys; 1 for spare wire; 1 spare.
- 1 roll, Type M–15—carrying mast sections, mats, etc.
- 6 stakes, Type GP–1 or GP–16—for guy ropes; 4 in use, 2 spare.
- 1 roll tape, friction.
- 250 feet wire, Type W–1—antenna, 75 feet; lead in, 25 feet; 150 feet spare.

1 Radio Communication Pamphlet, No. 25.

○

SIGNAL CORPS PAMPHLETS.

[Corrected to October 1, 1921.]

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

Elementary Principles of Radio Telegraphy and Telephony (edition of Apr. 28, 1921), W. D. D. 1064.
Antenna Systems.
Radio Receiving Sets (SCR-54 and SCR-54-A) and Vacuum Tube Detector Equipment (Type DT-3-A).
Airplane Radio Telegraph Transmitting Sets (Types SCR-65 and 65-A).
Ground Telegraphy or T. P. S. (Types SCR-71; SCR-72; SCR-72-B).
Radio Telegraph Transmitting Sets (Types SCR-74; SCR-74-A).
Airplane Radio Telegraph Transmitting Set (Type SCR-73).
Radio Telegraph Transmitting Set (Type SCR-69).
Sets U. W. Radio Telegraph (Types SCR-79-A and SCR-99).
Listening-in Stations.
Two-Way T. P. S. Set (Type SCR-76-A).
Airplane Radio Telephone Sets (Types SCR-68; SCR-68-A; SCR-114; SCR-116; SCR-59; SCR-59-A; SCR-75; SCR-115).
Theory and Use of Wavemeters (Types SCR-60; SCR-61).
Ground Radio Telephone Sets (Types SCR-67; SCR-67-A).
U. W. Airplane Radio Telegraph Set (Type SCR-80).
Tank Radio Telegraph Set (Type SCR-78-A).
Set, Radio Telegraph (Type SCR-105), W. D. D. No. 1077.
Sets, U. W. Radio Telegraph (Types SCR-127 and SCR-130), W. D. D. No. 1076.
The Radio Mechanic and the Airplane.
The Principles Underlying Radio Communication (edition of May, 1921), W. D. D. No. 1069.

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

The Buzzerphone (Type EE-1).
Monocord Switchboards of Units Type EE-2 and EE-2-A and Monocord Switchboard Operator Set Type EE-64 (W. D. D. No. 1081).
Field Telephones (Types EE-3; EE-4; EE-5).
Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
Trench Line Construction (formerly designated Training Pamphlet No. 6-a).
Signal Corps Universal Test Set Type EE-65 (W. D. D. No. 1020).
Wire Axis Installation and Maintenance Within the Division (W. D. D. No. 10[illegible]).

TRAINING PAMPHLETS.

Elementary Electricity (edition of Jan. 1, 1921), W. D. D. No. 1055.
Visual Signaling.
The Homing Pigeon, Care and Training (W. D. D. No. 1000).
Primary Batteries (formerly designated Radio Pamphlet No. 7).
Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

Directions for Using the 24-CM. Signal Lamp (Type EE-7).
Directions for Using the 14-CM. Signal Lamp (Type EE-6).
Directions for Using the Two-Way T. P. S. Set (Type SCR-76).
Directions for Using Airplane Radio Telegraph Transmitting Set (Type SCR-73).

SETS
UNDAMPED WAVE RADIO TELEGRAPH
TYPES SCR-127 AND SCR-130

Radio Communication Pamphlet No. 26

(SECOND EDITION)

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

January, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

War Department
Document No. 1056
Office of The Adjutant General

WAR DEPARTMENT,
WASHINGTON, *January 21, 1921.*

The following publication, entitled " Sets, Undamped Wave Radio Telegraph, Types SCR–127 and SCR–130," is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
Major General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

TABLE OF CONTENTS.

SETS, UNDAMPED WAVE RADIO TELEGRAPH,

TYPES SCR-127 AND SCR-130.

PURPOSES OF SETS.

These sets are designed to transmit and receive undamped wave radio telegraphy. The SCR–127 set is intended for communication between mounted organizations. The entire equipment is carried on pack animals. The SCR–130 set is intended for communication between organizations equipped with ample motor or wagon transport. The two sets have the same antennæ and set box, but differ in the means provided for transportation and in the source of electric current. They have sufficient power to assure communication between points 60 miles or less distant. Their transmitting wave-length range is from 550 to 1,100 meters; the receiving wave-length range is from 350 to 1,100 meters.

DESCRIPTION OF SETS.

Antennæ equipment.

The antenna equipment consists of a sectional mast, antenna wire, counterpoise wire, guy ropes, and ground stakes. The masts consist of 14 sections, each 4 feet 2 inches long. Including the coupling tube, the sections are 5 feet 2 inches over all. Ten sections are used for the mast itself, three sections for a tent furnished with the set, and one section is a spare. The standard antenna is of the umbrella type with six radiating wires, each 75 feet long, suitably insulated at the open ends and held as nearly horizontal as possible by guy-rope extensions 90 feet long, the outer ends of which are made fast to ground stakes. The standard counterpoise has six radiating insulated wires, each 90 feet long, laid out on the ground under the antenna wires. Both antenna and counterpoise wires are carried on hand reels for convenience in packing and quick reeling and unreeling in setting up and taking down the mast.

Shelter tent.

This tent is similar in dimensions and construction to the standard "common" wall tent issued by the Quartermaster's Department, but is made of lighter material and is not provided with ridge pole or uprights. In erecting the tent the extra sections furnished with the mast should be used as the ridge pole and uprights as follows: One mast section, one plug, and one extension piece for the ridge; and one mast section, one extension piece with spike for each upright. This is shown in figure 3–A.

A device is provided for use in insulating the antenna when the shelter tent is used in damp weather, consisting of a square piece of sheet rubber with small marginal holes for lacing into the ventilator at either end of the tent, and a tube attached to the center for admitting the antenna lead. When in use, a sufficient slack should be left in the antenna lead to form a drip loop outside of the tent, and if found necessary a piece of heavy insulated wire can be used as a leading-in wire.

Set box.

The set box contains the vacuum tubes, condensers, and other parts necessary in a radio set. The front of the box forms a shelf for the key and for writing when the box is open. The box is supported on removable legs. Figure 1 shows the panel with the front of the box lowered to the operating position.

The wave-length variometer is located in the lower right-hand corner of the set box. It is equipped with a pointer and wave-length scale, which is direct reading. The scale is marked at intervals of 25 meters. There is a locking device shown at A′ (fig. 1) which can be used to lock the variometer at any desired setting.

The antenna-tuning variometer is located in the lower left-hand corner of the panel. It is shown at B′ (fig. 1) and its slow-motion knob at C′ (fig. 1). The slow-motion knob which moves the variometer by means of gears may be used for making fine tuning adjustments. This knob may be meshed with the gears at will by pushing it in toward the panel, and released by pulling it out. When the gears are meshed, there is sufficient friction so that the variometer is practically locked in position but may be moved easily by means of the small knob. The antenna variometer and wave-length variometers are located at opposite ends of the box in order to obtain minimum reaction between the two circuits, due to their mutual induction.

The Transmit-Receive switch is located in the center of the panel. It is thrown to the right to transmit, and to the left to receive. The filament circuits are open when the Transmit-Receive switch is open.

The receiving condensers are located in the central portion of the panel (D′ and E′, fig. 1). Both primary and secondary condensers are provided with slow-motion knobs (F′ and G′, fig. 1).

The antenna-coil switch (H′, fig. 1) for changing taps is located directly above the primary antenna circuit condenser. It is a two-position dial switch and the positions are marked " Short wave " and " Long wave." The coil has sufficient inductance when the switch

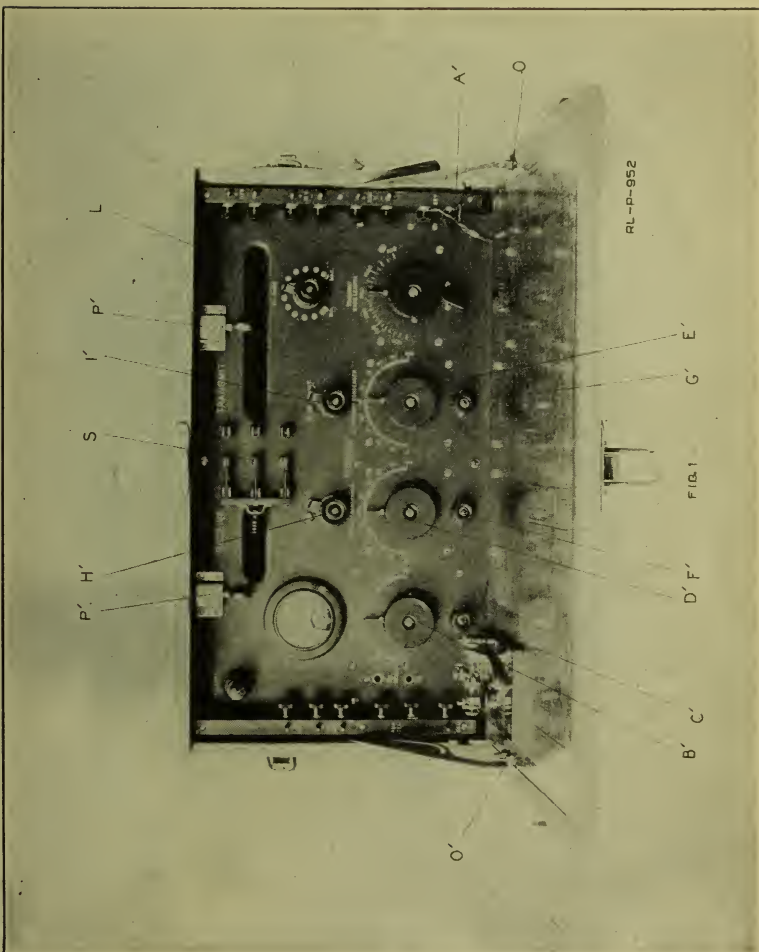


FIG. 1

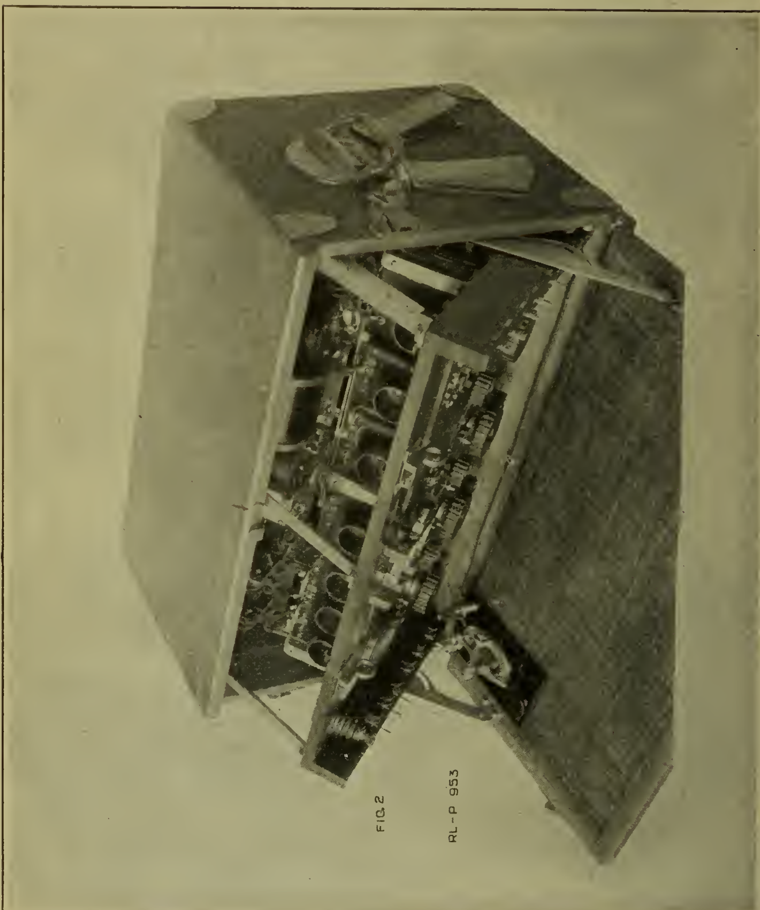


FIG.2
RL-P 953

is in the long-wave position to tune to 1,100 meters on a smaller antenna than the one usually supplied.

The tickler-coil switch is located directly above the secondary condenser (I′, fig. 1). When the switch is in the position marked "SP," the tickler coil is shorted.

The receiving-tubes filament rheostat (L, fig. 1) is provided for compensating for the drop in the filament battery voltage as the batteries become exhausted. It is also useful in regulating the filament current of VT–5 tubes for the best reception. It is only in the circuit when a separate receiving filament battery is used.

The connections to the power equipment for the transmitter are all arranged in a vertical row at the right-hand end of the set box. The two-bottom binding posts marked "Key" are to be connected across the leads of the key. Both pins for plug connectors and binding posts for wire connections are provided for making connections from the set box to either the hand generator and battery box or to a storage battery and dynamotor. The plugs and cords for connecting to the hand generator and battery box or to a storage battery and dynamotor are supplied with the set. The low-voltage side of the hand generator is connected to the 12-volt terminals and the high-voltage side to the 350-volt terminals. When a storage battery and dynamotor are used, the 12-volt battery is connected to the 12-volt terminals and the motor side of the dynamotor to the dynamotor terminals. The generator side is connected to the 350-volt terminals. One blade of the Transmit-Receive switch is arranged to close the battery circuit to the dynamotor when the switch is in the transmitting position.

The power supply for the receiver is connected to the binding posts on the left-hand end of the set box when VT–5 tubes are used. The + fil. battery and —40 volts are common. Cords with plugs are provided for making the connections from the battery box to the set box.

The panel may be pulled forward at the top, as shown in figure 2, for placing tubes in the sockets and manipulating the switches S_3 and S_6 (fig. 8). The panel is held in place by catches at the top of the panel.

All of the apparatus inside the set box is mounted on the panel or on an aluminum frame which is attached to the panel. The entire set may be removed from the box. In order to remove the set from the box the two brackets which support the shelf must be removed from the shelf and the shelf dropped down until the lower edge of the panel will clear the key. To remove the set, first disconnect the leads to the key, then pull the top of the panel forward as shown in figure 2, raise the panel up about one-fourth inch, and pull the entire panel forward.

Power equipment.

The SCR–127 set uses a special hand generator as the source of power for the transmitter and three No. 6 dry cells in series for lighting the filaments of VT–5 tubes in the receiver. The SCR–130 set uses storage battery for lighting the filaments of both transmitting and receiving tubes and to drive a dynamotor for furnishing the plate current to the transmitting tubes. Dry batteries, type BA–8, are used for the 40–volt plate battery on the receiver.

The VT–5 tubes draw about 0.25 of an ampere from the No. 6 dry cells and about 2 milliamperes from the plate battery. The VT–1 tubes (used in SCR–130 set) draw 1.1 amperes from the storage battery and about 2.5 milliamperes from the plate battery.

The filament current required for the four VT–2 tubes in the transmitter is approximately 5.5 amperes. The plate current required by the transmitting tubes is approximately 200 milliamperes at 350 volts.

Hand generator (set SCR–127 only).

The hand generator is a double commutator shunt-wound D. C. generator, which generates 8 volts on the low-voltage side and 350 volts on the high-voltage side when the load is on. The armature is driven through a gear system by two handles, which should be turned at a rate of approximately 35 revolutions per minute. The direction of rotation of the handles must be as shown by the arrow on the top of the gear case.

The voltage is kept constant by means of a vibrating regulator which is mounted under the metal cover on the side of the generator. The regulator will maintain a constant voltage when the handles are turned at any speed between 35 and 60 revolutions per minute. No speed indicator is necessary, because the generator speed can vary through such wide limits without affecting the voltage. The regulator is set for the proper voltage and should not be changed.

The gearing is a combination planetary worm and spur type of high efficiency when in proper alignment. The high-speed shafts have ball bearings and the gears run in grease or oil, so as to reduce the friction as much as possible. The gears should never be taken apart unless absolutely necessary to replace worn or broken parts and then only by an experienced person. The gears and ball bearings must be lubricated by a nonfluid oil, which must be free from acid or water to prevent rusting.

The canvas cover supplied with the generator should be kept on at all times when the generator is not in use.

Dynamotor (set SCR–130 only).

The dynamotor, type DM–1, is a machine which changes a low-voltage direct current to a direct current at high voltage. The low-voltage current is supplied by a 12-volt storage battery. The machine transforms this into a direct current having 350 volts. This type dynamotor is manufactured by Westinghouse. Its normal rate of rotation is 2,550 revolutions per minute. It supplies the power to the transmitting tubes of the set.

SETTING UP AND OPERATION OF SETS.

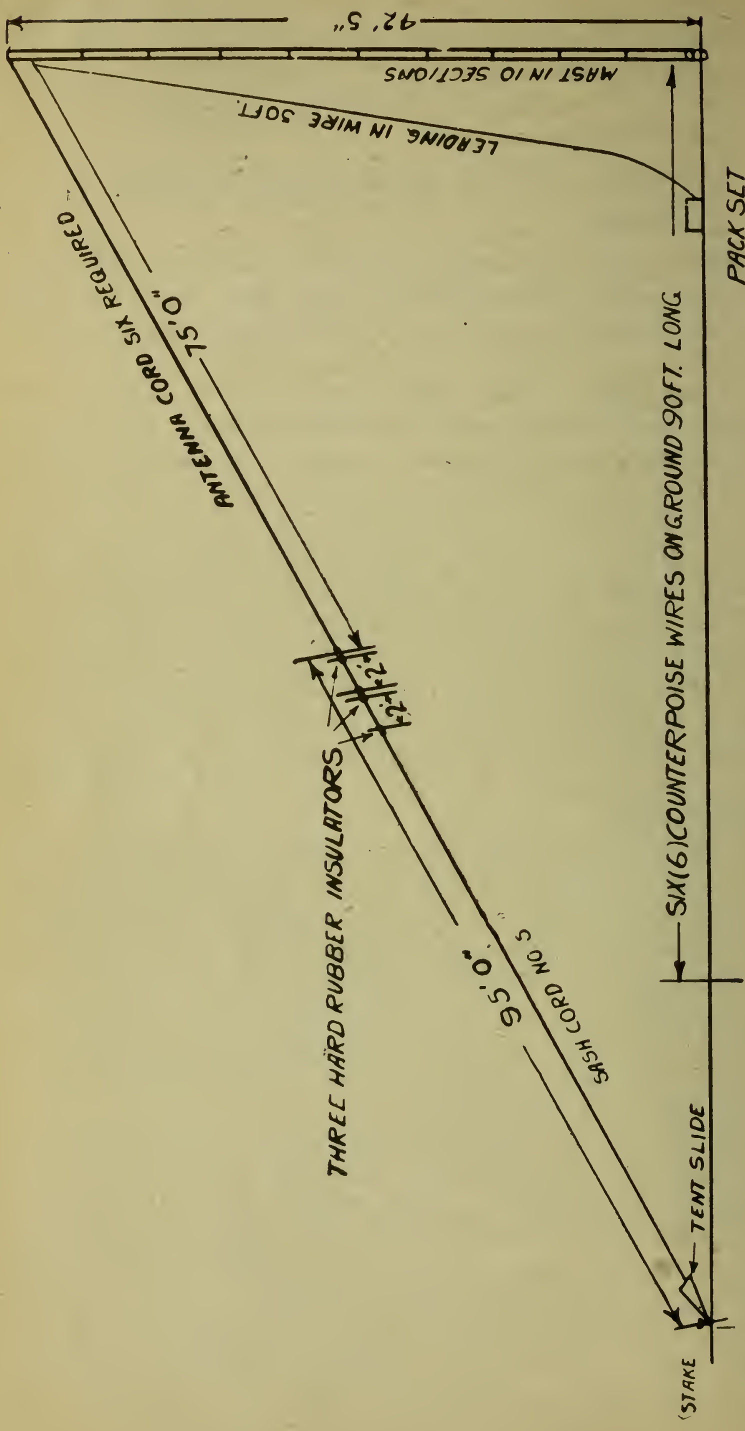
Setting up antenna.

At least five men are needed to erect the antenna. Three men are at the end of the antenna wires and guy ropes, two men raising the mast and adding the sections. The following directions should be observed:

Select clear space in which the antenna is to be erected. This clear space should be at least 225 feet in diameter. Unpack mast and antenna equipment and place in center of the space where the mast is to be erected. Take the top section (the one which has no iron pipe projecting from either end) and place the mast cap in one end of it. (The mast cap has eight sockets, which will hold the metal balls on the end of the antenna wires. It should have the antenna lead-in wire permanently fastened to it.) Attach the six antenna wires to the mast cap by means of the ball and sockets provided. Unreel and lay out on the ground the six antenna wires and the guy ropes fastened to them. The antenna wires are the smaller sized wires. They extend out radially from the mast. They should divide the circle in equal parts—that is, they should make angles of 60° with each other.

Place a man at every other guy rope, at the end of the guy rope. It is the duty of these three men to keep the mast upright as the sections are added. They do this by keeping the correct strain on the guy ropes, walking toward the mast as necessary. Select the eight other sections to be added (all alike) and the bottom section. (This has an insulator screwed on the bottom of it. If it is not screwed on, this should be done before adding the sections to the mast.) The mast will contain, when erected, 10 sections in all, 8 besides the top and bottom sections.

Add the sections, one man raising the mast directly upward and the other man adding the sections. Keep the mast upright, giving any directions that may be necessary to the men at the end of the guy ropes to do this. Having added all the sections, including the bottom one, allow the mast to rest on the ground. The two men at the mast then go out to the end of a guy rope and drive a stake in the ground and by means of the metal tent slide tighten the guy to the proper tension. This is done for each of the six guy ropes. Be careful that the mast is upright and that it is not bent. Make any changes in the strain on the guys necessary to do this.

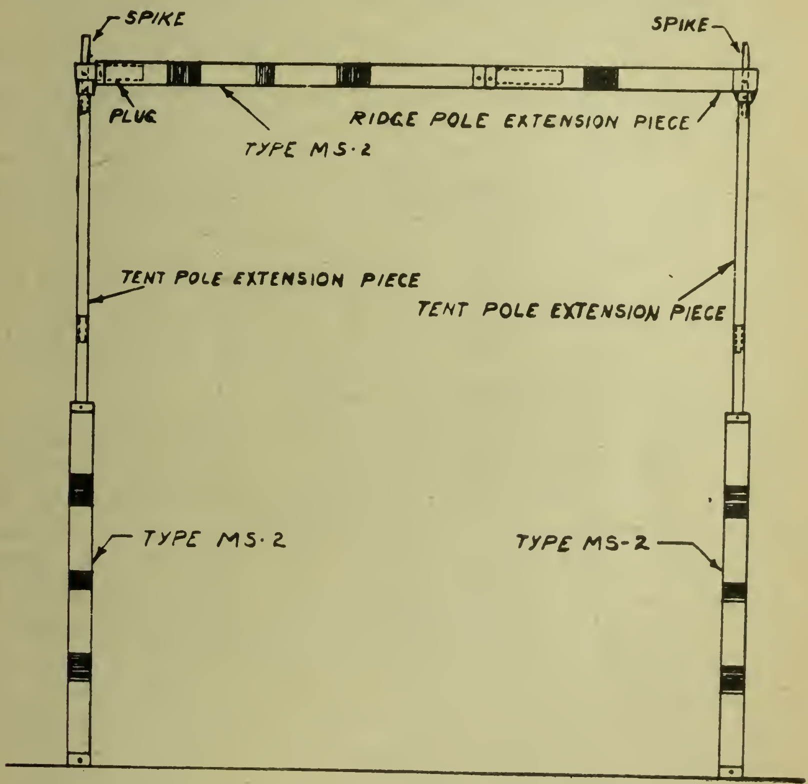


FIG·3

RL-P 1416

It is to be noted that on each guy rope there is an insulator between it and the antenna wire to which it is fastened. The rope is also divided by insulators. It is absolutely necessary that the antenna wires be well insulated. The antenna wires must not touch an object such as a tree, building, etc. The lead-in wire hangs down beside the mast.

Having erected the antenna, place the counterpoise connecting block on the ground near the mast. (This is fitted with holes in which the ends of the counterpoise wire are plugged.) A short wire



RL—P—1417 Fig. 3A.

leading to the set box is attached to it. Reel out the six counterpoise wires to their full extent. They rest on the ground, each directly under an antenna wire. No further insulation is necessary in addition to the insulation on the wire itself. The counterpoise connecting block should be raised off the ground, if necessary, to properly insulate it. Figure 3 shows the antenna properly erected.

Battery box.

The battery box (shown in fig. 4) is divided into 8 compartments, 4 in the front and 4 in the back of the box. The square compartment on the left front contains the terminals for the battery connections. The compartments in the front, covered by a black lid, hold the BA–8 (square) batteries. To connect these batteries observe the following rules: Having removed the lid, take a BA–8 battery and cut off the middle (green) wire as close to battery as possible. Put the battery in the front compartment, sealing wax side to front, and *red* terminal wire *up*. Slip the black terminal wire through the small hole in the end of the compartment near the bottom. Fasten the black terminal wire to the clip or binding post marked "Black (–)." Fasten the red terminal wire to the clip marked "40 V. Red (+)."

Take a second BA–8 battery and having cut off the *green wire* place it in the other compartment alongside the first battery. Put it in with the sealing wax side to the rear and the *black* terminal up. Slip the red terminal wire through the small hole in the end of the compartment near the bottom. Fasten it to clip on binding post marked "Red (+)." Fasten the black terminal wire to the clip marked "40 V. Black (–)."

Place the two spare batteries in the compartment alongside the two batteries in use. Be careful that the wires of the spare batteries do not touch each other. Place the black lid over the compartment.

Dry batteries No. 6 (SCR–127 set only).

These batteries are used only in the SCR–127 set. They belong in the two long compartments in the rear of the box. Only three are in use, the others are spare. To connect these batteries, connect the center terminal of one to the outer terminal of the second and the center terminal of the second to the outer terminal of the third. Now connect a short wire leading from the binding post marked "Zinc (–)" to the outer terminal of the first battery. Connect a wire leading from the binding post marked "Carbon (+)" to the center terminal of the third battery. Place the spare batteries in the compartment alongside those in use. Clamp all the batteries down by means of the sticks provided.

Generator (set SCR–127 only).

Mount the generator on the stand provided and attach the handles. The handles are placed to extend in a straight line one opposite to the other. The machine is turned by two men. The speed should be greater than 35 revolutions per minute and not greater than 60 per minute.

Set box.

Place set box on legs provided for it. Open the front of the box by pulling out after releasing the catches on both sides and top. *Pull the Receiver-Transmit switch directly outward so that it makes*

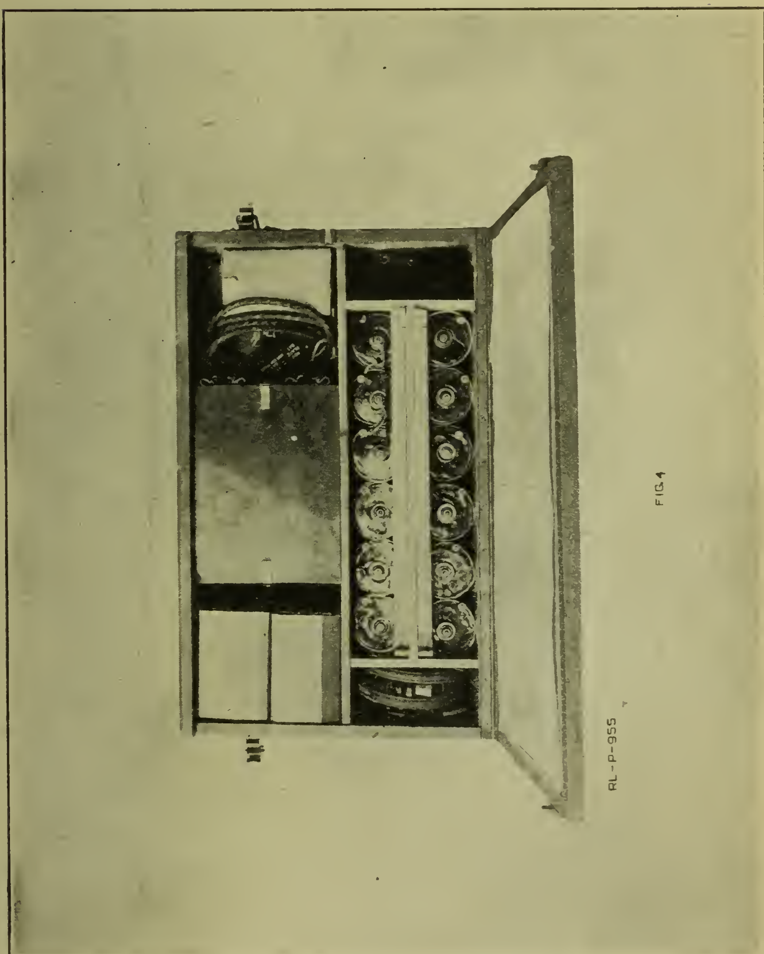


FIG.4
RL-P-955

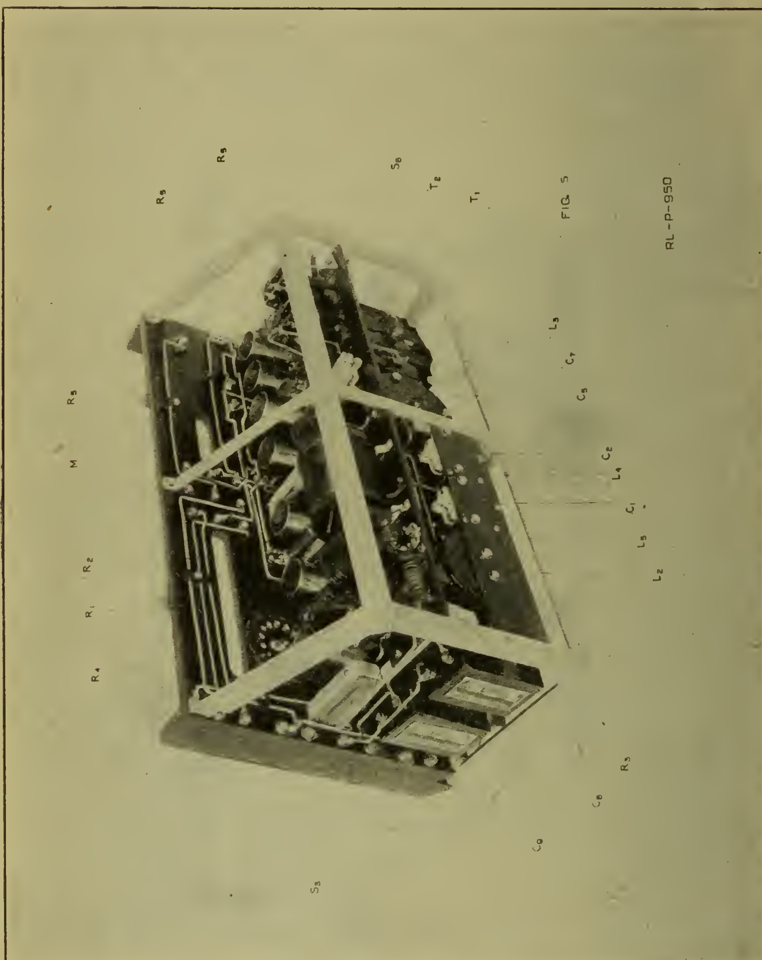


FIG. 5

RL-P-950

neither contact. The panel of the set tilts forward by pulling down and outward two catches mounted on the panel. Tilt it forward and place in each of the four sockets to the right a VT–2 tube. Place in each of the three sockets to the left a VT–5 or VT–3 tube for the SCR–127 set, and a VT–1 tube for the SCR–130 set. Close the panel. Connect the two leads of the key to the two lower right-hand terminals marked " Key." Connect the antenna lead-in wire to the upper left terminal marked "Antenna." Connect the lead-in wire from the counterpoise to the lower left terminal marked " GND." Take care to see that the lead-in wire is not wrapped around or touching the mast or the set box. It may be necessary to move the set box slightly to insure this condition.

Other connection for SCR–127 set.

On the right-hand side of the set box are pairs of plugs marked " Dyn.," " 12 V.," and " 350 V." The Dyn. plugs are not to be used. Take the connecting cord marked " 350 V." and connect the one end to the 350 V. terminals on the set box and the other end to the plug on hand generator marked " 350 V." Take the connecting cord marked " 8 V." on one end and " 12 V." on the other end and connect the end marked " 12 V." to the 12 V. plugs on set. Connect the 8 V. end to the 8 V. plug on the opposite side of generator.

On the left side of the set box are three plugs marked " 40 V. and Fil. Bat." Take the connecting cord marked " 40 V. Plate Bat. and Fil. Bat." and connect it to the plugs. Connect the wire from the + 40 V. plug to the unused part of the binding post in the battery box marked " + 40 V. Red." Connect the wire from the common middle plug of the connecting cord to the unused part of the binding post marked " — 40 V. Black." Take the wire connected to the — Fil. Bat. plug and connect it to the unused part of the binding post marked " Zinc —." The " carbon " binding post and the " — 40 V. Black " binding post in the battery box must be connected by a short length of wire.

Plug in your phones in either of the holes marked " Tel. Rec." Again tilt the panel forward and *close* the small knife switch (fig. 5, S_3) at the rear right-hand corner and throw the double-throw switch (fig. 5, S_6), mounted in the corresponding position on the left, *away* from the operator. (These need never again be changed while using the set as described.) Close the panel and the set is connected ready for operation when the Receive-Transmit switch is thrown to the proper side.

Other connections for SCR–130 set.

On the left-hand side of the set box are three pairs of plugs marked " Dyn.," " 12 V.," and " 350 V." Take the connecting cord marked " 350 V." on one end and having tinned copper terminals on the other end and connect one end to the set box plugs marked "350 V." Connect the tinned copper terminals to the 350-volt (generator) side of the dynamotor. Be sure to connect the positive (+) and negative (—) wires to the correct terminals.

Take the wire marked "Dyn." on one end and having tinned copper terminals on the other and connect one end to the set box plugs marked "Dyn." and connect the other end to the 12-volt (motor) side of the dynamotor. Be sure to connect the positive (+) and negative (—) wires to the correct terminals.

Connect three 4-volt batteries (type BB–14, lead) in series by means of the cords provided. Take the connector cord marked "12 V." on one end and having lead covered copper lugs on the other end, connect one end to the set box plugs marked "12 V." and the lugs to the terminals of the storage batteries.

On the left side of the set box are three plugs marked "40 V." and "Fil. Bat." Take the connecting cord marked "40 V. Plate Bat. and Fil. Bat." and connect it to the plugs. Connect the wire from the + 40 V. plug to the unused part of the binding post in the battery box marked "+ 40 V. Red." Connect the wire from the common middle plug of the connecting cord to the unused part of the binding post marked "— 40 V Black." The other wire is not used, because power for the receiving tube filaments is obtained from the storage battery. Wrap the end with tape so that it will not short circuit or come in contact with the other leads.

Plug in your phones in either of the holes marked "Tel. Rec." Again tilt the panel forward and *open* the small knife switch (fig. 5 S_3) at the rear right-hand corner and throw the double-throw switch (fig. 5 S_6), mounted in the corresponding portion on the left, *toward* the operator. (These need never again be changed while using the set as described.) Close the panel and the set is connected ready for operation when the Receive-Transmit switch is thrown to the proper side.

OPERATING INSTRUCTIONS.

The antenna tuning, the primary condenser, and the secondary condenser are variable. They should be varied when necessary by turning the small knob placed immediately beneath the larger knob. Do not attempt to vary them by turning the large knobs without first pulling outward the small knob below. The Transmit Wave Length is also variable. Throw the locking lever below it to the right before attempting to move it. When on the desired wave length, it is locked by throwing the locking lever to the left.

To transmit.

Set the Transmit Wave Length pointer to the desired wave length and lock it there by throwing the lever beneath it.

Turn the hand generator (SCR–127 set) at a speed of 35 to 60 revolutions per minute. (On the SCR–130 set the dynamotor will start when the switch is thrown.) Throw the Transmit-Receive switch to its transmitting position and note if the four tubes on the right are lighted. Close the key and turn the Antenna Tuning knob back and forth slowly until the greatest reading is obtained on the ammeter mounted on the set marked "Antenna Current." This reading should be greater than 0.7 ampere. It is to be noted that in transmitting, only the Transmit Wave Length and Antenna Tuning knobs are used.

To receive.

Turn the Fil. Rheo. knob all the way over to the left (Min.). Throw the Transmit-Receive switch to the receiving position and turn the Fil. Rheo. knob until the filaments of the three tubes to the left become cherry red. Place telephone receivers on head and test the tubes by throwing the SP–Het. knob from one side to the other. If the tubes are working all right a click should be heard in the receiver. If no click is heard, turn the Fil. Rheo. knob farther to the right and work the SP–Het. knob. Do this until a click is heard in the receiver. This shows that your set is oscillating properly. (Note: Filament rheostat is in circuit in SCR–127 set only.)

If receiving from a similar set, or any undamped wave set, turn the SP–Het. knob to the Het. side and leave it there. If it is desired to receive from station using spark (damped wave), the switch is thrown to the SP side.

If it is desired to receive wave lengths of from 350 to 550 meters, the S. W.–L. W. switch should be placed on S. W. (short waves). To receive wave lengths of from 500 to 1,100 meters, put the S. W.-L. W. switch on the L. W. side.

To tune, vary the primary condenser and the secondary condenser until the signals are heard on the telephone. Turn the knobs *slowly*. Only experience can teach how to get a desired signal. If no results are obtained after trying several minutes, it may be necessary to search the field. To do this, set the primary condenser at 0 and slowly move the secondary condenser through its whole range. Then move the primary condenser to 5 and slowly move the secondary condenser through its whole range. Repeat this until the desired signals are heard.

Hints and suggestions.

If the set fails to work, carefully examine all connections which *you* have made.

Interchange the receiving tubes until you have found the combination that works best. Some work better in one socket than in another. That is, some tubes are better detectors than others. One of the tubes is connected as a detector.

Do not try to take the set apart in any way or attempt to change any of the connections.

In transmitting, if any of the four tubes fail to light it may be due to a bad connection in the socket or a dirty contact pin. Clean the contact pin and replace the tube properly in the socket. If this does not remedy the defect, try a new tube. In exchanging tubes *always* pull the Transmit-Receive switch so that it makes no contact.

In receiving, all three of the tubes will light or none of them will, because their filaments are connected in series. If they fail to light, it is due to a bad tube or poor connection. Examine and clean your connection. If necessary, find by trial the defective tube and replace it.

The instruction contained in figure 6 for the care of the P–11 head set should be carefully observed.

When the SCR–130 set is first installed and no radiation can be secured after the proper connections have been made, the fault may be due to the reversal of the dynamotor polarity. To remedy this, reverse the leads from the dynamotor to the operating chest (set box), i. e., attach + lead to — terminal and — lead to + terminal.

(SCR–127 SET ONLY.)

If none of the transmitting tubes light, then the generator either does not build up or the circuit is open. Test the generator voltage. If the generator does not build up, remove the cover from the regulator and clean the contact on the vibrator carefully with a piece of sandpaper. If the generator still does not build up, connect the dry cells which are used for the receiving tube filament battery to the low-voltage terminals of the generator for an instant. Do not leave the cells connected. It only requires an instant to magnetize the field of the generator so that it will build up. If the trouble is not in the generator, test the voltage on the 12-volt binding posts on the set box. If the voltage is there, then clean the blades of the Transmit-Receive switch. If the tubes still do not light, remove the set from the box and examine the filament circuit for a broken connection.

CARE OF HAND GENERATOR (SCR–127 SET).

The large gear case is packed with grease which should never require renewal during the life of the machine. However, a hole is provided on one side near the top. The old grease can be washed out with gasoline and new grease supplied through this hole. About 1½ pints of grease are required.

At one end of the machine is a gear casing containing two gears, the smaller of which is on the armature shaft. These gears need only

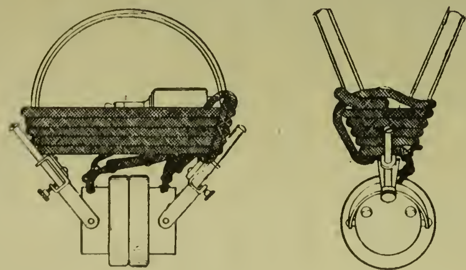
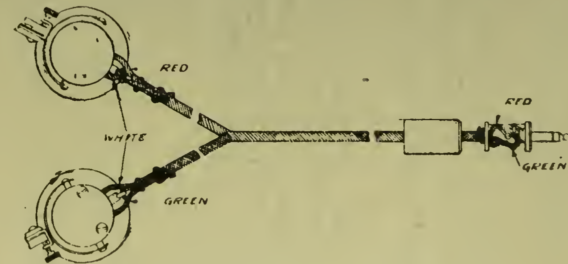


FIG 2



NOTES

AFTER THE TYPE P-11 RECEIVER IS ASSEMBLED, THE POLES OF THE PERMANENT MAGNETS ARE GROUND IN ORDER TO OBTAIN THE PROPER CLEARANCE UNDER THE DIAPHRAGM. THIS GRINDING IS REQUIRED BECAUSE THE STANDARD PARTS USED CANNOT OTHERWISE BE ASSEMBLED WITH SUFFICIENT ACCURACY. IT IS EXTREMELY IMPORTANT THAT THE RECEIVERS SHOULD NEVER BE TAKEN APART

IF IT BECOMES NECESSARY TO REMOVE THE CORD CONNECTIONS FROM EITHER THE TELEPHONES OR THE PLUG, THE WIRES MUST BE REPLACED ACCORDING TO THE COLOR SCHEME SHOWN IN FIG. 1. ALL THE TELEPHONE JACKS ARE CONNECTED WITH THE SPRING POSITIVE WITH RESPECT TO THE SLEEVE, SO THAT WHENEVER THERE IS A CONTINUOUS CURRENT FLOWING THRU THE RECEIVERS, ITS DIRECTION IS SUCH THAT THE FLUX SET UP WILL BE IN THE SAME DIRECTION AS THE FLUX FROM THE PERMANENT MAGNETS. IF THE CORDS ARE REMOVED AND REPLACED IN THE WRONG DIRECTION, THE PERMANENT MAGNETS WILL BE PARTIALLY DEMAGNETIZED, AND THE EFFICIENCY OF THE TELEPHONE RECEIVERS SERIOUSLY IMPAIRED

FIGURE 2 SHOWS THE STANDARD PRACTISE OF WRAPPING TELEPHONE RECEIVERS TO FIT CARRYING COMPARTMENTS. THIS METHOD IS CHOSEN BECAUSE IT PROTECTS BOTH DIAPHRAGMS AND TERMINALS. THIS METHOD SHOULD ALWAYS BE USED WHEN PUTTING AWAY TELEPHONE HEAD SETS.

RL-P-956

FIG. 6

a small amount of grease for lubrication. The ball bearing for the large upper gear and the bearing at each end of the armature is packed in grease, which only need be renewed at long intervals. Access to the bearings can only be obtained by disassembling the lower part of the machine.

The first experimental models of the generator provide no means of access to the brushes and commutators, so the lower part of the machine must be taken apart to get at them. The improved machines to be manufactured in quantity provide plates on the sides of the machines to facilitate getting at the brushes and commutators.

The lower part of the machine can be taken apart most easily by following the directions given below.

(*a*) Unscrew cover of side gear casing, which is fastened by 14 screws.

(*b*) Holding the flywheel stationary, unscrew the nut securing the large upper gear. Draw off this gear and unscrew the large clamping nut under it.

(*c*) Still holding the flywheel stationary, unscrew the nut securing the small lower gear. Draw off this gear and unscrew the large clamping nut under it. The inner half of the gear casing can now be removed.

(*d*) Still holding the flywheel stationary, unscrew the nut securing the flywheel. Then draw off the flywheel.

(*e*) The end plates are removed by unscrewing three screws and then prying off the plates. The armature bearings are in the end plates, so the armature will rest on its field pole pieces when the end plates are removed.

(*f*) If the generator is one of the improved type, the armature can now be withdrawn.

(*g*) If the generator is one of the first experimental models, the entire generator must be withdrawn from the casing. The single screw securing the connection-plug receptacle on each side is removed, the receptacles pulled out and disconnected, and the leads pushed back inside the casing. Three screws on each side of the casing and one on the bottom of the casing are removed. The entire generator can now be drawn out, allowing access to the brushes and commutators. The two long bolts extending through the machine are removed to allow removal of generator end plate if necessary to take out armature.

The generator is reassembled by following the above directions in the reverse order. Great care should be taken that all parts go together in exactly the same relative positions as they were originally.

CARE OF DYNAMOTOR (SCR–130 SET).

The bakelite panel in the dynamotor-carrying box should be kept clean.

Two oil holes are provided on the panel, through which the bearings are lubricated. A light machine oil should be supplied at the rate of a few drops for each hour of continuous operation.

A 20-ampere fuse is connected in the motor circuit. The fuse will blow for any undue load on the generator.

A D. P. S. T. switch affords a convenient method of opening the high-voltage circuit if for any reason it is desired to cut this voltage off from the set box panel.

If the generator fails to build up, it is probably due to a dirty commutator. The commutators of both the motor and generator should be kept clean and smooth by applying fine sandpaper and a piece of absorbent cloth. The commutators require no lubricant.

PRINCIPLES EMBODIED IN THE SETS.

Transmitter.

The transmitter is of the vacuum-tube type, Signal Corps VT–2 tubes being used. One tube is employed as an oscillator and three tubes in parallel are used to amplify the power from the oscillating tube. The characteristics of the power amplifier type of vacuum-tube transmitters are such that this type of circuit is particularly well suited for portable field sets. The adjustments are a minimum, and as the wave length of the oscillating circuit is varied by a single variable inductance, the other constants of the oscillating circuit are fixed, the variable inductance is provided with a pointer and scale reading directly in wave lengths. No wave meter is needed with this set. The antenna is not connected directly in the oscillating circuit or to it, but is connected to the plate circuit of the amplifying tubes by means of a transformer. The grids of the amplifying tubes are connected in parallel and are connected across one of the condensers in the oscillating circuit. The voltage across this condenser is impressed upon the grids of the amplifier tubes, thereby developing a voltage in the plate circuit which causes an alternating current of the same frequency to flow in the plate circuits of the amplifying tubes. The three tubes in parallel permit three times as large a current to flow through the primary of the transformer as could be obtained with one tube. The power supplied to the antenna is also three times as much, in this case, as would be supplied by one tube. The transformer is adjusted so that the effective antenna resistance as reflected in the common plate circuit of the tubes is such as to develop the maximum power output of the tubes. This output is limited by the heat developed at the plates of the tubes. The antenna is tuned with the oscillating plate circuit by means of a single variometer. The antenna circuit does not affect the wave length. The maximum deflection of the pointer on the ammeter is obtained when the antenna is tuned to the wave length of the current in the oscillating circuit.

A simplified diagram is shown in figure 7A; the complete circuit diagram being shown in figure 7. The oscillating circuit which acts as an exciter for the grids of the power amplifier tubes may be considered as an alternating-current generator. The frequency of the alternating current generated is determined by the constants of the oscillating circuit, in the same way as the frequency of an alter-

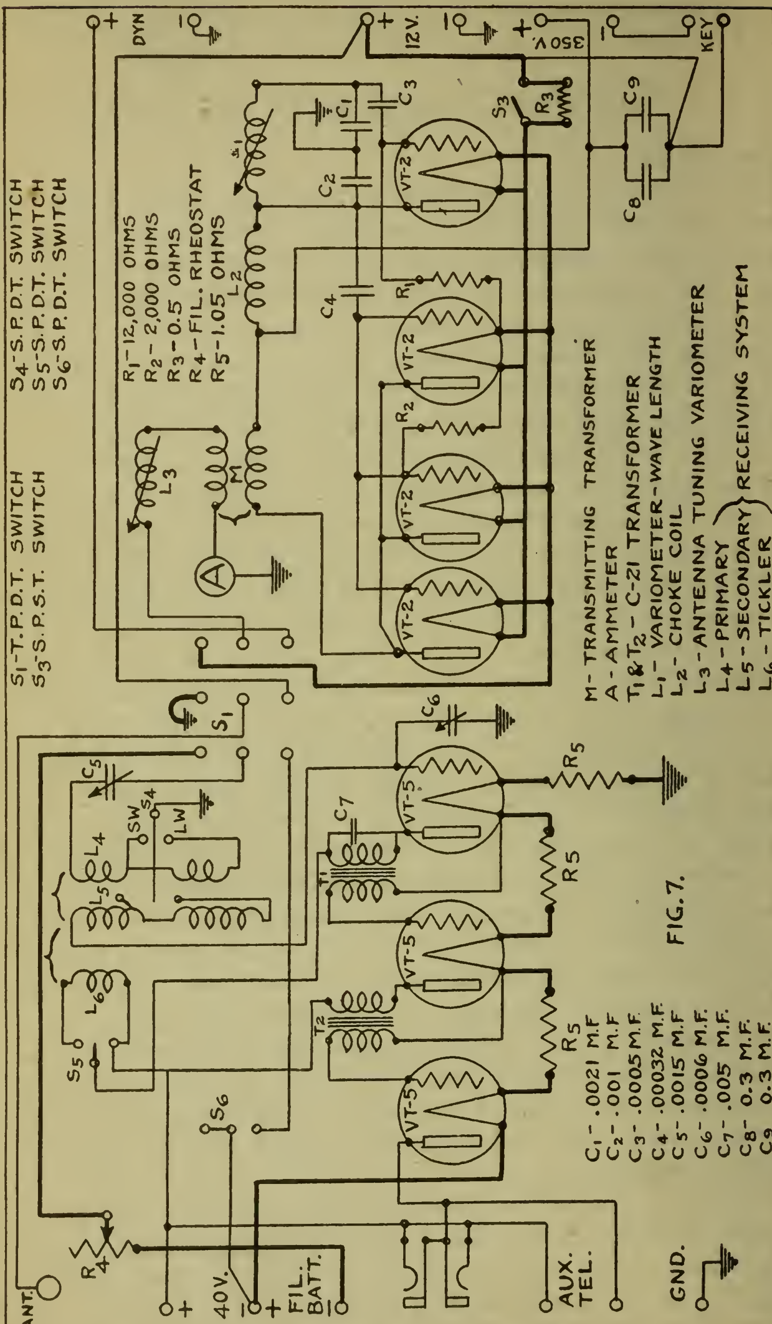

S1 - T.P.D.T. SWITCH
S3 - S.P.S.T. SWITCH
S4 - S.P.D.T. SWITCH
S5 - S.P.D.T. SWITCH
S6 - S.P.D.T. SWITCH
R1 - 12,000 OHMS
R2 - 2,000 OHMS
R3 - 0.5 OHMS
R4 - FIL. RHEOSTAT
R5 - 1.05 OHMS
M - TRANSMITTING TRANSFORMER
A - AMMETER
T1 & T2 - C-21 TRANSFORMER
L1 - VARIOMETER - WAVE LENGTH
L2 - CHOKE COIL
L3 - ANTENNA TUNING VARIOMETER
L4 - PRIMARY
L5 - SECONDARY
L6 - TICKLER
RECEIVING SYSTEM
C1 - .0021 M.F.
C2 - .001 M.F.
C3 - .0005 M.F.
C4 - .00032 M.F.
C5 - .0015 M.F.
C6 - .0006 M.F.
C7 - .005 M.F.
C8 - 0.3 M.F.
C9 0.3 M.F.
DYN
12 V.
350 V.
KEY
ANT.
40 V.
FIL. BATT.
AUX. TEL.
GND.
VT-2
VT-5

FIG. 7.

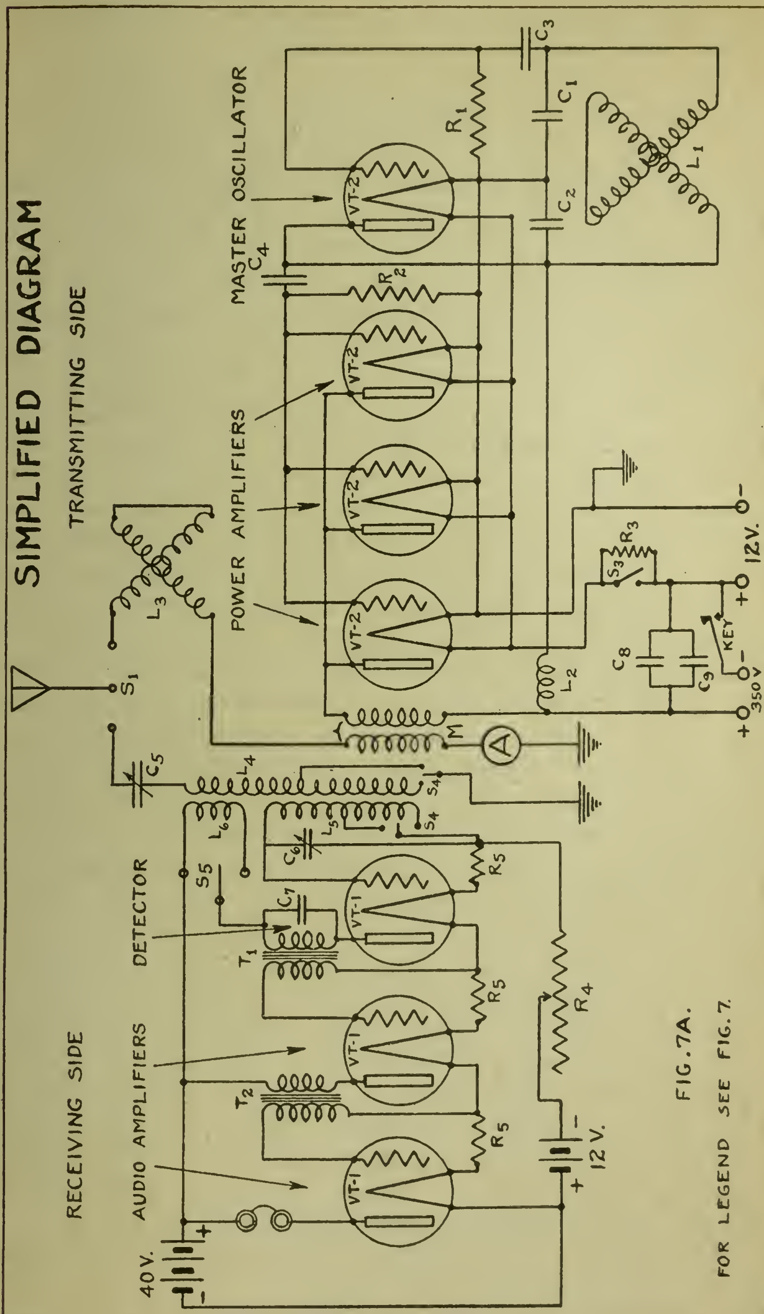


FIG. 7A.

FOR LEGEND SEE FIG. 7.

nator is determined by the number of poles and revolutions per minute of the rotor. The frequency of wave length is determined by the values of the inductance L_1 and the condensers C_1 and C_2 which are in series. The frequency is, approximately:

$$f=\frac{1}{2\pi\sqrt{L\frac{C_1C_2}{C_1+C_2}}}$$

The power necessary to maintain the oscillations in this circuit is furnished by one VT–2 tube. The condenser C_1 is connected between the grid and filament of the tube so that the voltage across the condenser is applied between the grid and filament. This voltage, because of the amplifying power of the tube, causes a greater voltage to act in phase with it across the condenser C_2 than is developed across this condenser by the oscillating current. The oscillating current reaches a value such that the losses due to the resistance of the circuit equal the power supplied by the tube. The power supplied by the oscillating tube to the circuit at high frequency is supplied to the plate circuit of the tube as direct current. The direct current flows from plate to filament and the variations of grid voltage cause variations in the resistance offered by the plate-filament circuit to the flow of this current. The choke coil L_2 maintains this current at a constant value; therefore the variations in the plate current flow through the condenser C_2. The voltage developed across C_2 then acts on the oscillating circuit to cause a current to flow, which is in proper phase to cause a further variation in the voltage applied between the grid and filament. The condenser C_3 serves to prevent the direct-current voltage supplied to the plate from reaching the grid. Since the alternating current passes through the condenser C_3, and since the grid-filament circuit of the tube conducts current in one direction only, a charge will accumulate on the condenser C_3. If no means were provided to rid the condenser of this charge it would soon reach a value which would cause the grid to have such a large negative voltage with respect to the filament that the plate current would be blocked and the tube would cease to operate. The resistance R_1 is provided to take care of this charge and allows it to leak off at a rate which maintains a steady negative voltage on the grid of the proper value to insure efficient operation of the tube. The values of the capacities, inductances, and resistance are shown in figure 7. The variometer L_1 is used to change the wave length of the oscillating current. This variometer has an inductance range of 0.5 m. h. to 0.12 m. h. C_1, C_2, and C_3 are small mica condensers. C_3 is inside the bakelite panel and can not be seen in the picture (fig. 5).

The three VT–2 tubes have their grids connected together and the plates connected together. The filaments are also connected to a common lead which connects to the filament of the oscillator tube.

The alternating current in the plate circuit of the amplifier tubes induces a current in the antenna circuit through the transformer M. The transformer is not tuned on the primary side. There is no variable coupling between the plate circuit of the amplifier and the antenna. The coupling is made as close as possible. The primary of the transformer has a high inductance, so that it acts as a choke coil to limit the plate current of the amplifier tubes when the antenna is detuned. The ratio of the primary turns to secondary turns is determined by the ratio of the antenna resistance to the internal impedance of the tube; this ratio is made suitable for the antenna which is supplied with the set. The grids of the amplifier tubes are connected through the condenser C_4 to the plate of the oscillator tube. Since the filaments of the amplifiers and oscillator are connected to a common lead, the alternating voltage across the condenser C_2 is applied through the condenser C_4 to the grids of the amplifier tubes. C_4 serves to prevent the direct-current voltage to the plate of the oscillator tube from reaching the grids of the amplifier tubes. The grid-filament circuit of the amplifier tubes permits current to flow only on the half of the cycle which makes the grids positive with respect to the filaments, and therefore the condenser C_4 becomes charged so that the grids become negative with respect to the filaments. The resistance R_2 has the correct value to keep the negative potential on the grids at a value which causes the tubes to operate on the part of their characteristic curves where the tubes operate efficiently as amplifiers.

The antenna circuit includes the secondary of the transformer, variometer for tuning, and the radiofrequency ammeter. The variometer L_3 is shown in figures 5 and 8. The inductance range of the variometer is sufficient to take care of variations in the capacity of the antenna which may occur due to soil conditions, etc.

Receiver.

The receiver consists of antenna circuit, tuned secondary circuit, vacuum-tube detector, and two-stage audiofrequency amplifier. A fixed tickler coupling with a short-circuiting switch provides for the reception of either damped or undamped signals. The receiver is designed primarily for the reception of undamped waves, and is designed so that the minimum number of adjustments is necessary for its operation.

The antenna circuit consists of a coil having one tap and a continuously variable air condenser connected in series between the antenna and ground connections. The coil L_4 and the condenser C_5 are shown in figures 5 and 8. The antenna inductance switch is shown at S_4.

The secondary circuit consists of a a coil L_5 and a continuously variable air condenser C_6, connected in parallel between the grid and filament of the detector tube.

Magnetic coupling between the antenna and secondary circuits is obtained by the mutual inductance between the entire secondary and primary coils. The coils are arranged so that the proper degree of coupling may be obtained by rotating the secondary coil longitudinally about the center of its axis. The motion is limited, but is ample for the necessary adjustment. The coupling is carefully adjusted for the best reception on undamped waves over the entire range of wave lengths and fixed so that it can not be changed from the panel. The coupling is not the most efficient for damped waves when adjusted for undamped wave reception, but it is not made variable because the set will be most frequently used on undamped waves and, as stated above, it is desired to make the operation as simple as possible.

The detector tube is made to oscillate by means of a coil L_6 which is connected in its plate circuit and inductively coupled to the secondary receiving coil. The inductive feed back is not variable, but is designed so that the feed back is sufficient to keep a VT–1 or VT–5 tube oscillating. The tickler coil is located inside of the secondary coil. The tickler coil may be short circuited for damped wave reception by means of the switch S_5.

Two stages of audio frequency amplification are provided. The coupling between successive stages is obtained through iron-core transformers. The primary windings of the transformers are connected in series with the plate battery in the plate-filament circuits. The first transformer primary is connected in series with the tickler coil in the plate circuit of the detector tubes. There is a condenser C_7 which serves as a by-pass for the radiofrequency current. The secondaries of the transformers (T_1 and T_2) are connected between the grids and filaments of the amplifier tubes. The two telephone jacks (*j*) are in parallel in the plate circuit of the second amplifier tube. Auxiliary binding posts are connected across the jacks for using receivers without plugs.

Power circuits.

The filaments of the transmitting tubes are in parallel across the 12-volt binding posts. The negative side is closed by one blade of the Transmit-Receive switch S_1. The resistance of 0.5 ohm, R_3, must be shorted by the switch S_3 when using the hand generator, which supplies 8 volts. It must be open when using a 12-volt storage battery. The receiving-tube filaments are in series. Either VT–1 or VT–5 tubes may be used in this set. When the set box is to be used with the SCR–127 Cavalry pack set, VT–5 tubes are used and the filament current is supplied by three No. 6 dry cells in series.

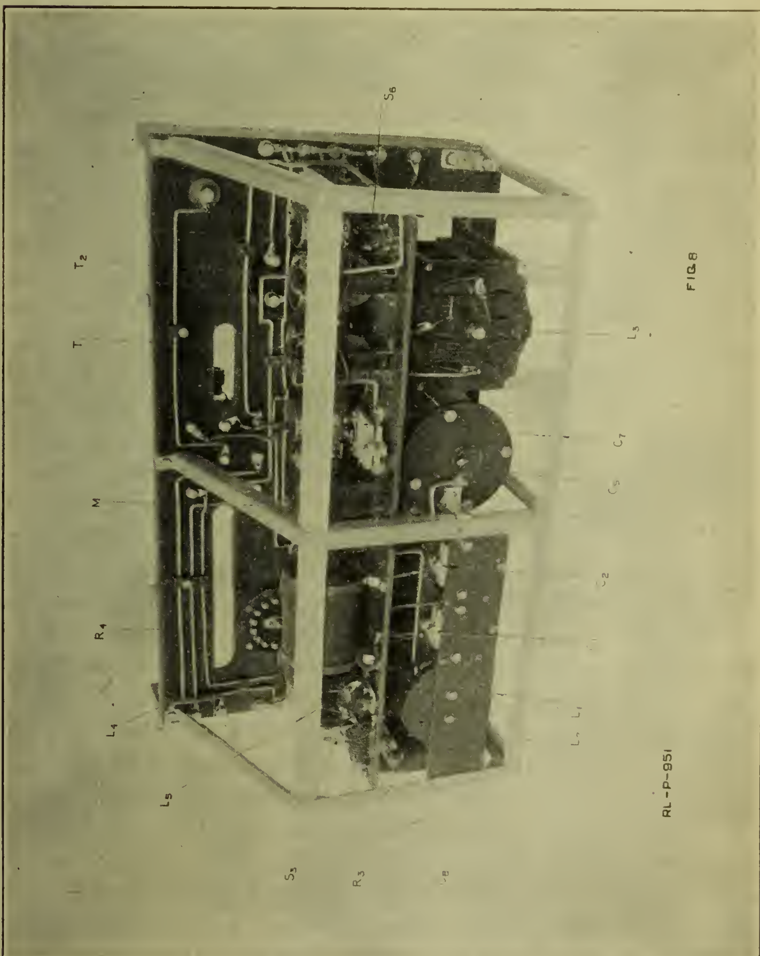


FIG 8

When VT–5 tubes are used the dry cells are connected to the binding posts on the left-hand end of the set box which are marked "+ and — filament battery." The switch S_6 must be thrown away from the panel and pressed firmly in the holding clips in order that it will be held in the open position. The filament rheostat R_4 is in series with the receiving-tube filaments when S_6 is in the open position, as it must be when VT–5 tubes are used. The filament circuit is closed by one blade of the Transmit-Receive switch when the switch is in the receive position. VT–1 tubes are used when the set box is used with the SCR–130 set. The filament current of the VT–1 tubes is supplied from the same battery which supplies power to the transmitting tube filaments and to the dynamotor. The switch S_6 when thrown toward the panel connects the positive end of the receiving-tube-filament circuit to a point on the Transmit-Receive switch so that when that switch is in the receive position the positive of the 12-volt transmitting battery is connected to the positive end of the receiving-tube filaments. The negative end of the receiving-tube-filament circuit is grounded, also the negative side of the transmitting battery. The filament rheostat in the receiving-tube-filament circuit is not in the circuit when S_6 is in the position for supplying the filament current to VT–1 tubes from the transmitting battery. The resistances R_5 serve to produce the necessary biasing voltages for the grids of the receiving tubes.

The Transmit-Receive switch serves to throw the antenna from the transmitter to the receiver, open and close the filament circuits, and to close the circuit from the 12-volt binding posts to the dynamotor binding posts. The secondary receiving circuit is also opened when the switch is thrown to the transmitting position. This is to prevent the receiving circuit from drawing energy out of the transmitting circuit if they should be tuned to the same wave length.

The plate circuits of the four transmitting tubes are in parallel. The plate voltage is applied between the — 350 and + 350 volt binding posts. The — 350 volts is connected through the key to the + 12-volt post. The condensers C_8 and C_9 are connected in parallel and across the key and + 350 volts. These condensers prevent arcing at the contacts of the key and also smooth out the commutator ripples in the plate voltage when the key is closed. The plate circuits of the receiving tubes are all in parallel across the + filament battery, — 40-volt binding post, and the + 40-volt binding post.

TRANSPORTATION SCR-127 SET.

The set is normally packed on three mules. The following is a packing list:

NO. 1 MULE.

1 generator, type GN-29.
2 cranks, type GC-1.
1 stand, type GS-1.
1 hood, type BG-9; for generator.
4 bolts, type M-2; for generator stand.
2 plates, type M-3; for generator stand.
6 mast sections, type MS-2.
1 frame, type M-1.
1 cincha band, type ST-7.
2 straps, type ST-8 (three straps connected to ring).
2 straps, with snap hooks at each end.

NO. 2 MULE.

1 set box BC-7, including following parts:
  4 tubes, type VT-2.
  3 tubes, type VT-5.
  3 adapters, type FT-65.
  1 instruction pamphlet.
4 legs for set box, type BC-7.
1 box, type BC-102, including following parts:
  1 cord, type CD-87; 350-volt leads, generator to set box.
  1 cord, type CD-86; 8-volt leads, generator to set box.
  1 cord, type CD-88; three-conductor, set box to dry batteries.
  5 tubes, type VT-2 (spare).
  6 tubes, type VT-5 (spare).
  1 adapter, type FT-65 (spare).
  4 batteries, type BA-8 (2 spare).
  12 batteries, dry, No. 6 ignition closed-circuit type (9 spare).
  2 head sets, type P-11.
4 mast sections, type MS-2.
1 frame, type M-1.
1 cincha band, type ST-7.
2 straps, type ST-8 (three straps connected to ring).
2 straps, with snap hooks at each end.

NO. 3 MULE.

1 bag, type BG-6, including following parts:
  1 mast cap, type MP-4; complete with 50 feet of antenna lead-in wire.
  1 antenna, type AN-4; six 75-foot lengths antenna cord, complete with insulators and guy ropes.
  1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
  13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
  1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
  2 connectors, type M-6; spares for antenna wires.
  1 insulator, type IN-4; electrose, mast bottom.

1 bag, type BG–6; including following parts:
1 bag, type BG–7, containing—
2 hammers, type HM–1.
6 stakes, type GP–2.
1 tool roll, type BG–10, containing—
1 wrench, 4-inch, single end, $\frac{7}{16}$-inch opening.
1 file, 4-inch, bastard, warding.
1 file, 6-inch, bastard.
1 knife, Empire No. 1013.
1 pliers, round nose, 6-inch, side cutting.
1 pliers, 6-inch, side cutting.
1 handle, file.
1 screw driver, 2-inch blade.
1 screw driver, 4-inch blade.
1 wrench, 9-inch, double end, $\frac{3}{4}$-inch and $1\frac{1}{16}$-inch opening.
1 spool wire, copper, spare.
1 tent, type TN–1, with following parts rolled up inside—
1 insulating device, type IN–13, for tent.
14 stakes, wood, for tent.
2 ropes, tent guys.
1 plug, for tent adapter.
1 voltmeter, type I–10.
2 pounds wire, type W–7.
1 pound tape, friction $\frac{3}{4}$-inch.
1 mast section, type MS–1.
2 mast sections, type MS–2.
1 mast section, type MS–3.
1 ridge pole extension piece, for tent adapter.
2 tent pole extension pieces with spike in end, for tent adapter.
1 frame, type M–1.
1 cincha band, type ST–7.
2 straps, type ST–8 (three straps connected to ring).
2 straps with snap hooks at each end.

PARTS LIST OF SCR–127 SET.

(Arranged by equipment.)

1 equipment, type PE–28; power:
1 generator, type GN–29.
2 cranks, type GC–1.
1 stand, type GS–1.
1 hood, type BG–9; for generator.
4 bolts, type M–2; for generator stand.
2 plates, type M–3; for generator stand.
1 equipment, type RE–21; radio:
1 set box, type BC–7; u. w. radio telegraph.
4 legs for set box, type BC–7.
1 cord, type CD–87; 350-volt leads, generator to set box.
1 cord, type CD–86; 8-volt leads, generator to set box.
1 cord, type CD–88; 3-conductor, set box to dry batteries.
1 box, type BC–102; for batteries and accessories.
9 tubes, type VT–5; 3 in use, 6 spares.
4 adapters, type FT–65; 3 in use, 1 spare.
12 batteries, dry, No. 6 ignition closed-cirucit type, 3 in use, 9 spare.

1 equipement, type RE–21; radio—Continued.
- 4 batteries, type BA–8; 2 in use, 2 spare.
- 9 tubes, type VT–2; 4 in use, 5 spare.
- 2 head sets, type P–11.
- 1 voltmeter, type I–10.
- 1 tool roll, type BG–10.
- 1 wrench, 4-inch, single end, $\frac{7}{16}$-inch opening.
- 1 file, 4-inch, bastard, warding.
- 1 file, 6-inch, bastard.
- 1 knife, Empire No. 1013.
- 1 pliers, round nose, 6-inch, side cutting.
- 1 pliers, 6-inch, side cutting.
- 1 handle, file.
- 1 screw driver, 2-inch blade.
- 1 screw driver, 4-inch blade.
- 1 wrench, 9-inch, double end, $\frac{7}{8}$-inch and $1\frac{1}{16}$-inch opening.
- 1 spool wire, copper, spare.
- 2 pounds wire, type W–7.
- 1 pound tape, friction, $\frac{3}{4}$-inch.

1 equipment, type A–1–A; antenna:
- 1 mast section, type MS–1.
- 12 mast sections, type MS–2; 8 for mast, 3 for tent, 1 spare.
- 1 mast section, type MS–3.
- 1 insulator, type IN–4; electrose.
- 1 mast cap, type MP–4; complete with 50 feet of antenna lead-in wire (Spec. 3055–A).
- 1 antenna, type AN–4; six 75-foot lengths antenna cord, complete, with insulators and guy ropes.
- 1 counterpoise, type CP–3; six 90-foot lengths counterpoise wire.
- 1 cord, type CD–89; set box to counterpoise, block type BL–2 on one end.
- 13 reels type RL–3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
- 6 stakes, type GP–2.
- 2 hammers, engineers, 2 pounds, 2 face.
- 2 bags, type BG–6.
- 1 bag, type BG–7.
- 2 connectors, type M–6; spares for antenna wires
- 1 adapters, set of, for tent, 4 pieces.

3 frames, type M–1.
3 cincha bands, type ST–7.
6 straps, type ST–8 (three straps connected to ring).
6 straps, with snap hooks at each end.
1 equipment, type LE–1; tent:
- 1 tent, type TN–1.
- 14 stakes, wood, for tent.
- 2 ropes, guy, for tent.
- 1 insulating device.

TRANSPORTATION SCR–130 SET.

The following list shows how the material is to be packed for transportation:

9 batteries, type BB–14; lead, storage, 4-volt, 3 in use, 6 spare.
1 case, type BC–25–A, containing 1 dynamotor, type DM–1.

1 set box, type BC–7, including following parts:
  4 tubes, type VT–2.
  3 tubes, type VT–1.
  1 instruction pamphlet.
1 box, type BC–102, including the following parts:
  1 cord, type CD–91; 350-volt leads, dynamotor to set box.
  1 cord, type CD–92; 12-volt leads, dynamotor to set box.
  1 cord, type CD–88; 3-conductor, set box to dry batteries.
  1 cord, type CD–90; 12-volt leads, set box to storage batteries.
  3 cords, type CD-38; connecting storage batteries in series (1 spare).
  4 tubes, type VT-1 (spare).
  5 tubes, type VT-2 (spare).
  4 batteries, type BA-8 (2 spare).
  2 head sets, type P-11.
1 bag, type BG-6, including following parts:
  1 mast cap, type MP-4; complete with 50-foot antenna lead-in wire.
  1 antenna, type AN-4; six 75-foot lengths antenna cord, complete with insulators and guy ropes.
  1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
  13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
  1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
  2 connectors, type M-6; spares for antenna wires.
  1 insulator, type IN-4; electrose, mast bottom.
1 bag, type BG-6, including following parts:
  1 bag, type BG-7, containing:
    2 hammers, type HM-1.
    6 stakes, type GP-2.
  1 tent, type TN-1, with following parts rolled up inside:
    1 insulating device, type IN-13; for tent.
    14 stakes, wood, for tent.
    2 ropes, tent guys.
    1 plug, for tent adapter.
  1 voltmeter, type I-10.
  1 pliers, combination, 6-inch.
  1 screw driver, 2½-inch blade.
  2 pounds wire, type W-7.
  1 pound tape, friction, ¾-inch.
  1 mast section, type MS-1.
  12 mast sections, type MS-2.
  1 mast section, type MS-3.
  1 ridge-pole extension piece, for tent adapter.
  2 tent-pole extension pieces with spike in end for tent adapter.
  4 legs for set box, type BC-7.
  6 straps, type ST-5; for bundling mast sections.

PARTS LIST OF SCR–130 SET.

(Arranged by equipment.)

1 equipment, type PE-7; power:
  9 batteries, type BB-14; lead, storage, 4-volt; approximately 100 ampere-hours at 10-ampere discharge rate; 3 in use, 6 spare.
  1 case, type BC-25-A, carrying, for dynamotor.
  1 dynamotor, type DM-1.

1 equipment, type RE-22; radio:
- 1 set box, type BC-7; u. w. radio telegraph.
- 4 legs for set box, type BC-7.
- 1 cord, type CD-91; 350-volt leads, dynamotor to set box.
- 1 cord, type CD-92; 12-volt leads, set box to dynamotor.
- 1 cord, type CD-90; 12-volt leads, set box to storage battery.
- 1 cord, type CD-88; 3-conductor, set box to dry batteries.
- 3 cords, type CD-38; connecting storage batteries in series, 2 in use, 1 spare.
- 1 box, type BC-102; for batteries and accessories.
- 7 tubes, type VT-1; 3 in use, 4 spare.
- 4 batteries, type BA-8; 2 in use, 2 spare.
- 9 tubes, type VT-2; 4 in use, 5 spare.
- 2 head sets, type P-11.
- 1 voltmeter, type I-10.
- 1 pliers, 6-inch combination.
- 1 screw driver, 2½-inch blade.
- 2 pounds wire, type W-7.
- 1 pound tape, friction, ¾-inch.
- 6 straps, type ST-5; for bundling mast sections.

1 equipment, type A-1-A; antenna:
- 1 mast section, type MS-1.
- 12 mast sections, type MS-2; 8 for mast, 3 for tent, 1 spare.
- 1 mast section, type MS-3.
- 1 insulator, type IN-4; electrose.
- 1 mast cap, type MP-4; complete with 50 feet of antenna lead-in wire.
- 1 antenna, type AN-4; six 75-foot lengths antenna cord complete with insulators and guy ropes.
- 1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
- 1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
- 13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
- 6 stakes, type GP-2.
- 2 hammers, engineers, 2-pound, 2-face.
- 2 bags, type BG-6.
- 1 bag, type BG-7.
- 2 connectors, type M-6; spares for antenna wire.
- 1 adapters, set of, for tent, 4 pieces.

1 equipment, type LE-1; tent:
- 1 tent, type TN-1.
- 14 stakes, wood, for tent.
- 2 ropes, guy, for tent.
- 1 insulating device.

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. 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 (Types SCR–65 and 65–A).

No.

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 November, 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 December, 1921) (W. D. D. 1020).
10. Wire Axis Installation and Maintenance within the Division (W. D. D. 1068).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21 (W. D. D. 1055).
4. Visual Signaling.
5. The Homing Pigeon, Care and Training (W. D .D. 1000).
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).

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SETS, RADIO TELEPHONE AND TELEGRAPH

TYPES SCR-109-A AND SCR-159

Radio Communication Pamphlet No. 27

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

June, 1922

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

WAR DEPARTMENT
Document No. 1111
Office of The Adjutant General

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WAR DEPARTMENT,
Washington, *June 30, 1922.*

The following publication, entitled "Sets, Radio Telephone and Telegraph, Types SCR–109–A and SCR–159," Radio Communication Pamphlet No. 27, is published for the information and guidance of all concerned.

[A. G. 062.1 (6–20–22).]

By order of the Secretary of War:

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

Official:

ROBERT C. DAVIS,
Acting The Adjutant General.

TABLE OF CONTENTS.

SETS, RADIO TELEPHONE AND TELEGRAPH.

(Types SCR–109–A and SCR–159.)

Section I.

PURPOSE OF SETS—RANGES.

1. *Purpose of sets—ranges.*—The SCR–109–A and SCR–159 are ground radio sending and receiving vacuum tube sets providing three means of communication—undamped wave radio telegraphy, buzzer modulated radio telegraphy, and radio telephony. The two sets differ only in the antenna equipment. Their range of transmitting wave lengths is from 300 to 500 meters and receiving wave length from 300 to 1,100 meters. The SCR–109–A set will furnish reliable communication with a similar set over a distance of 60 miles by undamped wave telegraphy; over a distance of 30 miles by buzzer modulated telegraphy; and over a distance of 20 miles by telephony. The SCR–159 set will furnish reliable communication with a similar set over a distance of 80 miles by undamped wave telegraphy; over a distance of 50 miles by buzzer modulated telegraphy; and over a distance of 30 miles by telephony. The minimum output of either set is 34 watts and under favorable circumstances the distances given above may be greatly increased.

Section II.

GENERAL DESCRIPTION OF SETS.

2. *Parts of set.*—Each set is composed of power, radio, and antenna equipment. The power and radio equipment of both sets are alike. The power equipment consists of twelve storage batteries and a dynamotor. The radio equipment is contained in two chests—one carrying both the radio transmitter and the radio receiver, the other carrying the auxiliary radio apparatus and spare parts, as well as the dynamotor. The SCR–109–A set is provided with a V antenna, each leg of which is 175 feet long. The SCR–159 set is provided with a 40-foot umbrella antenna. Appropriate counterpoises are furnished with each antenna.

3. *Transportation—weight and bulk.*—The sets are too heavy to be transported by hand, thus motor or wagon transport must be provided. The chest containing the radio transmitter, which is mounted in one box, and the radio receiver, which is mounted in another box, measures 13 by 35¼ by 17 inches high and weighs 35 pounds empty. This chest may be mounted upon the second chest and fastened to it by means of clamps provided. The second chest measures 13 by 35¼ by 17 inches high and weighs 28 pounds empty. It is provided with three main compartments, the dynamotor being carried in the middle compartment. The boxes containing the radio-transmitting and the radio-receiving apparatus are 9¼ by 16¼ by 14½ inches high and 9½ by 14¾ by 14½ inches high, respectively. Their respective weights are 30 and 25 pounds. The V antenna complete weighs 240 pounds, and has a bulk of 8 cubic feet. The mast sections are each 6 feet 10 inches long. The 40-foot umbrella antenna complete weighs 250 pounds and has a bulk of 12 cubic feet. Its mast sections are each 5 feet long. Each storage battery is 8 by 8 by 11 inches high and weighs 30 pounds. The dynamotor is 8¾ by 10 by 7¼ inches high and weighs 20 pounds. All figures given are approximate.

Section III.

DESCRIPTION OF POWER EQUIPMENT.

(Used in both sets.)

4. *Storage batteries.*—Twelve 4-volt storage batteries, type BB–28, are furnished with each set. These are 90-ampere-hour batteries of the lead acid type. Six batteries are in use at one time to furnish power. These are arranged in two groups in parallel, there being three batteries in series in each group. This arrangement provides a 12-volt, 180-ampere-hour source of power. Type BB–28 storage batteries have a nonspill plug. A compartment is provided in the cover of each battery for spare parts of this plug. For further information concerning storage batteries, see Signal Corps Training Pamphlet No. 8, entitled " Storage Batteries."

5. *Dynamotor.*—A dynamotor is provided for converting the 12-volt direct current furnished by the storage batteries to a 750–800-volt direct current. The motor takes 27 amperes at 12 volts; the output of the generator is approximately 0.2 of an ampere. The generator windings and terminals are well insulated, and all terminals are appropriately marked. The motor terminals are marked "+12 volts—"; the generator terminals are marked "+750 volts—." Lubrication is accomplished through dust-proof oil holes placed at

each end of the shaft. A 2-microfarad condenser, which is shunted across the generator terminals, is located in the base of the dynamotor.

Section IV.

DESCRIPTION OF ANTENNA EQUIPMENT.

6. *The* V *antenna* (*used in the SCR-109-A set*).—This antenna is a V-shaped antenna supported on three masts, each 20 feet high. The length of each leg is 175 feet. There is a lead-in wire 25 feet long. Each mast is made of three spruce sections, which are fitted with a spike at one end and a steel tube at the other to join with the next section. Six hundred feet of heavily insulated counterpoise wire is provided, which should be made in a V-shaped counterpoise with a third leg bisecting the V. The auxiliary antenna equipment comprises spare parts and such carrying rolls, reels, guy ropes, etc., as are needed to support or pack away the antenna. Ground mats, which may be used in place of the counterpoise under favorable conditions, are also a part of the antenna equipment.

7. *The umbrella antenna* (*used in the SCR-159 set*).—The umbrella antenna consists of six antenna wires each 50 feet long spread radially from the top of a 40-foot mast. At the end of each antenna wire there is attached a properly insulated guy rope, 95 feet long, by which the antenna wires are kept stretched out from the mast. The mast is composed of 10 spruce sections, each having a coupling tube to engage the next section. These sections are all alike except the top and bottom sections; the top section is fitted to receive the mast cap, the bottom section carries a heavy insulator on which it rests. The counterpoise system consists of six heavily insulated wires, each 90 feet long, radiating out from a central connecting block. Necessary spare parts and accessories are provided as a part of the antenna equipment.

Section V.

DESCRIPTION OF THE RADIO TRANSMITTER, TYPE BC-86-A.

(Used in both sets.)

8. *Exterior.*—The transmitting apparatus proper is all contained in a wooden box, the front of which is a bakelite panel upon which the various switches, controls, meters, and binding posts are

mounted. Figure 1 shows a view of this panel. At the upper left-hand corner is a milliammeter reading from 0 to 500 milliamperes which measures the plate current of the vacuum tubes used in the transmitter. To the right of this meter is a thermoammeter, reading from 0 to 2.5 amperes, which indicates the antenna current. In the upper right-hand corner is a 28-point dial switch controlling the number of turns of inductance included in the antenna circuit and hence controlling the transmitting wave length. Below this dial switch is a large four-pole double-throw switch marked "Transmit-

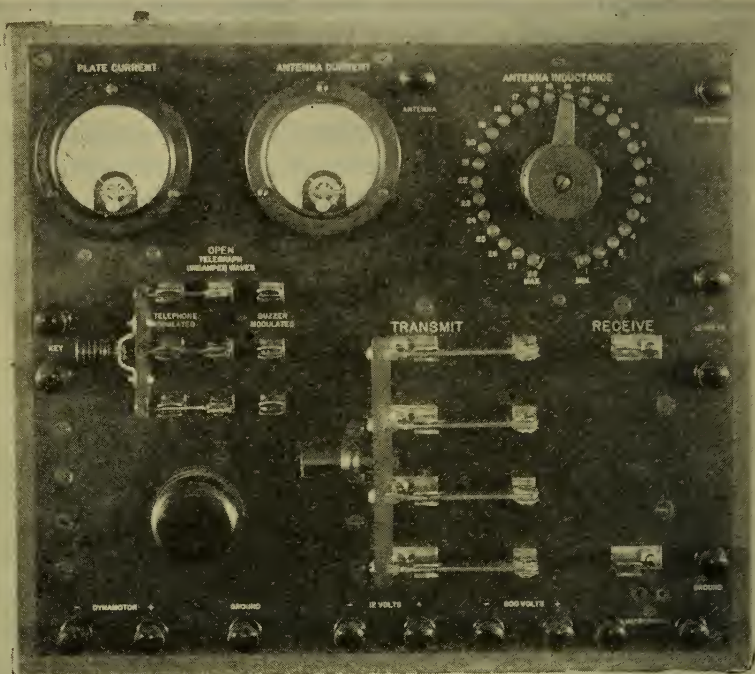

FIG. I.

Receive." When thrown to "Transmit" the upper blade connects the antenna to the transmitting apparatus; the second blade closes the 800-volt plate circuit; the third blade closes the circuit of the 12-volt supply of the dynamotor, thus causing it to start up; the bottom blade closes the filament circuit of the transmitting tubes. When thrown to "Receive," the upper blade connects the antenna to the receiving apparatus (in a separate box) and the lower blade closes the filament circuit of the receiver vacuum tubes.

Beneath the two ammeters is a small three-pole double-throw switch which must be considered as having three positions—closed to the left, closed to the right, and open. This switch is thrown to the left when it is desired to use radio telephony, to the right to use buzzer-modulated telegraphy, and left open for undamped wave telegraphy. Each position of the switch is appropriately marked. The upper blade of the switch connects either the buzzer or the microphone; the middle blade, in either position, closes the filament circuit of the modulator and the speech amplifier vacuum tube; the lower blade when thrown to the "Telephone Modulated" side short-circuits the key. The buzzer used in buzzer-modulated telegraphy is mounted just below the three-pole switch.

There are four binding posts along the right-hand edge of the panel which are to be connected to similarly marked binding posts

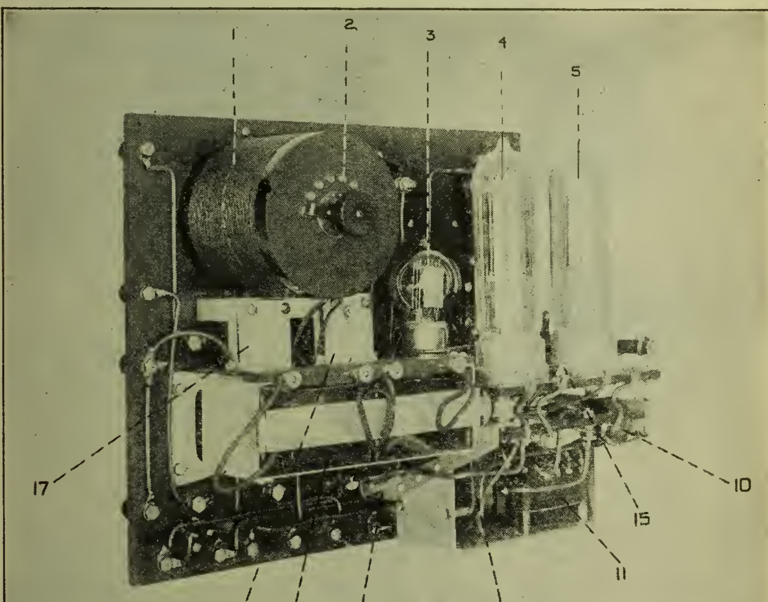

FIG.2.

on the left-hand edge of the receiving apparatus. No cords are provided for these connections. The annunciator wire provided with the set should be used. On the left-hand edge of the panel is a pair of binding posts marked "Key," to which the key is connected by means of the proper cord. (Cord type CD–49.) The lower edge of the panel bears nine binding posts. The left-hand pair marked "—Dynamotor+" are to be connected to the motor (12-volt) side of the dynamotor; the next post marked "Ground" is to be connected to the counterpoise or ground; the next pair marked "—12 volts+" are to be connected to the storage batteries; the next pair marked "—800 volts+" are to be connected to the generator side of the dynamotor. The right-hand pair, marked "Microphone" are to have the microphone transmitter connected to them if it is not provided with the two-terminal plug to fit the jacks mounted directly above the binding posts. A cording diagram is shown in Figure 6.

9. *Interior.*—Access to the interior of the box is gained by removing a part of the back, sides, and top, which are joined together to form a cover and which are fastened to the box by clasps. The equipment inside the box is either directly attached to the rear of the panel or is mounted on brackets attached to the panel. By removing six machine screws, one located at each corner and one at the center of the top and bottom of the panel, the entire apparatus can be re-

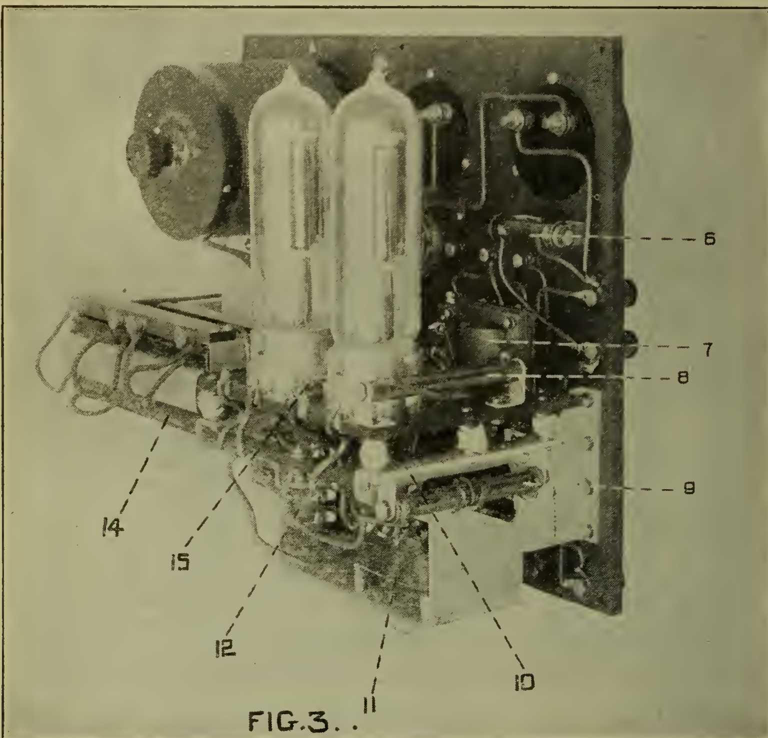

FIG. 3.

moved as a unit from the wood box. Interior views of the box are shown in Figures 2 and 3. The method of mounting of the various parts is clearly shown in the illustration. It is to be noted that the shelf carrying vacuum tubes is mounted on coiled wire spring shock absorbers. The plate-coupling control handle is placed on the inside of the box as shown at 2, Figure 2. In Figures 2 and 3 the numbers show apparatus as follows:

1. Oscillating circuit—inductance coil.
2. Variable inductance switch for plate coupling.
3. VT–2 speech amplifier tube.
4. VT–4 oscillator tube.
5. VT–4 modulator tube.

6. 5,000-ohm resistance across key.

7. Transformer (type C–51), secondary in grid circuit VT–2 speech amplifier, primary in microphone circuit.

8. 10,000-ohm resistance in series with plate circuit of VT–2 speech amplifier.

9. 10,000-ohm resistance, leak resistance for grid circuit of VT–4 oscillator tube.

10. Radio-frequency choke coil (type C–25) in series with leak resistance of grid circuit of VT–4 oscillator tube.

11. Transformer (type C–50) coupling plate circuit of VT–2 speech amplifier with grid circuit of VT–4 modulator tube.

12. Transformer (type C–50) coupling plate circuit of VT–4 modulator tube with plate circuit of VT–4 oscillator tube.

13. Radio-frequency choke coil (type C–25) in series with circuit supplying plate current to VT–4 oscillator tube.

14. BA–2 batteries used to supply negative grid biasing potential for VT–2 speech amplifier and VT–4 modulator tubes.

15. 0.2-megohm resistance (type RS–48) across secondary of transformers in grid circuit of VT–2 speech amplifier.

16. 1,500-mmf. condenser (type CA–93) used to block the high-voltage direct current on the plate of the VT–4 oscillator tube from reaching the grid.

17. 1,775-mmf. condenser (type CA–81) oscillating current condenser connected between the grid and the filament of the VT–4 oscillating tube.

Section VI.

DESCRIPTION OF THE RADIO RECEIVER, TYPE BC–98–A.

(Used in both sets.)

10. *Exterior.*—The receiving apparatus, consisting of a detector tube followed by two stages of audio-frequency amplification, is mounted in a wooden box having a bakelite panel for a front. This bakelite panel carries control handles and binding posts. A view of the front of the box is shown in Figure 4. Along the left-hand edge are four binding posts which are to be connected by annunciator or other suitable wire to similarly marked binding posts on the radio transmitter. Two binding posts on the upper right edge marked "+volts Aux. Plate Battery—" are provided in case it is necessary to use an external plate battery instead of the one that fits in the compartment provided in the interior. There are two binding posts marked "Aux. Tel." to which telephones may be attached if they are not provided with a plug to fit the jack located above the binding post. There are two such jacks, one for each headset provided with the set.

Control handles for the coupling between primary and secondary and for the tickler coil are located in the upper left hand part of the panel. The tickler control handle is in front of and concentric with the coupling control handle. Each has its properly marked scale. The tickler, secondary, and primary inductance coils are mounted one within the other in the order named. Changing the coupling between the primary and secondary coils does not change the coupling between the secondary and the tickler coil.

Below the coupling control handle is mounted a three-point switch that controls the number of turns of the primary inductance coil in circuit. Below this is the control handle for the primary variable air condenser.

FIG. 4.

An eight-day clock of the automobile type is located in the upper right hand part of the panel. Below this are two switches; the one to the left, a two-point switch, controls the number of turns of the secondary inductance in circuit; the one to the right, a six-point switch, controls the amount of amplification. Below these switches is the control handle of the secondary variable air condenser.

11. *Interior.*—Access to the interior of the box is gained by removing part of the top, back, and sides which are joined to make a cover. This is fastened to the rest of the box by clasps. The method of mounting the equipment is very similar to that used in the radio

transmitter. A view of the interior is shown in Figure 5. The tubes are mounted upon a shelf which is supported by shock-absorbing springs. The two air condensers are shielded to avoid outside objects affecting their capacity. A spare grid leak resistance is fastened by spring clips to the inside of the cover. The reference numbers in the illustration refer to apparatus as follows:

1. Amplifying tubes (type VT–1).
2. Detector tube (type VT–1).

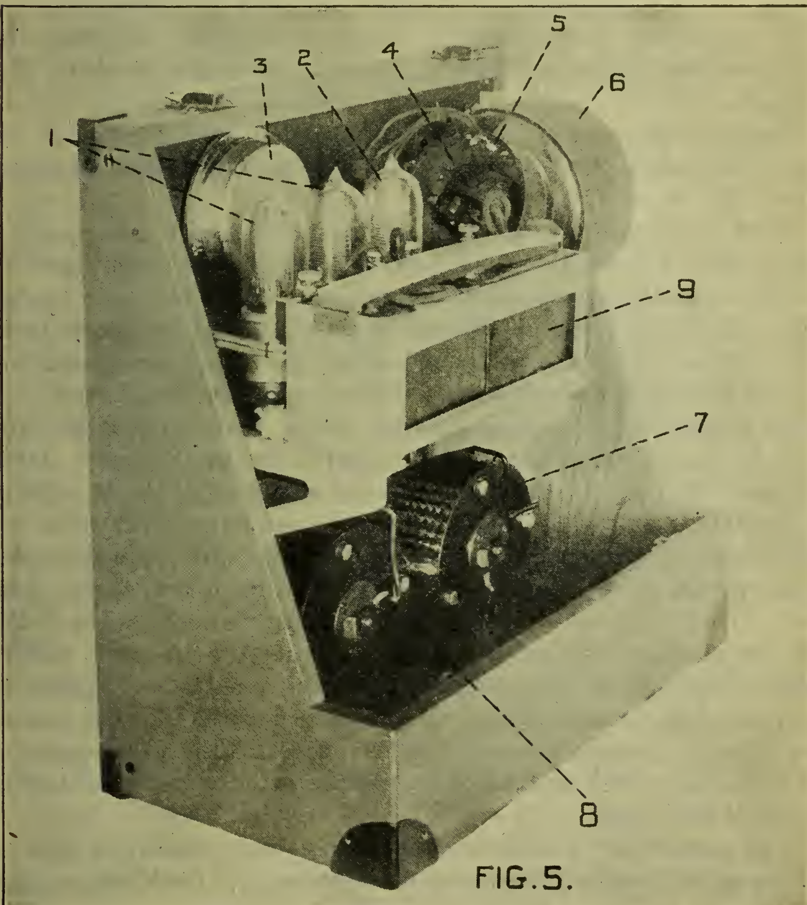

FIG. 5.

3. Eight-day automobile clock.
4. Tickler coil, coupled with secondary inductance.
5. Secondary inductance, coupled with primary inductance and with tickler coil.
6. Primary inductance, coupled with secondary inductance.
7. Primary variable air condenser (20 to 750 mmf.).
8. Secondary variable air condenser (20 to 750 mmf.).
9. Plate batteries (two type BA–2).

Section VII.

INSTALLING THE SETS.

12. *Erecting the antenna and ground system of the SCR–109–A set.*—The V antenna is used. This antenna can be installed for either of two purposes: (1) General use and (2) directional use. For the former the orientation of the wire is not important, but for the latter the point of the V should be directed toward the other station.

Measure the antenna wires to insure that each leg is 175 feet long and that the lead-in wire is 25 feet long. Correct any departure from this standard length.

Stretch out the antenna wires on the ground with an opening of about 60°. Couple three mast sections together for each mast and lay them on the ground alongside the wire and in the same straight line with it. Attach the antenna wires with their insulators to the tops of the three masts by means of the snap hooks and also attach two guys to each mast. Drive two ground stakes near each mast about 20 feet beyond the end of the wire, so that the guys will lie at an angle of about 45° with the line of the wire. Attach the lead-in wire to the antenna wires at the front of the V. Having raised the mast at the point of the V, raise the other mast tops gradually by using a light strain on the guys and, keeping the bottom ends of the masts on the ground, move them toward the points where they are to be when the mast is in the vertical position. Pass the guys around the ground stakes and take up the slack with the tent slides. If necessary, straighten up the masts and tighten the guys so that the antenna wires are nearly horizontal. Care should be taken in raising the masts to keep them in the prolongation of the antenna wires, as then there will be little or no stress tending to bend the masts.

For general use the three counterpoise wires should be laid out on the ground under the antenna with the point of the V-like arrangement near the radio transmitter. The counterpoise wires, each of which should be made 175 feet long, are arranged in a V with the third wire bisecting the angle made by the two legs of the V. For directional use the three wires should be laid out in the V-like arrangement with the point near the radio transmitter as before and with the free ends opening out toward the other station. The legs of the counterpoise are connected together electrically at the point of the V. Wherever possible the counterpoise wires should be supported on wood stakes about 1 foot high. This will give greater distance of transmission as well as better telephone communication.

Although ground mats are provided as a part of the antenna equipment, they are seldom used, for it is only under exceptional conditions that they will give as good results as the counterpoise. When used they should be buried under a few inches of earth, which should be well packed down on them. For general use the ground mats may be buried under the antenna wires. For directional use they should extend away from the radio transmitter toward the receiving station.

13. *Erecting the antenna and ground system of the SCR–159 set.*—At least five men are needed to erect the antenna. Three men are at the end of the antenna wires and guy ropes, two men raising the mast and adding the sections. The following directions should be observed:

Select clear space in which the antenna is to be erected. This clear space should be at least 200 feet in diameter. Place the mast and antenna equipment in the center of the space where the mast is to be erected. Take the top section (the one which has no iron pipe projecting from either end) and place the mast cap in one end of it. (The mast cap has eight sockets, which will hold the metal balls on the end of the antenna wires. It should have the 50-foot antenna lead-in wire permanently fastened to it.) Attach the six antenna wires to the mast cap by means of the ball and sockets provided. Unreel and lay out on the ground the six antenna wires and the guy ropes fastened to them. They should extend out radially from the mast, dividing the circle in equal parts—that is, they should make angles of 60° with each other.

Place a man at every other guy rope at the end of the guy rope. It is the duty of these three men to keep the mast upright as the sections are added. They do this by keeping the correct strain on the guy ropes, walking toward the mast as necessary. Select the eight other sections to be added (all alike) and the bottom section. (This has an insulator screwed on the bottom of it. If it is not screwed on, this should be done before adding the sections to the mast.) The mast will contain, when erected, 10 sections in all, 8 besides the top and bottom sections.

Add the sections, one man raising the mast directly upward and the other man adding the sections. Keep the mast upright, giving any directions that may be necessary to the men at the end of the guy ropes to do this. Having added all the sections, including the bottom one, allow the mast to rest on the ground. The two men at the mast then go out to the end of a guy rope and drive a stake in the ground and by means of the metal tent slide tighten the guy to the proper tension. This is done for each of the six guy ropes. Be careful that the mast is upright and that it is not bent. Make any changes in the strain on the guys necessary to insure this.

It is to be noted that on each guy rope there is an insulator between it and the antenna wire to which it is fastened. The rope is also divided by insulators. It is absolutely necessary that the antenna wires be well insulated. The antenna wires must not touch an object such as a tree, building, etc. The lead-in wire hangs down beside the mast.

Having erected the antenna, place the counterpoise connecting block on the ground near the mast. (This is fitted with holes in which the ends of the counterpoise wire are plugged.) A short wire leading to the set box is attached to it. Reel out the six counterpoise

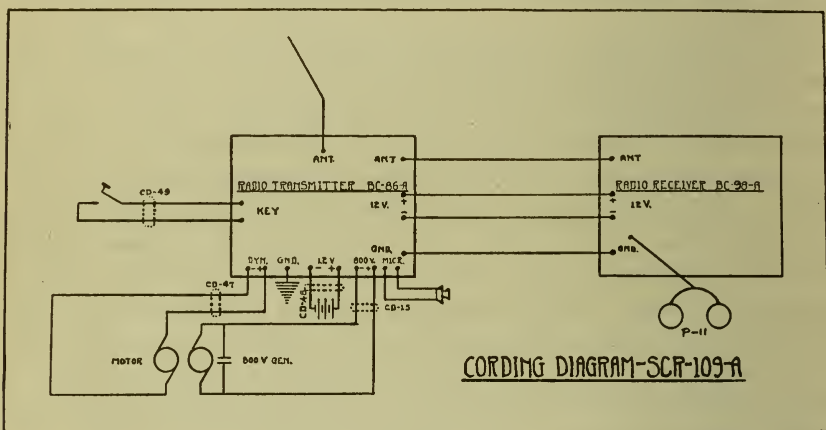

FIG. 6.

wires to their full extent, 90 feet. Each rests directly under an antenna wire. The counterpoise connecting block should be raised off the ground to properly insulate it. Wherever possible the counterpoise wires should be supported on wood stakes about 1 foot high. This will give greater distance of transmission as well as better telephone transmission.

14. *Installing the radio transmitting and receiving apparatus.*—A cording diagram is shown in Figure 6. The following directions should be observed:

a. Pull open the "Transmit-Receive" switch on the radio transmitter.

b. Remove the cover of the radio transmitter and place in the holder two BA–2 dry batteries. Connect the batteries to the terminals provided, being sure to observe the correct polarity as marked. Make all connections tight and clean. Fasten the batteries in place by the hinged clamp.

c. In a similar manner place two BA–2 dry batteries in the radio receiver. If no BA–2 batteries are available, an external 40-volt battery may be used. This should be connected with the proper polarity to the pair of binding posts on the radio receiver marked "+40 volt Aux. Plate Battery—."

d. Place in the radio transmitter a VT–4 vacuum tube in each of the two sockets, and a VT–2 tube in its socket. Leave off the cover of the radio transmitter, unless it is rainy or very damp.

e. Place in the radio receiver a VT–1 vacuum tube in each of the three sockets. Put on the cover of the radio receiver.

f. Connect in series three of the four-volt storage batteries, using the cords type CD–38. Similarly connect the other three four-volt storage batteries in series. Now connect these two sets of batteries in parallel. This is done by connecting the free *positive* terminal of the end battery in the first set to the free *positive* terminal of the corresponding battery in the second set; and by connecting the free *negative* terminal of the other end battery in the first set to the free *negative* terminal of the corresponding battery in the second set.

g. Using cord type CD–48, connect the storage batteries to the binding posts on the radio transmitter, marked "12 volts+." Observe the proper polarity. At the storage battery the positive end of the cord is attached to either of the two positive terminals that are connected together, and the negative end is attached to either of the two negative terminals that are connected together.

h. Connect by suitable lengths of annunciator wire (type W–7) the binding posts along the right-hand edge of the radio transmitter to the correspondingly marked binding posts along the left-hand edge of the radio receiver.

i. Connect the antenna lead-in wire to the binding post marked "Antenna" in the middle of the upper edge of the panel of the radio transmitter.

j. Connect the third binding post from the left at the bottom edge of the panel, marked "Ground," to the counterpoise block by means of the cord provided, if using the umbrella antenna. If using the V antenna, the binding post is connected by a piece of the counterpoise wire to the point of the V of the counterpoise.

k. Using cord type CD–47, connect binding posts on the radio transmitter marked "—dynamotor+" to the motor (12-volt) side of the dynamotor. Observe the proper polarity.

l. Using cord type CD–15, connect the binding posts on the radio transmitter marked "—800 volts+" to the generator (high voltage) side of the dynamotor. Observe the proper polarity.

m. Using cord type CD–49, connect the key to the binding posts marked "Key" on the radio transmitter.

n. Plug the microphone in the jacks provided in the radio transmitter. If no plugs are provided with the microphone, connect them to the binding posts beneath the jacks.

o. Plug the telephone receiver in one of the two jacks provided in the radio receiver. If a plug is not provided, connect the receiver to the binding post placed below the jacks. There is a right and wrong polarity for this connection to the binding post. To test for this connection, remove the cap of the telephone receiver and, using the diaphragm, test the strength of the permanent magnet of the receiver. Throw the "Transmit-Receive" switch to "Receive," thus causing the receiving vacuum tube to light up. If the strength of the magnet is increased, the telephones are connected with the right polarity.

Section VIII.

OPERATION AND CARE OF SETS.

15. *To transmit.*—Pull open the small three-pole double-throw switch on the radio transmitter. Throw the "Transmit-Receive" switch to the "Transmit" position, being sure to make good contacts by pushing it firmly into this position. The dynamotor should start and the oscillator tubes should light up. Turn the "antenna inductance" switch to that stud which will give the wave length desired. Close the key of the transmitter and adjust the plate current of the oscillator tube by means of the eight-point plate coupling control switch located at the rear of the inductance coil. Continue this adjustment until the plate current ammeter shows a reading of 125 milliamperes or the value nearest this that can be obtained. With this adjustment the antenna current should be approximately 1.5 amperes. If it is not known what stud is to be used to produce the wave length desired, and if the set has not been calibrated (see par. 17), it will be necessary to determine the setting of the antenna inductance by the aid of a wavemeter. (See Radio Communication Pamphlet No. 28.) In using a wavemeter, it is well to remember that the transmitter should always be adjusted so that its plate current is approximately 125 milliamperes before the reading is taken.

No matter what kinds of signals are to be transmitted, the above adjustment should always be made. The three-pole double-throw switch controls the circuits for the various kinds of signals.

To send undamped wave telegraph signals, leave the three-pole switch open and operate the key. Only the oscillator tube is lighted.

To send buzzer modulated telegraph signals, throw the three-pole switch to the "Buzzer Modulated" position. All three tubes should light up and the buzzer should give a clear note. Operate the key to transmit signals.

To transmit speech, throw the three-pole switch to the "Telephone Modulated" position. All three tubes should light up. Speak distinctly in the microphone, holding it in an upright position close to the mouth.

Under some conditions the plate current of the oscillator tube can be made more than 125 milliamperes. This should not be done except where the extra power is absolutely necessary in order to reach the distant station. The adjustment of the plate coupling control should be determined by the reading of the plate current ammeter and not by the reading of the antenna ammeter. If with proper plate current the antenna current is too low, the fault lies in the antenna system.

16. *To receive.*—The primary and secondary circuits must be tuned to each other in the usual way. When picking up damped wave, buzzer modulated, or radio telephone signals, the tickler coil should have zero coupling and the coupling between primary and secondary should be at maximum. The amplification control should be on the maximum position. When the signals are picked up the coupling between primary and secondary should be loosened and the tickler coupling increased. Continue this adjustment until clear signals are obtained without interference. The tickler coupling should be adjusted so that the detector tube is just at the point of oscillating. If it should oscillate—indicated by the character of the signal changing—the tickler coupling should be reduced gradually until the clear signal appears. Adjusting the coupling will to some extent throw the primary and secondary circuits out of resonance and hence these should be readjusted with every change in the coupling adjustment. After these adjustments have been made the amplification control may be changed to the stud that gives the best readable result. This control will oftentimes reduce interfering noises that can not be tuned out, including static, so that the desired signal may be read through the interference.

When receiving undamped wave telegraphy, all adjustments are much more critical than when receiving damped waves. *The setting of the tickler control coupling and secondary condenser is particularly critical.* For picking up undamped wave signals the tickler coupling should be placed near the maximum position. Make sure that the receiver is oscillating. Test by placing a wet finger in the antenna lead-in. A distinct sound will be heard if the set is oscillating. As soon as the desired signal is picked up final adjustments must be made. The heterodyne note heard is changed in pitch by adjusting either the tickler, coupling, or secondary variables. These should be adjusted to give the best results as regards selectivity and pitch.

After an operator becomes familiar with the set he will learn to pick up buzzer modulated and telephone signals with his tickler set at a point just below that which will cause the set to oscillate, and to pick up undamped wave signals with the tickler set just above that point which will cause the set to oscillate.

It is very difficult to pick up signals unless the radio receiver has been calibrated. If not calibrated and a signal of a definite wave length must be received, it will be found much easier to pick up this signal if the receiving set is tuned to that wave length by the use of a wavemeter.

17. *Calibration of transmitter.*—As soon as possible after receiving the radio set it should be calibrated. A table should be made out as follows:

Wave length.	Primary inductance tap.	Plate coupling tap.	Plate current.	Antenna current.
....	1........	....	....	....
....	2........	....	....	....
....	3........	....	....	....
....	Etc........	....	....	....

In making the table, the *standard antenna* should be used, great care being taken to have the correct length of the lead-in wire as well as each antenna wire. Any change in the antenna will invalidate the table, so that thereafter no change should be made in the antenna when it is erected. When completed the table should be labeled as to the height of antenna, length of each antenna leg, length of lead-in wire, and kind of ground used. It should then be firmly attached to the inside of the cover of the transmitter box.

The best method of procedure to get data for the table is, having erected the antenna, to place the antenna inductance dial on tap 1 and then vary the plate coupling control until the plate current is 125 milliamperes. The plate coupling tap, the plate current, and the antenna current are to be noted in their proper columns. The wave length is then to be measured and noted in its column. This is repeated for each tap of the antenna inductance switch. It is advisable to get the average of three readings before making the permanent table.

In using the table, the first three columns are to be directly used, the fourth and fifth columns being a check upon the condition of the transmitting apparatus. The whole table should be frequently checked so that it will always be known to be correct.

18. *Calibration of receiver.*—Picking up signals is made much easier if the approximate setting of the control handles for any wave length is known. These settings should be determined by the use of a wavemeter and noted in a table as follows:

Wave length.	Primary inductance.	Primary condenser.	Secondary inductance.	Secondary condenser.	Coupler U. W. Tgh.	Tickler U. W. Tgh.	Coupler telephony.	Tickler telephony.
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....

As in making the transmitter table, the standard antenna should be used and thereafter always erected without change. The completed table should be appropriately labeled and fastened to the inside of the receiver cover.

The first five columns can be filled in by the use of a wavemeter. Set the wavemeter oscillating at 300 meters and tune the primary and secondary circuits to resonance. Tune accurately and sharply, using a loose coupling. Note in the proper column the settings of the control handles. Repeat for 325 meters, 350 meters, etc., until the limit of wave length reception has been reached. The lower limit should also be determined and noted. It is advisable to get the average of three readings before making the permanent table.

The remaining four columns should be filled in as determined by settings when actually receiving signals from a distant station. It will be found that they can not be given a single accurate value. The limits of the value should be put in the column. For instance, it may be found for one wave length that the tickler coupling may vary from 4 to 7. This should be entered in the column thus: 4–7.

In using the table it must be remembered that the *settings are not final.* As soon as the signals are picked up, fine adjustment should be made. As previously noted, certain adjustments call for particular care.

19. *Notes on operation.*—For efficient operation, the SCR–109–A and SCR–159 sets require experienced operators who are familiar with the sets. If the operators are not familiar with the sets, it may be expected that at first only poor results will be obtained. The sets should be studied and their adjustments and peculiarities learned. The sets are capable of excellent transmission and reception. If a

set fails to operate satisfactorily the following points should be noted:

Carefully go over all connections made when installing the set. Check up as to correct connections, including correct polarity, and as to clean and tight connections.

Test the voltage of all batteries, both storage and dry.

See that the dynamotor is running properly and easily. See that it is properly oiled. The end covers of the dynamotor may be removed for ventilation if conditions are such that dirt, etc., will not get into the dynamotor.

Note that all switches make good contact. Press the double-throw switches firmly in their positions. *Clean their contacts frequently.*

Inspect the antenna. Check it as to correct length of legs and lead-in wire. See that the antenna wires are properly insulated. Improve the ground system if it admits of improvement.

When using the microphone, speak distinctly and directly into the transmitter. It is well to tap the transmitter smartly with the heel of the hand to make sure that its microphone element is not stuck.

Do not overlook the fact that the tickler adjustment is very critical, especially in receiving undamped wave radio telegraphy.

If the receiving set howls or sings try the same remedies you would on an amplifier. (See Radio Communication Pamphlet No. 9.)

In transmitting, if any of the three tubes fails to light, it may be due to a bad connection in the socket or a dirty contact pin. Clean the contact pin and replace the tube properly in the socket. If this does not remedy the defect, try a new tube. *In exchanging tubes always pull the "Transmit-Receive" switch so that it makes no contact.*

In receiving, all three of the tubes will light or none of them will, because their filaments are connected in series. Examine and clean the tube contact pins.

Sometimes a tube is defective. Find the defective one by trial of other tubes known to be in good condition.

Interchange the receiving tube until you have found the combination that works the best. Some tubes are better detectors than others. One of the receiving sockets is connected so that its tube is a detector.

In transmitting in an area where there is much traffic or under other conditions requiring an exact predetermined wave length, if your control settings have been made from the calibration curve, always check them by the aid of a wavemeter.

Be careful not to touch any of the metal parts of the transmitter when transmitting, as a shock will result. This applies particularly to the ammeters, the double-throw switches, and the various inductance taps. Even when not transmitting, if the dynamotor is running, a shock is likely to be received. Thus it is well to *open the "Transmit-Receive" switch if it is necessary to make any adjustments other than by the control handles.*

In transmitting, unless it is rainy or very damp, the cover of the transmitter should be left off to allow plenty of ventilation for the VT–4 tubes.

In transmitting radio telephony, the plate current should continually vary. If it does not, the set is not working properly.

During a thunderstorm or other severe electrical disturbance, disconnect the antenna and ground wires from their binding posts and connect them directly to each other. This should always be done if the set is left installed without an operator being present.

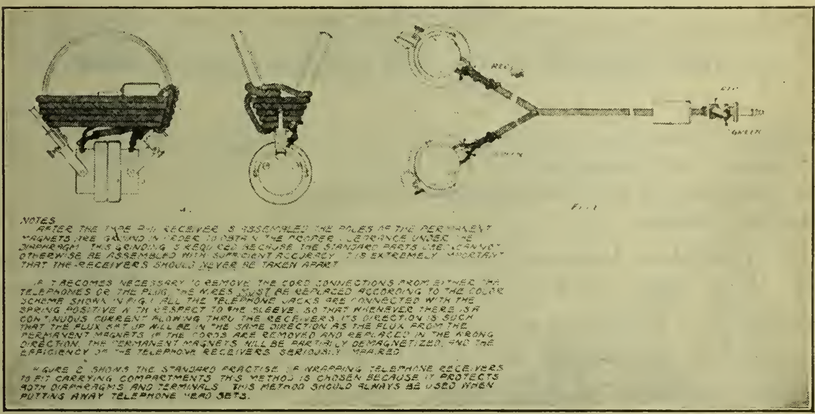

FIG. 7.

20. *Care of sets.*—The radio equipment must be handled with great care. The various parts are of delicate construction and rough handling will make the set inoperative. The transmitter and receiver boxes contain many parts closely packed together and with a great many connections. These are liable to become dislodged and the connection broken. The set should not be stored in a damp place nor unnecessarily exposed to rain. If the set becomes wet it should be carefully dried out but never exposed to intense heat.

The storage batteries must receive proper attention and care. (See Training Pamphlet No. 8.) The dynamotor panel should be kept clean and the dynamotor properly oiled. Use a good grade of oil and apply one or two drops after two hours' operation. It is important that not too much oil be used. It is much better to oil frequently with a small amount than to oil less frequently using a larger amount of oil.

The clock needs no attention other than winding and setting. It is wound by a key fastened at the top of the clock, access to which is gained by turning the rim counterclockwise about 45° and pulling outward. The clock is set in the usual manner by pulling the key up until a click is heard.

Great accuracy has been observed in assembling the telephones and the microphone. There is a right and wrong polarity in connecting the cords of the telephones. If the cords are removed for any reason this must be taken into account in replacing them. Figure 7 shows the scheme of connection. The colors referred to in the figure are small, colored tracer threads running through the insulator. Figure 7 shows the standard practice of wrapping the telephones for storage. This method should always be followed. The microphone must be carefully handled and packed. It should need no other attention.

Section IX.

PRINCIPLES EMBODIED IN THE SETS AND THEIR CIRCUIT DIAGRAMS.

21. *Complete transmitting circuits.*—The radio transmitter, type BC–86–A, uses a VT–4 vacuum tube to produce radio-frequency oscillation. The plate and grid circuits of this tube use a capacity coupling in producing the oscillations. One of these capacities is a fixed condenser of 1,775 mmf. capacity; the other is the antenna used with the set. The antenna, therefore, is a factor in determining the wave length of the set, and its electrical constants should not differ from those of the standard antenna. A complete circuit diagram of the transmitter is shown in Figure 8. The circuits are best studied by simplified circuits of each kind of transmission.

22. *Undamped wave transmission.*—Figure 9 shows the simplified circuit for undamped wave transmission. The VT–4 tube generates radio frequency, there being a capacity coupling. The inductance is controlled by two dial switches, a 28-point switch connected to the antenna and used for changing the wave length, and an 8-point switch determining within certain limits the coupling of the oscillatory circuit to the plate. The latter adjustment enables a fairly constant output to be obtained over the working range of wave length and with some variation in the antenna characteristics.

Radio-frequency choke coils limit the radio-frequency current to the proper circuits. The plate current is supplied from an 800-volt generator in series with a telegraph sending key having a 5,000-ohm resistance in parallel with it. The grid of the tube is connected

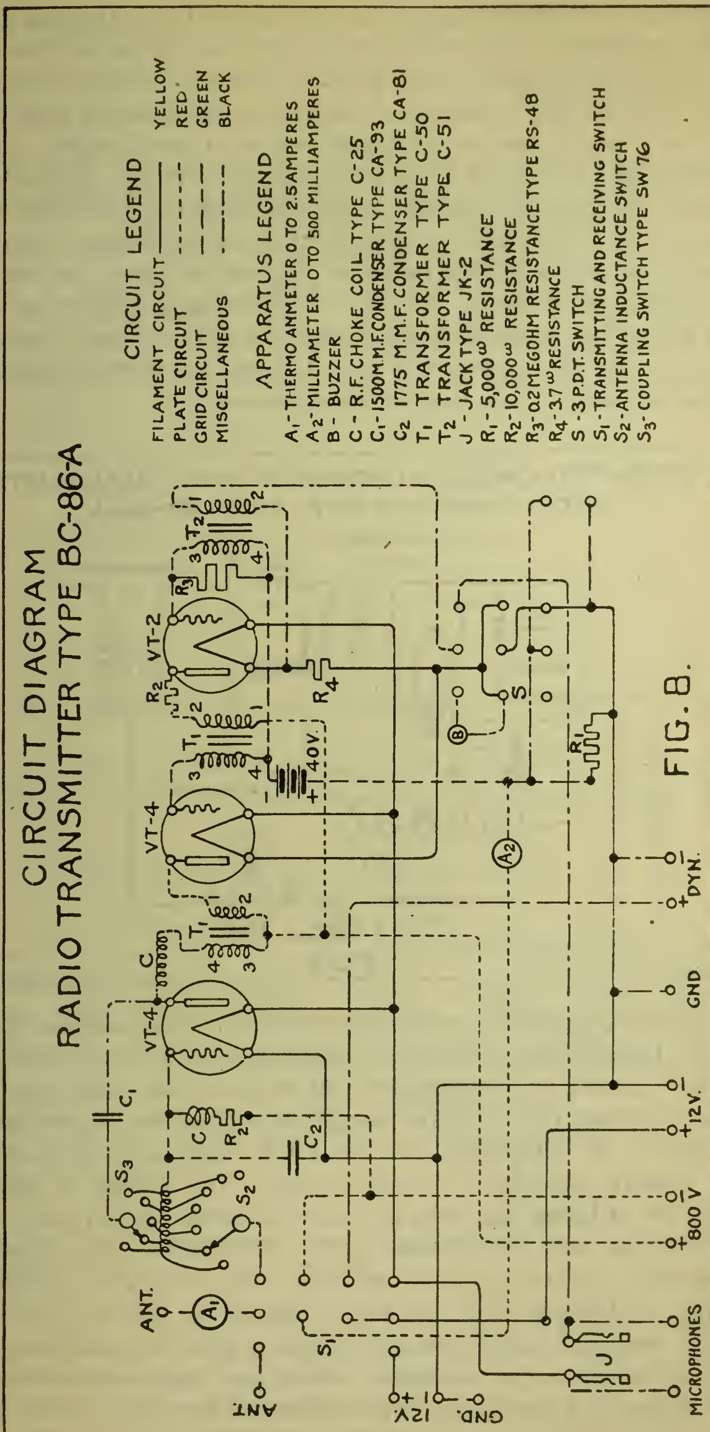
CIRCUIT DIAGRAM
RADIO TRANSMITTER TYPE BC-86-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
APPARATUS LEGEND
A_1 - THERMO AMMETER 0 TO 2.5 AMPERES
A_2 - MILLIAMETER 0 TO 500 MILLIAMPERES
B - BUZZER
C - R.F. CHOKE COIL TYPE C-25
C_1 - 1500 M.M.F. CONDENSER TYPE CA-93
C_2 1775 M.M.F. CONDENSER TYPE CA-81
T_1 TRANSFORMER TYPE C-50
T_2 TRANSFORMER TYPE C-51
J - JACK TYPE JK-2
R_1 - 5,000$^\omega$ RESISTANCE
R_2 - 10,000$^\omega$ RESISTANCE
R_3 - 0.2 MEGOHM RESISTANCE TYPE RS-48
R_4 - 3.7$^\omega$ RESISTANCE
S - 3 P.D.T. SWITCH
S_1 - TRANSMITTING AND RECEIVING SWITCH
S_2 - ANTENNA INDUCTANCE SWITCH
S_3 - COUPLING SWITCH TYPE SW 76
VT-2
VT-4
VT-4
40V.
ANT.
ANT.
12V.
GND.
800 V
12V.
GND
DYN.
MICROPHONES

FIG. B.

through a 10,000-ohm resistance to one side of the 5,000-ohm key resistance so that this key resistance is also in series in the direct current circuit between the grid and the filament. When the key is closed, the 5,000-ohm resistance is short-circuited and the grid potential is very nearly that of the negative side of the filament. Strong oscillations are then built up in the oscillatory circuit. When the key is opened the plate current has to pass through the 5,000-ohm resistance, causing a difference of potential to be established across the resistance so that a strong negative potential is placed on the grid, stopping the oscillations. The circuit therefore oscillates when the key is closed and stops oscillating when the key is opened. It will be noted that a 2 mf. condenser is placed across the 800-volt generator. This is contained in the base of the dynamotor.

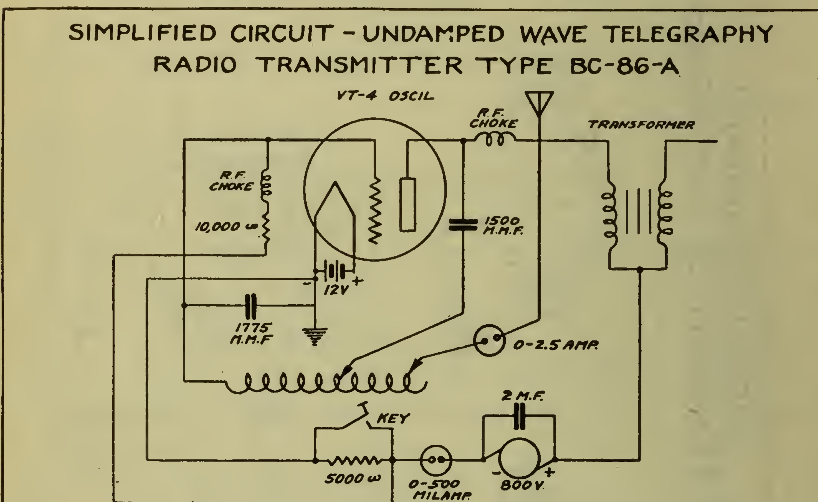

FIG. 9.

23. *Buzzer-modulated and radio-telephone transmission.*—Figure 10 shows the schematic circuit and apparatus when buzzer-modulated telegraph signals are transmitted. It will be noted that the VT–4 oscillator circuit, including the telegraph sending key, is the same as used for U. W. telegraph, but the VT–4 modulator tube and the VT–2 speech amplifier are now in use. The buzzer is operated steadily by utilizing the drop in potential across the 3.7-ohm resistance in series with the filament of the VT–2 tube. The telegraph sending key operates the same as for U. W. telegraph signals—by stopping oscillations when the key is opened, by reason of the large negative potential then impressed on the grid of the oscillator tube.

Figure 11 shows the schematic circuit and apparatus when telephone modulated signals are transmitted. The circuit of the VT–4 oscillator tube is still the same as for the other two conditions, except that the telegraph sending key is now short-circuited, and hence is not shown in the figure. The VT–4 oscillator is therefore producing oscillations continuously. A microphone transmitter is supplied

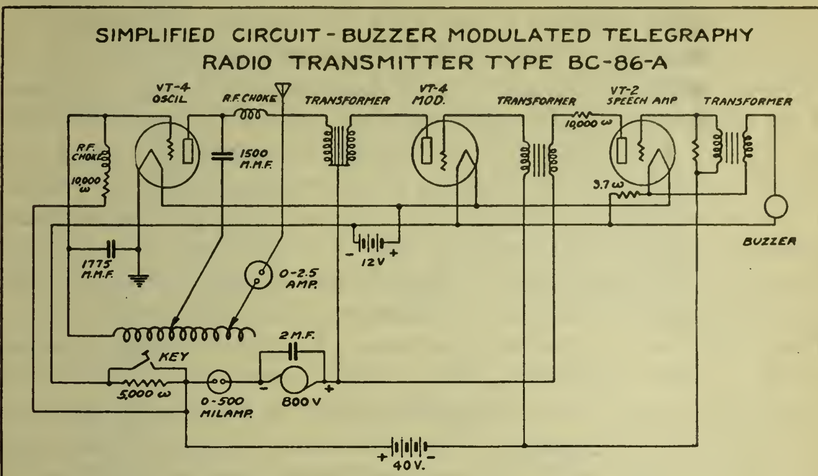

FIG. 10.

power by utilizing the voltage drop across the filament of the VT–2 tube.

The operation of the speech amplifier and modulator circuits is as follows, it being understood that the description applies to both

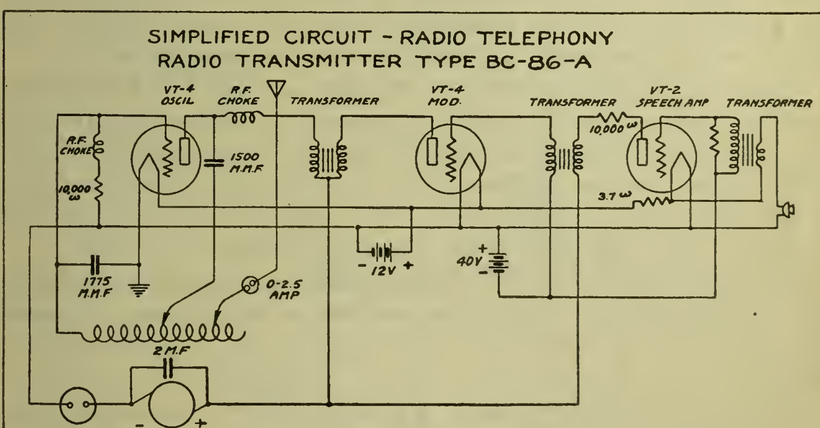

FIG. 11

the telephone-modulated and the buzzer-modulated telegraph conditions: Buzzer or voice frequency currents are set up in the primary circuits of the first transformer. The voltage set up across the primary is stepped up to a larger value by the secondary winding, and this voltage is impressed upon the grid of the VT–2 speech amplifier. This tube operates as an amplifier, so the alternating current voltages on the grid appear in the plate circuit in amplified form but undistorted. The alternating current voltage in the plate circuit of the VT–2 tube is then transferred to the grid of the VT–4 modulator tube by means of a one to one ratio transformer. The audio-frequency voltage on the grid of the VT–4 modulator tube then appears further amplified in the plate circuit as evidenced by large variations in the plate current. The plate circuits of the VT–4 modulated tube and the VT–4 oscillator tube are coupled by means of a one to one ratio transformer. The windings are so connected that an *increase* in the modulator plate current will cause an *increase* in the oscillator plate current. The magnetic flux set up by current in the windings is more or less neutralized, so that the flux density in the core does not change greatly, and the core therefore does not become saturated. This is necessary to prevent distortion of currents set up by sound waves of large amplitude. The plate currents of the two VT–4 tubes then increase and decrease together in accordance with the voice or buzzer frequency. This variation of the oscillator plate current causes the radio-frequency oscillations generated by the tube to increase and decrease in amplitude so that the wave sent out from the antenna undergoes the voice or buzzer frequency modulation.

The current delivered by the 800-volt generator varies between wide limits, so the generator must be bridged by a condenser of at least 2 mf. capacity in order to prevent the inductance of the generator retarding the rapid change of plate current, and to prevent the self-induction of the generator causing the production of voltages across the generator sufficient to cause its breakdown.

The grids of the VT–2 speech amplifier and the VT–4 modulator tubes are given a negative biasing potential by a 40-volt battery, so that with normal excitation the grids never become positive. If the grids become positive with respect to the filament a current will flow in the grid circuit for that part of the cycle during which the grid is positive, and distortion of the impressed voltage will result.

The plate circuit of the VT–2 speech amplifier is supplied from the 800-volt generator, a 10,000-ohm resistance being placed in series with the circuit to limit the current to the proper value for a VT–2 tube.

A 0.2 megohm leak resistance is connected across the secondary of the transformer in the grid circuit of the speech amplifier tube in order to definitely limit the otherwise high impedance of the winding and thereby prevent tube blocking.

24. *Receiver circuits.*—The wiring diagram of the radio receiver is shown in Figure 12. The antenna circuit consists of a variable air

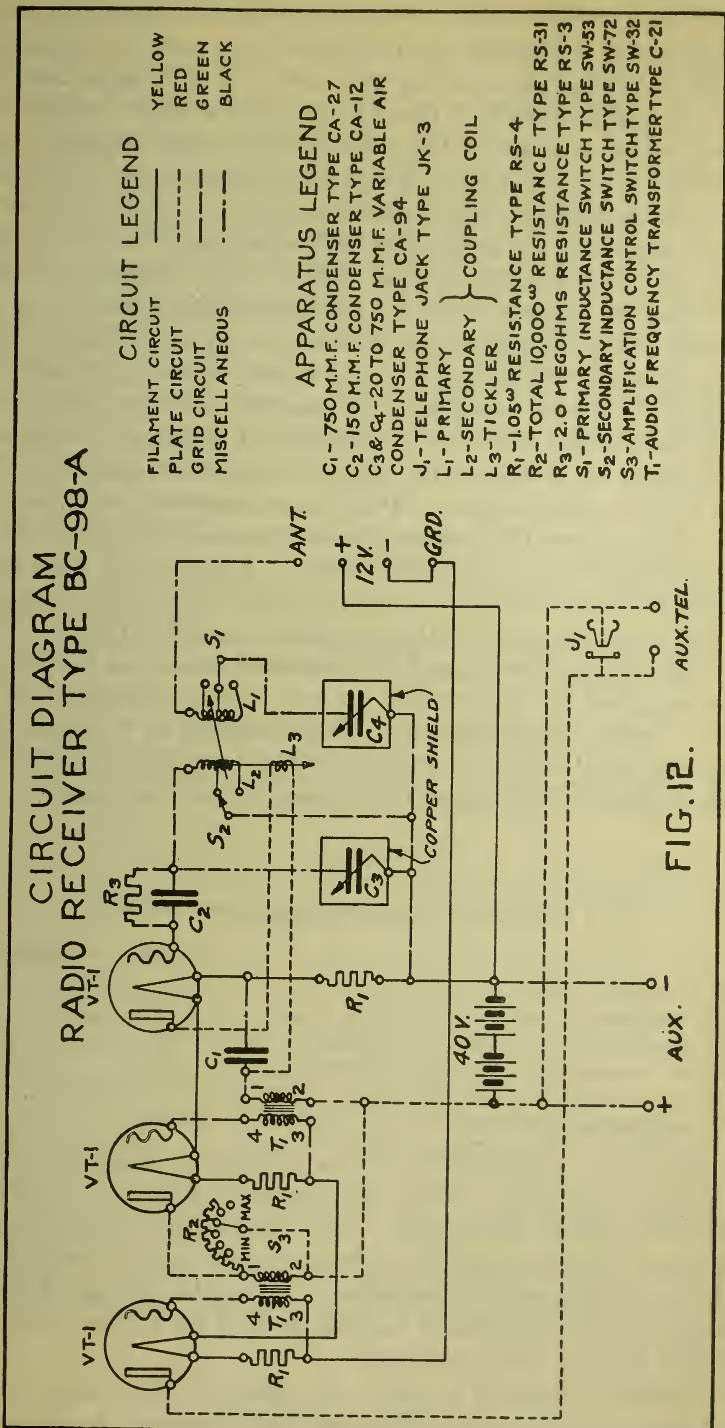
CIRCUIT DIAGRAM
RADIO RECEIVER TYPE BC-98-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
APPARATUS LEGEND
C1 - 750 M.M.F. CONDENSER TYPE CA-27
C2 - 150 M.M.F. CONDENSER TYPE CA-12
C3 & C4 - 20 TO 750 M.M.F. VARIABLE AIR CONDENSER TYPE CA-94
J1 - TELEPHONE JACK TYPE JK-3
L1 - PRIMARY
L2 - SECONDARY COUPLING COIL
L3 - TICKLER
R1 - 1.05 ω RESISTANCE TYPE RS-4
R2 - TOTAL 10,000 ω RESISTANCE TYPE RS-31
R3 - 2.0 MEGOHMS RESISTANCE TYPE RS-3
S1 - PRIMARY INDUCTANCE SWITCH TYPE SW-53
S2 - SECONDARY INDUCTANCE SWITCH TYPE SW-72
S3 - AMPLIFICATION CONTROL SWITCH TYPE SW-32
T1 - AUDIO FREQUENCY TRANSFORMER TYPE C-21
ANT.
12 V.
GRD.
COPPER SHIELD
AUX. TEL.
AUX.
40 V.
VT-1
MIN
MAX

FIG. 12.

condenser and an inductance having three taps connected in series. This inductance is inductively coupled to a secondary circuit, consisting of an inductance having two taps and a variable air condenser. The grid circuit of the detector tube contains a grid leak resistance and a condenser. The proper positive grid biasing voltage is obtained by using the drop across the resistance in the filament circuits. The detector tube is followed by two stages of audio-frequency amplification coupled by audio-frequency iron core transformers. The plate circuit of the detector tube contains a tickler coil. By careful adjustment of the coupling between the tickler coil and the secondary inductance the detector circuit will be made regenerative, increasing the strength of spark and telephone signals. By increasing the tickler coupling still more the detector circuit will oscillate, permitting heterodyne reception of undamped wave telegraph signals. A switch on the front of the set box panel provides control of the amplification. This is accomplished by placing a variable shunt across the primary side of the audio-frequency transformer coupling the two amplifier tubes. A type P–11 head set is to be plugged into the jack in the plate circuit of the second amplifier tube. The plate current for all three tubes is supplied from a 40-volt battery consisting of two type BA–2 batteries connected in series, or may be supplied by an external 40-volt battery connected to the auxiliary binding posts provided. The filaments of the three type VT–1 tubes are connected in series and are supplied through the "Transmit-Receive" switch on the transmitting set box panel.

Section X.

SPECIAL WIRING FOR LONG-DISTANCE TRANSMISSION.

25. *Purpose of special wiring.*—It is possible to change the wiring of the radio transmitter so that the modulator tube is connected in parallel with the oscillator tube. This practically doubles the output of the set and hence greatly increases the distance of reliable undamped wave telegraph transmission. When the wiring of the set is changed for this purpose, it can not be used for buzzer-modulated telegraphy nor for radio telephony.

26. *Authority required to make the change.*—The change in the wiring should not be made unless absolutely necessary to obtain the

extra power for the distance over which communication must be maintained. Special authority of the signal officer of the unit must be obtained before the change is made. The work should be done by a competent radio electrician. The set should never be turned back to the depot without it being changed back to the standard wiring.

27. *Detailed instructions for making the change.*—The following directions should be strictly observed: The wiring diagram after changes have been made is shown in Figure 13. This should be compared with Figure 8. In Figure 13 the drawing items have the same labels and number as Figure 8, but with an exponent added to more clearly identify them. A study of the other illustrations of this pamphlet, as well as Figures 8 and 13, will aid in the identification. *Make only the specific changes listed.* These have been found to give the best results possible while permitting the set to be changed back to its standard wiring at any time.

$(VT\text{–}4)^1$ refers to VT–4 tube at left of diagram.
$(VT\text{–}4)^2$ refers to VT–4 tube at right of diagram.
R_2^1 refers to R_2 connected through choke coil C^1 to grid of $(VT\text{–}4)^1$. (This is the lower resistance tube at extreme right of set looking at the back of set.)
R_2^2 refers to R_2 connected to plate of VT–2 tube. (This resistance is just above resistance R_2^1 at extreme right of set looking at the back of set.)
C^1 refers to choke coil connected to grid of $(VT\text{–}4)^1$.
C^2 refers to choke coil connected to plate of $(VT\text{–}4)^1$.
T_1^1 refers to transformer T_1 connected to choke coil C^2 and plate of $(VT\text{–}4)^1$. (This transformer is left-hand one of the two large ones looking at the back of set.)
T_1^2 refers to transformer T_1 connected to grid of $(VT\text{–}4)^2$ through R_2^2 to plate of VT–2 tube. (This transformer is same size as the above and is at the right looking at back of the set.)

Using the above symbols, the following changes in connections should be made:

a. Remove connection from terminal 1 of transformer T_1^1 going to plate of $(VT\text{–}4)^2$.

b. Connect plate of $(VT\text{–}4)^2$ to plate of $(VT\text{–}4)^1$.

c. Connect together terminals 3 and 4 of transformer T_1^1. This will produce same results as if +800-volt lead was connected direct to choke coil C^2.

d. Remove connections from grid of $(VT\text{–}4)^2$ going to terminal 3 of transformer T_1^2.

e. Connect grid of $(VT\text{–}4)^2$ direct to grid of $(VT\text{–}4)^1$.

f. Remove +800-volt connection from terminal 1 of transformer T_1^2.

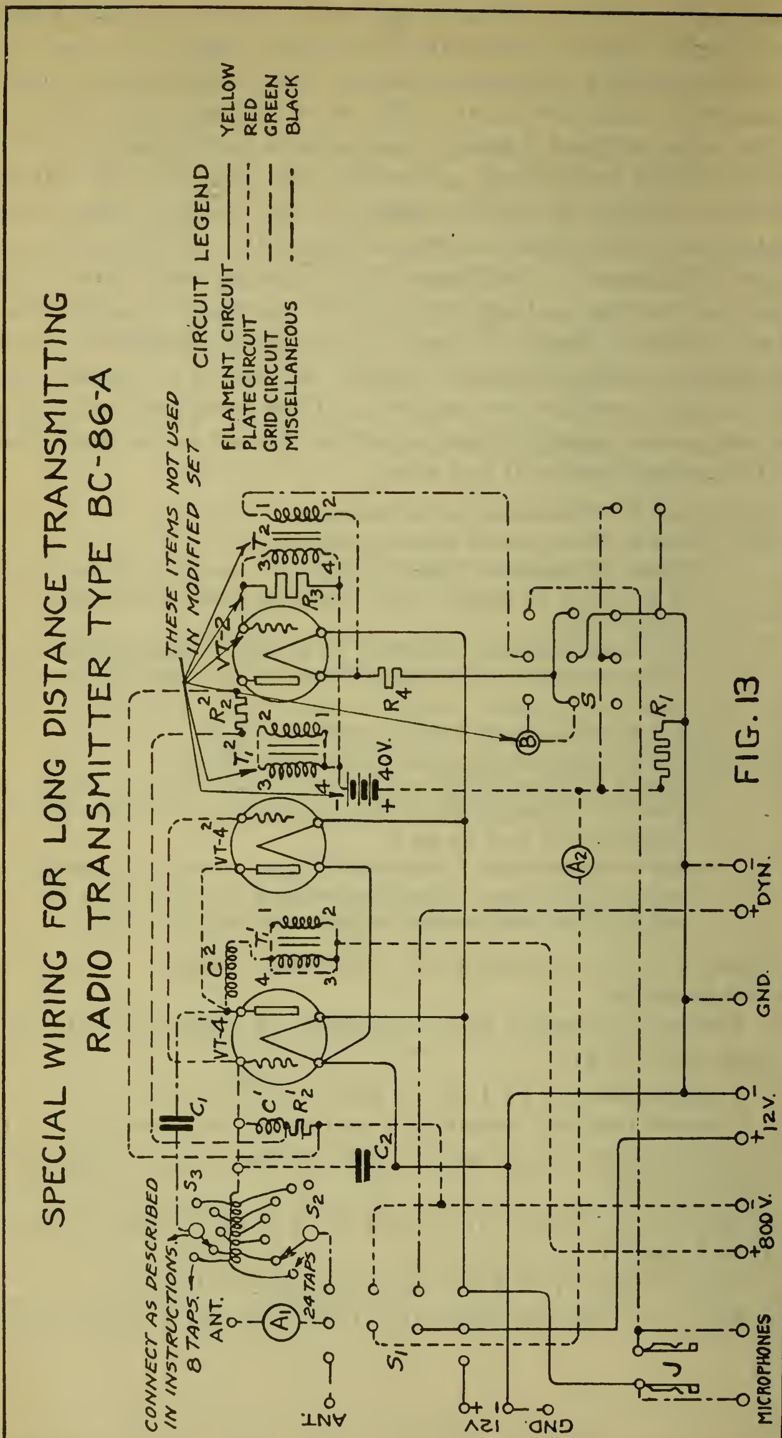
SPECIAL WIRING FOR LONG DISTANCE TRANSMITTING
RADIO TRANSMITTER TYPE BC-86-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
THESE ITEMS NOT USED IN MODIFIED SET
CONNECT AS DESCRIBED IN INSTRUCTIONS
8 TAPS
24 TAPS
ANT.
ANT.
12V.
GND.
40V.
DYN.
GND.
12V.
800V.
MICROPHONES
VT-4
VT-4
VT-2

FIG. 13

g. Disconnect R_2^2 from plate of VT–2 and terminal 2 of transformer T_1^2.

h. Connect R_2^2 in parallel with R_2^1. This will make the resistance of the two in parallel 5,000 ohms. These two resistances are placed one directly over the other in the set as stated above.

i. Remove left filament lead of $(VT–4)^2$ going to three-pole double-throw switch at right.

j. Connect left filament terminal of $(VT–4)^2$ to left filament terminal of $(VT–4)^1$. That is, the filaments of $(VT–4)^1$ and $(VT–4)^2$ will be in parallel.

k. Remove back of antenna inductance. Disconnect all eight leads going from switch S_3 on back disk of antenna coil. Reconnect the eight leads of coupling switch S_3 to coil taps connected to following numbers on front panel: 4, 5, 6, 8, 10, 12, 14, and 16.

l. The switch contacts on front of the set are numbered; those on coupling switch at back of set are not numbered. Looking at the unnumbered contacts on the back of the set, the left-hand contact after the above change would be connected to the lead inside of the coil going to contact No. 4 on the front of the set. The next to the left contact on the back of the set will connect to the lead connected to contact No. 5 on front of set, etc., as enumerated in *k*.

m. For use with some antennae, the condenser at C_1 should have double its present capacity; that is, 3,000 mmf. New condensers of 3,000 mmf. should be installed if available after removing the condenser originally supplied in the set.

28. *Precautions necessary in using the modified set.*—In using the set after the changes outlined above have been made, care must be taken to overload as little as possible the output of the high-voltage side of the dynamotor. The current from the dynamotor is shown on the plate ammeter. Two hundred milliamperes is the normal output. With the two tubes in parallel the plate current will probably be between 250 and 400 milliamperes. The plate current can be kept at a minimum by taking care to adjust the coupling switch on the back of the antenna coil for minimum plate current and yet keep the antenna current at the desired value. If the plate current used for transmission is over 200 milliamperes, care should be taken that the key is kept closed no longer than necessary. It is believed a plate current of 300 to 350 milliamperes or over can be used safely for transmitting (measured when key is closed), as the average current during sending will not exceed one-half to two-thirds of the current with the key closed.

29. *Marking the modified set.*—Any sets modified described above should be tagged in some manner to show that they have been modified and can not be used for telephony or modulated telegraphy.

30. *Parts of modified set not in use.*—As indicated in Figure 13, certain parts of the set are not in use after it is modified. As these include the VT–2 tube and the 40-volt dry battery, they should be removed from the set.

SECTION XI.

PARTS LISTS OF SETS.

31. *Equipments in the SCR–109–A set.*—The SCR–109–A set comprises the following equipments:

One power equipment, type PE–36.
One radio equipment, type RE–19–A.
One antenna equipment, type A–9–B.

32. *Equipments in the SCR–159 set.*—The SCR–159 set comprises the following equipments:

One power equipment, type PE–36.
One radio equipment, type RE–19–A.
One antenna equipment, type A–14.

33. *Parts lists of above equipment.*—These equipments are made up of parts as noted below:

Power equipment, type PE–36:
- Battery, type BB–28; 12, 6 in use, 6 spare.
- Dynamotor, type DM–13; 1.

Radio equipment, type RE–19–A:
- Battery, type BA–2; 8, 4 in use, 4 spare.
- Chest, carrying, type BE–49; 1, for radio transmitter and receiver.
- Chest, carrying, type BE–50; 1, for spare parts and accessories including dynamotor.
- Cord, type CD–15; 1, transmitter to high voltage side of dynamotor.
- Cord, type CD–38; 8, for storage battery connections.
- Cord, type CD–47; 1, transmitter to low voltage side of dynamotor.
- Cord, type CD–48; 1, transmitter to storage batteries.
- Cord, type CD–49; 1, transmitter to key.
- Head sets, type P–11; 2.
- Key, type J–12 or J–2; 1, telegraph sending.
- Pliers, side cutting, 6-inch; 1 pair.
- Radio receiver, type BC–98–A; 1.
- Radio transmitter, type BC–86–A; 1.
- Screw driver, electricians, 3-inch blade; 1.
- Tape, friction, $\frac{3}{4}$-inch; 1 pound.
- Transmitter, type T–3; 1, microphone.
- Tube, type VT–1; 6, 3 in use, 3 spare.
- Tube, type VT–2; 2, 1 in use, 1 spare.
- Tube, type VT–4; 4, 2 in use, 2 spare.
- Wire, type W–7; 2 pounds.

Antenna equipment, type A-9-B (V antenna):
- Antenna, type AN-8-A; 2, on 2 reels, 1 in use, 1 spare.
- Bag, type BG-12; 2, carrying.
- Cord, type RP-3; sash No. 5, olive drab, 300 feet.
- Guy, type GY-4; 8, complete on 4 reels, 6 in use, 2 spare.
- Hammer, 2-pound crosspein; 1.
- Insulator, type IN-10; 4 spare.
- Mast section, type MS-14; 12, 9 in use, 3 spare.
- Mat, type M-5; 3, ground.
- Pliers, combination, 6-inch; 1 pair.
- Reel, type RL-3; 10 hand, 4 for counterpoise, 4 for guys, 2 for antennas.
- Roll, type M-15; 1, carrying.
- Stake, type GP-8; 12 ground, 6 in use, 6 spare.
- Tape, friction; 1 roll.
- Wire, type W-4; 50 feet, lead-in.
- Wire, type W-24; 750 feet on a spool, antenna.
- Wire, type W-30; 600 feet, on 4 reels, counterpoise.

Antenna equipment, type A-14, 40-foot umbrella:
- Antenna, type AN-12; 1, six 50-foot wires with insulators and cords attached.
- Bag, type BG-6; 2, carrying.
- Bag, type BG-7; 1, carrying.
- Connector, type M-6; 2 spares for antenna wires.
- Cord, type CD-94; 1, to counterpoise. Insulator block BL-2 on one end.
- Counterpoise, type CP-3; 1, six 90-foot wires.
- Hammer, 2-pound crosspein; 2.
- Insulator, type IN-4; 1, for bottom of mast.
- Mast cap, type MP-4; 1, with 50 feet lead-in wire.
- Mast section, type MS-1; 1, top.
- Mast section, type MS-2; 8, intermediate.
- Mast section, type MS-3; 1, bottom.
- Reels, type RL-3; 13, 6 for antenna, 6 for counterpoise, 1 for lead-in.
- Stakes, type GP-2; 6, ground.
- Straps, type ST-5; 6, for bundling mast sections.

SIGNAL CORPS PAMPHLETS.

(Corrected to June 1, 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. 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 (Types SCR-65 and 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.)
27. Sets, Radio Telephone and Telegraph, Type SCR–109–A and SCR–159. (W. D. D. 1111.)
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 Type 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. (W. D. D. 1020.) (2d edition.)
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 (edition of 6–9–22). (W. W. D. 1112.)
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).

TRAINING REGULATIONS.

(Signal Corps subjects.)

450–190—Elements of Cryptanalysis.

○

WAVEMETERS AND DECREMETERS

Radio Communication Pamphlet No. 28

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

January, 1922

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

CERTIFICATE: By direction of the Secretary of War the matter contained herein is published as administrative information and is required for the proper transaction of the public business.

WAR DEPARTMENT

Document No. 1094

Office of The Adjutant General

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WAR DEPARTMENT,
WASHINGTON, *January 17, 1922.*

The following publication, entitled "Wavemeters and Decremeters," Radio Communication Pamphlet No. 28, 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.

TABLE OF CONTENTS.

WAVEMETERS AND DECREMETERS.

RADIO COMMUNICATION PAMPHLET NO. 28.

Section I.

USES OF WAVEMETERS AND DECREMETERS.

1. Definitions and uses.—A *wavemeter* is a radio frequency instrument used (1) to measure the length of electro-magnetic waves generated by some other circuit; (2) to emit, as a low-power transmitter, waves of a known length; (3) with the help of other apparatus to measure the inductance of a coil, the capacity of a condenser, etc.; and (4) in certain special cases, to measure the logarithmic decrement of the waves. A *decremeter* is a special type of wavemeter which can function in all respects like a wavemeter and in addition has a direct reading scale which can be used to measure the logarithmic decrement of a transmitter. Both are thus calibration instruments which are useful in the field and the laboratory.

A wavemeter or decremeter can be used either at a transmitting or a receiving station, where (1) an unknown wave length can be measured; (2) the circuits can be set at any predetermined wave length; (3) the circuits can be calibrated over their scales of wave lengths; and (4) the logarithmic decrement of a transmitter can be measured in the case of certain wavemeters.

Section II.

FUNDAMENTAL PRINCIPLE OF WAVEMETERS; FORMULAE.

2. Fundamental principle.—The fundamental principle upon which all wavemeters operate is the same. The meter almost invariably contains three essential elements: (1) A coil as an inductance; (2) a condenser, as a capacity; and (3) auxiliary apparatus that varies with the use to which the meter is to be put. A circuit of inductance and capacity has a certain natural frequency of oscillation, or natural wave length, which depends upon the values of the inductance and capacity. In a meter these are known and the wave length can be accurately computed from their values. By varying the capacity or the inductance, the wave length of the meter can be changed so as to bring it into resonance with another circuit. As the wave length of two circuits at resonance is the same, the wave length of the circuit under measurement thus becomes known. The general circuit diagram of a wavemeter is shown in figure 1.

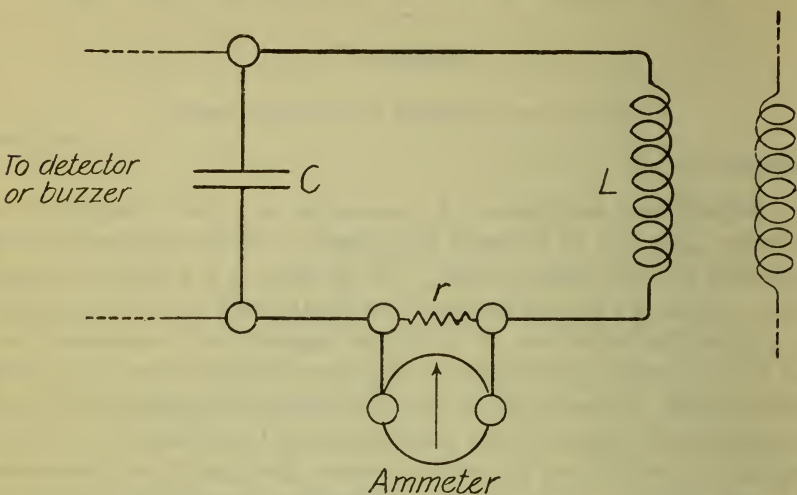

FIG. 1

3. Fundamental formulae.—The fundamental formula for the computation of the wave lengths of a meter with its known inductance and capacity is as follows:

$$\lambda = \frac{2\pi V}{\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}}$$

where λ (read "lambda") is the wave length,

π (read "pi") 3.14,

V Velocity of light, 3×10^8 meters per second.

L Inductance of the coil,

C Capacity of the condenser,

R High frequency resistance of the circuit,

all to be expressed in a consistent system of units. In all practical cases the quantity $\frac{R^2}{4L^2}$ is so small as compared with $\frac{1}{LC}$ that it can be neglected in comparsion with it, so that the formula simplifies to

$$\lambda = 2\pi V\sqrt{LC}$$

This formula can be expressed in many different systems of units, of which only the one in most common use will be given here:

If λ is in meters, L in milli-henrys, and C in microfarads, then

$$\lambda = 59{,}600 \times \sqrt{LC} \text{ meters.}$$

A numerical example in the use of the formula is as follows:

Let L be 0.040 milli-henrys.

And C 0.004 micro-farads.

Then $L \times C$ is 0.00016.

And $\sqrt{LC}$ is 0.01265.

And hence λ is $59{,}600 \times 0.01265$, or 754 meters.

Section III.

COMPONENT PARTS OF WAVEMETERS.

4. General design features.—A wavemeter may be set at any one of its wave lengths by varying either (1) the capacity of its condenser, or (2) the inductance of its coil. If the capacity is variable, then generally the inductance is constant, and similarly if the inductance is variable, the capacity is constant. The design of the inductance and capacity should be such that their high-frequency resistances are as low as possible, so that the losses in the wavemeter circuit are small. In general, the smaller these losses the more sensitive is the wavemeter, the sharper its tuning to resonance, and the lower its decrement, as will be explained in later paragraphs.

4a. Capacity.—If a variable capacity is used, it is almost always an air condenser, with a continuous change from a certain minimum, which is not zero, to a maximum value. The design and construction should be such that the internal losses at high frequency are as small as possible; thus a good contact must be made between all the fixed plates and also between all the moving plates; there should be no material between the fixed and moving plates or elsewhere in circuit, where the electric field of the charged plates may cause the flow of wasteful high-frequency currents, etc. The handle of the variable condenser carries a pointer for reading either on a scale of wave lengths or a scale of degrees or numbers. Some wavemeters have both these scales. As the maximum value of the capacity may be perhaps 20 or more times greater than the minimum, and as the wave length increases as the square root of the capacity (see paragraph 3), the longest wave length on a scale may be $\sqrt{20}$, or about 4.5 times the shortest wave length. In some types of condensers there are two sets of fixed and moving plates in the space usually occupied by a single set of each. This design permits the moving plates to be mechanically balanced; and also gives a larger change in capacity from minimum to maximum than in the usual condenser, and hence a longer scale of wave lengths for any given coil. The condensers are often contained in a compartment with a metal lining, on which the fixed or moving plates may be grounded, which shields the condenser from the influence of outside circuits and keeps the capacity more nearly constant as the meter is being handled by the operator.

4b. **Inductance.**—If a variable *inductance* is used, it is almost always in the form of a variometer with a continuous change from a certain minimum, which is not zero, to a maximum value. In general, a variometer consists of two coils connected in series, one of which is smaller than the other and is rotatable within it. When the two coils are in the same plane and the direction of the current is the same in both coils, the inductance is a maximum; and when the smaller one has been turned through 180 degrees and the current is in opposite directions in the two coils, the inductance is a minimum but is not zero. At intermediate positions the inductance has intermediate values. The wire used in the variometer should be of low resistance so that its high frequency loss is as small as possible. In some meters a special low resistance wire, know as "Litzendraht," consisting of a large number of separately insulated fine wires, is used. It has been found best not to use a large inductance for long waves and taps on it for short waves, but rather to use a set of coils each adapted to a different range of wave lengths. In explanation it may be stated that actual experience has shown that if there are "dead ends" of a coil in the magnetic field of the active coil, high frequency currents will be induced in them which will cause losses therein and change the inductance of the coil. When a set of coils is used, it is evidently necessary that the choice of coils be such that with the given condenser, the different ranges or scales overlap so as to include all wave lengths within the range of the wavemeter.

In some types of wavemeters, the coil is contained within the set box of the wavemeter. As it is necessary to know where the coil windings are in order to be able to make the proper coupling with the coil of the circuit under measurement, the plane of the windings or "Plane of coil" is generally marked by an arrow on the box. Sometimes the "Axis of coil," which is perpendicular to the plane of the windings, is marked instead of the "Plane of coil."

5. Auxiliary apparatus.—The auxiliary apparatus depends entirely upon the use to which the meter is to be put. At a transmitter the wavemeter is used as a receiver and the auxiliary apparatus is some device which indicates when the transmitter and the wavemeter are in resonance. At a receiver the wavemeter is used as a low power damped wave transmitter and the auxiliary apparatus is almost always a buzzer driven by a dry cell battery which furnishes the power to the meter. The circuits of the receiver and the wavemeter are tuned to resonance, which fact is indicated by the detector of the receiver.

5a. Resonance indicators.—When the wavemeter is used at a transmitter, the resonance indicator may be any one of the following devices, depending on the character of the transmitter, as will be explained in later paragraphs: (1) Hot-wire ammeter; hot-wire wattmeter; thermo-couple and galvanometer or thermo-galvanometer; miniature lamp, etc.; or (2) crystal detector and telephone; vacuum-tube detector and telephones, etc. If the device is of low resistance, as an ammeter, wattmeter, etc., as mentioned in (1), it is connected in series in the wavemeter circuit. Although the ammeter, etc., may be of only a few ohms resistance, yet in some cases even this may be too high a resistance to be included in series and it is therefore shunted by a resistance, so that the joint resistance is much reduced. (See Fig. 1.) It is evident that the shunt must be carefully chosen, for if it is of *very low* resistance, only a very small current will flow through the ammeter, etc., and the sensitivity of the wavemeter will be seriously reduced. Most meters are provided with an adjusting screw so that the needle can be set on the zero mark, but this is not absolutely necessary.

If the device is of high resistance, as a crystal detector and telephones, etc., in (2) of the previous paragraph, they are connected in shunt to the wavemeter circuit as in figure 1. In the shunt circuit (1) the detector and telephone may be in series; or (2) the telephones may be in shunt to the detector and the two in series with a small condenser. In the so-called "Unipolar" connection the telephones are in shunt to the detector and the two connected by a single wire to one terminal of the wavemeter. Although this connection is less sensitive than the usual type, it has the possible advantage of adding less outside capacity to that of the variable condenser than any other connection. In some cases the metal lining of the condenser compartment and the machine screws on the panel are used as a convenient means of connecting parts of the detector circuit and for this reason the meter will be inoperative unless it is assembled with all parts in place.

Although a wavemeter with a crystal detector, etc., is much more sensitive than one with an ammeter, galvanometer, etc., yet it is not generally as useful as the latter type for the following reasons: The ammeter, etc., is operated by every type of spark and continuous wave transmitter, whereas the detector and telephones are operated only by spark transmitters, and those types of continuous wave transmitters that are modulated at an *audio* frequency. Many meters of recent design, therefore, are provided with an ammeter, galvanometer, etc., but not with a detector. However, in a few cases binding posts at the terminals of the condenser have been added so that a detector, etc., can be connected into circuit if desired.

5b. Buzzer.—When the wavemeter is used at a receiver, a buzzer operates or excites the wavemeter so that it acts as a low-power, damped wave transmitter giving wave trains at an audio frequency. Its action may be explained as follows: A buzzer in series with a battery is connected to the terminals of the meter and at each break at the buzzer contacts, part of the energy of the buzzer circuit is released to charge the condenser of the meter; the condenser then discharges through the coil of the meter; and thus the circuit is set into oscillation at a known wave length corresponding to the known values of its inductance and capacity. Most meters are provided with a battery compartment and the insertion of a battery in place automatically makes the necessary connections. In some cases the metal lining of the condenser compartment and the machine screws on the panel are used as a convenient means of connecting parts of the buzzer circuit as well as the detector circuit, and for this reason the meter will be inoperative unless it is assembled with all parts in place.

6. Wave-length scales.—As the range of wave length in meters with any *one* coil, or with any *one* condenser is limited, many meters are provided with a set of coils or condensers so that their range is greatly increased thereby. Generally the various coils have marked on them the range of wave lengths to which they apply and they may be connected into circuit as needed. The insertion of any coil in circuit may operate a device which sets a pointer on the scale to be used with the given coil. The various condensers are generally thrown into circuit by a switch and their capacities are so chosen that the corresponding wave lengths are a whole number of times smaller or greater than the scale reading. Thus, if the wave lengths on the scale for one condenser are from 150 to 450 meters and the other two condensers are respectively nine times smaller and larger than the one for 150 to 450 meters, it is evident that the wave lengths will be respectively three times ($\sqrt{9}$) smaller and three times ($\sqrt{9}$) larger than the scale value. In this case the condenser switch may have the values of the multipliers, as 1/3, 1, 3, marked on the contact corresponding to the capacity in use.

If on account of the overlapping of two scales, a wave length can be measured on both, it is generally best to use the end of the first scale rather than the beginning of the second, as the accuracy is greater in the former case.

7. Calibration curves.—In some cases where special accuracy is desired, the meter is calibrated by reference to a standard meter, in which the wave lengths are measured for certain points on its scale, as at every 20 degrees, and a curve is plotted with the degrees along the horizontal line, called abscissas, and the wave lengths in

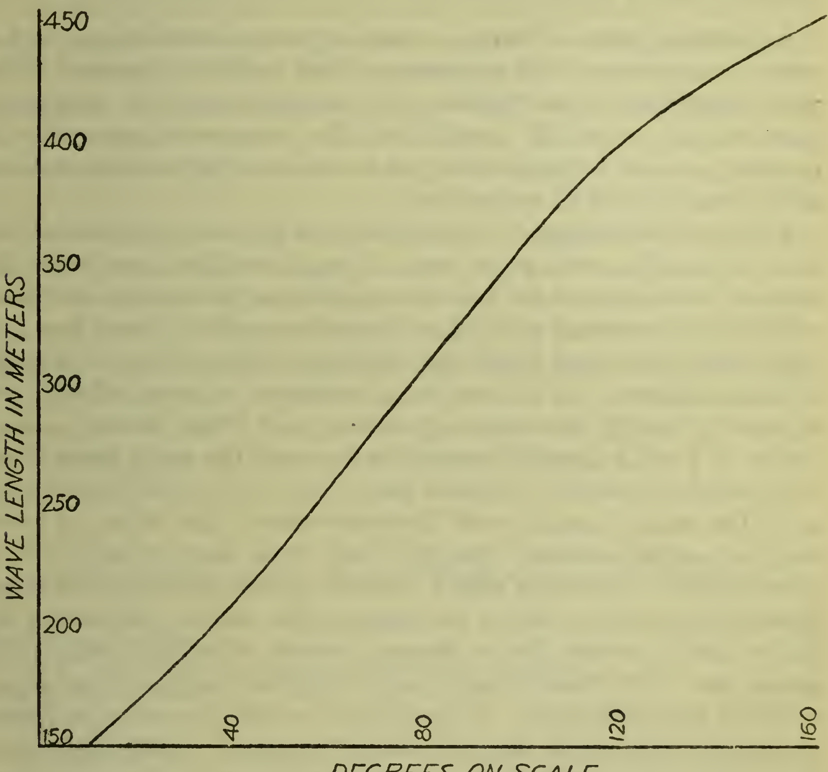

FIG. 2.

meters along the vertical line, called ordinates. The various points are connected by a smooth curve called a calibration curve, so that the wave lengths can be read off for any degree or fraction. Such a curve is shown in figure 2. In special cases meters are calibrated by reference to standard meters by the Bureau of Standards, Washington, D. C. In some meters it is found that there is a slight difference in the calibration curves, depending on whether the meter is used (1) with a buzzer, (2) detector and telephones, or (3) wattmeter. This is due to the small differences in capacity that may be added when the buzzer, etc., are connected into circuit. In such a case separate calibration curves will be given, each correct for its special use.

Section IV.

CARE OF WAVEMETERS AND DECREMETERS.

8. General care.—There are certain general instructions on the care of wavemeters and decremeters that must be observed. The most important are as follows: A wavemeter and its component parts must be carefully handled; all the component parts must be properly secured in place when not in use or during transportation; and it must be kept in a dry place.

9. Care in handling.—A wavemeter is a delicate instrument which must be handled with great care. Rough handling may break the internal mechanism of the hot-wire ammeter or thermo-galvanometer which is an essential part of a decremeter and of many types of wavemeters; and may injure the windings of the coils and the plates of the condensers. In this respect a wavemeter is more delicate than a receiving set for the following reasons: If either the coil or condenser of a set is slightly changed in any way, the set in general can be retuned to resonance without loss of any of its functions, whereas if the same changes occur in a wavemeter, the values of wave lengths may be seriously changed from those marked on the wave length scales. In meters with a variable air condenser it is the usual practice to provide a device for clamping the moving plates and the *plates should always be so clamped* except when the meter is in actual use. Care must be taken not to drop the telephone receivers or to injure the diaphragm. In the former case the caps may be broken so that the diaphragm can not be held in place. In the latter case the diaphragm may be bent or dented and so touch the pole pieces of the permanent magnets where, if the attraction is strong enough, it may be "frozen" and the telephone made inoperative although otherwise in perfect condition. The telephones should never be taken apart, as it is certain that the adjustments will be disturbed. In explanation it may be stated that in order to get the correct clearance between the diaphragm and the pole pieces, it has been found necessary to grind the latter after the assembly of the telephone, as the standard parts can not be assembled with the necessary accuracy.

10. Care of component parts.—It is absolutely essential that *all* the component parts of a wavemeter, as given in its parts list, be kept with it, as otherwise the meter may be made useless; thus the loss of a coil would make it impossible to measure the wave lengths within its range; the loss of the thermo-galvanometer might make it impossible to obtain measurements at a continuous wave transmitter, etc. For this reason all parts not in actual use should be kept in their proper places in the set box. All types of wavemeters which use a buzzer exciter should have a battery in place in the battery compartment, but the battery *should not be kept there* if the wavemeter is to be stored away, as its deterioration may cause corrosion at the battery contacts and elsewhere. When the wavemeter is to be shipped special care should be taken that (1) the moving plates are clamped; (2) the telephones are stored away according to the following standard practice: Put the two receivers with the faces of the caps together so that all access to the diaphragm is closed; and then bind them together in this position by winding the telephone cord around the outside of the head bands beginning close to the caps; (3) all parts are securely fastened in place; and (4) all parts on the parts list are included.

11. Protection against moisture.—A wavemeter must be kept dry under all conditions. This precaution is particularly necessary in meters having coil forms of wood, whose shape may be greatly changed by exposure to moisture and whose wave lengths would also be changed thereby. If for any reason a wavemeter gets wet, it should be carefully dried out but not by direct exposure to heat.

Section V.

COUPLING AS APPLIED TO WAVEMETERS AND DECREMETERS.

12. Definition of coupling.—In all cases where a wavemeter or a decremeter is used, one of the things that must be done is to bring the wavemeter or decremeter circuit in resonance with another circuit or conversely bring another circuit in resonance with a wavemeter or decremeter circuit. In order to obtain resonance between two circuits, it is necessary to have a transfer of energy between the two. This transfer of energy in all types of wavemeters and decremeters now in use is brought about by inductive coupling. Inductive coupling is obtained by having the magnetic lines of force from one circuit pass through another circuit. In other words, there is a mutual interlinkage of lines of force. It is these mutual magnetic lines of force which transfer energy between the two circuits. If a large proportion of the lines of force from one circuit interlink with another circuit, the coupling is said to be close. If only a small proportion of the lines of force interlink, the coupling is said to be loose.

13. Effect of coupling on natural wave length of a circuit.—As has been shown, the natural wave length of a circuit depends upon the value of inductance and capacity in that circuit. The value of an inductance in a circuit for any given current depends upon the number of magnetic lines of force passing through the parts of the circuit. The inductance, and hence the natural wave length of a circuit, is changed by a change in the number of lines of force passing through it, such as is brought about by adding the magnetic lines of force from an outside circuit. Thus if an external circuit is coupled to a wavemeter circuit, the latter circuit will have its natural wave length changed. Therefore, in order to make the least possible change in the natural wave length of a wavemeter circuit, the outside circuit should be coupled to it as loosely as possible and yet permit a transfer of energy.

14. How to vary coupling.—Coupling between two circuits may be accurately expressed by the following formula: $\frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance, and L_1 and L_2 are the inductances that are coupled together. It is seen from this formula, therefore, that a variation of M or a variation of the inductances in either or both circuits will change the coupling. The mutual inductance, M, may be varied by a lateral or an angular movement between the two coils which comprise the inductances in question. If the coils are moved closer together, the coupling is made closer or tightened. If the coils are moved apart, the coupling is loosened. Also the coils may be rotated with respect to each other. If the two coils are parallel, the coupling is the tightest. If the two coils are at right angles, the coupling is loosest. In some cases inductance coils have taps on them so that a varying number of turns in the coils may be employed. Changing the number of turns in use changes the inductance and, as has been noted, this changes the coupling between that coil and the circuit with which it may be linked. Of course it is possible to use any combination of these methods in varying the coupling.

It is seen that in order to vary the coupling by moving one coil with respect to another, the position of the coils must be known. In some wavemeters these coils can not be seen, as they are mounted inside the set box. However, in this case, the outside of the set box usually shows by appropriate marking the position of the coil.

15. Tests for correct coupling.—The correct coupling to use is a *loose* coupling. A good method of testing for this proper coupling is as follows: Bring the two circuits in resonance, using what is judged to be a loose coupling. Loosen the coupling by moving one circuit farther away or by any other method, and note whether or not the two circuits remain in resonance. If the two circuits do remain in resonance, the coupling is sufficiently loose. If the two circuits do *not* remain in resonance, continue to loosen the coupling until they do remain in resonance, and then the coupling is sufficiently loose.

Section VI.

GENERAL DIRECTIONS FOR USING A WAVEMETER AT A TRANSMITTER.

16. Various uses.—The following instructions apply generally to the uses of a wavemeter at a transmitter of either damped or continuous waves. In later sections explicit instructions will be given for the use of each type of Signal Corps wavemeter. At a transmitter the wavemeter is used as a receiving set to receive the signals at resonance and to measure them from the known electrical constants of its own circuit. It may be used (1) to measure an unknown wave length; (2) to set the transmitter at a predetermined wave length; (3) to calibrate a transmitter in wave lengths; and (4) in some cases to measure the logarithmic decrement of the radiated waves. (See Section XIV.) A careful record should be kept of the adjustments at all measured wave lengths. It must be remembered, however, that in general the antenna circuit adjustments will differ with different antennas, unless it should so happen that they have the same electrical constants.

17. Type of resonance indicator to be used.—Some wavemeters have more than one indicating device, and the one to be used depends in general on the type of the transmitter. If it is a spark set (damped wave), any of the devices mentioned in paragraph 5a may be used—thus, the ear can hear the note of the signals in the telephones of any of the detectors, and the eye can see the movement of the needle of the ammeter, galvanometer, etc. If, however, it is a tube or other continuous wave set, there will be no sound in the telephones unless it is modulated at an audio frequency, and for this reason the ammeter, galvanometer, etc., is used at a tube transmitter.

If a wattmeter or galvanometer is used, care must be taken to use loose coupling not only so as not to change the wave lengths, but also so as not to obtain more than a full scale deflection, otherwise the meter may be burnt out by the excessive current. It is not necessary that the needle of the ammeter or galvanometer be adjusted to zero, as the meter is used to indicate relative and not absolute values. Similarly, if a lamp is used, care must be taken not to burn it at more than normal candlepower.

18. Measuring an unknown wave length.—During these measurements the following general directions are to be observed: (1) The transmitter circuits must be kept *unchanged* at the unknown wave length; (2) the wavemeter coil must be loosely coupled only with the *antenna coil* of the transmitter; and (3) the wavemeter must be tuned to resonance with the transmitter.

If the unknown wave length is approximately known, the wavemeter coil or condenser should be selected which includes this wave length within its range; but if it is entirely unknown, the correct coil, etc., can be found only by trial of the various units. Having chosen the proper indicating device, the wavemeter should then be assembled, taking care that only the necessary connections are made to it—thus, if a wattmeter is to be used, the buzzer and detector circuits must be opened, etc. Next the wavemeter coil should be loosely coupled with the *antenna coil* of the transmitter, and thereafter the coupling between the wavemeter and the transmitter must *remain unchanged.* The wavemeter is then tuned to the transmitter by varying its condenser or variometer slowly over the scale until resonance is obtained, as shown by the maximum response of its indicator. When the two circuits are thus in resonance, the unknown wave length can be read from the wavemeter scale or from the calibration curve.

19. Setting on a predetermined wave length.—During these measurements the following general directions are to be observed: (1) The wavemeter must be set on the predetermined wave length which must *not be changed* thereafter; (2) the wavemeter coil must be loosely coupled with the *antenna coil* of the transmitter; and (3) the transmitter must be tuned to the wavemeter.

The wavemeter coil or condenser should be selected which includes the predetermined wave length within its range and the wavemeter set at this length. Having chosen the proper indicating device, the wavemeter should be assembled, taking care that only the necessary connections are made to it. Next the wavemeter coil should be loosely coupled with the *antenna coil* and the transmitter adjustments varied until resonance with the wavemeter is obtained, as shown by the maximum response of its indicator. When the two circuits are thus in resonance, the transmitter is set at the predetermined wave length.

20. Calibrating a transmitter.—The procedure is the same as outlined in the previous paragraph except that the transmitter is set in succession at a series of predetermined wave lengths, say 100 meters apart, over its range of wave lengths. The various adjustment points are tabulated, or plotted as a calibration curve similar to that in paragraph 7. From this curve a transmitter can be correctly set at any wave length within its range.

21. Wavemeter without a resonance indicator.—At a tube transmitter under certain special circumstances a wavemeter can be used to measure a wave length *without* the use of a resonance indicating device. The method can be applied if there is a sensitive ammeter, (1) in the circuit supplying power to the plate circuits of the vacuum tubes; or (2) in the antenna circuit. In both cases the essential principle is the same, and is as follows: When the wavemeter is loosely coupled to the antenna coil of the transmitter and it is being tuned to the transmitter, or vice versa, there will be a small amount of energy withdrawn from the transmitter by the wavemeter. When the two circuits are *in resonance*, there will be a small but sudden increase in the amount of energy withdrawn. This will be indicated by a corresponding *change* in the reading of either or both ammeters. This method of indicating when the two circuits are in resonance can be used in setting a transmitter at a predetermined wave length and in calibrating a transmitter in addition to the other methods described in this section.

22. Precautions in using a wavemeter at a transmitter.—Referring to paragraph 18 on the precaution of opening the buzzer and detector circuits when the wattmeter is in use, it will be seen from figure 1 that they are connected in shunt to the wavemeter coil and condenser. If either of these circuits is permanently closed, it is evident that both the coil and condenser are short-circuited, and that the meter will probably be made inoperative for this reason.

In coupling the wavemeter coil with the antenna coil, care must be taken that it is coupled *only with this coil*, as it is evident that it is the antenna coil which carries the current of the same wave length as that supplied to the antenna for radiation. This precaution is particularly necessary at a *spark* transmitter where the primary circuit coil may carry a current of a wave length different from that in the antenna.

In applying the method outlined in paragraph 19 to the setting of a *spark* transmitter at a predetermined wave length, it is often difficult to keep the primary and secondary circuits *in resonance* as the transmitter is tuned to the wavemeter. For this reason it may be more convenient to tune the two transmitter circuits to resonance and then to tune the wavemeter to the transmitter. If the measured wave length is not correct, the transmitter circuits should be retuned to resonance at a slightly longer or shorter wave length, according to the results of the previous measurement, and the wavemeter again tuned to the transmitter. This should be repeated until the wavemeter, when tuned to the transmitter, shows resonance at the predetermined wave length. In the calibration of a *spark* transmitter, it is more convenient to use the method of this paragraph than that of paragraph 20. Although in general the calibration points will not be at a uniform distance apart, yet the calibration curve itself will be the same as in the other method.

Section VII.

GENERAL DIRECTIONS FOR USING A WAVEMETER AT A RECEIVER.

23. Various uses.—The following instructions apply generally to the uses of a wavemeter at a receiver. In later sections explicit instructions will be given for the use of each type of Signal Corps wavemeter. At a receiver the wavemeter is used to generate damped waves of a wave length in meters which is known from the electrical constants of its own circuit. It may be used (1) to measure an unknown wave length; (2) to set a receiver at a predetermined wave length; and (3) to calibrate the receiver circuit in wave lengths.

24. General instructions.—The adjustments of the primary or antenna circuit will differ with different antennas, unless it should so happen that they have the same electrical constants, but the adjustments of the secondary circuit will be practically independent of the antenna.

The adjustments of the following circuits of the receiving set will be known or desired: (1) Antenna and secondary; (2) only the antenna; or (3) only the secondary. In the first two cases the ground and antenna connections should be made and the wavemeter coil loosely coupled with the *antenna circuit coil;* and in the third case the ground and antenna should be disconnected; the antenna circuit coupled as loosely as possible with the secondary so as to avoid any reaction between them; and the wavemeter coil loosely coupled with the *secondary coil.* A careful record should be kept of the adjustments of all measured wave lengths.

25. Measuring an unknown wave length.—During these measurements the following directions are to be observed: (1) The circuits should be set according to the instructions of the previous paragraph at the same adjustments as when receiving the unknown wave length, and they must be kept *unchanged;* (2) the wavemeter coil must be loosely coupled with the proper coil in the receiving circuit; (3) the wavemeter caused to generate oscillations; and (4) the wavemeter tuned to resonance with the receiving set, as shown by the telephones of the latter circuit.

If the unknown wave length is approximately known, the wavemeter coil or condenser should be selected which includes this wave length within its range; but if it is entirely unknown, the correct coil, etc., can be found only by trial of the various units. The wavemeter should be assembled and the buzzer connected into circuit. Care must be taken that only the necessary connections are made to the wavemeter—thus, the detector circuit must be opened, etc. Next the buzzer should be started and the wavemeter tuned to the receiver by slowly varying its condenser or variometer over the scale until the loudest signals are heard in the telephones of the receiving set. The wavemeter is then in resonance with the receiver at the unknown wave length, which can be read from the wavemeter scale or calibration curve.

26. Setting at a predetermined wave length.—During these measurements the following general directions are to be observed: (1) The wavemeter should be set at the predetermined wave length, which must *not be changed* thereafter; (2) the wavemeter coil must be loosely coupled with the proper coil in the receiving circuit; (3) the wavemeter caused to generate oscillations; and (4) the receiver tuned to resonance with the wavemeter, as shown by the telephones of the receiver circuit.

The wavemeter coil or condenser should be selected which includes the predetermined wave length within its range and the wavemeter set at this wave length. The wavemeter should be assembled and the buzzer connected into circuit. Care must be taken that only the necessary connections are made to the wavemeter—thus, the detector circuit must be opened, etc. Next the buzzer should be started and the receiving circuits tuned to the wavemeter, as though it were a distant station, until the loudest signals are heard in the telephones of the receiving set. The receiving circuits are then in resonance with the wavemeter at the predetermined wave length.

27. Calibrating a receiver.—The procedure is the same as that outlined in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths over its range of wave lengths. The various adjustment points are tabulated or plotted as a calibration curve similar to that described in paragraph 7. From this curve a receiver can be correctly set at any wave length within its range.

Inasmuch as the secondary circuit wave lengths are independent of the antenna, it is the general practice to mark the wave lengths only on the scales of this circuit. If, however, the primary values are known, even for a temporary antenna, they should be tabulated as they will permit of a quicker use of the set on all its wave lengths.

28. **Wavemeter without a resonance indicator.**—At a receiver, under certain special conditions a wavemeter can be used to measure a wave length *without* the use of the buzzer or other auxiliary device. The method is similar in principle to that described in paragraph 21, and can be applied if the receiver is provided with an oscillating tube detector or "autodyne." When the wavemeter is loosely coupled with the proper receiving circuit coil and it is being tuned to the receiver, or vice versa, a small amount of energy is withdrawn from the receiving circuits by the wavemeter. When the two circuits are *in resonance* there will be a small but sudden increase in the amount of energy withdrawn and a corresponding *change* in the current in the telephones of the receiving set. This will be indicated by a "click" in the telephones. This method can be used in setting a receiver at a predetermined wave length and in calibrating a receiver in addition to the methods described in this section.

29. **Precautions in using wavemeter at a receiver.**—In almost all cases only a single dry cell is needed to operate the buzzer, and if, with the cell in circuit, the buzzer can not be operated, the cell should be replaced. No more batteries should be used than are needed for the operation of the buzzer, as additional batteries tend to cause an arc at the buzzer contacts, which may prevent the generation of any oscillations. This is similar to the case of a spark transmitter where an arc instead of a spark is produced at the gap when the voltage of the transformer is excessive.

Section VIII.

MEASUREMENT OF INDUCTANCE OR CAPACITY BY THE USE OF A WAVEMETER OR DECREMETER.

30. **Measurement of inductance or capacity.**—As stated previously, a wavemeter or a decremeter can be used with other apparatus to measure an inductance or a capacity. If a local resonant circuit containing either a known inductance and an unknown capacity, or an unknown inductance and a known capacity, is set into oscillation by any convenient means, such as a buzzer, small spark coil, tube oscillator, etc., then according to paragraph 3—

$$\lambda = 59{,}600 \times \sqrt{LC} \text{ meters.}$$

If now the wave length of the local circuit be measured by a wavemeter or a decremeter, then all but one of the quantities in the formula are known, and the unknown inductance or capacity can be found from either of the two following formulas which are derived by simple algebra from the formula above:

$$L = \frac{\lambda^2}{3.56 \times 10^9 \times C}$$

$$C = \frac{\lambda^2}{3.56 \times 10^9 \times L}$$

where as before L is the inductance in milli-henrys,
C is the capacity in microfarads,
λ is the wave length in meters.

SECTION IX.

WAVEMETER; TYPE SCR-60-C.

31. Use and range of wave lengths.—This wavemeter can be used at either a damped or a continuous wave transmitter, and at a receiver, for all purposes except the measurement of the logarithmic decrement of a transmitter. Its range of wave lengths is from 75 to 2,000 meters.

32. Description of meter.—The meter is of the type that uses a set of coils for the inductance; and a variable air condenser for the capacity. It is provided with a hot wire galvanometer; with a crystal detector but *no* telephones; and with battery and buzzer, etc. All parts are mounted on a panel, and are contained in a box with a removable cover. The top view is shown in figure 3, and the interior in figure 4. The over-all dimensions are approximately 9½ by 9 by 8 inches high, including the carrying handle. It's weight is about 7 pounds.

33. Component parts.—There are three *coils* permanently mounted on the underside of the panel and connected in series. A three-way rotary switch in the upper center of the panel makes the connections at numbered contacts, as follows: (1) Short-circuits two of the coils, leaving the third coil in circuit for the shortest wave lengths; (2) short-circuits one coil, leaving the two others in circuit in series for the medium wave lengths; and (3) removes the short circuits and leaves all three coils in series for the longest wave lengths. The three scales of wave lengths corresponding to the three positions of the switch are marked on the dial of the variable condenser and are as follows: (1) 75 to 200 meters; (2) 200 to 550 meters; and (3). 550 to 2,000 meters. The coils are in the right end of the set box or wavemeter and the plane of the windings is parallel to the front and rear of the box, although not indicated by an arrow as is usually the case.

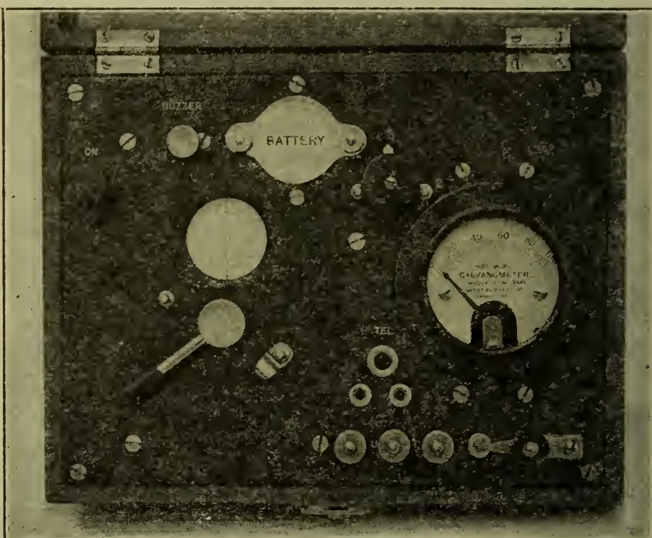

Fig. 3.

The *condenser* is a variable air condenser of the usual type. The handle at the left of the panel carries the wave length scales on a depressed dial that is read through a circular opening in the panel just above the condenser handle. The moving plates can be clamped by turning the handle to its extreme position, where it is locked in place by a spring catch.

The meter is provided with two means of indicating resonance: (1) A *hot wire galvanometer;* and (2) a *crystal detector.*

The galvanometer is connected in series in the circuit and is not shunted by a resistance. It is provided with a zero adjusting screw.

The *detector* is a galena crystal (lead sulphide) in light contact with a metal point on a flat spring which is adjustable as to pressure by means of a screw. It may be put into circuit in either of two types of connections, depending on the manner in which the telephones are connected: (1) In series with the telephones across the condenser; or (2) in the "unipolar" connection to one terminal of the condenser.

The *telephones*, which must be supplied from outside sources, should be of the high impedance type, and may be provided with (1) ordinary tip terminals; (2) standard plug, type PL–5, as in the standard head sets, type P–11; or (3) standard plug type PL–7, as in the standard head sets, type HS–2. In the first case two different connections can be made depending on which two of the three binding posts at the lower edge of the panel are used. If the telephones are

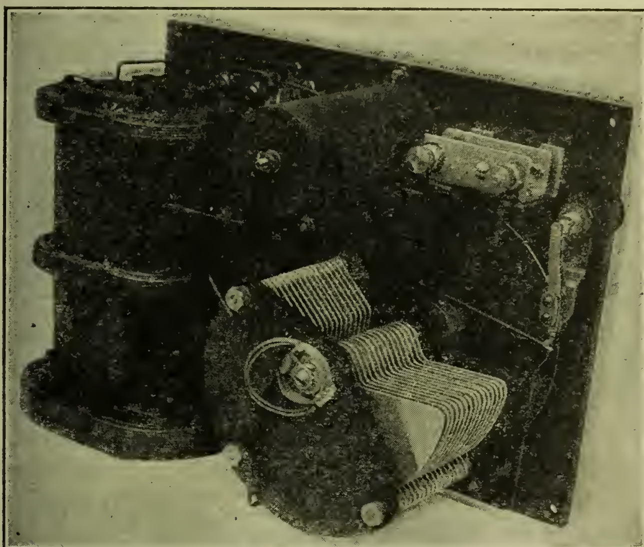

Fig. 4.

connected to the two posts between which the letter "D" is stamped, the detector and telephones are in series across the condenser terminals. If they are connected to the two posts between which the letter "U" is stamped, the detector and telephones are in the unipolar connection. If either of the standard plugs is used, the telephones are in series with the detector across the condenser.

The buzzer exciting circuit comprises the buzzer, battery, and switch, which is connected to the terminals of the condenser as shown in the schematic wiring diagram in figure 5, with the circuit completed through the three inductance coils. The *buzzer* is mounted on the underside of the panel with an adjustment screw for the vibrator projecting through the panel in the left corner and marked "Buzzer." It is driven by a single dry cell *battery*, that is contained in the compartment at the top of the panel marked "Battery." The *buzzer switch* is the button at the left edge of the panel and is closed when the arrow on the button is pointing to "On" and open when pointing away. The schematic wiring diagram of the wavemeter is shown in figure 5.

34. **General instructions.**—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI and VII for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the condenser plates should be clamped by the spring catch.

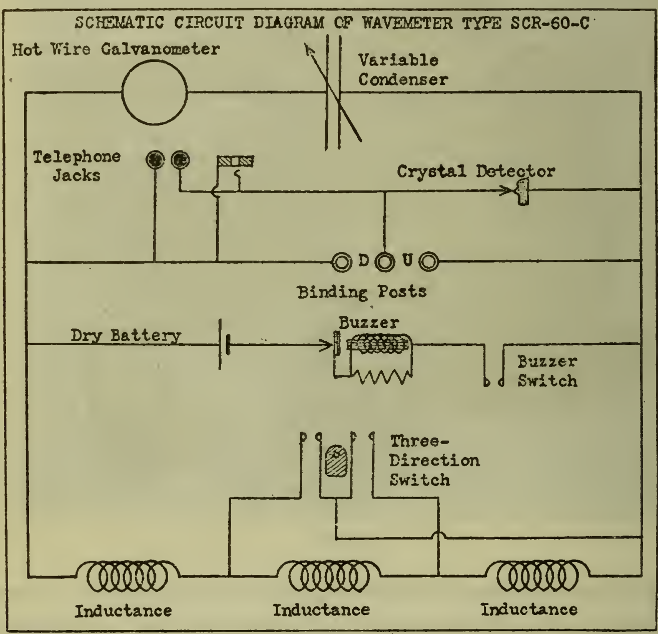

FIG. 5.

35. **Measuring an unknown wave length at a transmitter.**—Set the three-way switch on the scale that includes within its range the wave length to be measured; unclamp the condenser plates; disconnect the telephones; open-circuit the detector; and set the buzzer switch in the "Off" position. Make no other connections on the meter. Loosely couple the wavemeter coils with the *antenna coil* of the transmitter; and turn the condenser handle slowly over its scale until a maximum reading is obtained on the galvanometer, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the position in which the three-way switch is set.

At a *damped wave* (spark) transmitter when the detector and telephones are to be used, the following directions are to be followed: Set the three-way switch on the scale that includes within its range the wave length to be measured; set the buzzer switch in the "Off" position; and plug the telephones in the jacks or connect them to the binding posts as the case may be—for present purposes there is no essential difference between the two types of connections. Make no other connections on the meter. Loosely couple the wavemeter coils with the *antenna coil;* and adjust the detector to a sensitive point. Turn the condenser handle slowly over its scale until the loudest signals are heard in the telephones, thus indicating that the wavemeter is in resonance with the transmitter, etc., as above.

36. Setting a transmitter at a predetermined wave length.—Set the three-way switch on the scale that includes the predetermined wave length, and the condenser at the wave length; set the buzzer switch at the "Off" position; connect in the galvanometer or the detector and telephones; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer or telephones show by the maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark transmitter* it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

37. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

38. Measuring an unknown wave length at a receiver.—Set the three-way switch on the scale that includes within its range the wave length to be measured; disconnect the telephones; and open-circuit the detector. Be sure that there is a battery in circuit in the battery compartment, and then turn on the buzzer switch, adjusting the vibrator by the screw at "Buzzer," if necessary, until the buzzer gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiver circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

39. Setting a receiver at a predetermined wave length.—Set the three-way switch on the scale that includes the predetermined wave length, and the condenser on the wave length; disconnect the telephones; open-circuit the detector; turn on the buzzer switch;

and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter with the proper receiving circuit coil, as described in paragraph 24, and tune the receiver circuits to the wavemeter, as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

40. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

Section X.

WAVEMETER; TYPE SCR–61.

41. Use and range of wave lengths.—This wavemeter can be used at a damped wave transmitter and at a receiver for all purposes, except the measurement of the logarithmic decrement of a transmitter. If provided with an external "current squared" meter or an ammeter, it can be used at a continuous wave transmitter. Its range of wave lengths is from 150 to 2,600 meters.

42. Description of meter.—The meter is of the type that uses a set of coils for the inductance and a variable air condenser for the capacity. It is provided with a crystal detector and telephones; and with a battery and buzzer, etc. There are also provided binding posts for connection to an external vacuum tube detector, and galvanometer or ammeter. Most of the parts are mounted on a panel and the rest carried in compartments. The meter is self-contained in a box with hinged cover and a carrying strap. It is shown assembled and ready for use in figure 6. The over-all dimensions are approximately 15½ by 9 by 11 inches high, including the carrying strap. Its weight is about 23 pounds.

43. Component parts.—Three *coils* are provided, wound on mahogany forms with the windings protected by insulating covers. Each coil is marked with a letter and its inductance in milli-henrys as follows: "A" 0.052 M. H.· "B" 0.319 M. H.; and "C" 1.715

M. H. Three scales of wave lengths, "A," "B," and "C," are marked on the dial at the variable condenser to correspond with the three coils and their ranges are as follows: "A," from 150 to 500 meters; "B," from 400 to 1,200 meters; and "C," from 800 to 2,600 meters. There is also provided a scale of degrees from 0 to 180 so that a calibration curve can be made for each coil if desired. A coil is connected into circuit by placing it in the left end of the cover of the box with the lettered side uppermost and toward the top of the cover. Two centering pins, a large one at the left and a small one at the right, fit into corresponding holes in the brass strip across the center of the coil, and automatically permit only the correct placing of the coil in circuit. It should be fastened in

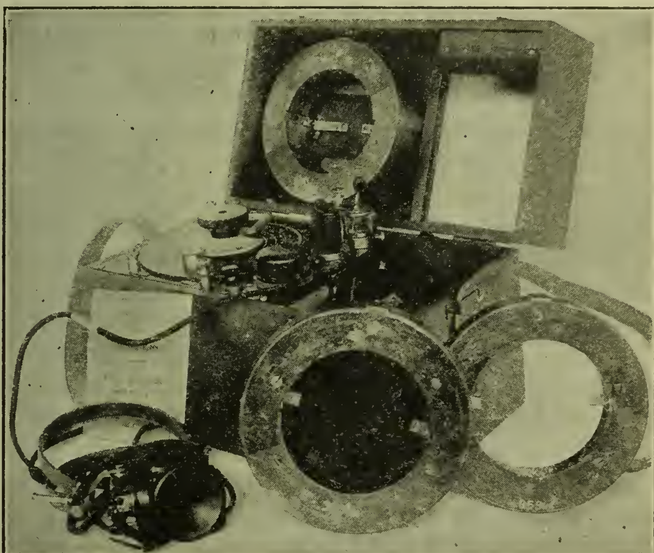

FIG. 6.

place by giving the winged thumb nut one-quarter of a turn. In this position the terminals of the coil at the two small brass plates on the underside of the wood form are connected to the two spring contacts in the cover and thence by flexible leads to the air condenser.

The *condenser* is a variable air condenser of the mechanically balanced type with two sets of fixed and moving plates. The moving plates can be clamped in place by the nut close to the condenser handle either to keep the meter at a constant wave length when desired or to secure the plates in place during transportation. One set of the fixed plates is grounded on the metal lining of the condenser compartment.

The *detector* is a galena crystal (lead sulphide) in light contact with a brass wire, and is inclosed to keep it dry and clean. The crystal is held in place by a screw on the outside of the detector stand, and the contact wire is adjustable by a ball and socket joint, the pressure on which is controlled by the nut on top of the brass post close to the stand. If desired, a *vacuum tube detector* can be used instead of the crystal detector by making suitable connections to the "Grid" and "Fil" binding posts on the front edge of the panel.

Similarly an external *ammeter* or *thermo-galvanometer* may be used instead of the detector by making suitable connections to the "Meter" binding posts in the upper left corner of the panel which ordinarily are short-circuited by a wide strip of brass. Except when the ammeter, etc., is in use, care must be taken to see that the strip makes good connections as it is in series in the wavemeter circuit.

The *telephones* are of the high impedance type adapted for use either with a crystal or vacuum tube detector. They may be provided

SCHEMATIC DIAGRAM FOR SCR-61

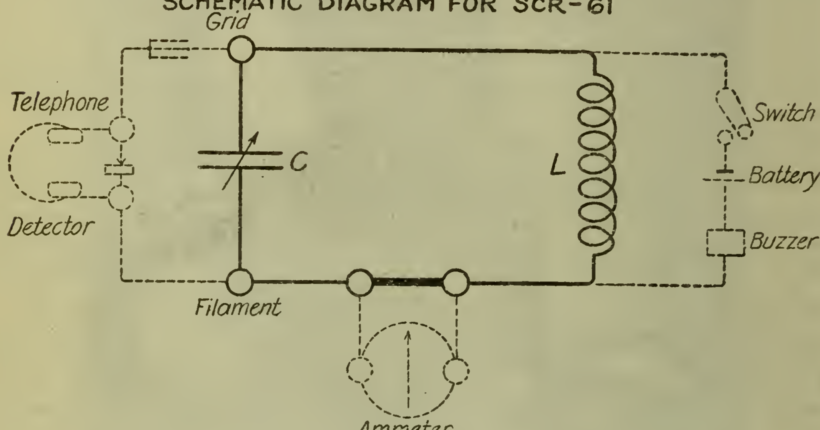

FIG. 7.

with either the standard plug, type PL–5, as in the standard head sets, type P–11, or with tip terminals. In the former case, they should be plugged into the jack just in front of the detector stand and in the latter case they may be connected to the "Grid" and "Fil" binding posts. The connections are the same in both cases, being directly in shunt to the detector, one terminal of which is connected through the metal lining of the box to one side of the variable condenser, and the other terminal through a very small condenser to the other side of the variable condenser. This differs slightly from the usual detector connection which puts the telephones in shunt to a condenser and not a detector. These connections are as shown schematically in figure 7 except that the "Grid" post is at the common terminal of the telephone and detector.

The buzzer exciting circuit comprises the buzzer, battery, and switch, which is connected to the terminals of the condenser with the circuit completed through the metal lining of the box and the inductance coil in circuit. The *buzzer* is mounted on the top side of the panel and is driven by a single dry cell *battery* that is held in spring clips on the underside of the panel just below the buzzer. Access to the battery for its renewal, etc., is through a hinged door opening out into the right-hand compartment of the box. The buzzer *switch* is the black push button on the front edge of the panel, which is in the " Off " position when pulled up and in the " On " position when pushed down.

As the metal lining of the box is used as a part of both the detector and buzzer circuits and as contact is made under three of the four machine screws in the corners of the panel, all of the screws should be kept screwed into place, otherwise the meter may be inoperative both at a receiver and at a transmitter.

44. General instructions.—Before making any measurements with the wavemeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the three coils should be put in the right-hand compartment; the *condenser plates clamped;* the telephones secured as in paragraph 10, and placed centrally on top of the condenser with the caps between the buzzer and the detector stand; and the cover securely fastened in place.

45. Measuring an unknown wave length at a transmitter.—Connect the coil into circuit, which includes within its range the wave length to be measured; unclamp the condenser plates; and pull up the buzzer switch to its " Off " position. Be sure that the two " Meter " binding posts are firmly short-circuited by the strip of brass. Plug in the telephones and make no other connections to the meter. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter and adjust the detector to a sensitive point. Turn the condenser handle slowly over its scale until the loudest signals are heard in the telephones, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the coil in use.

45a. Use of external vacuum tube detector.—If such a detector—which is assumed to be complete and operative—is to be used, instead of the crystal detector, the following directions are to be observed: Open-circuit the detector; remove the telephones; connect the grid and the filament of the tube set respectively to the " Grid " and " Filament " binding posts; make no other connections to the wavemeter; and use the telephones of the tube set. Loosely couple the wavemeter and proceed as in the previous paragraph.

45b. Use of external galvanometer.—If such a detector is to be used, the following directions are to be observed: Connect the coil into circuit which includes within its range the wave length to be measured; pull up the buzzer switch to its "Off" position; open-circuit the detector; remove the telephones; and open the short-circuiting strip at the "Meter" binding posts. Connect the galvanometer into circuit at these posts, being sure to use the shortest possible leads in order to avoid adding inductance into circuit, and thus changing the computed values on the wave-length scales. Make no other connections to the wavemeter. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter; turn the condenser handle slowly over its scale until a maximum reading, etc., similar to above.

46. Setting a transmitter at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser at the wave length; pull up the buzzer switch to its "Off" position; connect in the galvanometer or detector and telephones; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer or telephones show by the maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter as described in paragraph 22.

47. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

48. Measuring an unknown wave length at a receiver.—Connect the coil into circuit which includes within its range the wave length to be measured; disconnect the telephones; and open-circuit the detector. Be sure that there is a battery in circuit and then push down the buzzer switch to its "On" position, adjusting the vibrator if necessary until the buzzer gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

49. Setting a receiver at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser at this wave length; disconnect the telephones; open-circuit the detector; pull up the buzzer switch; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter with the proper receiving circuit coil, as described in paragraph 24, and tune the receiver circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

50. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

Section XI.

WAVEMETERS—TYPES SCR–95, SCR–111, SCR–125, SCR–125–A, AND SCR–128.

51. Use and range of wave lengths.—These meters are all of the same general type, differing principally in the range of wave lengths and in minor details of construction. They can be used at either a *damped* or a *continuous wave* transmitter and at a receiver for all purposes, except that they can not be used to measure the logarithmic decrement of a transmitter. The ranges of wave lengths for the different meters are given here for the sake of convenient reference:

SCR–95	500 to 1,100 meters.
SCR–111	900 to 1,900 meters.
SCR–125	70 to 560 meters.
SCR–125–A	70 to 560 meters.
SCR–128	50 to 75 meters.

52. Description of meters.—The meters are of the type that use a variometer for the inductance and one or more fixed condensers for the capacity. They are provided with a miniature lamp with rheostat for indicating resonance; a buzzer and battery, etc. All parts are mounted on a panel which can be removed from the set box, and the meter is self-contained. Instructions and a wiring diagram for each type of meter are contained on the inside of its set box cover. A top view of the SCR–95 is shown in figure 8, and an inside view in figure 9. The over-all dimensions of the various meters differ slightly, but do not exceed 5 by $5\frac{1}{2}$ by 5 inches high. The weight is about 4 pounds.

53. Component parts.—The *variometer* is mounted on the underside of the panel and is of the type described in paragraph 4b, wound with enamel wire on two forms or frames of an insulating material known as bakelite. The rotation of the inner coil changes the in-

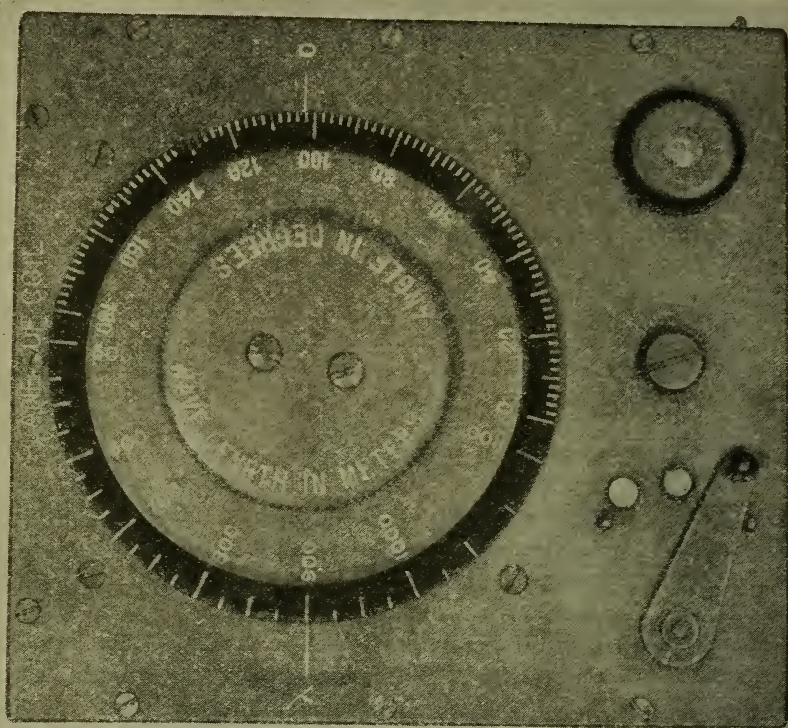

FIG. 8.

ductance in circuit and hence the wave length, and its shaft carries the dial and the wave length scale. The maximum value of the inductance is between 4 and 9 times larger than the minimum value, so that the longest wave length on the scale is between 2 ($\sqrt{4}$) and 3 ($\sqrt{9}$) times longer than the shortest wave length. The "Plane of coil" is indicated by an arrow on top of the meter, and in this case refers to the plane of the larger and fixed variometer coil.

The *condenser* is mounted on the underside of the panel and is of mica, sealed in a waterproof compound to exclude air and moisture.

In some meters three condensers are provided which can be connected into circuit by a *condenser* or *wave length* "*multiplier*" *switch* so as to give three ranges of wave lengths. In this case the capacities are in the ratio of either 1, 4, and 16; or 1, 9, and 81, so that the wave lengths will be as 1, 2, and 4; or 1, 3, and 9. Thus a single direct reading scale of wave lengths may be used, which as the different condensers are put into circuit by the switches, should be multiplied by the corresponding numbers 1, 2, and 4, etc., to give the other wave lengths.

The *miniature lamp* is mounted on top of the panel with a screw base and is protected by a hood which is removable for the renewal of the lamp by rotating it a fraction of a turn. It is permanently

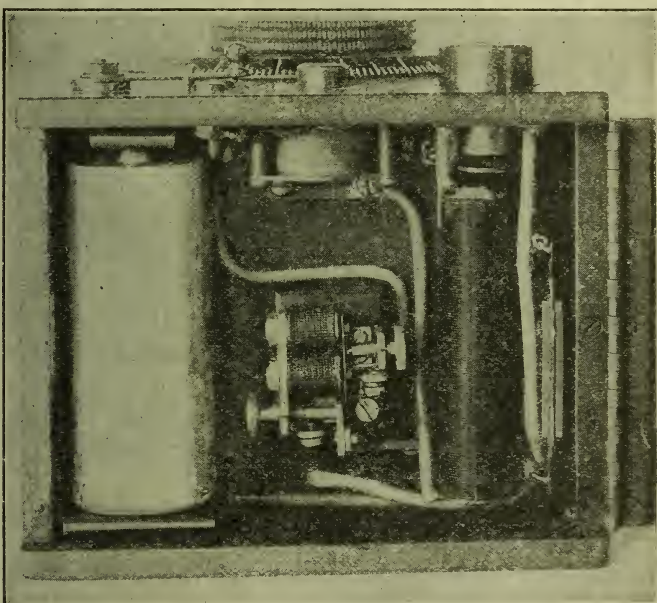

Fig. 9.

connected in circuit in series with the variometer and condenser. The lamp filament is most sensitive in showing any small increase in current when it is lighted to a dull red glow. For this reason the buzzer battery and an adjustable resistance are connected in series across the lamp terminals at the "C" contact at the three-way switch, so that the filament can be brought to its sensitive point. The *resistance* consists of a pile of carbon plates on the underside of the panel, which is adjustable by means of a screw on top of the panel marked "Lamp resistance." A *choke coil* of enamel wire is mounted on the underside of the panel in the front compartment and is used in the lamp and battery circuit to prevent the high frequency oscillations from flowing through that circuit instead of through the lamp. Although the battery is disconnected at the "A" contact of the three-way switch so that the filament is not lighted thereby, yet it is to be noted that the wavemeter is still operative as its circuit is still complete and the filament *may* be lighted at resonance by *strong* signals.

The *buzzer* is connected in circuit at the " B " contact of the three-way switch and is driven by a single dry cell battery that is held in place by spring clips in the front compartment of the set box. The *battery* is cut out of circuit at the "A" or " Off " position of the three-way switch.

54. General instructions.—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI, and VII, for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use the battery switch should be at the " A " or " Off " position, and when stored away, the battery should be removed from its compartment.

55. Measuring an unknown wave length at a transmitter.—If there is a condenser or wave length " Multiplier " switch, set it on the scale that includes within its range the wave length to be measured; be sure there is a battery in circuit in the battery clips; set the battery switch on the " C " or "On " position; and adjust the " Lamp resistance " by means of its screw until the filament burns at a dull red glow. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter; and turn the variometer handle slowly over its scale until the lamp glows brightest, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale in use.

56. Setting a transmitter at a predetermined wave length.—If there is a condenser or wave length " Multiplier " switch, set it on the scale that includes within its range the predetermined wave length; set the variometer handle at the wave length; be sure that there is a battery in circuit in the battery clips; set the battery switch at the " C " position; adjust the " Lamp resistance " by means of its screw until the filament burns at a dull red glow; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the *antenna coil* and tune the transmitter to the wavemeter until the lamp shows by its brightest glow that the two circuits are in resonance at the predetermined wave length.

At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

57. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

58. Measuring an unknown wave length at a receiver.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes within its range the wave length to be measured; be sure that there is a battery in circuit at the battery clips; set the battery switch on the "B" contact, adjusting the buzzer if necessary until it gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil as described in paragraph 24. Turn the variometer handle slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiver circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

59. Setting a receiver at a predetermined wave length.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes the predetermined wave length; set the variometer handle at the wave length; set the battery switch on the "B" contact, adjusting the buzzer if necessary until it gives a clear, steady note; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

60. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

61. The SCR–95.—This is a *single-scale* wavemeter, with a range of wave lengths from 500 to 1,100 meters. As can be seen from the wiring diagram in figure 10, the 3-point battery switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set-box cover:

To measure wave length, set switch on "C" and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial.

To set receiver for given wave length, set switch on "B," adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above, and tune receiver until buzzer is heard loudest in phones.

CAUTION.—Replace battery when it fails to operate buzzer or lamp. When meter is not in use leave switch on "A" only.

62. The SCR–111.—This is a *single-scale* meter, with a range of wave lengths from 900 to 1,900 meters, almost identical with the

SCR–95 except for the wave lengths. The wiring diagram is identically the same as in the SCR–95 (fig. 10). The 3-point battery switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set-box cover:

To measure wave length, set switch on "C" and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil

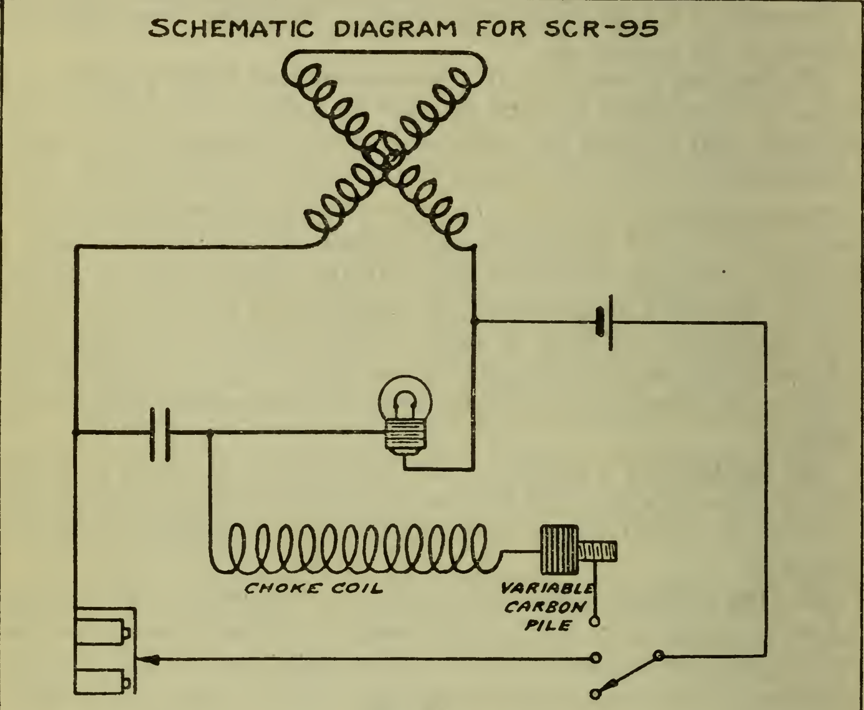

FIG. 10.

of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial.

To set receiver for given wave length, set switch on "B," adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above, and tune receiver until buzzer is heard loudest in phones.

CAUTION.—Replace battery when it fails to operate buzzer or lamp. When meter is not in use leave switch on "A" only.

63. The SCR–125.—This is a *3-scale* meter with a range of wave lengths from 70 to 560 meters. It is direct reading from 70 to 140 meters, and as the multipliers are 1, 2, and 4, the scale also reads from 140 to 280 meters, and from 280 to 560 meters. As can be seen from the wiring diagram in figure 11, the 3-point switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set box cover:

This instrument has three wave length ranges obtained by three values of capacity. With the condenser switch on position 1, the wave length range is approximately 70 to 140 meters, the wave length dial reads directly in meters. With the condenser switch on position 2, the wave lengths indicated

SCHEMATIC DIAGRAM FOR SCR-125

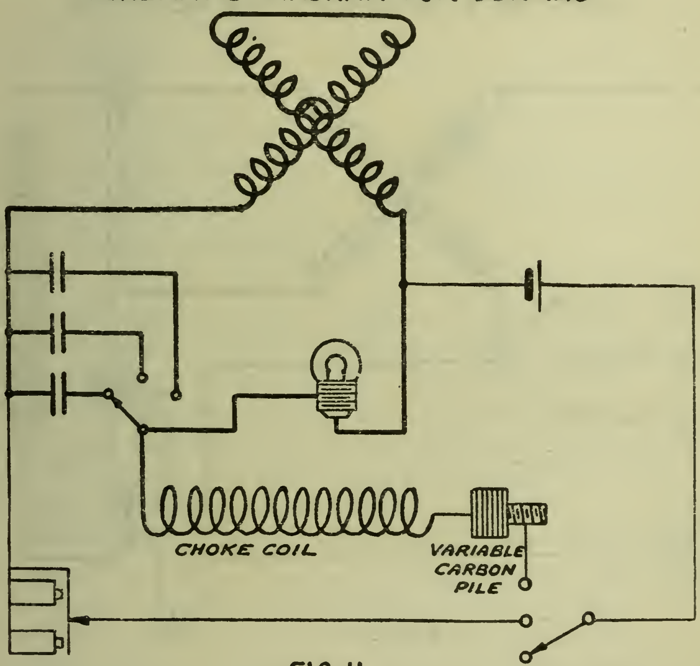

FIG. 11.

on the dial must be multiplied by 2, and correspondingly with the condenser switch on position 4, the dial reading must be multiplied by 4.

To measure wave length, set circuit switch on "C," and adjust carbon resistance until the lamp glows a dull red. Couple the wavemeter by holding it near the inductance coil of the sending set. Rotate the dial slowly until the lamp shows maximum brilliance, the wave length will then be indicated on the wavemeter dial.

To set the receiver for a given wave length, set the "circuit switch" on "B." Adjust the buzzer to give a clear note, and turn the dial to the desired wave length. Couple as above and tune the receiver until the buzzer is heard loudest in the telephone receivers.

Caution.—Leave circuit switch in "A" position when the wavemeter is not in use.

64. The SCR–125–A.—This is a *3-scale* meter, very similar to the SCR–125, with a range of wave lengths from 50 to 1,350 meters. It is direct reading from 150 to 450 meters, and as the multipliers are 1/3, 1, and 3 the scale reads also from 50 to 150 meters, and from 450 to 1,350 meters. As can be seen from the wiring diagram in figure 12, the 3-point switch has contacts as follows: "A" to disconnect the battery, "B" to connect the battery to the buzzer, and "C" to connect the battery to the lamp. The "Plane of coil" is *diagonal* and lies in a vertical plane parallel to a line through the multiplier

SCHEMATIC DIAGRAM FOR SCR-125-A

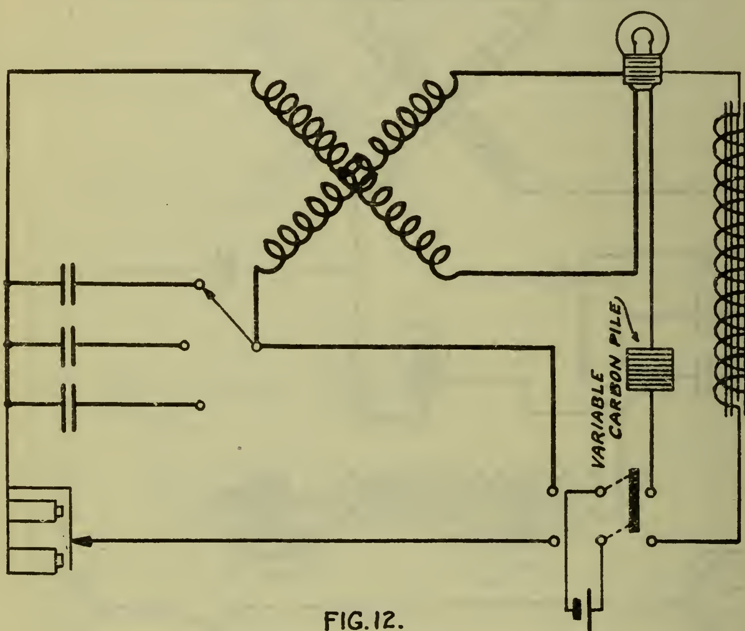

FIG. 12.

switch and the lamp. The following brief instructions are contained on the inside of the set box cover:

This instrument has three wave length ranges obtained by three values of capacity. With the condenser switch on position 1, the wave length range is approximately 150 to 450 meters. The wave length dial reads directly in meters. With the condenser switch on position 3, the wave lengths indicated on dial must be multiplied by 3, and correspondingly with the condenser switch on position 1/3, the dial reading must be multiplied by 1/3.

To measure wave length, set circuit switch on "C" and adjust the carbon resistance until the lamp glows a dull red. Couple the wavemeter by holding it near the inductance coil of the sending set. Rotate the dial slowly until the lamp shows maximum brilliance. The wave length will then be indicated on the wavemeter dial.

To set the receiver for a given wave length, set the circuit switch on "B." Adjust the buzzer to give a clear note, and turn the dial to the desired wave length. Couple as above and tune the receiver until the buzzer is heard loudest in telephone receiver.

65. The SCR–128.—This is a *single-scale* wavemeter for very short wave lengths, with a range from 50 to 75 meters. It is so closely similar to the SCR–95 that the same general instructions, wiring diagram, etc., may be used for both meters.

Section XII.

WAVEMETER; TYPE SCR–137.

66. Use and range of wave lengths.—This wavemeter can be used at either a damped or a continuous wave transmitter, and at a receiver with an oscillating vacuum tube detector for all purposes, except the measurement of the logarithmic decrement of a transmitter. With the equipment that has been provided it can *not* function at a receiver with a crystal or other nonoscillating detector. Its range of wave lengths is from 1,000 to 20,000 meters.

67. Description of meter.—The meter is the Bureau of Standards "Long Wave Meter, type L." It uses a set of coils for the inductance and a variable air condenser for the capacity. It is provided with a thermo-galvanometer, and binding posts for connection to an external detector, buzzer, etc. All parts are mounted on a panel in an oak box with a removable cover, and the meter is self-contained. A top view is shown in Fig. 13. The over-all dimensions are approximately 8¼ by 16¾ by 10¼ inches high and the weight about 28 pounds.

68. Component parts.—Four *coils* are provided permanently mounted on the underside of the panel and are connected into circuit in three combinations for the three scales of wave lengths, as follows: (1) For short waves, 1,000 to 5,000 meters, the four coils are all in parallel; (2) for medium waves, 2,000 to 10,000 meters, two coils are connected in series and this combination is in parallel with the other two coils, also in series; and (3) for long waves, 4,000 to 20,000 meters, the four coils are all in series. These various connections are made by means of a switch which is operated by the handle near the rear edge of the meter. This handle can be turned in either direction and at the three points in the revolution where the connections are made, the number of the scale in use is indicated in a circle at the peephole near the handle, and at the same time the index points to the direct reading scale of wave lengths in use. The coils are in the right-hand end of the set box and the axis of the coils is parallel to the right end, as indicated by the legend "Axis of Coils" on the end. The plane of the windings is therefore parallel to the front and rear of the box.

The *condenser* is of the mechanically balanced type with two sets of fixed plates and two sets of moving plates. Owing to the rapid change of capacity as the moving plates are rotated, the motion is geared down about 5½ to 1 and the condenser handle is the one near

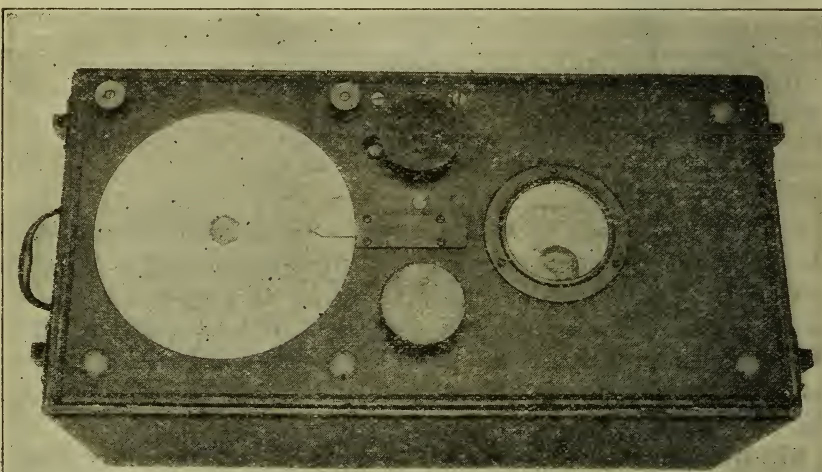

FIG. 13.

the front edge of the panel marked "Press." The condenser compartment is in the left end of the set box shielded by a metal lining.

The *galvanometer* is provided with a small screw extending through the glass cover so that its needle can be adjusted to zero if desired. It is shunted by a resistance and is cut out of circuit by a switch which is closed except when the condenser handle is *pressed down*. This pressure does not change the condenser reading or wave length.

No other auxiliary apparatus has been provided with the meter. There are, however, two binding posts on the rear edge of the panel which are connected to the terminals of the condenser. A detector and telephones, or buzzer and battery can be connected to these if desired for use as described in Section VII. The schematic wiring diagram of the wavemeter is shown in figure 14.

69. General instructions.—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of meters and their use at a transmitter and at a receiver. In making the meter ready for transportation the only step that need be taken is to be sure that the cover is firmly clamped in place.

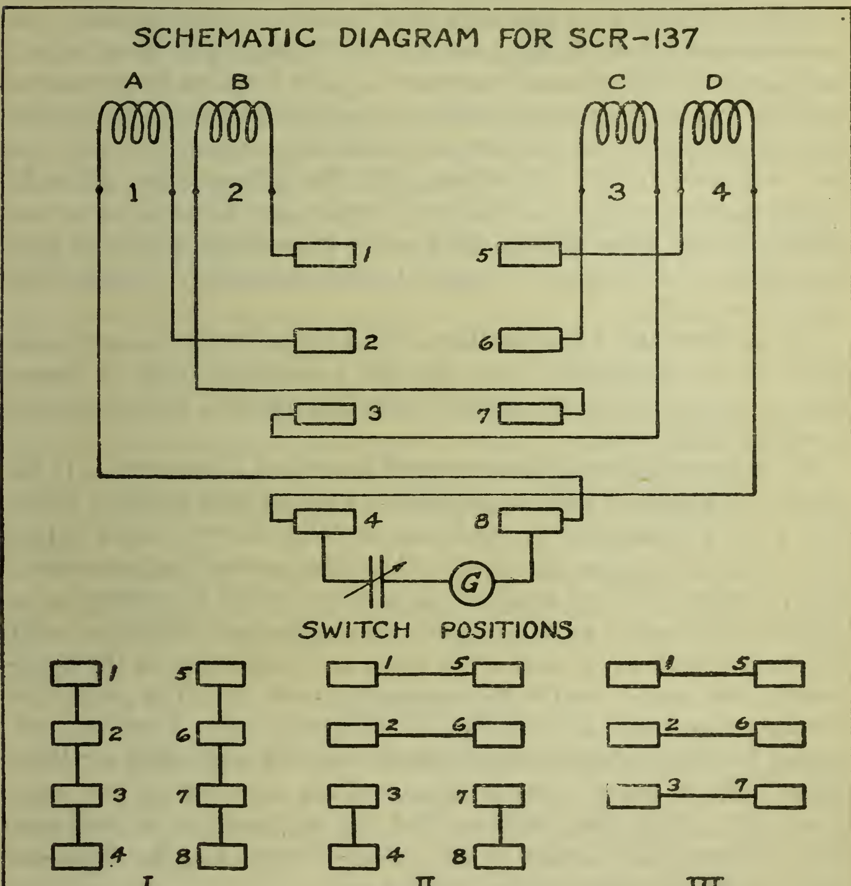

FIG. 14.

70. Measuring an unknown wave length at a transmitter.—Set the coil switch at the rear edge of the meter on the scale that includes within its range the wave length to be measured, taking care that the circle containing the scale number is central in the peephole. Loosely couple the wavemeter coils with the *antenna coil* of the transmitter; press down on the condenser handle on the front edge of the panel; and turn it slowly over its scale until a maximum reading is obtained on the galvanometer, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale in use.

If an *external detector* and telephones are to be used (as at a spark transmitter), they should be connected either in series between the two binding posts or in a unipolar connection to the inner post. Then set the coil switch, etc., similar to the previous paragraph.

71. Setting a transmitter at a predetermined wave length.—Set the coil switch on the scale that includes within its range the predetermined wave length; set the condenser at the wave length; make no connections to the wavemeter; press down on the condenser handle; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer shows by its maximum reading that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

72. Calibrating a transmitter.—The procedure is the same as in the previous paragraph except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

73. Measuring an unknown wave length at a receiver.—If the receiver is provided with an *oscillating vacuum tube detector* (autodyne) two methods may be used, one in which the wavemeter is provided with a buzzer as described in the latter part of this paragraph; and the other with no auxiliary apparatus, which is preferable, as follows: Set the coil switch on the scale that include within its range the wave length to be measured; make no connections to the wavemeter; and loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until a "Resonance click" is heard in the telephones of the receiving set (see paragraph 78), which thus indicates that the wavemeter is in resonance with the receiving circuits at the unknown wave length. Read the wave length in meters on the scale in use.

If the receiver is provided with a *crystal* or *vacuum tube detector* (nonoscillating), the following directions are to be followed: Connect an external buzzer and dry-cell battery in series to the two binding posts at the rear of the panel. Then set the coil switch on the scale that includes within its range the wave length to be measured and adjust the buzzer to a clear, steady note. Loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters, etc.

74. Setting a receiver at a predetermined wave length.—At a receiver with an *oscillating vacuum tube detector*, set the coil switch on the scale that includes the predetermined wave length, and the condenser on the wave length; make no other connections to the wavemeter; and do not change the wavemeter adjustment thereafter. Loosely couple the wavemeter with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the wavemeter as though it were a distant station until a "Resonance click" is heard in the telephones of the receiving set, thus indicating that the circuits are in resonance with the wavemeter at the predetermined wave length. (See paragraph 78.)

At a receiver with a *crystal* or *vacuum tube detector* (nonoscillating), set the coil switch on the scale that includes the predetermined wave length, and the condenser on the wave length; connect the battery and buzzer as in paragraph 73; adjust the buzzer to a clear, steady note; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24; and tune the receiving circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

75. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

Section XIII.

HETERODYNES AND AUTODYNES AS WAVEMETERS.

76. Uses.—A heterodyne set calibrated in wave lengths can be used as a wavemeter at a receiving set provided with an oscillating tube detector. Similarly, a receiving set with an oscillating tube detector (autodyne) calibrated in wave lengths can be used as a wavemeter at a continuous wave transmitter. Other uses of heterodynes and autodynes as substitutes for wavemeters may be devised, but will not be described in this pamphlet.

77. Beat note test for resonance.—In all uses of the heterodyne wavemeter, both the heterodyne and other circuits must be oscillating. When the two circuits are oscillating at nearly the same wave length, a "*beat*" note is heard in the telephones of the receiving set. The pitch of the beat note will vary with the tuning adjustments of either circuit. If the tuning adjustments of either circuit are slowly and continuously varied through resonance, the beat note will pass from inaudibly high to high pitch, becoming lower and lower in pitch until it becomes inaudibly low; after which it will reappear as a note of low pitch which becomes higher and higher, finally becoming inaudibly high. The two circuits are in resonance when the beat note is of zero pitch—that is, in the inaudibly low range of tuning. This point is halfway between the points where the low note disappears and reappears as the tuning is varied.

78. **"Click" test for resonance.**—When a steady current flows through a telephone receiver—as in a vacuum tube detector—any sudden change in the current will produce a click in the receiver. Thus in an autodyne which is oscillating there will be a sudden decrease in the current if a near-by circuit is tuned to the same wave length, as the near-by circuit then draws a large amount of energy from the autodyne circuit and decreases the current in the telephone. When a "click" is produced by this cause it therefore indicates resonance between the autodyne and the external circuit.

79. **Autodyne at a transmitter.**—A receiving set with an oscillating tube detector and calibrated in wave lengths can be used to measure unknown wave lengths at a continuous wave transmitter. In this case the primary of the receiver is left open circuited and the coupling between the primary and secondary of the receiver made as loose as possible. In general, the secondary of the receiver will pick up energy enough from the transmitter to give a signal without the use of the receiver primary circuit and with no special regard to coupling. Leaving the transmitter circuits unchanged, adjust the receiving circuit to resonance (zero beat note). Similarly a transmitter can be set at a predetermined wave length and calibrated. (See paragraphs 19 and 20.)

80. **Heterodyne at a receiver.**—A heterodyne set can be used to measure unknown wave lengths, etc., at a receiver in several different ways as follows: It may be connected (1) in the antenna circuit; (2) in the secondary circuit; or (3) loosely coupled with the proper receiving circuit coil but not connected into circuit. In the first case the secondary circuit must remain unchanged and the heterodyne set adjusted to produce zero beat signals as shown by the telephones of the receiving circuit; in the second case, the primary circuit must remain unchanged, etc.; and in the third case, both circuits must remain unchanged, etc. The first and third methods are the most commonly used. The Signal Corps set, type BC-104,

may be used for the first method. Similarly a receiving circuit can be set at a predetermined wave length and calibrated according to the directions of paragraphs 26 and 27.

SECTION XIV.

THEORY OF DAMPING AND ITS MEASUREMENT BY DECREMETER AND WAVEMETER.

81. Damped oscillations and logarithmic decrement.—Whenever a condenser discharges through an inductance and a resistance, the discharge current in general takes place as a train or series of oscillations, the first of which is the most intense, and the following ones of steadily decreasing values as they die away to zero. Such a train of oscillations is said to be *damped*, and the *logarithmic decrement* is the *mathematical measure* of the damping, or the dying away of the oscillations. If the oscillations in a train die away quickly, the decrement is said to be large; and if they die away slowly, the decrement is said to be small. The damping of tube and arc sets is practically zero, and for this reason measures of damping are confined to spark sets.

82. Mathematical definition of decrement.—Mathematically, decrement may be defined as follows: Let figure 15 represent part of a wave train. The largest value in a positive or negative half cycle or alternation is called the *amplitude:* Thus I_0, I_1, and I_2 are the three amplitudes of figure 15, in which I_0 is the largest amplitude and I_1 and I_2 are amplitudes of successive half cycles in the wave train as it dies away. In mathematical language the logarithmic decrement is defined as the natural logarithm of the ratio of any amplitude to the next following amplitude in the same direction.

$$\text{Decrement} = \delta = \log \frac{I_0}{I_2}$$

where δ (read "delta") is the symbol for the decrement. It is constant in any one wave train.

This may be rewritten and restated in other ways as follows:

$$\delta = \log I_0 - \log I_2$$

Thus the decrement is a number which is the *constant difference* between the natural logarithms of any two successive amplitudes in the same direction.

$$\delta = \log I_0 - \log I_2$$
$$\text{And } \log I_2 = \log I_0 - \delta$$

Thus the decrement is the constant number by which the natural logarithm of the amplitude of any oscillation in a train must be decreased to find the natural logarithm of the next following amplitude in the same direction. In other words, it is a constant decrement or decrease in a natural logarithm, whence the name "logarithmic decrement."

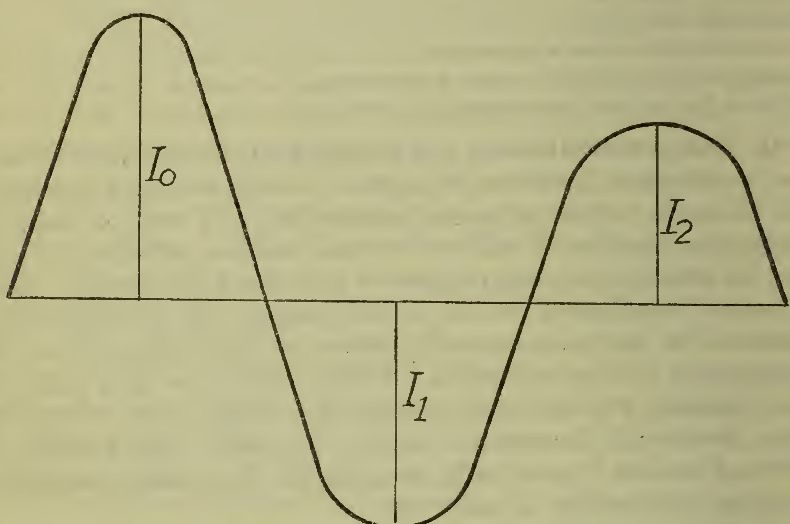

FIG. 15.

If $I_0 = I_2 = I_4$, etc., that is, if the amplitude of all the oscillations in the train is the same, it is evident that the logarithmic decrement is zero, and these oscillations are *undamped*. Reference will be made to this relation later on in the theory of the decremeter.

83. Calculation of decrement in an isolated circuit.—The decrement of any isolated or very loosely coupled oscillating circuit can also be defined by its *electrical constants*, as in the following formula:

$$\delta = \frac{R}{2\,LN}.$$

R=High frequency resistance in ohms.
L=Inductance in henrys.
N=Number of cycles per second at which the circuit is oscillating.

The quantity N is connected to the wave length λ by the following formula:

$N\lambda = V = 300{,}000{,}000$ meters per second where λ is in meters.

For example, if the wave length is 754, the value of N is $\frac{300{,}000{,}000}{754}$, or about 398,000 cycles per second.

84. General formulas.—When the decremeter is used to measure the wave length or the decrement of a transmitter, it is loosely coupled with its circuit. Under these conditions it can be shown mathematically that by means of suitably chosen readings the decrement of the transmitter can be determined by the following formula which makes use of the decrement of the meter itself, as well as certain readings of its capacity and current:

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C} \sqrt{\frac{I^2}{I^2_r - I^2}}$$

δ_1 is the decrement of the transmitting circuit under measurement.

δ_2 is the decrement of the meter itself.

C_r is the capacity of the decremeter condenser when it is in resonance with the transmitter.

I^2_r is the square of the current in the decremeter circuit at resonance.

C is the capacity of the decremeter condenser when it is slightly off resonance, or detuned.

I^2 is the square of the current in the decremeter circuit at the detuned adjustment.

In order to avoid the necessity of squaring the ammeter current reading to get I^2, the meter actually provided has its scale graduated as I^2 or it is a "current squared" meter. It is a hot wire wattmeter or galvanometer, whose reading depends upon its I^2R value. The resistance "R" of the wire is fixed so that the readings are proportional to the square of the current.

85. Simplified formulas.—In practically all cases where the decrement formula can be correctly used, it is possible to simplify it by a suitable choice of its readings. If the reading I^2 at the capacity C is so taken that $I^2 = \frac{1}{2} I^2_r$, then the quantity under the square root sign becomes unity, and hence

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C}$$

where all the quantities are known except δ_1, which can be computed.

If the decremeter is loosely coupled to an undamped wave source, as a vacuum tube oscillator, whose decrement is zero, and if the readings are taken in the usual way, the decrement of the meter can be immediately determined, as δ_1 is now zero, and all quantities are known except δ_2 which becomes

$$\delta_2\pi = \frac{C_r - C}{C}.$$

From formula $\delta = \frac{R}{2LN}$ it is seen that the decrement will vary with N and hence with the wave length, as well as with the high frequency resistance R, and that, therefore, it is not constant for any one decremeter coil. It is the general practice, however, to give an *average* value for each coil over the range of wave lengths for which it is to be used. In some cases for accurate work a curve is supplied showing the variation in decrement for each coil over the entire range of its use.

86. Decremeter scale.—It can be shown mathematically that the plates of the decremeter condenser can be so shaped that for any change in capacity from C_r to C, the quantity $\frac{(C_r - C)}{C}$ will be constant. If a scale is attached to the variable condenser whose value is proportional to $\frac{(C_r - C)}{C}$ and whose readings are π times $\frac{(C_r - C)}{C}$, it is evident that the scale will read directly $\delta_1 + \delta_2$ in accordance with the formula of paragraph 85. From the known value of δ_2, δ_1 can be immediately determined. A wavemeter whose condenser is designed to give such readings is called a decremeter. The complete theory of the decremeter is given in Bureau of Standards Scientific Paper No. 235.

87. Use of a wavemeter as a decremeter.—Although the logarithmic decrement can be obtained from a direct reading scale of a decremeter, yet it can also be obtained by computation from readings of certain types of wavemeters. For this purpose, (1) the wavemeter must be of the type using a fixed inductance and variable capacity; (2) its own decrement must be known; and (3) it must be provided with either a current measuring instrument, as an ammeter, or preferably a "current squared" instrument, as a hot wire galvanometer or a thermo-galvanometer.

If the wavemeter coil is loosely coupled with the antenna coil of the transmitter, and if the capacity of its condenser is varied, it will be found that the ammeter or galvanometer will show a maximum reading when the wavemeter is in resonance with the transmitter, and steadily decreasing readings as the condenser is varied more and more from its resonant position on either side of the resonance point. When these results are plotted with the condenser capacities along the horizontal line and the square of the currents along the vertical line, the curve so obtained is one form of a *resonance curve.*

88. Example of a wavemeter used as a decremeter.—Such a resonance curve is shown in figure 16, and from it the logarithmic decrement can be computed as follows: Referring to paragraph 85, it

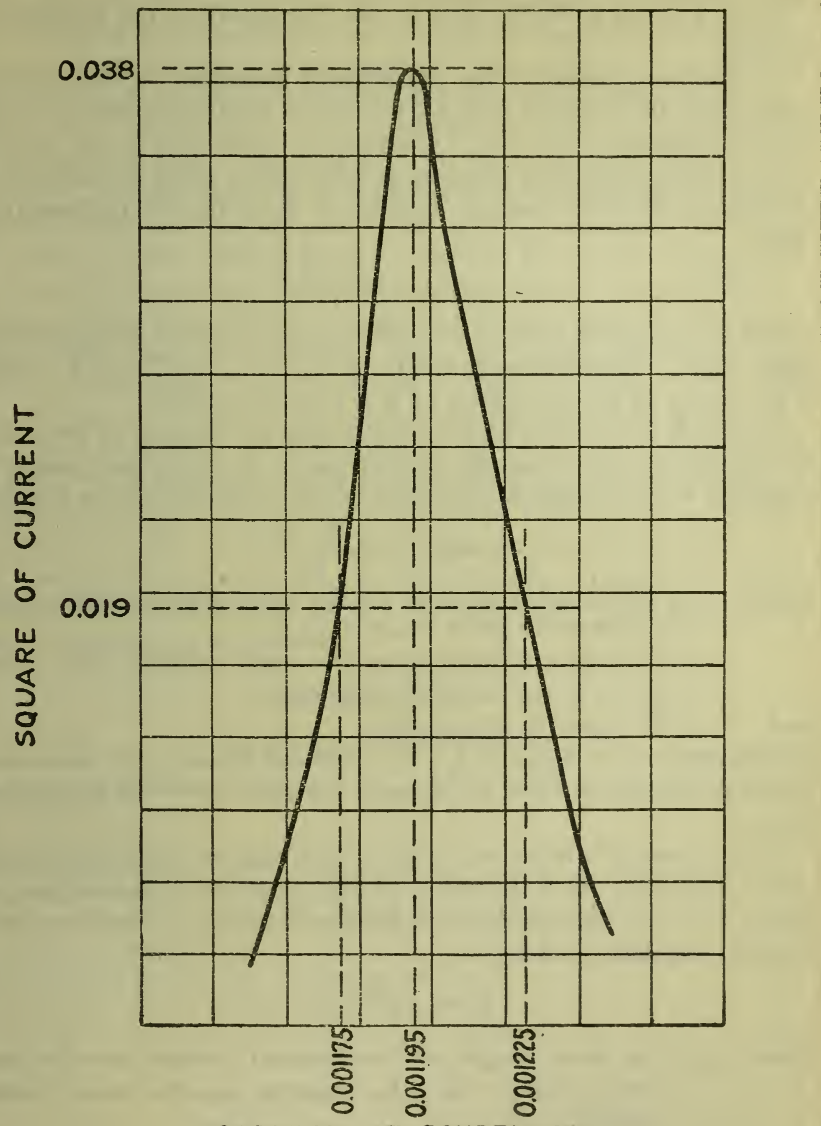

FIG. 16.

is seen that it is necessary to know the capacity at resonance, C_r, where the galvanometer reads I^2_r; and at the detuned position C, where the galvanometer reads $\frac{1}{2}I^2_r$. From the curve, C_r is 0.001195 mfd. at $I^2_r=0.038$ and C is 0.00117 mfd. at $\frac{1}{2}I^2_r$ Substituting in the formula, the formula

$$\delta_1+\delta_2=3.14\ \frac{0.001195-0.001175}{0.001175}=0.054.$$

If δ_1 is given as 0.016, then δ_2, the decrement of the transmitter is 0.038.

In the computation of the logarithmic decrement in the previous paragraph, the capacity at resonance and at a detuned position on one side of resonance was used. Inasmuch as the curve is not exactly symmetrical, it is best to compute another value, using the capacity at resonance and at the detuned position on the other side of resonance. Thus

$$\delta_1+\delta_2=\pi\frac{C-C_r}{C}$$

where C_r is 0.001195 mfd. at $I^2_r=0.038$ as before; and C is also 0.001225 mfd. at $\frac{1}{2}I^2_r$. Substituting in the formula, $\delta_1+\delta_2=0.077$ and $\delta_2=0.061$ The average of the two values of δ_1 is therefore 0.049.

Although the method of thus computing the decrement twice and taking its average is strictly correct, yet it is somewhat quicker in practical work to combine the two formulas and methods as follows:

$$\delta_1+\delta_2=\frac{\pi}{2}\times\frac{C_1-C_2}{C_r}$$

where C_1 is the detuned capacity on the large capacity side of resonance at the point where $I^2=\frac{1}{2}I^2_r$;

C_2 is the detuned capacity on the small capacity side of resonance at the corresponding point;

and C_r is the capacity at resonance.

Substituting in the formula $\delta_1+\delta_2=0.066$ and hence δ_2, the decrement of the transmitter$=0.050$, which agrees closely with 0.049 as obtained above.

In some cases it is more convenient to plot another form of resonance curve, especially where the values of the wavemeter capacities are not given, but only those of the wave lengths in meters. The formula is slightly changed, as follows:

$$\delta_1+\delta_2=\pi\frac{\lambda_1-\lambda_2}{\lambda_r}.$$

where λ_1 is the wave length at the detuned position on the long wave length side of resonance at the point where $I^2=\frac{1}{2}I_r{}^2$;

λ_2 is the wave length at the detuned position on the short wave side of resonance at the corresponding point;

and λ_r is the wave length at resonance.

89. Notes on the use of a wavemeter as a decremeter.—In the previously described methods of measurement of decrement, a "current-squared" instrument was used to indicate resonance, but the same measures can also be made under certain conditions with an ammeter. In this case another form of resonance curve is drawn, in which the condenser capacities or wave lengths in meters are plotted along the horizontal line and the currents along the vertical line. The values of the capacity or wave length are taken at resonance as before, but the detuned values must be taken where I is at 0.707 I_r and not at $\frac{1}{2}I_r^2$, as will be seen from the following: The relative positions of I_r and 0.707 I_r on the resonance curve of the currents is the same as that of I^2_r and $\frac{1}{2}I_r^2$ on the resonance curve of the squares of the currents, for if each value on the former is squared the latter curve is obtained and I_r and 0.707 I_r become I_r^2 and $\frac{1}{2}I_r^2$. Thus the previous formulas can be used if the detuned capacities or wave lengths are read from the current curve at I_r and 0.707 I_r.

The previously mentioned resonance curves can be more accurately taken and the decrement more accurately computed, the smaller the resistance and decrement of the wavemeter. It is thus seen why the wavemeter or decremeter resistances in coil, condenser, and wattmeter should be kept as low as possible. The sharpness of the peak of the resonance curve depends upon the sum of the decrements of the circuit under measurement and of the wavemeter. In general, the smaller the sum of the decrements the sharper the peak, and vice versa, the larger the sum the broader the peak. It must be noted that a wavemeter with a variable inductance can *not* be used in measuring a decrement.

Section XV.

DECREMETER; TYPE SCR-87.

90. Use and range of wave lengths.—This decremeter can be used at either a damped or a continuous wave transmitter and at a receiver for all purposes as a wavemeter as well as a decremeter. It is designed especially for the measurement of the logarithmic decrement of a transmitter, as described at length in Section XIV. Its range of wave lengths is from 75 to 3,000 meters and of decrement from zero to 0.30.

91. Description of meter.—The meter is of the type that uses a set of coils for the inductance; and a special variable air condenser for the capacity. It is provided with a thermo-couple galvanometer; crystal detector and telephone; and with battery and buzzer, etc. Some of the parts are mounted on a panel and the rest are carried in

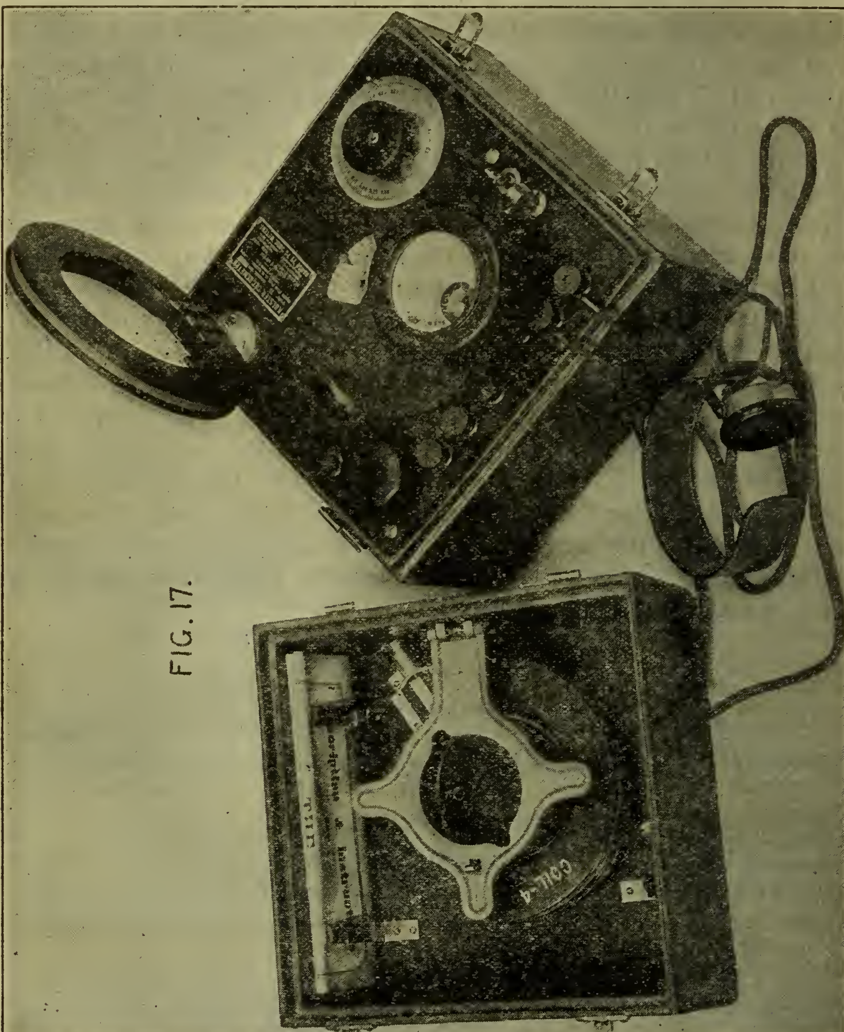

FIG. 17.

the cover. The meter is self-contained in a leather case with hinged cover and carrying strap. It is shown assembled in figure 17, and with an interior view in figure 18. The over-all dimensions are 10¼ by 10¾ by 9¾ inches high, and its weight is about 20 pounds.

92. Component parts.—Four *coils* are provided, numbered 1 to 4, which are stored away in the cover of the case under a clamp which also holds the galvanometer in place. Each coil is provided with a special plug to which the coil terminals are connected. A coil is connected into a circuit by plugging it into the jack in the upper right corner of the panel and pressing it down until it is seated. This automatically sets a pointer to read on a scale of wave lengths at the condenser corresponding to the coil in use, as follows: (1) 60 to 200 meters; (2) 150 to 480 meters; (3) 400 to 1,300 meters; and (4) 1,000 to 3,200 meters.

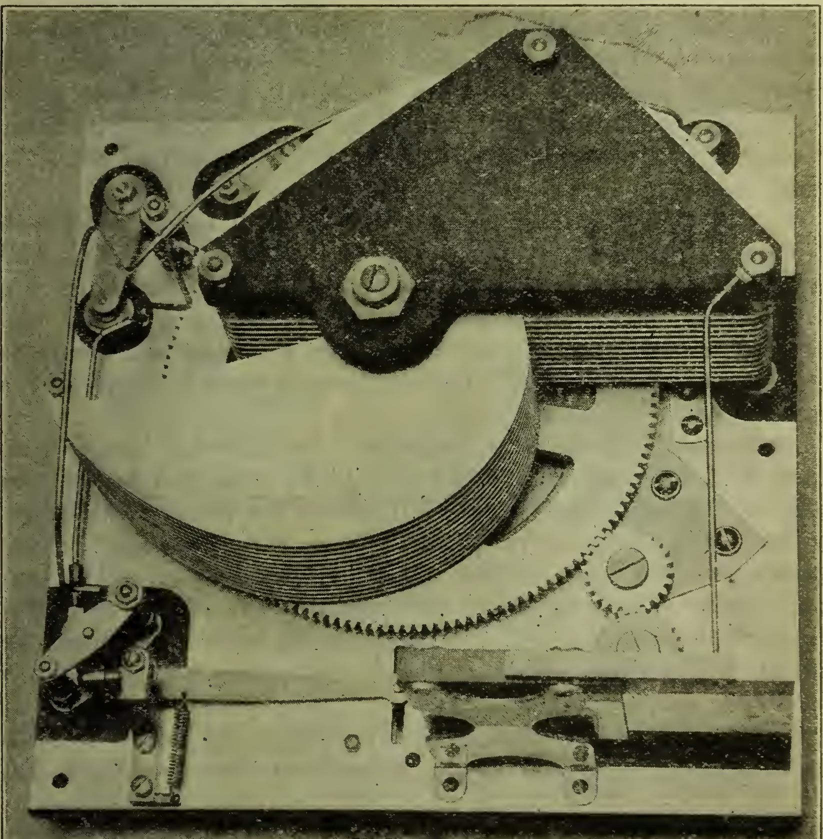

FIG. 18.

The *condenser* is a variable air condenser with specially shaped fixed and moving plates. The moving plates can be clamped by turning the "Lock" switch on the left edge of the panel so that the arrow points in toward the meter, and should always be *so clamped* for transportation. The rotation of the plates is geared down so as to be able to get a fine adjustment and for this reason the condenser handle is off center and in the lower right-hand corner of the panel. The moving plates are grounded on the metal lining of the condenser compartment. The condenser handle carries the scale of decrements, 0.00 to 0.30; and the condenser shaft carries the four wave-length scales and a depressed scale of degrees which can be read through a slot near the top of the panel. There is a small fixed air condenser in parallel with the variable condenser.

Resonance may be indicated either by (1) a thermo-galvanometer or (2) crystal detector and telephones. The *galvanometer* is stored away on the cover of the case in the center of the coils by inserting its plugs into jacks provided for this purpose. It is provided with an adjusting screw extending through the glass cover so that the needle can be set on the zero mark. It is connected into circuit by inserting its plugs into the jacks in the left corner of the panel which puts the meter in series in the decremeter circuit. The meter is shunted by a low resistance so as to keep the decrement of the circuit low.

The *crystal detector* is galena (lead sulphide) in light contact with a fine wire, the pressure of which is adjustable by means of a ball and socket joint. It is connected in series with the telephone in a shunt circuit between two points on the fixed plates of the condenser. The *telephone* is provided with tip terminals and should be connected to the two "*Tel*" binding posts in the left corner of the panel.

The *buzzer* is driven by a single "*Silver chloride*" battery provided with terminal lugs, which should be connected to the two "*buz bat*" binding posts on the left side of the panel. The buzzer circuit is completed by pressing down on the "*buz key*" on the upper edge of the panel. When not in use the battery should be kept in the spring clips in the upper left corner of the cover. If desired, a single dry-cell battery, such as type BA–4, can be used instead of the special battery above. The schematic wiring diagram is shown in Figure 19.

93. General instructions.—Before making any measures with the decremeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of the meter and its use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the following component parts should be secured in their proper places in the cover: Galvanometer, four coils, battery, telephone, and instruction sheets. The condenser plates should be clamped in place by turning the "Lock" switch so that its arrow points toward the center of the meter.

94. Measuring an unknown wave length at a transmitter.—Connect the coil into circuit which includes within its range the wave length to be measured; unclamp the condenser plates; open-circuit the detector; disconnect the telephone; open the buzzer switch; and connect the galvanometer into circuit. Make no other connection to the decremeter. Loosely couple the decremeter coil with the *antenna coil* of the transmitter and turn the condenser handle of the decremeter slowly over it's scale until a maximum reading is indicated on the galvanometer, thus indicating that the decremeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the coil in use.

If a crystal detector is to be used at a *damped wave* (*spark*) transmitter, the following directions are to be followed: Connect the coil into circuit which includes within its range the wave length to be

SCHEMATIC DIAGRAM FOR DECREMETER TYPE SCR-87

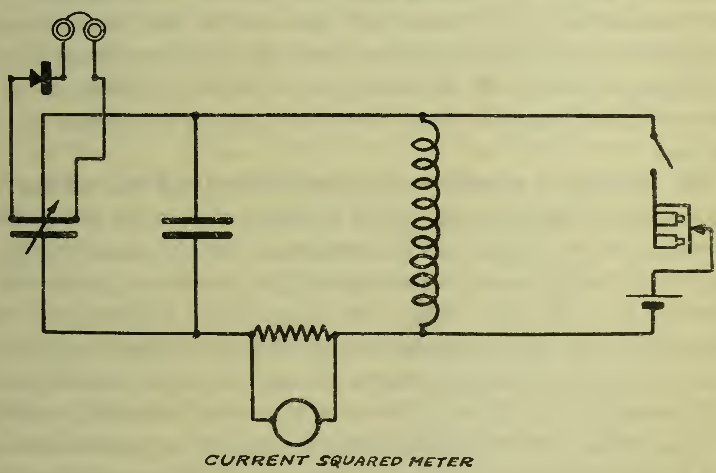

FIG. 19.

measured; disconnect the galvanometer; open the buzzer switch; connect the telephones to the two "Tel" binding posts in the left corner; and make no other connections to the meter. Loosely couple the decremeter coil with the antenna coil and adjust the detector. Turn the condenser handle of the decremeter slowly over its scale until the loudest signals are heard, etc.

95. Setting a transmitter at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser on the wave length; open the buzzer switch; connect in the galvanometer or the detector and telephones; and do not change the decremeter adjustments thereafter. Loosely couple the decremeter coil with the *antenna coil* and tune the transmitter to the decremeter until the galvanometer or telephone shows by its maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter, it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

96. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

97. Measuring an unknown wave length at a receiver.—Connect the coil into circuit which includes within its range the wave length to be measured; disconnect the telephones; open-circuit the detector; connect the battery into circuit; and close the buzzer switch. Loosely couple the decremeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the decremeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving circuits are in resonance with the decremeter at the unknown wave length. Read the wave length in meters on the scale in use.

98. Setting a receiver at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser on the wave length; disconnect the telephones; open-circuit the detector; close the buzzer switch, and do not change the decremeter adjustment thereafter. Loosely couple the decremeter coil with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the decremeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the decremeter at the predetermined wave length.

99. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the decremeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

100. Measuring decrement at a transmitter.—Connect the coil into circuit whose range includes the wave length at which the decrement is to be measured; open-circuit the detector and the buzzer; disconnect the telephones; put the galvanometer into circuit; and make no other connections to the meter. Adjust the galvanometer needle to zero by means of the small screw extending through the glass cover. This must be carefully done as the measures of the decrement depend in part at least on the correctness of this adjustment. Loosely couple the meter coil with the *antenna coil* of the transmitter; tune the meter to resonance with the transmitter, in which case the deflection of the galvanometer should preferably be about full scale and not less than half scale. If the transmitter is of low power it is best to work with not more than half scale deflection at resonance in order to be certain that the coupling is loose.

As soon as these approximate adjustments have been made, the meter should be firmly put in place on some stand and the coupling varied slightly by turning the meter coil until at resonance the needle of the galvanometer is on some convenient scale marking as full scale or half scale. In any case, it is preferable that this reading be on an even scale division so that the half scale deflection can be quickly and easily obtained. After these two adjustments have been made, *neither the position of the meter nor the coupling should be changed.* Having noted the galvanometer deflection at resonance, turn the condenser knob in the right-hand corner so that the wave length is decreased and until the galvanometer deflection is reduced to one-half the value at resonance. Keeping the condenser knob fixed, turn the ring outside the decrement scale by means of the pin until either of the two index marks rests on the zero mark of the decremeter scale. Keeping the ring fixed, turn the condenser knob back toward resonance and continue on the other side of resonance until the galvanometer reading is again one-half the value at resonance. Read the value on the decremeter scale opposite the same index mark of the ring. This gives one value of $\delta_1+\delta_2$ A second value of $\delta_1+\delta_2$ should be obtained as follows: Set the meter at resonance as before, and noting the scale deflection turn the condenser knob so that the wave length is increased and until the galvanometer deflection is reduced to one-half the value at resonance. As in the previous case, keep the condenser knob fixed; turn the ring by means of the pin until either of its index marks rests on the zero mark of the decremeter scale. Keeping the ring fixed, turn the knob back toward resonance and continue on the other side of resonance until the galvanometer reading is again one-half the value of resonance. Read the value on the decremeter scale opposite the index mark of the ring. This gives a second value of $\delta_1+\delta_2$. Take the average of the two measures of $\delta_1+\delta_2$; subtract the value of δ_1 for the given coil, which gives the decrement, δ_2, of the transmitter at the given wave length.

Detailed instruction sheets are provided with each decremeter which give additional information, calibration curves, decrements of each coil, etc.

Measures of decrement are of value only when a single wave length or "hump" is noted in tuning. The meter can not be correctly used when two waves or "humps" are observed.

Section XVI.

PARTS LISTS OF SETS.

101. Wavemeter, type SCR–60–C.—This comprises:

Battery, type BA–4 (1).
Crystal, type DC–1 (1).
Set box, type BC–50 (1).

102. Wavemeter, type SCR–61.—This comprises:

Battery, type BA–4 (1).
Coil, type C–13 (1).
Coil, type C–14 (1).
Coil, type C–15 (1).
Crystal, type DC–1 (1).
Head set, type P–11 (1).
Set box, type BC–37 (1).
Strap, type ST–5 (1).

103. Wavemeter, type SCR–95.—This comprises:

Battery, type BA–4 (1).
Lamp, type LM–4 (1).
Set box, type BC–40 (1).

104. Wavemeter, type SCR–111.—This comprises:

Battery, type BA–4 (1).
Lamp, type LM–4 (1).
Set box, type BC–49 (1).

105. Wavemeter, type SCR–125.—This comprises the wavemeter set box and the following:

Battery, type BA–4 (1).
Lamp, type LM–4 (2); 1 in use, 1 spare.

106. Wavemeter, type SCR–125–A.—This comprises the wavemeter set box and the following:

Battery, type BA–4 (1).
Lamp, type LM–4 (2); 1 in use, 1 spare.

107. Wavemeter, type SCR–128.—This comprises the wavemeter set box and the following:

Battery, type BA–4 (1).
Lamp, type LM–4 (2); 1 in use, 1 spare.

108. Wavemeter, type SCR–137.—This is self-contained in its box and has no spares nor accessories.

109. Decremeter, type SCR–87.—This is self-contained in its case and cover. The following detachable parts are carried in the cover:

Set of 4 coils (1).
Thermo-galvanometer, Weston (1).
Battery, silver chloride, with clips (1).
Instruction leaflet (1).
Head set, single (1).

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. 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 (Types SCR-65 and 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) (edition of Nov., 1921). W. D. D. 1056.
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.

TRAINING PAMPHLETS.

No.

1. Elementary Electricity (edition of Jan. 1, 1921). W. D. D. 1055.
4. Visual Signaling.
5. The Homing Pigeon, Care and Training. W. D. D. 1000.
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).

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The Radio Mechanic and the Airplane

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RADIO PAMPHLET No. 30

Second Edition, Revised to November 26, 1918

Signal Corps, U. S. Army

PRO PATRIA VIGILANS

Washington : Government Printing Office : 1919

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THE RADIO MECHANIC AND THE AIRPLANE.

General Survey of Types of Machines—Brief Treatise on the Mechanics of the Airplane—Special Precautions in the Installation of Radio Apparatus—Airplane Nomenclature and Dictionary.

1

IN ORDER that a radio mechanic may undertake the work of installing radio apparatus on airplanes, it is essential that he have some knowledge of the mechanics of the airplane. It is the purpose of this pamphlet to give the reader a general idea of the various types of machines in use and their respective purposes, and to point out in a very brief way the principal features in the mechanics of the airplane with which a radio mechanic should be thoroughly familiar in order to go about his task of installing radio apparatus with assurance that his work will result in no bad effect in the operation of the airplane, and at the same time will produce satisfactory operation of the radio apparatus.

The various types of airplanes now in use in Europe may be classified into four general groups; namely, pursuit, fighting, reconnaissance, and bombing planes. The principal characteristics of these types may be summed up as follows:

Pursuit Planes.—These are small, heavily armed, one motor, one seater, mono-, bi- or triplane machines, with a mounting of one, two or three machine guns, and even in some cases a cannon. They are capable of speeds from 180 to 250 kilometers per hour (110 to 155 m. p. h.) and more, and will climb to a height of 1,000 meters in about two minutes. The maximum elevation or ceiling of their climbing ability is about [illegible],000 meters and more. They are called upon for an endurance of from two to three hours flight at a time. They are often spoken of as scout machines.

Fighting Planes.—These are medium or large sized, heavily armed two or three seater or more biplanes, mounting two to six or more machine guns and often a cannon. Occasionally a monoplane or biplane is used as a fighter. Many of them are armored. They are driven by two or more motors and equipped with radio apparatus. High speed and good climbing ability are characteristics of this type.

Reconnaissance Planes.—These are medium and large sized biplanes equipped chiefly for reconnoitering purposes. They are armed for defense only and are equipped with radio and photographic apparatus and carry a crew of two or three men. They develop a medium speed and climbing rate, but have long endurance.

Bombing Planes.—These machines are large biplanes and triplanes, with capacity for carrying heavy bombing loads. They are equipped with high-powered motors, but due to the heavy load which they carry they are naturally slow machines and of rather poor ceiling, although these characteristics improve as the bombs are dropped. They are usually equipped with radio apparatus and electrical night-flying apparatus. They have an endurance of at least four hours.

As an example of the bombing class of airplane may be mentioned the English Handley Page machine, the wings of which have a spread of 98 ft. It is driven by two 275-h.p. Rolls-Royce engines and will carry its load of bombs and crew of three men at a speed of 80 m.p.h. and at an altitude of 6,000 ft. These great planes naturally climb slowly, taking 42 minutes to make an elevation of 10,000 ft. The Italians have the large Caproni biplanes and triplanes, driven by three Isotta Fracchini motors of 300 h.p. and more each. The biplanes have a wing spread slightly less than the Handley Page machines and the triplanes a greater spread. They carry a great load of bombs and a crew of five men, including two gunners in some cases. The French have the Caudron, the Letard, and the De Haviland, which are all twin engined, three seaters, with large wing spreads.

In general appearance, the chief points to be noted in connection with this type of machines are: first, the great wing spread; second, the single fuselage (with the exception of the Caproni which has two fuselages), with the two engine housings, one on either side of the fuselage; and third, the balanced ailerons, rudders, and elevators.

In the reconnaissance class of airplanes may be included the Sopwith two seater, the Morane two seater tractor, the Voisin, Farman Freres, the Armstrong-Whitworth-Beardmore, Maurice Farman, Martinsyde, and others. These types of machines are generally equipped with a single engine mounted in the fuselage and are usually arranged for carrying two passengers. They are used for observation work, photographing, for fire control work with artillery, and for general reconnaissance purposes.

Fighting in the air is the most spectacular use to which the military airplanes are put. Speed and climbing ability are the principal characteristcs. These features are absolutely essential, as they are weapons of offense and defense second only to the guns which the machine carries. The tendency in design for this type of plane at the present time is toward very lig weight in ratio to the horsepower of the engines employed. Such machines are very difficult to land on account of the high speed necessary to create sufficient lift.

Examples of the fighting type machine are the single seater Sopwith "Pup," so called because of its small size; the Sopwith "Camel," thus named because it carries two machine guns instead of one; the Morane "Parasol," Nieuport, Bristol "Bullet," the 190 h.p. Bristol Fighter, the Vickers, the Spad, which was a great favorite of the famous Guynemer, the F. E. 8, F. E. 2d, built by the Royal Aircraft factory, the Morane Monocoque, De Haviland, and scores of others. The British aviators alone use at least 15 or more different types of fighting planes.

The smallest machine flown to-day is the Sopwith "Kitten." This tiny plane has a wing spread of but 19 feet. It is driven by a 30-h.p. engine at a speed of 90 m.p.h. Next in size is the Sopwith "Pup," which has a spread of 26 ft. 6 in., and then the Sopwith "Camel," having a wing spread of 28 ft. and driven by a 130-h.p. Clerget engine. This latter fighter can make 97.5 m.p.h. at an altitude of 10,000 ft., and can gain his altitude in 17 minutes. The De Haviland 4 is one of the most efficient larger fighters. It has a spread of about 42 ft. and is driven by a 375-h.p. Rolls-Royce engine. It will climb 10,000 ft. in 9 minutes, to 15,000 in 16.5 minutes, and maintain a speed of 136 m.p.h. at an altitude of 6,000 ft., 133.5 m.p.h. at 10,000 ft. and 126 m.p.h. at 15,000 ft.

Among the bombing machines used by the enemy are the Friedrichshafen, driven by two 225-h.p. Benz engines, and the Gothas. In the reconnaissance class are the Aviatik two seater, the Albatross two seater, the Gothas, and other types. In the fighting class, the Germans are using the Fokker single seater monoplane, the Halberstader biplane, the Albatross single seater biplane, the Aviatik single seater, the Friedrichshafen fighter, with its whale-type fuselage, the Albatros Scouts 1 and 2, Roland and Ago, etc. The last mentioned machine has back tapered wings and but one metal strut where other machines carry two. The reason for the peculiar construction of this machine is that it enables the gunner to direct the fire of his machine gun on either side of the pilot, forward as well as backward.

In our own country, machines of the bombing, reconnaissance, and fighting types are being built and equipped with the Liberty motor. They compare most favorably with the British and

French machines. Several different types of training planes ar in use at the American training schools. The Curtiss JN-4-] has a wing spread of 43 ft. and is equipped with a 90-h.p Curtiss motor and arranged with a dual control so that eith of the two passengers may operate the plane. This plane wi make 72 m.p.h. and climb at the rate of 300 ft. per minut The Curtiss JN-4-H machine is practically a duplicate, exce that it is equipped with a 150-h.p. engine and consequently i somewhat faster than the JN-4-D. The Curtiss S-3 triplan having but a single seat, a 100-h.p. motor, and smaller wing will climb at the rate of 900 ft. per minute. The Standard J- airplane is a rather slow machine, which is equipped with Hall-Scott 100-h.p.motor. It has a wing spread of some 38 f The Thomas Morse S-4-B single seater, having a 26 ft. 7 i spread, is also a training plane.

Airplane Types and Ratings.

Type.	Motor.	Number of cylinders.	Horsepower.	Weight (empty with water).	Gross weight.	Maximum speed at 6,500 ft. elevation.	Conti uous fligh abilit
				Pounds	*Pounds*	*M.p.h.*	*Miles*
JN-4-D	Curtiss	8	92	1,430	1,920	75	172
JN-4-H	Curtiss	8	150	1,595	2,145	90	225
Thomas-Morse	Le Rhone	9	89	....	....	....	......
De Haviland 4	U. S.-12-A	12	360	2,391	3,582	120	312
Handley-Page	U. S.-21-A	2-12	300	8,270	13,700	93	......

The Mechanics of the Airplane.

The flight of an airplane is secured by driving through th air a surface or surfaces inclined to the direction of motio Such inclination is called the angle of incidence. In this wa the surface, that is, the lifting planes, secure an upward pre sure from the air by virtue of the angle of the plane as it cut through the air. And when the speed is sufficient, this lift be comes greater than the weight of the airplane, which mus then rise. It is well to bear in mind that the lift is alway trying to collapse the planes upward.

The resistance of the air to the passage of the airplane i termed the "head resistance," and is also commonly called th "drift." This is overcome by the action of the propeller, whic thrusts the airplane through the air. The head resistance is always tending to collapse the plane backward. Thus it is seen that there are four forces always acting on the airplane: the lift, which is opposed to the weight, and the thrust, which is opposed to the drift. The lift is useful, while the drift is detrimental. The proportion of lift to drift is known as the lift-drift ratio, and it is of paramount importance, for upon it depends the efficiency of the airplane. In rigging an airplane greatest care must therefore be taken to preserve the lift-drift ratio, and the radio mechanic should keep this in mind.

The angle of incidence is the inclination of the lifting surfaces to the direction of motion, most commonly, to the horizontal. If the angle of incidence is increased over the angle specified in the original design, then both the lift and the drift are increased also, and the drift is increased in greater proportion than the lift. On the other hand, if the angle of incidence is decreased over the correct amount, the lift and drift are decreased, and the lift is decreased in greater proportion than the drift. Hence it is seen, that any process which will alter the angle of incidence in either direction will act to impair the efficiency of the machine.

The whole weight of the airplane is balanced upon or slightly forward of the center of the lift. If the center of weight is too far forward, then the machine will be nose heavy. If it is too far behind the center of lift, then the airplane is tail heavy. By the stability of the airplane is meant its tendency to remain upon an even keel and to keep its course; that is, not to fly one wing down, tail down, or to try to turn off its course.

The directional stability of an airplane is its natural tendency to hold its course. If this does not exist, the airplane is continually trying to turn to the right or the left, and the pilot may be unable to control it. For an airplane to have directional stability, it is necessary for it to have, in effect, more keel surface behind its turning axis than in front of it. By keel surface is meant everything in view when looking at the airplane from the side—the side of the fuselage, landing gear, wires, struts, etc. Directional stability is sometimes called "weathercock" stability. Everyone knows what would happen in the case of the weathercock if there was too much keel surface in front of its turning axis, which is the point upon which it is pivoted. It would turn around and point the wrong way. That is exactly the manner in which the keel surfaces affect the airplane. Directional stability will be badly affected if there is more drift, i. e., resistance on one side of the airplane than on the other side. Consequently, in installing apparatus on airplanes this matter of balancing the amount of head resistance on the two sides and in front of and behind the center of lift of a machine must be constantly borne in mind.

One reason why an airplane may be directionally bad in its flying, is that the plane surfaces may be distorted. It must be understood that the planes are "cambered" (curved), so that they will pass through the air with the least possible resistance. If the leading edge, bars, or trailing edge should become bent or warped slightly, the curvature is changed with the result that the amount of drift on one side of the plane outbalances that on the other side, giving the machine a tendency to turn off its course.

Stress and Strain.

In order to be able to intelligently install radio apparatus on an airplane without impairing the strength or operating characteristics of the airplane, it is necessary to have a correct idea of the work every wire and every part of the airplane does. The work any part of the machine does is called stress. If it is subjected to undue strain, the material becomes distorted and this distortion is called strain. The simple stress of compression is a force which produces a crushing strain. Examples of airplane members under compression are the interplane and fuselage struts. The simple stress of tension is one which results in the strain of elongation. For example, all the wires of an airplane are under tension—a force tending to pull them in two. When a piece of material is bent, it is subjected to a compound stress, composed of both tension and compression.

Suppose, for instance, that a straight piece of wood is bent to form a circle. Before being bent, a line at either edge and one through the center, longitudinally, are all of the same length, Fig. 1. After the wood is bent into a circle, the center line is still of the same length as it was before, but it will be noted that the top line, now being on the outside of the circle, must be longer than the center line. This could only be brought about through a strain of elongation or stretching of the fiber of the wood at the outer rim, which is then under tension. Hence it is seen that the portion of the wood between the center line and the outer edge of the circle is in tension, and that the greatest tension is at the outer edge of the wood because the greatest elongation takes place there.

It will also be noticed that the line at the inside of the circle, which before being bent was of the same length as the center ine, must now be shorter because it is nearest to the center of the circle, and the three circles are concentric. This could nly be brought about by the strain of crushing, which is a state f compression. Hence, it is seen that the wood between the enter line and the inside circle is in compression, and the greatest compression is nearest the inside edge because the fiber at

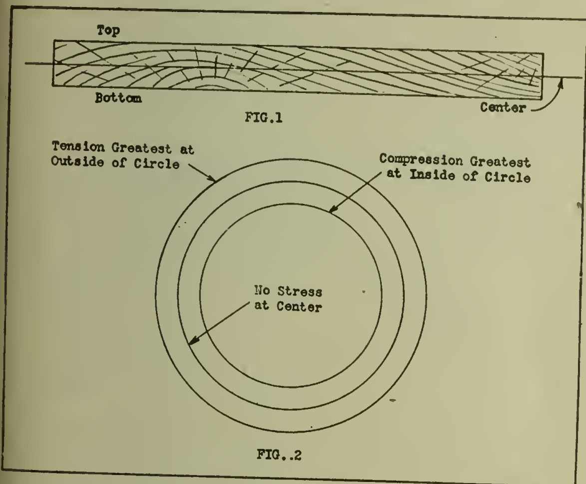


FIG. 1

FIG. 2

s innermost edge has been crushed together the greatest ount. The circles of Fig. 2 represent the three lines of the aight stick in Fig. 1.

From the above paragraphs it will be seen that the wood arest the center line of the piece does the least work, and this he reason that it is possible to hollow out the center of spars l struts without weakening them unduly. In this way it is sible to reduce the weight of the wood in an airplane by 25 33 per cent without sacrificing much of the strength.

shearing stress is one such that the forces tend to slide one of the piece over the other. An example of this may be found ordinary machine bolts used to connect any two members of an airplane together. The two members tending to pull ap or to push toward each other place a stress on the bolt tend to cut it in two, or shear it off.

The stress of torsion is one involving a tendency to twist fiber of a rod or stick. A twisting stress may be a combinat of compression, tension, and shear. An example of torsio found in the propeller shaft or crank shaft of the engine wh the forces at the opposite ends of the shaft are in opposite di tions, thus tending to twist the shaft off.

Character of Wood Under Stress.

For its weight, wood takes the stress of compression be than other materials. For instance, a walking stick weigl about ½ lb. will probably stand up to a compression st of a ton or more before crushing, provided it is kept fectly straight. If the same stick is put under a bending l

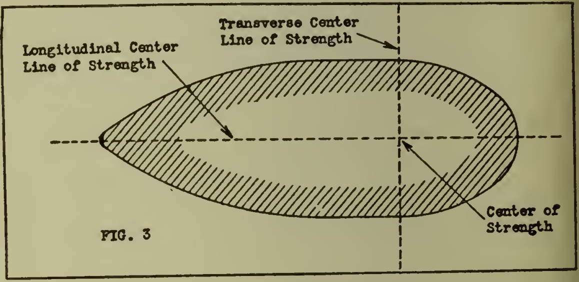


FIG. 3

it will probably collapse under a stress of not much more t 50 lb. These two conditions show a very great differenc strength, and since weight is of greatest importance in an plane, the wood must be kept as far as possible in a stat direct compression, that is, in direct line with the direc of stress upon it. This involves the careful observance of following conditions:

1. All the spars and struts of an airplane must be perfe straight. Fig. 3 shows a section through an interplane st If a strut is to be prevented from bending, then the comp sion upon it must be equally disposed around the cente strength. If it is not straight, there will be more compres on one side of the center of strength than on the other side this will be a step toward the condition of having a compres

ı one side and a tension on the other side. In this case the rut will be forced to take a bending stress for which it is not signed. Even if it should not break, it would become someıat shorter and thus throw all the wire bracing attached to e top and bottom of it out of adjustment and greatly lessen e flight efficiency of the airplane, to say nothing of the resultɡ undue and dangerous stress placed upon other wires (see g. 4). This simply emphasizes the importance of not placing bracing any radio apparatus on an airplane in a manner ıich will cause a bending moment in any direction in any od member.

2. All struts and spars must be symmetrical. By that is ant that the cross-sectional dimensions must be correct

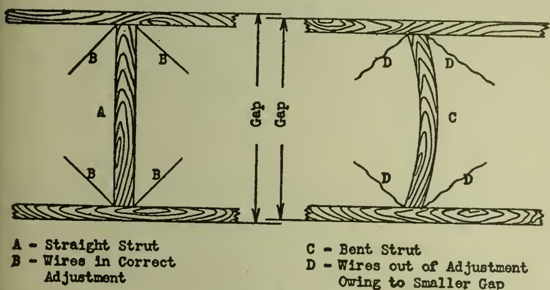


FIG. 4

ɔughout the full length, otherwise there will be bulging ·es on the outside with the result that the stress will not be formly disposed around the center of strength, and a bending ss will be produced.

Struts, spars, etc., must not be damaged. It should be embered from what has been stated about bending stresses the outside fibers of the wood are doing by far the most work. strut or spar is bruised or scored, it suffers in strength much e than one might think, and if a bending stress occurs, the e is most likely to break at that point during a flight.

The wood must have a good clear grain with no cross grain, ;s or shakes. Such blemishes mean that the wood is weaker ome places than in others and that if there is a tendency end, the piece will be likely to break at the weak points.

5. All struts, spars, and other wood members must be prope bedded into their sockets or fittings. They must make a gc pushing or gentle tapping fit. They must never be so tight to require driving in with a heavy hammer. Also, they mu bed well down all over the cross-sectional area, otherwise t center of compression will be shifted to one side of the cro sectional area with the result that the force will not be eve disposed around the center of strength and this will produce bending stress. The bottom of the strut or spar should be c ered with some sort of paint, bedded into the socket or fitti and then withdrawn to see if the paint has stuck all over t bottom of the fitting. This last is a test to see that the st or member is in bearing at all points on its cross-sectional ar

6. The atmosphere is sometimes much damper than at ot times, and this causes the wood to expand and contract app ciably. This would not matter but for the fact that it does expand and contract uniformly, but becomes unsymmetri that is, distorted. This effect of the elements should be mi mized as much as possible by thoroughly varnishing the wood keep the moisture out of it.

Boring Holes in Wood.—It is a strict rule in airplane constr tion that no spar shall be used that has an unnecessary hole it. Before boring a hole in any member, its position should passed upon by whoever is in charge of the shop. The h should be of such size that the bolts can be pushed in, or, at rate, not more than gently tapped into place. Bolts must be hammered in as this may split the spar. On the other ha a bolt must not be loose in the hole as in this case it may w sideways and split the spar, or at least throw the wires lead from the lug or socket underneath the bolt head, out of adju ment. Whenever it is possible, a clamp should be used to att anything to a strut or other wooden member in preference boring a hole, as the former does not weaken the member.

Washers.—A washer should be placed under every bolt h and also underneath the nut. The size of this washer sho be very large as compared with that normally used in ordin construction work. The purpose of this large washer is to perse the stress over a large area of wood, otherwise the was might be pulled into the wood and weaken it, possibly throw the wires attached to the bolt or fitting out of adjustment.

Locking Nuts.—If split pins are used for the purpose of lo ing nuts in place, they should be used in such a way that nut can not possibly unscrew. If the nut is locked by means of burring the bolt, this burring should not be done by means of a heavy hammer in an attempt to spread out the head of the bolt, as that might damage the woodwork inside the plane and possibly bend the bolt inside the strut or member, causing it to split. A small light hammer should be used for the purpose, gently tapping around the edge of the bolt until it is burred over.

Tension of Wire Bracings.—The tension to which wires must be adjusted is of greatest importance. All the wires on an airplane should be of the same tension, otherwise the airplane will likely become distorted and fly badly. As a rule the wires are tensioned too much. The tension should be sufficient to keep the framework rigid. Anything more than that changes the factor of safety, throws various parts of the framework into undue compression, pulls the fittings into the wood, and may in the end distort the whole framework of the airplane. Experience is about the only instructor of what tension to employ and to assist in securing the same tension on all wires. This comes by cultivating a touch for proper tensioning of the wires.

In some cases, wires occur in the airplane which have no opposition wires, as the overhang in the Curtiss machines. In such cases it is essential to be extremely careful not to tighten the wires beyond taking up the slack. These wires must be a little slack, or otherwise they will distort the top spar downward. That will change the camber of the plane and result in changing both the lift and drift of that part of the airplane. Such a condition will cause the machine to lose its directional stability and also to fly one wing down.

In view of the above considerations, the radio mechanic must be very cautious in adjusting the tension of bracing wires whenever he may have occasion to do any work on a plane which requires the temporary removal of any wires, or when he finds it necessary to place additional wires on the plane to support radio apparatus. The general rule to be followed, except in emergency, is that the radio mechanic should not touch any bracing wires or other vital parts of the airplane, this being left to the airplane mechanics.

Wire Loops.—Wires are often bent to form a loop at the end. These loops even when perfectly made have a tendency to elongate and throw the wire tension out of adjustment. Great care should be taken to minimize this as much as possible (Fig. 5). The rules which should be observed are as follows:

1. The size of the loop should be as small as possible within reason. By this is meant that it shoud not be so small as to create the possibility of the wire breaking.

2. The shape of the loop should be symmetrical.

3. The loop should have good shoulders in order to prevent the ferrule from slipping up, but at the same time the shoulders should have no angular points.

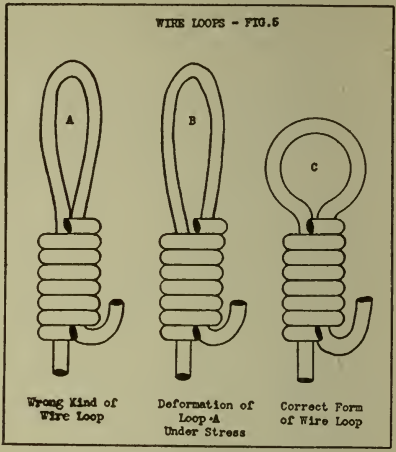


FIG. 5.—Wrong and Right Wire Loops.

4. When the loop is finished it should be undamaged, that is, not badly scored from the tools used in making it, as is often the case.

Produce No Bending Stresses.

It should be remembered that nearly all the wood of an airplane is designed to take the stress of direct compression, and it can not be safely bent. In blocking up an airplane from the ground to do any work upon it, the blocking must be used in such a way as to come underneath the interplane strut and the fuselage strut. Padding should always be placed on the surfaces upon which the airplane is to rest. When pulling a machine along the ground for any purpose, always pull it from the landing gear if possible. If necessary to pull it from some other point, grasp the interplane struts as low down as possible.

In handling parts of an airplane, never lay anything covered with fabric on a concrete floor, as any slight movement will cause the fabric to scrape over the concrete with resultant damage. Struts, spars, etc., should never be left about the floor, as they are likely to become damaged, and it has already been explained how important it is to protect the outside fiber of the wood. It should be remembered also that wood becomes easily distorted; this applies particularly to interplane struts. The best method of caring for them while they are off the plane is to stand them up in as nearly vertical position as possible.

Apparatus on Airplanes.

In order to give the radio mechanic an idea of the large amount of apparatus which must be installed on an airplane, and hence the competition which exists for space within the fuselage, the several different instruments and apparatus are listed in part in the table below. The small pursuit airplanes are usually equipped with very little auxiliary apparatus and few instruments, and with no radio apparatus. The apparatus on the bombing and reconnaissance type planes follow:

APPARATUS ON BOMBING TYPE AIRPLANES.

In Pilot's Cockpit.

Air speed indicator.
Aneroid.
Clock.
Compass.
Drift indicator.
Flare dropping device.
Radio sending key.
Incline indicator.
Lateral indicator.
Map case or roll.
Electric light fixtures.
Oil pressure gauge.
Tachometer.
Fire extinguisher.
Telephone.

In Bomber's Cockpit.

Air speed indicator.
Aneroid.
Bomb dropping device.
Clock.
Compass.
Drift indicator.
Radio apparatus.
Radio sending key.
Incline indicator.
Lateral indicator.
Map case or roll.
Electric light fixtures.
High altitude sighting device.
Camera.
Fire extinguisher.
Telephone.

APPARATUS ON RECONNAISSANCE TYPE AIRPLANES.

In Pilot's Cockpit.	*In Observer's Cockpit.*
Air speed indicator.	Air speed indicator.
Aneroid.	Aneroid.
Tachometer.	Camera.
Clock.	Clock.
Compass.	Compass.
Gasoline gauge.	Gasoline gauge.
Map case or roll.	Map case or roll.
Oil pressure gauge.	Radio apparatus.
Radio sending key.	Radio sending key.
Fire extinguisher.	Fire extinguisher.
Interphone.	Interphone.

Installation of Radio Apparatus on Airplanes.

The mounting of any auxiliary apparatus on airplanes involves many considerations of great importance. The responsibility therefore rests heavily upon radio mechanics and radio personnel generally to make absolutely certain that all of these considerations are given mature thought before proceeding to mount any radio apparatus which may in the slightest degree alter the structural make-up, control or balance of an airplane. The following general precautions must be observed, and in addition it will usually be strongly advisable to consult an aeronautic expert before making any change in the airplane.

Fire Hazard.—The liability of an airplane catching fire is perhaps the most serious danger encountered, and for this reason an open spark should be guarded against, above all things. Under normal conditions, with the motor running at its best and all gas connections good, there is nevertheless a small amount of unburned combustible gas passing back from the motor section into the cockpit at all times. A small leak in the piping tank, or carbureter, or a missing cylinder will add to the amount of gas and consequently to the hazard. Under such conditions an open spark from any source would be disastrous. For this reason, vibrator contacts and spark gaps are completely inclosed or at least covered with fine mesh metal gauze. Connections should always be well made, and soldered and taped. All wiring should be firmly secured in a position entirely clear of moving parts such as control wires, wheel supports and foot bar.

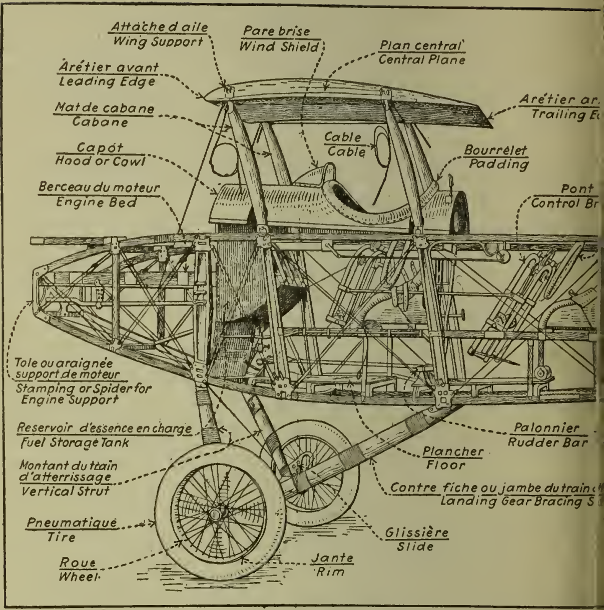
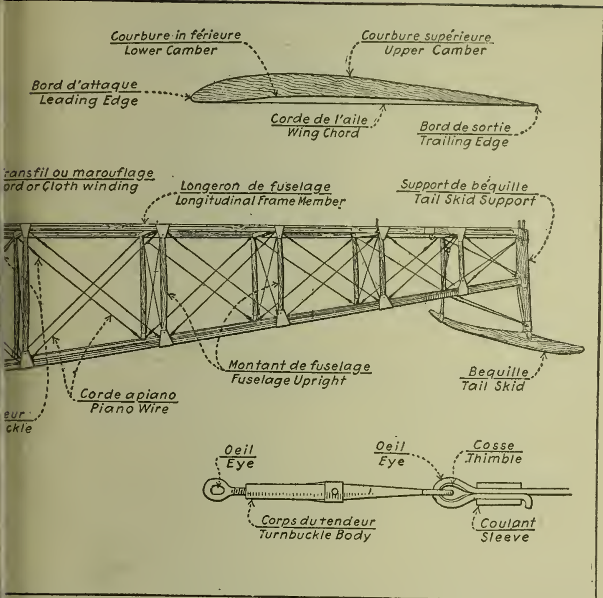


FIG. 6.—Skeleton View of Tractor Bipl



Parts Named in French and English

The antenna and counterpoise leads should be heavily insulated from the metal stays and framework of the machine generally, and run in as direct a route as possible. There should not be any uninsulated portion of a circuit where it can possibly come in contact with the pilot, the observer, or the plane. The more powerful the raio set, the greater must be the precautions against leakage. Airplane wings and control surfaces are covered with linen, which is coated with 8 or 10 layers of acetone base material, forming a highly inflammable substance easily ignited by a spark. A fire once started on the wing surface, is fanned by an 80 to 120 mile per hour breeze, and will completely envelop the machine in a few seconds.

Ruggedness of Construction.—Except for the fire hazard, the loss of control of airplanes is the most serious danger. All fittings must be made sufficiently rugged to absolutely prevent failure or breakage during flight. A piece of metal or wood weighing an ounce may easily strike the operator or pilot a disabling blow, if it breaks away at flying speed, and, at the very least, a broken fitting renders a set inoperative and makes the flight useless. Radio wires, fittings, etc., must not touch the control wires, foot bar, wheel, or wheel supports when they are in any position. Aside from the danger of wearing away insulation and causing dangerous sparks, there is a further danger of jambing the controls and bringing the machine to earth. After the installation of any radio apparatus is completed, the controls should be operated to the extreme of their movements in all directions, in order to make certain that it is impossible for any part of the apparatus to touch any moving part of the airplane. Wiring in the vicinity of the pulleys must be especially guarded against, as a jambed pulley probably will be fatal to the plane. When apparatus is directly exposed to the wind pressure, as is the case when a generator is mounted on the wing, it should be doubly safeguarded so that no parts can possibly fly off. Control wires have been cut in this manner.

Avoiding Injury to the Airplane.—Airplanes have a smaller factor of safety than practically any other piece of machinery, in order to make them faster and more easily controlled. This should be kept constantly in mind when mounting auxiliary apparatus. No struts, longerons, or other woodwork should ever be weakened by drilling. It is always preferable to clamp or lash around the wood whenever possible. When something must be fastened otherwise, wood screws should be used, the safe rule being that the screws should not enter the wood more than one-sixth its thickness. Only a sufficient number of screws should be used to hold the fittings rigidly in place. All parts of a fitting should be fastened together before mounting on the plane, and dependence should never be placed on the woodwork of the airplane for holding two pieces of auxiliary equipment together when they could be held by exterior fastenings. In lashing or clamping apparatus in place, it is very important that the tension on the fittings should not distort the members or disturb the alignment of the plane. Storage batteries should be carried where there will be no possibility for any electrolyte to spill over or come in contact with metal parts or canvas of the machine or with the skin of the observer or pilot. In cutting the covering fabric to install fittings, the edges cut should be secured or bound, in order not to weaken the fabric to any great extent.

Ease of Operation.—In locating apparatus on an airplane, it should be borne in mind that the operator is usually strapped in his seat and his movements are limited. Any apparatus requiring adjustment during flight should therefore be within easy reach of the operator and made as accessible for manipulation as possible. Accessibility, however, should be sacrificed for the precautions outlined in the three previous paragraphs. The sending key and control switches and adjusting handles should be mounted so as to be worked conveniently from the operator's seat. Good sending from an airplane on a rough day is difficult under the best arrangement of apparatus, and is almost impossible if the key is so mounted that the operator is placed in a constrained position while sending. A rest should be provided for the sending arm, or the key should be so placed as to allow the operator to rest his arm upon his knee while sending.

Interchangeability of Auxiliary Apparatus.—A very important consideration in the mounting of auxiliary apparatus on airplanes is that it shall be quickly and easily taken off and replaced in case of trouble. It should always be possible for a plane to arrive at the hangar with a defective set or exhausted storage battery, have the defective apparatus taken out of the machine and replaced with new equipment, and the machine get away again within five minutes or less.

Location of Apparatus.—In addition to the influence of accessibility and ease of operation upon the location of auxiliary apparatus, there are other considerations which have a bearing in determining the location of this apparatus on a machine. It should be remembered that an airplane is designed for a fine balance in all directions. For this reason, no great weight should be placed anywhere without consulting the aeronautical expert. In general, however, weight can be borne forward more easily than aft and with less liability of disaster, as a heavy aft weight brings about grave danger of a tail spin. Also, the right-hand side of the plane is better for balancing additional weights than the left side, for up to a certain amount the side torque of the propeller will counteract the weight.

On fighting planes, where speed is a prime requisite, all auxiliary apparatus must be mounted inside of the fuselage. It should be remembered that approximately six or eight times as much weight can be carried inside the fuselage as can be carried when the additional surface is exposed to the air currents outside. In this connection, it is interesting to note that the resistance of a fan when revolving is approximately twice as great as it is when locked still. The apparatus can be mounted at exterior positions upon training machines or on those used for observation purposes, since speed is not so important in this work, and more space is sometimes acquired inside the fuselage by this means. Specific detailed instructions as to the location and method of mounting radio apparatus on the airplane will be supplied with each set, and these directions must be followed faithfully. One very important precaution is that of avoiding the installation of any wires, even though insulated, along the metal cowl or other metal part of an airplane, as this would result in considerable loss in radiation.

Compass Location Relative to Radio Sending Apparatus.—It is very important that the radio sending apparatus on airplanes should be installed at such a point that it will not affect the operation of the compass; otherwise, this instrument will be entirely useless. In some airplanes, the observer is placed in the forward seat with a cockpit for the pilot behind him, while in other machines this order is reversed; but in either case, if the sending set is installed in the fuselage somewhere behind the rear cockpit, it will probably have no effect upon the compass, whether the latter is installed in front of the rear seat or in front of the front seat. In any event, the sending set must be far enough away from the compass so that it will have no effect upon it. If it does affect the compass, it will make that instrument useless while messages are being sent. Or in some instances, it has been found that the sending apparatus had a permanent effect upon the compass and put it entirely out of true orientation.

The test to determine whether or not the wireless apparatus has any detrimental effect upon the compass is to place the nose of the airplane toward each of the cardinal directions and then operate the wireless instrument and observe whether it has any effect on the compass in any of these positions. It may frequently happen that in one position the wireless set will have no effect upon the compass, while in another it will affect it seriously.

Airplane Nomenclature and Dictionary.

Aerial.—Pertaining to the air, or in radio work, the wires which radiate the electric oscillations.

Aerobatics.—The art, or almost science, of performing acrobatically in the air, including looping, tail sliding, nose diving, and so forth, all of which are necessary to fighting pilots.

Aerodonetics.—An invented word, to describe the science of soaring flight.

Aerodrome.—An open space arranged for the starting and alighting of airplanes, and with accommodation for machines and repair work.

Aerodynamics.—The science of dynamics as applied to the action of the air, especially in relation to mechanical flying.

Aerofoil.—Literally an "air leaf." A lifting surface of an airplane, which is commonly called a "plane," though it is not a plane surface.

Aero-hydroplane.—A hydroplane boat with wings and empennage fitted so that it flies; more generally called a flying-boat.

Aeronaut.—One who navigates the air, commonly designating an airship pilot (or any of his crew), to distinguish him from an aviator.

Aeronautics.—The science of aerial navigation of all kinds.

Aeronef.—French for aircraft.

Aeroplane.—See Airplane.

Aerostat.—Any lighter-than-air craft, not necessarily navigable, and thus including spherical and kite-balloons.

Aerostatics.—The science of aerostats.

Aerostation.—The general art of handling aerostats.

Aileron.—The flap at the rear of an airplane wing-tip, used for lateral control; i. e., rotation about the fore and aft axis.

Air bottle.—Container for compressed air used for starting big engines.

Air-cooled (engine).—Cooled by air, as opposed to water.

Aircraft.—Any kind of machine which will convey people into the air.

Airman.—One who comprehends the handling of aircraft. The difference between an aviator and an airman is the difference between a sailor and a seaman. A man may be a good sailor and yet a poor seaman.

Airmanship.—The art of handling aircraft. A parallel quality to seamanship.

Airplane.—Commonly, any heavier-than-air craft, with fixed wings and driven mechanically, as opposed to an "airship," which is lighter than air.

Airscrew.—Any screw propeller which moves an aircraft, whether a "pusher" propelling from behind, a "tractor" pulling in front, or a side screw as used on airships; generally called "propeller" on pusher planes and "screw" on tractors.

Airship.—Specifically a dirigible aerostat, as opposed to an airplane.

Air-speed meter.—An instrument designed to measure the velocity of an aircraft with reference to the air through which it is moving.

Albatros.—A famous make of German airplane.

Albatross.—A large seabird, notable for its soaring ability.

Altimeter.—An instrument for indicating the height of an airplane above the surface of the earth.

Amerissage.—French for an alighting on the sea.

Anemometer.—An instrument with which to measure air speed, with reference to the earth or some fixed body.

Aneroid.—A barometer arranged to indicate barometric pressure (and height above starting level) on a dial.

Angle of entry, attack, incidence.—The angle to the horizontal of a line drawn from front to back of an airplane's wings when flying.

Angle iron.—A bent piece of iron or steel used for reinforcing angles of a structure, or a strip of iron or steel of, or approximately of, L section.

Anti-drift (wires).—Wires to stay the wings or spars horizontally backward, against strains likely to force them forward, as in a sudden stoppage on landing, or in a tail slide.

Anti-friction metal.—A soft metal used for engine bearings which melts at low temperatures and so prevents the freezing up of bearings in case of defective lubrication.

Anti-lift (wires).—Wires or cables which take the weight of the wings when on the ground (landing wires).

Aspect ratio.—The ratio between the span and chord of an aerofoil, or of a complete pair of airplane wings.

Atterrissage.—French for a "landing."

Aviatic.—Pertaining to aviation.

Aviatik.—A famous make of German airplane.

Avion.—The French term for an airplane of war, as distinct from commercial or instructional or pleasure airplanes. (*e. g. Avion de chasse,* a "chaser" or "destroyer." *Avion de bombardement,* a bombing machine. *Avion canon,* a machine carrying a gun bigger than a machine gun. *Avion de combat,* a fighting machine.)

Aviation.—The whole art of flying, as opposed to aerostation.

Aviator.—One who flies.

Babbit metal.—An anti-friction alloy.

Backplate.—The sheet-steel plate in the front of a fuselage or nacelle, to which a rotary or radial engine is attached.

Back-wash.—The air disturbance behind an aircraft in motion.

Balanced (rudder or elevator).—A rudder or other control plane which has a portion of its surface in front of its axis to facilitate the work of moving it and to make it more effective.

Balance (to).—To maintain a state of equilibrium.

Ballonet.—An air bag inside an aerostat, to maintain gas pressure, or the separate gas bags of an airship.

Balancing plane.—See Aileron and Elevator.

Balloon.—Practically any flexible receptacle for gas.

Banking.—Inclining an airplane so that the wings assume an angle, or bank, to a transverse horizontal line.

Barograph.—A barometer designed to register its readings on a chart; otherwise, to make a "graph."

Bat boat.—Specifically a Sopwith flying boat, in which the tail booms and empennage are not integral with the hydroplane, as in other flying boats.

Bay.—The portion of a biplane or multiplane wing composed of two contiguous pairs of struts and the wing structure and bracing between them.

Beam.—Any structure designed to sustain weight when supported at points and not along its whole length. Also a ray of light.

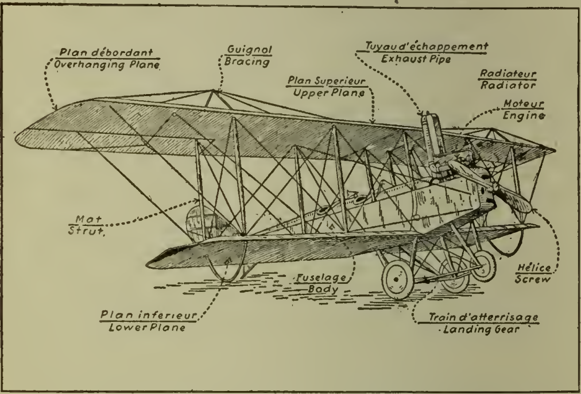


FIG. 7.—Front View of Tractor Airplane.

Bell crank.—Any lever of approximately L shape, with which to transmit motion round a corner.

Bevel gear.—A pair of cog wheels designed with the teeth on the bevel, or at an angle, to transmit power round a corner.

Bifurcate.—To form into a two-membered fork.

Biplane.—An airplane with two pairs of wings, one above the other.

Blades.—The paddle-shaped portions of air screws, outside the boss.

Blower.—A mechanical fan with which to blow up ballonets.

Body.—The portion of an airplane which incloses the pilot, passengers (if any), and generally the engine of an aircraft. (Also called fuselage and nacelle.)

Bonnet.—The metal covering or cowl over the engine and the end of the fuselage or nacelle, as the case may be.

Box kite.—Properly a box-shaped kite, but generally applied to the early types of "pusher" biplanes with front elevators.

Bracing.—Tension members, generally of wire, in a girder structure (load wires, landing wires, drift wires, etc.).

Bushing.—A circular metal lining. Generally the detachable portion of a bearing.

Cabane.—The trestle-shaped or pyramidal structure of tubes above the fuselage of a monoplane, which hold the landing wires. A similar structure is also used in most German biplanes for the attachment of the upper wings, and in some British and French biplanes also.

Cable.—A series of wires, or other material calculated to endure tension, twisted or woven into strands for increased strength.

Cabre.—A flying attitude in which the angle of attack is greater than normal; tail down; down by the stern—tail low.

Camber.—The convexity or rise of a curve of an aerofoil from its cord, usually expressed as the ratio of the maximum departure of the curve from the cord as a fraction thereof. "Top camber" refers to the top surface of an aerofoil, and "bottom camber" to the bottom surface. "Mean camber" is the mean of these two.

Canard.—Literally a duck, French slang for a rumor, but aviatically an airplane with the elevator in front and without a tail, and thus having a duck-like appearance when in the air.

Canvas.—A fabric made of coarse cotton thread, a term frequently employed erroneously for the fine linen fabric of airplanes.

Capacity:

Lifting.—The maximum flying load of an aircraft.

Carrying.—Excess of the lifting capacity over the dead load of an aircraft, which latter includes structure, power plant, and essential accessories.

Car.—Aeronautically, the basket of a balloon, or the nacelle of an airship.

Carlingue (*Carling*).—French for that portion of a "pusher" biplane which incudes the engine-bearers, tank-seating, and the attachments for the seats for the crew, and control mechanism.

Castle nut.—A nut with notches cut in its top surface to permit of the insertion of a split-pin into the bolt on which the nut is screwed.

Cavitation.—The action of a screw (air or water) in sucking fluid in behind it, or rather in causing a vacuum behind it, owing to its section being incorrect for its work.

Cellule.—A useful French term for the whole or part of the box-girder structure which is formed by the wings of a biplane or multiplane; e. g., the right cellule would be the whole of the upper and lower right wings considered as a unit. The right outer cellule would be the box structure comprising the front and rear outside struts, the front and rear struts next toward the fuselage, and everything in between them.

Center of gravity.—The theoretical line along which the weight of the aircraft (or any other body) operates.

Center of lift.—(See Center of pressure.)

Center of pressure.—The theoretical vertical line along which an airplane is supported by the air.

Center of resistance (*or of drift*).—The theoretical line along which the resistance of the air to the forward progress of the aircraft is centralized.

Center of side pressure.—The theoretical line along which the pressure of the air is centralized if the aircraft tries to move sideways (as in turning).

Center of thrust.—The theoretical line along which the air-screw operates.

Chassis.—Landing gear, or undercarriage of an airplane.

Cord.—The distance from the entering edge to the trailing edge of an aerofoil, measured in a straight line.

Cockpit.—The portion of a fuselage designed to accommodate the pilot and passenger or passengers.

Colonnette bolt.—A long bolt, or column, connecting the top of a cylinder direct to the crank case or sometimes to the crank-shaft bearings.

Control.—Generally the lever or wheel which controls the motions of the aircraft laterally and longitudinally. Also applied to the control surfaces.

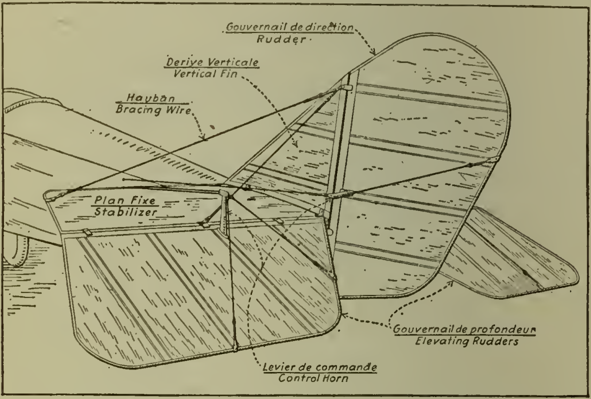


FIG. 8.—Control Members of an Airplane.

Cowl.—The metal covering or bonnet over the engine and the end of the fuselage or nacelle.

Dashboard.—The board in front of an aircraft pilot, on which the navigating instruments are fitted.

Die-casting.—A casting made in a metal die instead of in sand.

Dihedral angle.—An open angle upward—as in airplane wings, the right and left wings form a dihedral angle owing to the outer tips being higher than the butts of the wings where they join the fuselage.

Direct-driven.—A term generally used on an air screw to indicate that it is fixed direct to the engine crank-shaft, instead of being driven by gear.

Dirigible.—A form of balloon, the outer envelope of which is of elongated form, provided with a propelling system, car, rudders, and stabilizing surfaces.

Disk-wheels.—Landing wheels in which the spokes are covered by disks of fabric or metal to reduce head-resistance.

Disk area of a propeller.—The total area of the disk swept by the propeller.

Diving rudder.—See Elevator.

Dope.—A special acetyl-cellulose varnish used to shrink and harden fabric used on airplanes.

Double-surfaced.—Aerofoils or control surfaces in which (as is now almost universal) a framework or skeleton is covered on both sides by fabric, the two surfaces not touching one another.

Drag.—The total resistance to motion through the air of an aircraft.

Drift.—An erroneous expression for "head resistance."

Drift-wires.—Wires or cables designed to prevent wings from folding backward under the strain of head resistance, an erroneous but handy substitute for "head resistance wires."

Dual control.—An arrangement of control mechanism by which either the passenger or pilot (or both) can direct the movements of an airplane.

Dual ignition.—An arrangement of magnetos by which two spark plugs are fired in one cylinder simultaneously. Or an arrangement by which an engine is started by a storage battery system of ignition and subsequently run on a magneto.

Elevator.—A hinged surface for controlling the longitudinal attitude of an aircraft—i. e., its rotation about the lateral axis.

Empennage.—Literally the feathering (of an arrow). In an aircraft, the fixed tail (or stabilizer) with the elevator, plus the vertical fin and rudder considered as a complete unit.

Engine.—The machine which by expansion of gas in its cylinders imparts motion to the aircraft. (Specifically a hydrocarbon engine, as no steam engines are used for the purpose.)

Engine bearers.—The heavy members of the fuselage or nacelle which carry the engine, or its back-plate.

Entering edge.—The front edge of the wing or aerofoil, which enters the air first.

Envelope.—The fabric, or skin bag, which contains the gas of an aerostat or airship.

Extension.—That portion of the upper wings of a biplane or multiplane which extends beyond the span of the lower wings.

Fabric.—The woven material, generally fine linen, which forms the covering of the wings, body, and control surfaces of an airplane. Or the material, generally cotton, of which an airship envelope is made.

Factor of safety.—The figure representing the strength of any portion of an aircraft in proportion to the stress it is called upon to bear; e. g., a factor of safety of 6 implies that the part is six times as strong as the greatest stress which will be put upon it when in use.

Fairing.—A light casing or addition to any part of an aircraft placed and shaped so as to give the part a better stream line shape.

Fan.—Either the cooling fan used on certain air-cooled engines or the blower of an airship, but never the propeller.

Fin.—Small planes on aircraft to promote stability; for example, vertical tail fins, horizontal tail fins, skid fins, etc.

Flatten out (to).—To raise the nose of an airplane after a nose-dive and to make it return to its proper flat flying path.

Flight.—The action of flying a heavier-than-air craft, but can not be correctly applied to the navigation of an airship—which floats.

Float.—A water-tight box, or pontoon, used to sustain seaplanes when on the water.

Flying-boat.—A hydroplane with which wings, empennage, and air scre have been combined. Originated in America by Mr. Glenn Curtiss.

Flying machine.—Virtually an airplane, as opposed to an airship, thoug the term applies to ornithopters, orthopters, and helicopters.

Foot-bar.—The pivoted horizontal bar which operates the rudder of a airplane.

Fokker.—The name of a famous German airplane.

Frame.—Any arrangement of solid material which acts as a skeleto on which to build up other material.

Fuselage.—The shuttle-shaped body of a tractor airplane, in which th engine is placed in front, the pilot (and passengers, if any) behind i and the empennage at the after end. (From the French *fusel,* shuttle.)

Gap.—The distance between the projections on the vertical axis of th entering edges of the upper and lower wing of a biplane.

Gas-bag.—The fabric envelope used to contain gas in any aerostat airship.

Gills.—The flat plates fitted to the water tubes of radiators other tha those of honeycomb pattern.

Girder.—Any structure built of compression struts and tension bracin designed to carry a big load in proportion to its own weight.

Glide.—To descend on an airplane under proper control after the engir has been stopped (*volplane*).

Glider.—A small airplane without an engine, designed to be launche from a high place and to descend under control to lower groun Used largely for experiments in the past.

Gliding angle.—The flattest angle (i. e., the most acute angle to th horizontal) at which an airplane will descend after the engine ha been stopped, and without getting out of control.

Gondola.—The German term for the car or nacelle of an airship.

Gun-bus.—A slang term for a gun-carrying airplane; specially applie to the Vickers' "pusher" biplane, the first machine to be built speciall to carry a machine gun.

Guy.—A rope, chain, wire, or rod attached to an object to guide steady it, such as guys to wing, tail, or landing gear.

Hangar.—French for any kind of shed. Used specifically in English f an airplane shed.

Head resistance.—The resistance offered by the air to the moveme ahead of an aircraft. This is actually caused to a greater extent the suction behind the parts of the aircraft than by the direct resis ance in front.

Helix.—Strictly any kind of screw. Aeronautically an air screw.

Hoik (to).—A slang term indicating the action of jerking an airpla rapidly onto an upward path.

Hydro-airplane.—An airplane designed to start from and alight water. Officially called a "seaplane" and inaccurately called by th daily press a "waterplane."

Hydrogen.—The lightest gas which can be produced commerciall Largely used for the purpose of floating airships.

Hydroplane—A motor boat with a bottom designed so that is slide or "planes," along the surface of the water. Not a flying machine any sort.

Ignition.—Primarily the action of firing the gas charge in the cylinder of an engine. Generally the whole system of mechanism which produces ignition.

Incidence (angle of).—The angle at which the cord of an aerofoil or wing is inclined when flying in relation to a horizontal line.

Incidence bracing.—The wires between the front and rear struts of a biplane or multiplane, by which the incidence of the wings is varied or adjusted.

Inclinometer.—An instrument for measuring the angle made by any axis of an aircraft with the horizontal.

Interplane struts.—The vertical, or slightly inclined struts, generally in pairs front and rear, in biplanes and multiplanes, connecting the spars of a lower wing to the corresponding spars of the wing above.

Instrument-board.—(See Dashboard.) Generally contains a revolution indicator, an air speed indicator, a clock, a compass, the ignition switches, and an angle of climb indicator.

Joy stick.—A slang word for the control lever.

Kat-hedral.—Kata-hedral, a jesting word coined to express downward drooping wings, as opposed to a dihedral angle.

Kite-balloon.—The German "drachen-ballon." A sausage-shaped balloon used as an elevated observation post in war. The tail, or lower end of the balloon, is designed so that the whole affair operates in the manner of a kite and does not sway up and down or revolve, as does a spherical captive balloon.

Laminations.—A series of strips of solid material placed together to build up a stronger and thicker member. (e. g., the leaves of a spring of a motor car.) Air screws are built up of laminations, or laminæ, of wood glued together.

Landing-carriage.—The struts and wheels below the wings, on which an airplane rests when normally on the ground. (See Chassis.)

Landing-gear.—(See Landing-carriage.)

Leading-edge.—(See Entering-edge.)

Limiting height.—The extreme height to which an aircraft will rise, without altering its design, or its engine, or some other inherent characteristic. Familiarly known as the "ceiling" or "roof" of that particular machine.

Loop (to).—Looping the loop consists in lifting the nose of an airplane, either when flying level or after a preliminary dive, and keeping the elevator up so that the machine finally passes the upward vertical path and falls over backwards. If skillfully done, centrifugal force maintains the pressure of the wings on the air, and the machine performs a perfect loop instead of a back-somersault.

Longerons.—The longitudinal members, generally of wood, in the fuselage or nacelle of an aircraft. Also used by the French for the main spars of the wings.

Long-horn.—A familiar name for the old type Maurice Farman biplane, which had an elevator in front (as well as behind), carried on two long, curved, wooden booms.

Magneto.—An electric generator producing the spark which fires the gas charge and gives power to the engine.

Mast.—A single strut or tube, used in some monoplanes instead of a cabane.

Monocoque.—Literally, a "single-hull." Applied to fuselage of the type originated by the Deperdussin firm in which the fuselage is built up on a former or mold from alternate layers of thin wood strips and fabric cemented together, thus forming a shell without internal longerons or bracing. Erroneously applied to fuselages which are overlaid with a fabric or wood streamline fairing built up on hoops outside the longerons.

Monoplane.—An airplane which has only one pair of wings on the same level, or plane.

Monosoupape.—Literally, "single valve." Applied to the type of Gnome engine which has a single valve in the cylinder-head for the air inlet and the exhaust of the explosion, the gasoline being taken in from the crank-case through ports in the lower part of the cylinders.

Motor.—A common expression for an internal combustion engine.

Multiplane.—Strictly, any airplane with more than one pair of wings, but generally applied to any with more wings than a biplane or triplane.

Nacelle.—Literally, "a cradle." Applied to the bodies of "pusher" airplanes and to the cars of airships.

Negative (angle).—The angle to the true horizontal made by an aerofoil, either wing or tail plane, which is flying with its leading edge lower than its trailing edge.

Non-rigid.—An airship without a rigid frame or keel, and dependent on the gas pressure in the envelope for the maintenance of its shape, the car, or nacelle, suspended direct from the envelope.

Nose dive.—The action of diving an airplane vertically nose first toward the ground.

Obturator ring.—A thin ring of special flexible metal used on Gnome pistons to give extra gas-tightness, and acting like the "sucker" of a pump.

Outrigger.—A term frequently applied to the tail booms of a "pusher" airplane, but originally used only for the booms carrying the front elevators of box-kites of the early Farman types.

Parasol.—A type of monoplane in which the wings are raised above the fuselage to about the position of the upper wings of a biplane, thus covering the pilot's head, and leaving a perfectly clear view below.

Petrol.—Petroleum spirit used as fuel for internal-combustion engines. Known in America as "gasoline," in France as "essence," and in most other countries as "benzin."

Pilot.—An aviator or aeronaut who pilots an aircraft, as distinct from the passenger, observer, gunner, or other occupant. Also any person who has qualified to act as a pilot.

Piston.—The pot-shaped plunger which, by sliding up and down in the cylinder, conveys the expansion of the exploding gas via the connecting-rod to the crank shaft.

Piston ring.—An expanding spring ring placed round a piston to make it gas-tight in the cylinder.

Pitot tube.—An arrangement of tubes, with one end facing the direction of flight, invented by M. Pitot, to indicate the speed of air currents. Now used to indicate the speed of airplanes through the air.

Plane.—Strictly, a perfectly flat surface, but colloquially and erroneously applied to any aerofoil, or surface of an airplane, and sometimes to the whole machine (as in "seaplane," "war plane," "battle plane," etc.).

Positive angle.—The angle made with the horizontal by an aerofoil or surface, which has its leading edge above its trailing edge.

Post.—*Stern post,* the last vertical strut in a fuselage. *Rudder post,* the vertical tube or strut to which the rudder is hinged.

Power plant.—The engine, plus all its accessories, such as tanks, radiators, instruments, control levers, and switches, and possibly including the airscrew.

Propeller.—Strictly, anything that propels, correctly applied to a "pusher" airscrew as distinguished from a "tractor." Commonly used for any airscrew.

Pusher.—Specifically an airscrew placed in back of an airplane and pushing it along instead of drawing it along. Loosely applied to any airplane moved by a pusher screw.

Pylon.—Literally, any kind of post, but generally a built-up post, of uprights and cross-bracing. Used to mark the course on an aerodrome; also, pyramids of tubes used on some monoplanes, instead of masts or cabanes, for supporting the landing wires above and the warp-wires below the fuselage.

Quadruplane.—An airplane with four pairs of wings, one above another.

Race of a propeller.—The air stream delivered by the propeller.

Radial engine.—An engine with the cylinders fixed radially around the crank-case, and with three or more connecting-rods on each crank pin. The cylinders remain still and the crank shaft revolves, as in ordinary engines, and unlike rotary engines.

Radiator.—A metal receptacle for hot water from the engine, arranged to permit the percolation of air so as to cool the water.

Radius rod.—A rod fixed at one end to one part of an aircraft and attached at the other end to another moving part, so as to insure the latter always maintaining the same distance from the former.

Ratchet.—A row of teeth, each tooth being vertical on one side and sloped on the other, so that a spring-held catch, or pawl, can slip up the sloping side. It is then held by the vertical side against return until it is lifted at the will of the person in control.

Revolution indicator.—A mechanism which indicates on a dial in front of the pilot the number of revolutions made per minute by the engine.

Rib.—The fore and aft members of an aerofoil or wing which support the fabric and mantain it in the proper curve.

Rigid.—An airship having an external skeleton so that it does not depend on gas pressure to maintain its shape.

Rotary engine.—An engine in which the cylinders are arranged radially around the crank-case, which rotates with the cylinders around a stationary crank-shaft, the airscrew being fixed to a beak-shaft fitted to the front of the crank-case.

Rudder.—The movable vertical control surface which directs the course of an aircraft over a horizontal plane.

Sausage-balloon.—(See Kite-balloon.)

Scout.—Literally, a maker of military reconnaissances, and so applied to small fast single-seat airplanes, though this type of machine is now used almost entirely for fighting, and reconnaissances are almost always made on two-seaters, carrying a pilot and an observer. The title of "scout" was first applied to the small Bristol biplane.

Seaplane.—The official term, entirely erroneous in origin, for a hydro airplane.

Section (wing).—(See Camber.)

Semi-rigid.—An airship with a non-rigid envelope, but stiffened by a keel or a long spar, along the greater part of its length, the nacelle or nacelles being suspended from the keel or spar, instead of direct from the envelope.

Self-starter.—A mechanism, generally an electric motor driven by a storage battery, but sometimes a small auxiliary petrol engine, which is geared to the main engine of an aircraft to make it possible for the crew to start the main engine without manual labor.

Shock absorber.—Any contrivance designed to diminish the shock of landing an aircraft. Generally the spring contrivance between the wheel-axles and landing carriage of an airplane, which is usually either rubber cord or an oil-pneumatic device.

Side-area.—The projected area of an aircraft when viewed in side elevation.

Side slipping.—Sliding toward the center of a turn. It is due to excessive banking for the turn made and is the opposite of skidding.

Single-surface.—Any surface of an aircraft which consists of fabric exposed on both sides to the air, without an intermediate frame or skeleton. This is irrespective of the number of layers of fabric which compose the single surface.

Skidding.—Sliding sideways in flight away from the center of the turn. It is usually caused by insufficient banking in a turn, and is the opposite of side slipping.

Skids.—Long wooden or metal runners designed to prevent nosing of a land machine when landing, or to prevent dropping into holes or ditches in rough ground. Generally designed to function should the wheels collapse or fail to act.

Skin-friction.—The friction of the air over the skin, or surface, of car body passing through it, as distinct from direct resistance in front or suction behind.

Slip.—This term applies to propeller action and is the difference between the actual velocity of advance of an aircraft and the speed calculated from the known pitch of the propeller and its number of revolutions.

Socket.—Any fitting into which a compression member of a girder fits, generally applied to strut sockets. (See Interplane struts.)

Soaring.—The sustaining of an aerofoil by an upward current of air, without mechanical means. Man-carrying gliders have been known to soar for several minutes at a time in winds blowing up a hill-side. The word is frequently applied erroneously to an airplane climbing steeply by means of its own power plant.

Span.—The measurement of an airplane from the extreme tip of the right wing to the extreme tip of the left wing. Also the extreme measurement, across the machine, of any other horizontal surface, such as the tail, or elevator.

Spar.—The main members of an airplane wing, running from the butt of the wing, where it joins the fuselage or cabane, outward to the wing-tip. Generally made of wood, frequently hollow. Sometimes made of steel tube. The word spar may also be correctly applied to any main compression member of considerable length.

Spark plug.—A plug screwed into a cylinder, and so constructed that an electric spark generated by the magneto takes place between two points inside the cylinder and ignites the gas charge.

Spread.—The maximum distance laterally from tip to tip of an airplane wing. (See Span.)

Stabilizer.—A term for the fixed horizontal tailplane of an aircraft, which governs its longitudinal stability, or pitching tendency. Sometimes erroneously applied to the elevator.

Stabilizer.—See Fins (mechanical). Any automatic device designed to secure stability in flight.

Stability.—The tendency of an aircraft to return to its normal flying position if deflected therefrom by an air current, or by the operation of the controls. *Automatic stability* is procured by mechanical means, such as a gyroscope. *Inherent stability* is procured by the inherent design of the machine combining the effects of its own surfaces on the air with the action of gravity. *Longitudinal stability* refers to the stability of the aircraft fore and aft, or its pitching up and down in a vertical plane. *Lateral stability* refers to the movements sideways, i. e., the twisting around its own longitudinal axis, analogous to the rolling of a ship. *Directional stability* refers to movements on a horizontal plane, analogous to the direction of a motor car on a road.

tagger.—The amount of advance of the entering edge of the upper wing of a biplane over that of the lower; it is considered positive when the upper surface is forward.

all (to).—To allow an airplane to slow down below its proper flying speed so that it falls, either by nose-diving or by rolling over sideways and side-slipping.

ay.—A wire, rope, or the like, used as a tie piece to hold parts together, or to contribute stiffness; for example, the stays of the wing and body trussing.

ep.—A notch in the bottom of a hydroplane which assists it to plane, or skim over the surface of the water.

rainer (wire).—(See Turnbuckle.)

reamline.—The natural flow of air streams. A streamline shape is one given to a body so that in passing through the air it causes the minimum amount of disturbance to the air streams which pass over it or around it, thus minimizing the head resistance.

inger.—A longitudinal member placed to stiffen a structure; e. g., stringers are used between the hoops of a mock-monocoque fuselage to stiffen the fairing outside the main longerons.

ut.—Strictly, any compression member in a girder structure. In airplanes, generally applied to the interplane struts of biplanes or multiplanes, which strut the upper apart from the lower wings, each front strut running from a point on top of the lower front spar to a corresponding point on the bottom of the upper front spar, and having behind it on the bottom rear spar a companion rear strut to the top rear spar.

Swept-back wings.—Wings designed so that when viewed in plan th tips are behind a straight line drawn at right angles to the cente line of the airplane from a point at the butt-end of the leading edg Commonly used on many German machines until the end of 1916 (e. g., all "Taube" type monoplanes had swept-back wings).

Tachometer.—A device for indicating the speed (r. p. m.) of the engin or propeller. Usually operates on centrifugal principle, but sometime is a magnetic device.

Tailboom.—Any one of the protecting tubes or wooden members, whic carry the tail of a "pusher" airplane.

Tail.—Loosely, the whole empennage, but more correctly only the fixe horizontal tail-plane or stabilizer.

Tail-slide.—The result of forcing the nose of an airplane as nearly a possible vertically upward, so that in falling it does so tail first, in stead of nose-diving or side-slipping.

Tappet.—The plunger which operates a valve of an engine, more com mony called the "lift rod."

Taube.—German, literally a dove or pigeon, hence applied to all air planes with wings swept back and narrowing to an upward-curve tip, in the style originated by the Austrian inventor, Herr Igo Etrich

Thrust deduction.—Due to the influence of the propellers, there is reduction of pressure under the stern of the vessel which appreciabl reduces the total propulsive effect of the propeller. This reduction i termed "thrust deduction."

Tinclip.—A slang term applied by aircraft workers to all sheet or stri metal clips, irrespective of material.

Torque.—The force which reacts against the air screw, and endeavors t turn the airplane around on the shaft of the air screw, instead o turning the air screw around on its own axis.

Tractor.—Specifically, an air screw placed in front of an airplane an drawing it along by traction instead of pushing it. Loosely applie to any airplane moved by a tractor screw.

Trailing edge.—The rear edge, when flying, of any aerofoil or surfac of an airplane.

Triplane.—An airplane with three pairs of wings, one above another

Turnbuckle.—A metal barrel threaded internally right handed at on end and left handed at the other, so that by turning it one way i draws both bolts together internally, or vice versa, drives them ou simultaneously. For this reason it is used largely in screwing u the tension of airplane wires or cables by inserting a turnbuckle int the line of the wire or cable.

Twin-engined.—An airplane with two engines placed usually side b side in separate nacelles or fuselages.

U-bolt.—A two-legged bolt of U section, used frequently in attachin wires to woodwork.

Undercarriage.—(See Chassis, Landing carriage, Landing gear.)

Useful load.—A term applied to the load which an airplane can carr after being equipped with all necessary fittings for flying, and witl water in the radiators. Useful load includes pilot, passenger, fue bombs, guns, ammunition, cameras, wireless apparatus, etc.

Volplane.—French for a glide. Literally, planed flight, as opposed to mechanically driven flight.

Wake.—(See Back-wash.)

Warping.—The twisting of an airplane wing by raising or lowering the rear spar to control the machine laterally. Now practically superseded by the use of ailerons.

Warplane.—Press term for an airplane of war, or avion.

Water-cooled (engine).—An engine kept at correct working temperature by water cooling instead of air cooling.

Water-jacket.—The casing outside the cylinder of an engine which contains the cooling water.

Web.—Specifically the vertical part of an airplane rib. More generally any thin vertical member of any girder.

Whirling table.—A species of "round-about," consisting of a long girder arm revolving horizontally on a central pivot, the extreme end being fitted with mechanism for observing experiments with parts of aircraft, such as aerofoils, engines, and air screws.

Wind screen.—A small screen fitted in front of the pilot or passenger to protect him from the air pressure.

Wing.—Any one of the aerofoils of an airplane which supports the weight of the machine, as distinct from the control or stabilizing surfaces, whether aerofoils or not.

Wing loading.—The weight carried per unit area of supporting surface.

Wing-tip.—The extreme outer end of the wing of an airplane.

Yaw.—To swing off the course about the vertical axis owing to gusts or lack of directional stability. *Angle of.*—The temporary angular deviation of the fore and aft axis from the course.

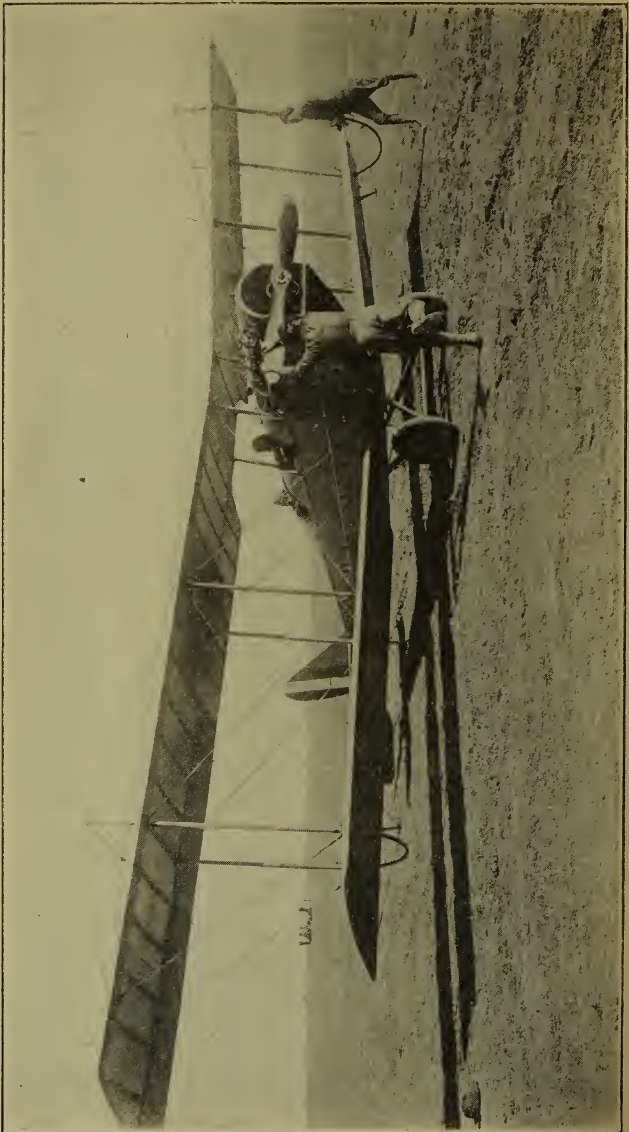


FIG. 9.—Cranking the Engine of a Curtis JN-4-H Airplane.

Prepared in the
Office of the Chief Signal Officer
Training Section
Washington

INTRODUCTION TO LINE RADIO COMMUNICATION

Radio Communication Pamphlet No. 41

PREPARED FOR THE OFFICE OF THE CHIEF SIGNAL OFFICER

January, 1923

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

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INTRODUCTION TO LINE RADIO COMMUNICATION.

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SECTION I.

PREFATORY REMARKS.

1. *Definition.*—Line radio communication is the method of telephony and telegraphy that combines the methods of radio communication and wire (ordinary telephony and telegraphy) communication. In pure radio communication, electric oscillations are set up in an antenna which produces electric waves in the ether, these waves being propagated in all directions. In line radio communication, electric oscillations are impressed upon a wire or some other conducting line, setting up electric waves which are guided by the line, the propagation being confined to one direction.

2. *Relation of radio to line radio.*—Radio communication embraces the following fundamental processes:

(*a*) The generation of electric oscillations of any desired frequency.

(*b*) The selection and separation of a desired frequency from other frequencies. This involves tuning, in some cases filtering, and the generation of an oscillation containing no objectionable harmonics.

(*c*) The modification of the electric waves so that they can be used to convey intelligence. This includes breaking up into groups (radio telegraphy) and voice modulation (radio telephony).

(*d*) The transfer of oscillations from one circuit to another by one of the various methods of coupling.

(*e*) The production of electric waves in the ether by radiation.

(*f*) The rectification and detection of the electric oscillations produced by these waves.

(*g*) The amplification of electric oscillations.

Line radio utilizes all those processes except (*e*), the production of electric waves in the ether by radiation. Cautions are taken to *reduce radiation to the minimum.*

3. *Relation of wire communication to line radio.*—The methods of wire communication are involved in line radio because the electric oscillations are impressed on a line conductor. In considering the transfer of the oscillation energy along the line, account must be taken of the characteristics of the line, which includes the various electrical constants, resistance, leakage, capacity, and inductance. Transposition and other details of line construction, which enter into the design of an ordinary telephone or telegraph line, are also involved in line radio. Cross talk must be prevented, relays installed, switchboards used—in fact the whole art of wire communication is used to a large extent in the installation of a line radio system.

4. *Advantage of line radio over wire communication.*—The advantage of line radio communication over wire communication lies in the fact that a great number of messages, either telegraphic or telephonic, or both, may be sent simultaneously, in either or both directions over the same circuit. The number of messages is limited, in telegraphy, only by the selectivity of the tuning and filtering devices that may be used. It is to be noted that a very large range of frequencies may be employed. In telephony, the number of messages is limited by the above conditions and by the fact that the frequency used in one message must differ from the next higher or lower frequency by 3,000. This is because the range of effective frequencies of the human voice is within the limit of 3,000 per second. The necessity for having this difference in frequency will be fully explained later. It is obvious that this multiplexing of telephony and telegraphy effects a great saving of wire and eliminates much line-construction work. Another advantage of line radio telephony over ordinary telephony lies in the fact that more perfect speech transmission is obtained, the distortion prevailing in ordinary telephony being largely eliminated in the case of line radio. This is especially true where the distance between stations is considerable.

5. *Advantage of line radio over pure radio.*—The advantage of line radio over pure radio lies in the fact that less power is required for communication over equal distances; that line radio communication is comparatively secret; and that line radio will not produce interference with other stations, not electrically connected to the line, even when using the same frequency. Multiplex line radio communication may be carried on without any interference arising over a line which, at the same time, is being used for ordinary telephonic and telegraphic communication. Line radio may utilize

ordinary power lines for its channel without interfering with or being interfered by the simultaneous use of the circuit to carry power.

The statements made in the foregoing paragraph are more than statements of possibilities; they are the statements of facts already attained in line radio. The future of this new art holds enormous possibilities, both for use in the arts of peace and in the arts of war.

6. *Nomenclature.*—Whenever a new technical practice arises there also arises with it the necessity of a term describing this practice. If the subject is investigated and developed by different experimenters, working more or less independently of each other, each is apt to choose his own particular terms to describe the appliances used and the subject itself. In line radio this condition has arisen and has resulted in a multiplicity of terms being used to denote it. These terms include "wired wireless," "wired radio," "wire radio," "guided wave telephony and telegraphy," "carrier current telephony and telegraphy," "high-frequency telephony and telegraphy," "alternating current telephony and telegraphy," "multiplex telephony and telegraphy by means of electric waves guided by wires," and "line radio." Other terms, such as "M. F. (mega frequency) system," "cymoline," "Squier system," etc., have also been proposed.

Of the terms mentioned in the preceding paragraph, the most complete and descriptive one is the title of Squier's original paper, "Multiplex Telephony and Telegraphy by Means of Electric Waves Guided by Wires." An analysis of the characteristics of a term that is to come into general and popular use shows that it must be simple, short, distinctive, descriptive, and explicit. Furthermore, it should be translatable into foreign languages without giving rise to an inconvenient or paradoxical expression and, if possible, in addition, it should suggest the history and development of the art.

The terms "wired wireless," "wired radio," "wire radio," fill many of the requirements set forth above but are objectionable in that they are either paradoxical expressions in the English language or give rise to paradoxical expressions when translated into foreign languages. The terms "multiplex telephony and telegraphy by means of electric waves guided by wires," "guided wave telephony and telegraphy," "high-frequency telephony and telegraphy," "alternating current telephony and telegraphy," and "carrier current telephony and telegraphy" lack simplicity and brevity. The term "high frequency" is not distinctive, as the expression "high frequency" has no implicit value of its own but is only a relative term. The term "carrier current" is not distinctive. It is not distinctive because it would apply to the use of very low or zero frequency current in place of the superaudio frequency current used. In a certain sense many other systems of telephony and telegraphy make use of a "carrier current." Thus in ordinary telegraphy and in common battery telephone systems the signals constitute variations in a direct current, which is thus the carrier of the signals. Also in ordinary radio the signals are impressed upon a high-frequency current, which is thus truly the carrier.

Of the proposed terms "cymoline," "M. F. system," "Squier system," none seem suitable. The term "cymoline" makes use of a Greek derivative (cymo) not commonly used in English words in the sense used in this particular case (wave). It also meets with all the objections which the coinage of a new word raises. The term "mega" frequency does not describe the art. Mega frequency connotes frequencies of the order of a million per second. Line radio embraces frequencies many octaves below this. The term "Squier system" was suggested to honor the recognized inventor and proponent of the system. However, attempts in the past to use the name of an inventor have failed, a notable case in recent years being the failure to apply to radio communication a term derived from the name of Marconi. Furthermore, the term "Squier system" is not favored by the inventor himself.

The term "line radio" fills all the requirements for a new term set forth in the above discussion. It is particularly suitable as it suggests, in the name, the history and development of the subject. The development of line radio was made possible by the achievements accomplished in the two older arts; those of radio telephony and telegraphy and of ordinary line telephony and telegraphy.

7. *References for further study.*—The following references on the subject of line radio are given so that the reader, if he desires, may gain further knowledge of the subject by consulting and studying them. These references have been selected from a large bibliography with a view to eliminating the less informative ones. An abstract of each reference is given so as to indicate the scope of the article.

Multiplex Telephony and Telegraphy by Means of Electric Waves Guided by Wires. George O. Squier (Major, now Major General, Signal Corps, U. S. A.). Professional Paper of the Signal Corps, U. S. A. War Department Document No. 390 (102 pages), 1911.

This article describes results of over a year's work by the author. The apparatus and instruments available for the work are described. The telephone line used is described and its constants given. The methods of operation and the result of experiments are described in detail. A great number of measurements were taken. These are described, tabulated, and illustrated by appropriate graphs. In the summary the significance of the facts presented in the paper is shown. The appendix contains the complete specifications of the patents taken out by the author at the time the paper was written. The paper contains many appropriate diagrams.

Carrier Current Telephony and Telegraphy. E. H. Colpitt (Western Electric Co.) and O. B. Blackwell (American Telephone & Telegraph Co.). Journal American Institute of Electrical Engineers (26 pages), April, 1921.

This extensive article gives a history of the development of line radio from the viewpoint of the telephone engineer. The principles of operation are given in detail. A discussion of the operating characteristics of lines for high-frequency currents is given. A description of commercial apparatus and installations made by the American Telephone & Telegraph Co. is given. A fairly complete bibliography is attached. The article is a worthy technical but nonmathematical account of the brilliant electrical engineering work done by the American Telephone & Telegraph Co. in this art.

Recent Attainments in Wired Radio. R. D. Duncan, Jr. (Radio Engineer, Signal Corps, U. S. A.), pp. 23–56. Journal of the Frankin Institute, January, 1921.

This paper describes line radio telephony tests between Washington and Baltimore. Describes extensive series of experiments with line radio communication along the New York Central Railroad lines, these experiments including communication with a moving train. Gives theory of high-frequency load characteristics of the telephone lines. Gives methods and results of line load measurements. Article is well illustrated with photographs and diagrams.

Guided-Wave Telephony. Chas. A. Culver, Ph. D. (Canadian Independent Telephone Co., Ltd., Toronto), pp. 301–328. Journal of the Franklin Institute, March, 1921.

The first part of this article discusses the principles involved in line radio, including the application of the vacuum tube. The latter part of the article discusses the application of these principles under the following headings: "Number of superchannels"; "Conductors which may be used"; "Functioning of a physical circuit as a high-frequency carrier"; "Interference"; "Attenuation and efficiency"; Uses and advantages." Full credit is given in the article to the work of General Squier.

Multiplex Telegraphy and Telephony by Means of High-Frequency Alternating Currents. K. W. Wagner (German Telegraph Experimental Bureau), pp. 383–386 Elecktrotechnische Zeitschrift, August 7, 1919, and pp. 394–397, August 14, 1919.

This paper gives a historical résumé of the subject. It summarizes the results of tests and experiments made in Germany under the direction of the author. High-frequency resistance of various wires are given.

High-Frequency Multiple Telegraph and Telephony on Wires. H. Fassbender and E. Habann (German Telegraph Experimental Bureau), pp. 451–478 Jahrb. d. Drahtl. Tel., October, 1919, and pp. 407–423, May, 1920.

The first of these papers gives the practical side of experiments in line radio made by the author. Gives method of generating the high-frequency oscillations. Describes successful operation of multiple telephony and telegraphy over a single pair of wires. Shows limitations of art. Describes a method of starting and stopping the generation of high-frequency currents by automatic-voice control. Describes a line radio telegraphy system.

The second article compares the suitability of aerial line and cables for line radio. Most of the paper is given over to the calculation, measurement, and tabulation of the electrical properties of aerial lines and cables.

Multiplex Telephony and Telegraphy over Open-Circuit Bare Wires Laid in the Earth or Sea. Major General George O. Squier (Chief Signal Officer, U. S. A.), pp. 693–714, Journal of the Franklin Institute, June, 1920.

Gives detail description, diagrams, and results of a series of experiments in which the sending and receiving stations were joined by bare wires and high-frequency current transmitted between stations. Successful communication was obtained. The frequency used was about 300,000 cycles per second. Discusses the use of a vacuum tube as a potentially operated instrument. Describes a resonance wave coil and shows how it is applied to direction finding.

Simultaneous Transmission and Reception in Radio Telephony. N. Marumo (Imperial Japanese Electric-Technical Laboratory), pp. 199–219. Proceedings American Institute of Radio Engineers, June, 1920.

Article gives a list of publications dealing with the same subject. Gives circuits for simultaneous transmission and reception in radio telephony and in line radio telegraphy. Gives general theory (mathematically expressed) of these circuits. Gives brief description of "wired radio" telephone and telegraph over power transmission line.

The Use of Alternating Currents for Submarine Cable Transmission. Frederick E. Pernot, Ph. D. (Consulting Engineer, Signal Corps, U. S. A., Research Laboratory), pp. 323–371. Journal of the Franklin Institute, September, 1920.

Paper contains results of experiments performed by Signal Corps in submarine cable transmission. Gives analysis of electrical properties of a cable when carrying an alternating current. Gives methods and results of the measurement of these electrical properties on Alaskan cables. Describes results and trials of transmitting signals by means of alternating currents simultaneously with direct current operation of the cable. Currents of different frequencies are separated at the receiving end by tuning or equivalent methods.

Section II.

SIMPLE TELEGRAPHY.

8. *Elements of a simple telegraph system.*—The simplest method of electrical communication is by means of the ordinary telegraph. A circuit containing a source of direct current is closed and opened, and at another point in the circuit the magnetic effect of the current thus varied causes motion of a piece of iron. It is difficult to imagine a simpler method of accomplishing the essential functions of every system of electrical communication, viz, the conversion of a signal

into a varying electric current, and the change of the current back into a signal at the place where it is to be received.

The essential parts of a telegraph system are: (*a*) A battery or other source of direct current; (*b*) a key for interrupting the circuit; (*c*) a device at the receiving end for detecting this interruption; and (*d*) a conducting line connecting two points in communication. This is shown in Figure 1. Closing the key closes the circuit, thus allowing a current to flow through it. Opening the key breaks the circuit and thus stops the flow of current. The key is closed and opened at the proper intervals to make the dots, dashes, and spaces which comprise the telegraph code. The key is thus a very simple arrangement for controlling the current. The current is varied from full strength to zero strength, or vice versa. Current which is controlled and varied in any desired way is said to be modulated. The telegraph key may therefore be looked upon as a very simple device for modulating the current.

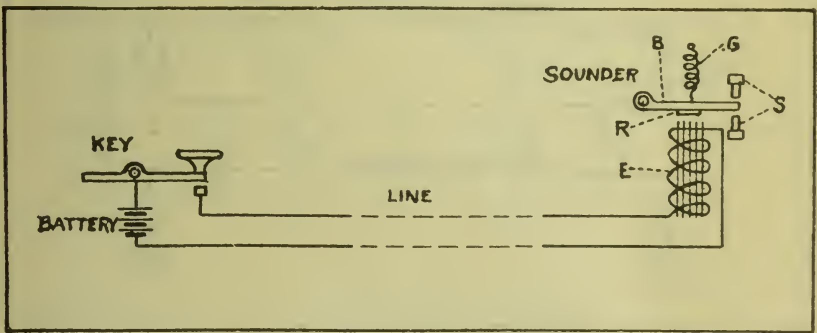


FIG. 1.—Essentials of a telegraph system.

9. *Telegraph sounder.*—The sounder is the device ordinarily used at the receiving station to detect the interruption in current made by the key. The telegraph sounder consists of an electromagnet (*E*, fig. 1) near the poles of which is mounted a movable piece of iron (*R*, fig. 1). The iron is fastened to a heavy piece of brass (*B*, fig. 1) or similar metal which moves between two rigid supports (*S*, fig. 1). As it strikes either support, it gives a characteristic click. The method of operation is as follows: A current flowing through the electromagnet attracts the iron bar toward it; the iron bar carries with it the piece of brass which strikes against one of the rigid supports. As long as the current is flowing the iron is held against the electromagnet. When the current ceases, the electromagnet loses its strength, and a spring (*G*, fig. 1) pulls the iron and the piece of brass away from the magnet. The brass piece strikes the second support thus making another click. Thus the interruptions in the current are transformed by the "sounder" into sounds. It

will be noted that in any system of communication some method of receiving capable of affecting one of the human senses, usually the sense of hearing, is always needed.

10. *The conducting line.*—The circuit between the stations may consist of a pair of wires, but in ordinary telegraph practice is usually formed of a single bare metal wire grounded at each end, the ground itself being the return conductor. Figure 2 shows the method of doing this. The source of current, usually a battery, may be placed at either station or there may be two batteries, one at each station; in either case the path of the current is from station to station through the wire and back to the starting station through the ground. It is the American practice to have a current constantly flowing through the line except when interrupted for the purpose of making the Morse signals.

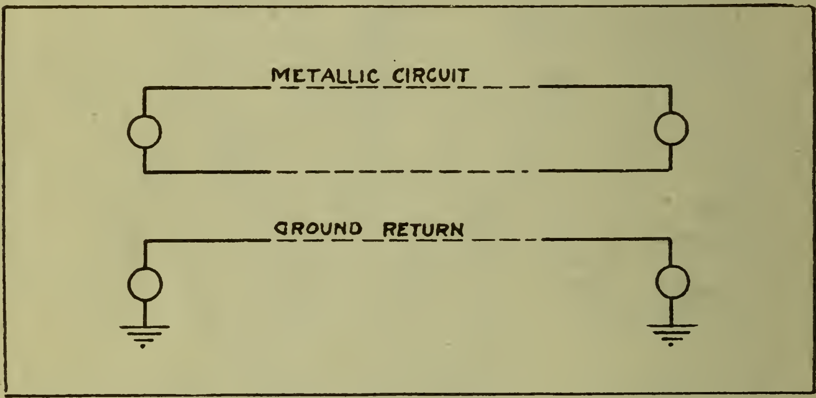


Fig. 2.—Ground return line.

11. *Duplex telegraphy.*—It has been found possible to arrange telegraph apparatus so that simultaneous two-way communication can be held over the *same line.* This is called duplex operation. By duplex methods, then, it is possible for one operator, say in Baltimore, to send to another operator, say in Washington, and at the same time over the same wire for a second operator in Washington to send to a second operator in Baltimore; there being four operators working on this one line.

There are a number of different ways of duplexing a telegraph line. Figure 3 shows a "bridge duplex" line. In the figure S and SA are telegraph sounders, K and KA are keys, B and BA are batteries, L is the line connecting the two stations, and l is the return line. (In actual practice the ground itself is the return line.) When the key at station Y is open, let the sending operator at station X depress his key, thus breaking the circuit at C and starting a current through the line. At E the current has two paths, one through the resistance R, the line L, the apparatus at station Y, including the sounder SA at that station, and back through the return line l to point F; the second path from E to F is through the resistance r and the artificial line AL. At F the divided current unites and flows back to the battery, B. The resistance R and r are exactly equal, the artificial line AL has the same electrical constants as the actual line and the apparatus connected to it at the station Y. Thus at E, the current divides equally, as the two paths which it may follow are equal, electrically. Therefore the potential on either side of S is equal because, as has been stated, R is equal to r and the sounder S receives no current. This explanation holds for either station. Note that the operator at one station has his key open when the other key is closed. This con-

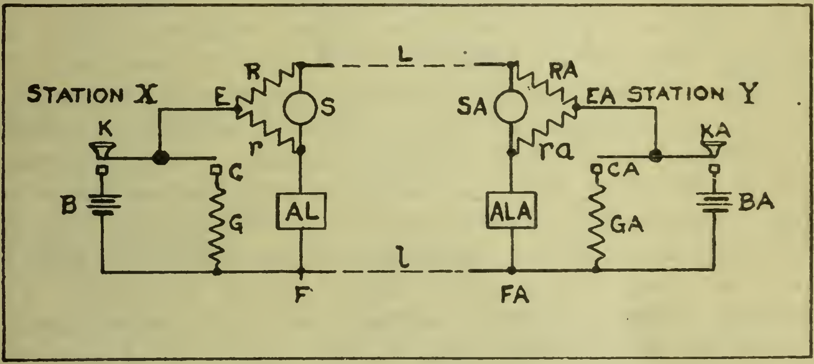


FIG. 3.—Bridge duplex telegraph.

dition prevails only a part of the time, the rest of the time both keys are depressed.

When both keys are depressed the currents attempt to divide as before but they oppose each other on the line. As this opposition makes the passage of a current through the line impossible, that part of the current which starts through R from station X must go through the sounder S. Thus the sounder at station X is operated by the current starting at station X. The same result obtain at station Y. It is seen, then, that the sounder at station Y responds to the key at station X at all times, even though at times the current received is furnished by the battery at its own station.

It is possible to arrange a telegraph circuit in which simultaneous two-way transmission of more than one message over the same line is possible. This is called multiplex operation. The arrangement for this is rather complicated and will not be described here. It is accomplished by taking advantage of the fact that direct currents may differ from each other both in direction and in strength.

12. *Cable telegraphy.*—The essential parts of a submarine cable telegraph system are identical with those of the ordinary land telegraph system. The conducting line must be very carefully insulated, as it is immersed in sea water which is a conductor of electricity. Care must be taken also to make the insulation waterproof; otherwise the dielectric material would lose its insulation properties. Furthermore the conducting line must be protected against abrasions and must be very strong, as it is subject to heavy strains. The above conditions have been met by the construction of a cable containing a conductor heavily insulated with a gutta percha compound. Around this is placed an armor of iron wires which gives the cable both protection and strength.

This construction of a submarine cable gives it a large electrostatic capacity. The conducting line within the cable is separated from the armor wire by the insulating material. Thus it is a condenser—the one "plate" being the copper conductor within the cable, the other "plate" being the armor wires in contact with the sea water. An ordinary land telegraph line also has electrostatic capacity, but, as compared with a submarine cable, this capacity has a small value. The large capacity of the submarine cable together with its resistance, which is usually considerable because of its length, permits only a small current to pass through it. The receiving instrument for the signals must be very sensitive in order to detect the change in the current which produces the signals. The receiving instrument consists essentially of a very delicate galvanometer (see R. C. P. No. 1, par. 64, and R. C. P. No. 40, par. 60) which will show any change in a current. To this galvanometer may be attached a device which will record on paper the change in current, thus enabling the operator to read the signals. The transmitting device, as in land telegraphy, is a key which interrupts the current.

While cables are used in the simple manner above described, recent developments show that it is possible to apply the principles of line radio to this type of communication, though this will not be discussed in this pamphlet.

13. *Buzzer telegraphy.*—Another method of communication is by means of the service buzzer. This has the essential parts necessary to the methods of electrical communication already discussed: (*a*) A battery which is the source of direct current; (*b*) a key and a vibrator for interrupting the circuit; (*c*) a device for detecting the interruption at the receiving end; and (*d*) a conducting line connecting the two points in communication.

As in the ordinary telegraph, the conducting line usually consists of one wire between the two points and a ground return. The detecting device at the receiving end is a telephone receiver which will be described under telephony. The signals are made by modulating the direct current from the battery by means of the key and vibrator. The key breaks up the current into periods which make the dots and dashes into a large number of impulses of current. The telephone receiver at the receiving point responds to these impulses by current which are of such a frequency as to be audible.

For efficiency in transmission the impulses of current caused by the vibrator action are led into the primary of a transformer and the secondary of the transformer sends these impulses out on the conducting line. It is obvious to the reader who is familiar with the induction coil (R. C. P. No. 1, par. 78, and R. C. P. No. 40, par. 157) that the sending apparatus just described is a simple induction coil with a key in its primary circuit to control the current.

Section III.

SIMPLE TELEPHONY.

14. *Elements of a telephone system.*—The essentials of a telephone system are very similar to those of a simple telegraph system. An electric current is used to reproduce the human voice or any sound wave instead of the dot-and-dash signals used in telegraphy. To do this requires that the electric current be varied in a manner which imitates the sound waves and is able to reproduce them. The essential parts of a telephone system are: (*a*) A battery or other source of direct current: (*b*) a device, called the microphone transmitter, by means of which sound waves cause corresponding variation of an electric current; (*c*) a device, called the telephone receiver. for changing the electric current variation back into corresponding sound waves; and (*d*) a conducting line connecting the two points in communication. These are shown in Figure 4.

15. *Modulating device.*—The device by means of which sound vibrations cause corresponding variation of an electric current is usually the carbon microphone transmitter. The action of this transmitter is based on the fact that the resistance of carbon varies with a variation of the pressure exerted upon it. The sound waves are made to cause a variation in pressure upon the carbon and hence causes a variation in resistance of the carbon. A variable resistance

causes a variable current (Ohms Law) and hence the current variation corresponds to the sound waves impinging upon the transmitter.

Figure 5 shows a telephone transmitter of a type which is in general use throughout the United States, called the "solid back"

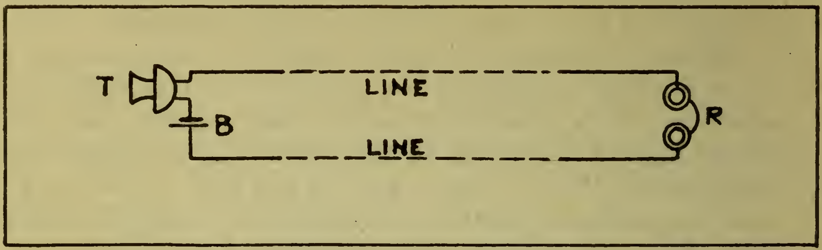


FIG. 4.—Essentials of a telephone system.

transmitter. This name is used because the cup containing the carbon granules is supported on a solid back which consists of a metal bar attached at its ends to the case of the transmitter. In

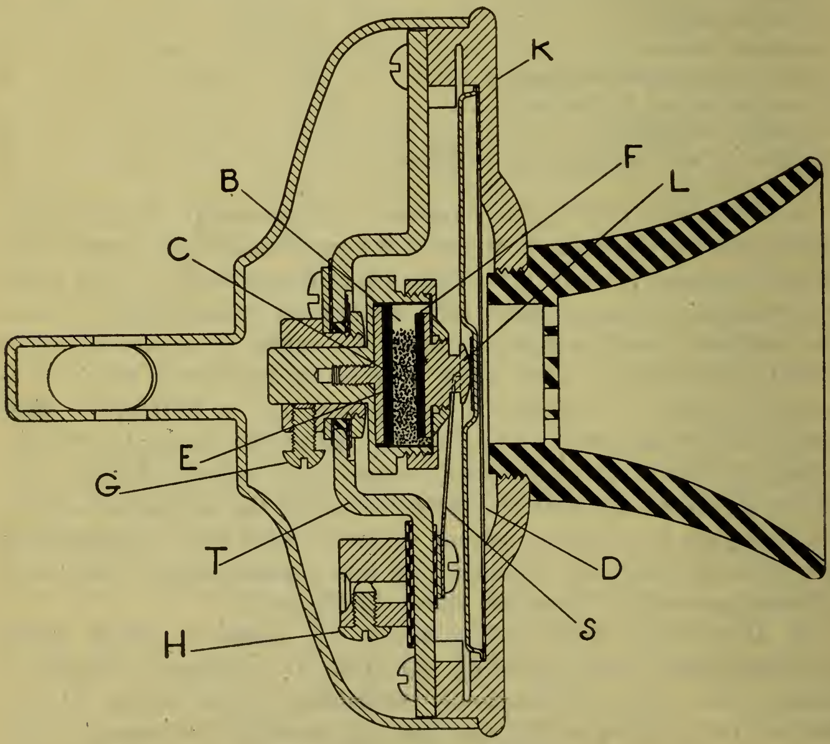


FIG. 5.—Telephone transmitter.

the figure, D is the diaphragm, usually an aluminum disk about $2\frac{1}{2}$ inches in diameter. T is the solid back, on which is mounted the metal cup B, containing the carbon granules C. At the back of the cup is a small hardened carbon plate E which serves as one electrode of the carbon microphone. At the front is another very hard carbon plate F which serves as a lid for the small metal cup; the diameter of this plate is a little less than the diameter of the inside of the cup, but the cup is completely closed by a flexible mica disk which is attached to the rim of the cup and to the carbon disk. This carbon lid or cover forms the second electrode of the transmitter. The button L attached to the carbon plate F is maintained in contact with the diaphragm by a metal spring S, which serves also to damp the vibrations of the diaphragm. The space between the carbon cover F and the back electrode E is nearly filled with carbon granules, and the electrodes E and F are so insulated that the electric current in the

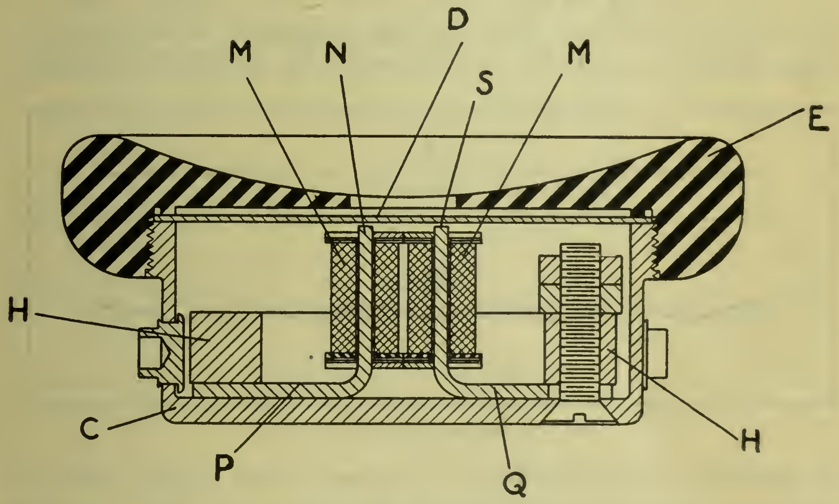


FIG. 6.—Telephone receiver.

transmitter circuit, in passing from one electrode to the other, passes through the entire mass of carbon granules. The two wires leading to the transmitter are connected to the binding posts G and H. The metal face K of the transmitter is made heavy to prevent excessive vibration, and the exposed metal parts are usually insulated from the current-carrying parts.

16. *Telephone receiver.*—The device by means of which variation in the electric current reproduces the corresponding sound waves is the telephone receiver. Although made in several forms, the essential parts of all forms are very similar and are shown in Figure 6. C is a cup for the case of the receiver; this cup may be metal, or hard rubber or a composition. In the bottom of this cup a permanent magnet of horseshoe shape is placed: the ends of this permanent magnet are shown at HH. To the ends of the permanent magnet are attached the bent, soft-iron pole pieces, NP, SQ. The earpiece E

is usually hard rubber or a composition, and is threaded to the cup *C*. Around each pole piece a coil of fine insulated wire is wound, forming the windings *MM*. These two windings are usually connected in series, so that the received current passes through both windings.

In some instruments for use with feeble currents the wire is very fine and the two coils contain some thousands of turns, sometimes as many as 10,000 turns. In the ordinary standard receiver the number of turns is, roughly, about 1,000. The resistance measured with direct current of a receiver for wire telephony may vary considerably, but for the standard receiver is usually about 100 ohms.

Above the pole pieces and very close to them is a thin circular soft-iron disk *D*, called the "diaphragm." The diaphragm of a receiver can be seen through the hole in the center of the earpiece. The distance between the pole pieces and the diaphragm is important in determining the sensitivity of the receiver; in standard instruments

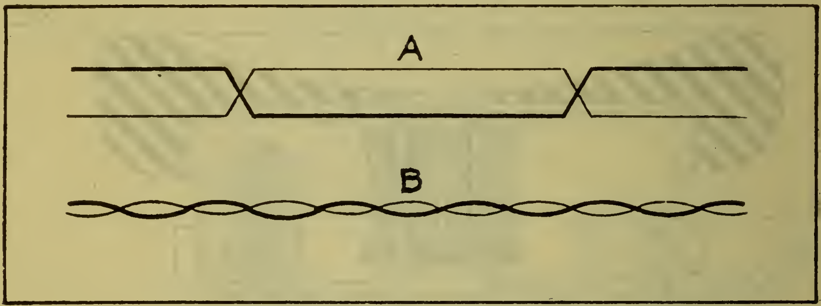


FIG. 7.—Methods of transposition.

this distance is about 0.003 inch. The permanent magnet pulls the diaphragm toward the pole piece a certain distance which depends upon the flexibility of the diaphragm. The variations in the current in the receiver windings, corresponding to the sound vibrations of the voice spoken into the transmitter, produce corresponding variations in the magnetic field of the pole pieces, and the diaphragm moves in accordance with these variations and reproduces the voice spoken into the transmitter.

17. *Conducting line used in telephony.*—The circuit of a telephone line consists of a wholly metallic circuit made of wire of good conductivity. A ground return is not usually used, for it has been found that the very small stray currents existing in the earth affect the telephone receiver and thus make the line "noisy." The two wires of this circuit are always transposed, that is, they are made to cross each other at intervals as shown in Figure 7A. This is done so that any electromagnetic field from adjoining telephone wires or other source will be neutralized in the transposed wire. The wire used locally at telephone stations, the wire making a circuit in cables, and

the wire used throughout the telephone system of a field army is a twisted pair. This is shown in Figure 7B and gives the best kind of transposition. In many telephone lines coils of wire wound on iron cores are inserted in the line. These are called "loading coils" and introduce lumped inductance in the line. The use of loading coils properly placed on a line improves the transmission of the telephone current.

18. *Sources of current in telephony.*—The current in a line is furnished in either of two ways—by the local battery system or by the common battery system. Rural telephone systems, as well as the telephone system used by an army in the field, are of the local battery type, that is, the battery which supplies the current to the transmitter

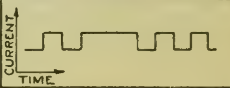
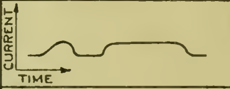
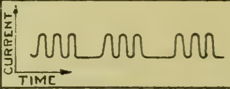
TYPE OF COMMUNICATION	SOURCE OF CURRENT	MODULATING DEVICE	RECEIVING DEVICE	CONDUCTING LINE	TYPE OF MODULATED CURRENT
TELEGRAPHY	BATTERY	KEY	SOUNDER	SINGLE WIRE WITH GROUND RETURN	
CABLE TELEGRAPHY	BATTERY	KEY	GALVANOMETER AND ACCESSORIES	CABLE WITH RETURN THRU SEA WATER	
BUZZER TELEGRAPHY	BATTERY	KEY AND VIBRATOR	TELEPHONE RECEIVER	SINGLE WIRE WITH GROUND RETURN	
TELEPHONY	BATTERY	MICROPHONE TRANSMITTER	TELEPHONE RECEIVER	COMPLETE METALLIC CIRCUIT	

FIG. 8.—Summary of wire communication.

is located at each telephone station. The battery current does not traverse the line between stations but passes through the transmitter and the primary of a transformer. The transformer changes the modulations of the direct current produced by the transmitter into a current of higher voltage, thus giving better transmission.

In the common battery system a battery at some central point furnishes the current for a number of conducting lines. When a telephone connection between two points is made, the current from the common battery passes through the conducting lines between the points and through the transmitters where it is modulated by the voice speaking into either transmitter. The voltage of the common battery is high enough to supply the necessary current in all parts of the system in this method of telephony. The common battery system is always used in city installation.

19. *Telephone accessories.*—Besides the essential parts necessary for telephone communication there are other devices utilized in a complete telephone system. For instance, a telephone switchboard is necessary so that one telephone circuit may be connected to any other telephone circuit in the same system. This may be done by an automatic device under the control of the person making the call. It is more usually done by an operator at the central station. The telephone bell is the means used to summon some one to the phone at a station. The bell is operated by a current different from that used in the telephone conversation.

20. *Summary of wire telegraphy and telephony.*—Figure 8 summarizes the various kinds of ordinary wire communication in common use. Note that in each type of communication there are the same elements: (1) A source of current; (2) a modulating device; (3) a receiving device; and (4) a conducting line.

The modulated current for each kind of communication is given to depict the actual type of current variation used.

SECTION IV.

FUNDAMENTAL PRINCIPLES OF LINE RADIO.

21. *Use of alternating current.*—In all of the methods of electrical communication the signal or voice or any sort of sound is converted into a varying electric current and then changed back into a signal at the place where it is to be received. In the simple systems of telegraphy and telephony already discussed the electric current upon which the variations caused by the signal or voice are impressed is unidirectional, i. e., flows always in the same direction. Thus, in such systems the electric current variations which correspond to the signal or voice are really variations of a direct current (produced by a battery) which has a constant value except when variations in it are caused by the signal. The electrical circuits and apparatus must be such as to produce this direct current and facilitate its flow. The direct current may be thought of as a vehicle or carrier of the signals, since it is the variations of this current which constitute the signals.

The systems now to be considered differ from the systems already discussed in that the vehicle or carrier of the signals is alternating instead of direct current. While this introduces some complexity, the student should not regard it as making the subject exceptionally difficult. It is just as natural to use alternating current as the means for conveying signals as to use it for conveying power, and the latter use of alternating current is very common. The current brought into our houses by the electric power lines for lighting and other purposes is alternating current. Alternating current has many advantages over direct current; it is more easily generated in forms desired for use, and is more readily handled and transmitted over great distances. (For review of the principles of alternating current, see The Principles Underlying Radio Communication, R. C. P. 40, secs. 49 to 58 and 64, 65.)

Alternating current has very particular advantages as a means of conveying signals. Among these advantages are: (*a*) Apparatus can be made selective, so as to receive only alternating current of a particular frequency, and thus many messages may be sent simultaneously by using alternating current of different frequencies and each receiving apparatus be free from interference from the others; and (*b*) alternating currents produce electric waves which spread out in all directions, thus making possible the transmission of signals without wires.

22. *Development of line radio from pure radio.*—The use of alternating current as the vehicle for conveying signals is the method both of pure radio communication and of line radio. Perfected first in the development of pure radio, commonly called "simple radio," the method has made possible the development of line radio. The difference between radio and line radio is that in radio the alternating currents are converted into waves which are detached from the conductors, whereas in line radio the alternating electrical actions are guided along a conducting line between the transmitting and receiving points. Outside of this essential difference, radio and line radio are practically identical in principle, method, and practice.

Nothing has been said here as to how the signal is impressed upon the alternating current which carries it. This subject of modulation, together with other features common to pure radio and line radio, is explained later, following the discussion of radio waves. Thus, except for the early portion on the wave phenomena themselves, the radio principles which will now be given all apply directly to the subject of line radio. The theory and practice of pure radio communication are given more fully in Radio Communication Pamphlet No. 1, Elementary Principles of Radio Telegraphy and Telephony, and No. 40, The Principles Underlying Radio Communication. Section 5, which follows, is not strictly essential to the understanding of line radio, but shows the origin of some of its essential features.

Section V.

PURE RADIO COMMUNICATION.

23. *Production of radio waves.*—Wherever there is an electric circuit in which alternating current is flowing an electric wave starts out just as a sound wave starts out from a vibrating tuning fork. A powerful sound can be produced by using a very large tuning fork, and similarly a powerful electric wave is produced by making some part of the electric circuit large in dimensions. The antenna used in radio work, as is well known, often consist of long conductors supported on very high towers. A mechanism for producing a radio wave, therefore, is simply an enlarged or extended portion of an electric circuit in which an alternating current is made to flow. In the space near the antenna, alternations of electric pressure are produced just as alternations of air pressure are produced around a tuning fork. At any instant the electrical condition of the space around an antenna which is sending out radio waves could be shown by a diagram such as Figure 9. The arrow on the lines extending between the antenna and ground indicates that the electric pressure at a particular moment is in the direction indicated. When the current changes in direction, the direction of this electric pressure will be reversed and the electric pressure already mentioned will have handed on its effect to the surrounding space. Thus the effect of an electric pressure is handed on and spreads out through space, the direction of this pressure at any point constantly alternating as the direction of the current in the antenna producing it alternates. Lines of electric pressure alternating in direction are thus constantly spreading out from the antenna just as the ripples spread out on a pond. Something very similar to the ripples would be seen if, in some way, the alternations of electric pressure could be made visible and a person were to look down from above upon the antenna and the space around it. The waves of electric pressure spreading out and successively alternating in direction would look something like the lines shown in the upper part of Figure 9. The waves spread out in all directions and go to great distances.

It at once suggests itself that the waves will produce an effect at a point far distant from the source if there is any way of converting the electric pressure in the wave into electric current in a circuit placed at the distant point. In this way electric communication without connecting wires would be established.

24. *Nature of radio waves.*—We can not see electric waves as we see ripples or the waves on a rope, but there is nothing specially mysterious about them. We can not see sound waves. If a tuning fork is struck, it gives off sound waves, which, starting at the tuning fork, travel out into the air in all directions like the ripples

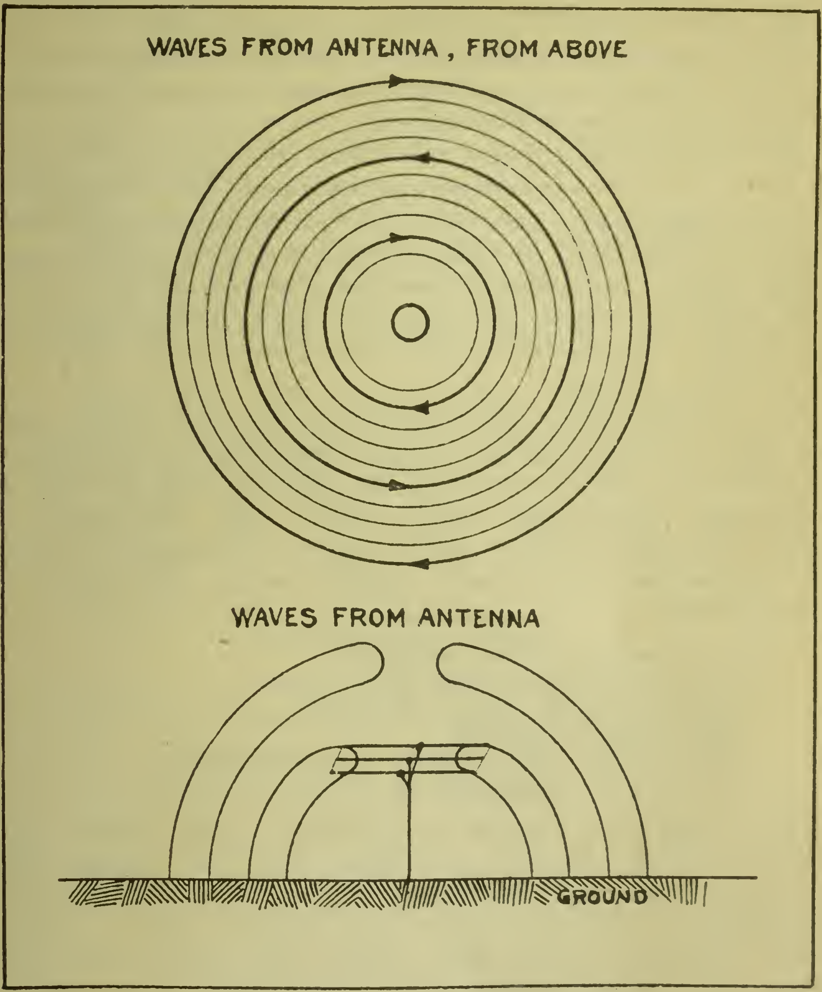


FIG. 9.—Production of waves around an antenna.

referred to. Sound waves are produced by the motion of the metal prong of the tuning fork. As the prong moves back and forth it causes the air next to it to move back and forth. This motion is handed on to the surrounding air and so moves out to a great distance in the air just as the ripple on the pond spreads out. The

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slight to-and-fro motion of the air spreading out in this manner is called a sound wave.

Electric waves also consist of a certain kind of to-and-fro motion. Just as the motion of the tuning fork causes alternating pressure in the surrounding air, similarly whenever an alternating electric current flows in an electric circuit the to-and-fro motion of the current causes alternating electric pressure in the space next to the wire. This to-and-fro or alternating electric pressure in the space around the wire affects the surrounding space and spreads out in exactly the same way as a sound wave in air.

The electric waves are also called radio waves, and it is by means of them that radio communication is carried on. It is an interesting fact that radio waves are really of the same kind as light waves. We are all familiar with light waves, and it should help to make radio waves less mysterious to know that they are both electric waves. The difference between light and radio waves is the frequency of alternation. Thus electric waves are much more common things than is sometimes supposed.

25. *Use, velocity, and frequency of electric waves.*—Electric waves are used for many purposes, their use depending on the frequency of the waves. This is shown by the following table showing the frequencies of the various kinds of electric waves. By frequency is meant the number of vibrations per second or the number of to-and-fro alternations of the electric pressure as the wave travels out through space.

Vibrations per second of waves produced by:
- Commercial alternating currents: 25 to 500.
- Ordinary telephone currents: 16 to 3,000.
- Radio: 10,000 to 30,000,000.
- Heat and light: 3,000,000,000,000 to 3,000,000,000,000,000.
- X rays: 3,000,000,000,000,000,000.

All of these waves travel at the same speed. These electric waves are of an entirely different nature from sound waves. Sound waves are not at all electrical; they consist of actual to-and-fro motions of the air particles and travel with a speed of about 1,000 feet per second. The speed at which electric waves travel is much greater than this; it is so great that the passage of any kind of electric wave is practically instantaneous. The various kinds of electric waves shown in the table are much alike in many ways, but they have some characteristic differences. Thus, radio waves are different from light waves in that they go through ordinary walls of buildings and other obstacles which are opaque to light.

The waves are radiated and spread out more effectively the higher the frequency. The ordinary low frequencies used in the alternating currents which light our houses alternate very slowly. In order to get a wave which will travel effectively through space, higher frequencies must be used; that is why the waves used in radio communication make a large number of vibrations per second.

It is to be noted that these frequencies are not, however, as high as the frequencies of light waves. Light waves travel in straight lines, which is one of their characteristic differences from low-frequency waves of alternating-current power, which follow along wires. Radio waves are intermediate in character between the two, and can travel in straight lines and also travel along conducting wires.

The fact that radio waves, which are able to travel out into space without conducting wires, are of high frequency is one of the important characteristics of radio communication.

26. *Wave reception.*—Now think of what is happening at a distance from an antenna which is sending out waves. As the wave passes any point there is an alternation of electric pressure going on

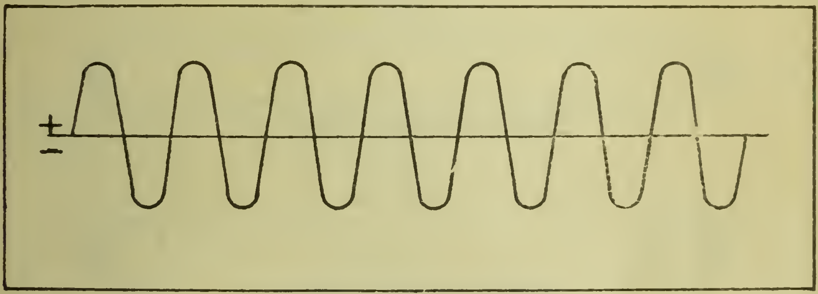

Fig. 10.—Continuous waves.

continuously at that point. The alternating electric pressure or wave action at that point could be illustrated by the wavy line of Figure 10. The portions of the wave above the horizontal line correspond to the electric pressure in one direction, and the portions below correspond to the electric pressure in the other direction. This can be understood by thinking again of the ripple on the water. Suppose there is a cork or other floating object on the surface of the water at a distance from the place where the ripple starts. As the ripple takes place, the cork rises and falls, partaking of the to-and-fro motion of the surface of the water. Or consider the sound wave. As the sound wave passes out through the air, it will set in vibration any object which is capable of taking up the motion. Suppose, for instance, that a sound wave produced by a tuning fork passes a second tuning fork which is in tune with it; that is, having the same natural pitch or frequency of vibration as the first tuning fork. The to-and-fro motion of the air will start the second tuning fork into motion. This can be readily shown with two tuning forks, striking one of the forks, thus producing a sound wave. It can be proved that the second tuning fork is set into vibration by grasping the first with the hand so as to prevent its further motion. A sound from the second one can then be heard. The same thing is sometimes illustrated in a room. If a note is sung or produced on some instrument, a response may be heard from one of the strings of the piano, or from a loose portion of a chandelier or other resonant object in the room.

An electric wave can produce an effect at a distance in just the same manner. In any electric circuit the moving wave of electric pressure can produce an electric current alternating with the same frequency as the wave. The moving wave is accompanied by a magnetic field, just as a current is. This moving magnetic field produces an electromotive force in any conductor across which it cuts, just as an electromotive force is produced by any other case of

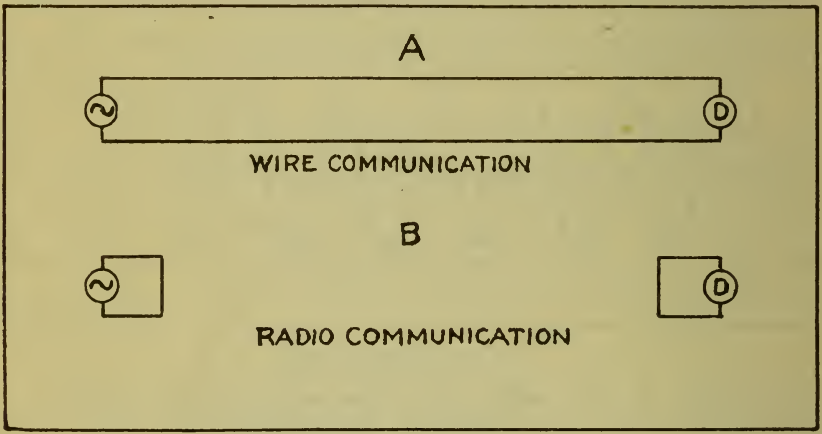

FIG. 11.—Comparison of radio and wire communication.

relative motion between a conductor and a magnetic field. The electromotive force thus produced is what causes a current in the receiving antenna.

27. *Comparison of radio with ordinary wire communication.*—In the preceding sections the mechanism by which an electrical action can be made to affect a distant point without wire connection has been explained. The ether which fills all space can be considered to replace the wire connection. Thus, in wire communication we could have a system as represented in Figure 11A, which shows a conducting wire line indicating a source of varied current with a detecting device *D*. In radio communication the wires are eliminated so that the corresponding simplified system would be as represented in Figure 11B, which shows the similar source of varied current and detecting device *D*, each of these, however, being placed in a simple electrical circuit and the conducting wires between being eliminated.

Both of these diagrams have been so greatly simplified that neither of them is really just like an actual telegraph or telephone system. Certain additional features must be used beyond what is shown in either Figure 11A or Figure 11B to carry on telegraphy or telephony. More accurately, a species of telegraphy is possible by merely adding a key in either Figure 11A or Figure 11B. Wire communication of this kind would thus be the use of an alternating current generator as the source of power and a telephone receiver as the detector D. The corresponding radio system would be the use of an alternating current generator of high but still audible frequency, together with a telephone receiver as the detector *D*. As a matter of fact, simple systems of just this kind are not used because great advantages are secured by the addition of certain features which will now be discussed. Furthermore, these features not only improve telegraphic communication but are necessary for telephonic communication.

SECTION VI.

PRINCIPLES COMMON TO RADIO AND LINE RADIO.

28. *High frequency and tuning.*—Some of the characteristic features of radio communication as actually carried on, other than its use of waves, will now be considered. As will be shown below, these are all characteristic of line radio as well as pure radio. The extremely simple system of radio communication indicated in Figure 11B is not effective unless the alternating current used is of high frequency. Even then the current produced in the receiving circuit would be very small indeed unless the receiving circuit were electrically tuned to the transmitting circuit. As to the necessity of using high frequencies, it will be recalled that radio waves do not spread out or radiate effectively unless the frequency is high. The waves produced by an alternating current are of the same frequency as the current itself. The higher the frequency the more effectively do the waves leave the circuit at the transmitting end and spread out through space. If the frequency is only a few hundred or a few thousand per second, the waves received at a distance are very feeble.

The effect of a wave in producing current in a receiving circuit is very small unless the receiving circuit is in tune with the wave. That is, it must be arranged to respond to the frequency of alternation possessed by the first circuit and the wave which it sends out. This is just like what happens with the two tuning forks and the sound wave. The second tuning fork does not respond to the wave from the first unless the two are in tune. This can be shown by placing a bit of wax on one of the prongs of the second tuning fork, changing the pitch of that fork. When the first tuning fork is struck under these conditions it can readily be demonstrated that the second fork does not respond. In the same way the electrical arrangements in the receiving circuit which are used to receive radio waves must be such that the receiving circuit is electrically in tune with the radio wave. By this means the radio receiving circuit can pick out the particular wave which it is desired to receive and not be affected by other waves. This is fortunate, because otherwise the interference between different radio messages would be hopeless. It would be just as though every sound wave which passed through the air set absolutely everything which it touched into vibration.

Just as the frequency to which a tuning fork responds depends upon its mass and its elasticity, the frequency to which the electrical circuit responds depends upon two corresponding electrical proper-

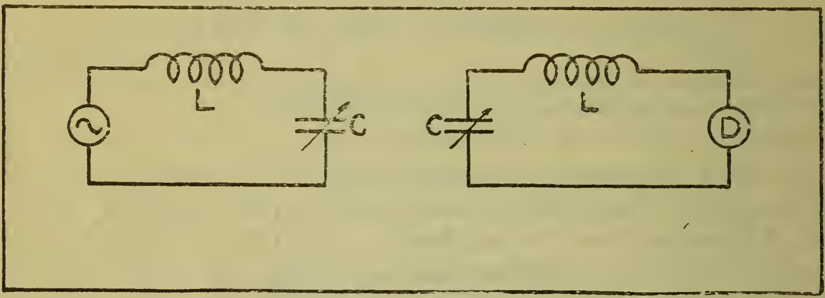

Fig. 12.—Tuned radio circuits.

ties called the inductance and capacity, respectively. The greatest current is produced in a receiving circuit when both the transmitting and receiving circuits are tuned—that is, arranged so that the product of the capacity and inductance is the same in each. The elements of a typical radio circuit are thus rather more complicated than shown in Figure 11B which should be replaced by Figure 12. The symbols *C* and *L* indicate the conventional diagrams for capacity and inductance. Both in the transmitting circuit shown at the left and the receiving circuit shown at the right, either the capacity or the inductance is made large and then constitutes the antenna.

29. *Modulation and rectification.*—As just mentioned, the frequency of alternation of radio waves is very high. It is so high, in fact, that a sound wave of such frequencies could not be heard. Suppose, for instance, that an ordinary telephone receiver is used as a detector, *D*, in the circuit which is receiving a radio wave. Electric currents produced in a receiving circuit are of the same frequency

as the wave frequency and tend to cause motions of the telephone receiver diaphragm. These motions are, however, of such great frequency that the diaphragm produces no audible sound. In order to permit the radio wave to be received and transformed into a sound, it is therefore necessary to break up the radio wave in some manner. Ordinarily this is done in radio telegraphy by interrupting the wave completely so that it consists not of a single regular series of alternations but of a succession of groups of such alternations; that is, instead of the continuous wave shown in Figure 10 we use the interrupted wave or group of waves illustrated in Figure 13. The frequency of the interruptions or of the groups of waves is the frequency which can be heard. This process of varying the high-frequency wave so that it is no longer a single regular series of alternations is called modulation.

Instead of breaking the wave up into simple groups of alternations, it is possible to modulate it or cause it to vary in a manner

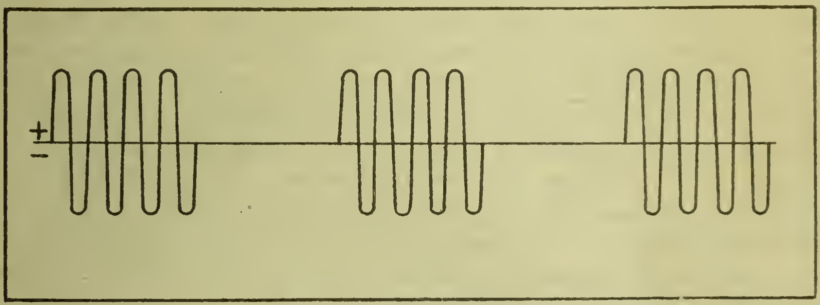

Fig. 13.—Interrupted waves.

which follows the sound variations produced by the human voice. It is thus possible to make a radio wave carry a voice wave. This is the process of radio telephony. In order that satisfactory radio telephony be possible, the radio wave must be of higher frequency than the frequency of the speech variations which modulate it. This is true because at the receiving end it is desired to hear the speech only and not the frequency corresponding to the wave itself. This supplies another reason why high frequencies must be used in radio.

Besides the reason given for the use of high frequency, there is another very powerful reason. When it is desired to carry on telephony, it is necessary that the alternating current which produces the waves be of a frequency to which the sense of hearing does not respond. This is necessary because if the waves were of an audible frequency, the current which they produce in the receiving circuit would produce a sound that would be heard and would interfere with the voice or other sound which it was desired to hear. The wave frequency must, therefore, be so high that a sound wave of such frequencies could not be heard.

There is another thing that is to be taken into account before it becomes possible to translate the received radio current into a sound that can be heard. When one of the groups of alternations shown in Figure 13 acts on the telephone receiver it causes no motion of the diaphragm because each variation of the current in one direction is immediately followed by the current in the opposite direction so that the resulting effect of the group of waves upon the telephone receiver diaphragm is no motion at all. It is therefore necessary, in order to convert the current into a sound, to use something else with the telephone receiver. This something else must be such as to make the current flow through the telephone receiver in only one direction. It must allow the electric current to flow through it in one direction and stop current which tries to flow through it in the opposite direction; that is, it must be some sort of electric valve. The effect of such an electric valve may perhaps be understood more clearly by taking a sheet of paper and placing it upon Figure 13 so as to block out the lower half of the waves shown. This leaves only the upper halves of the little groups of waves and this is exactly what the electric valve does. The process is called "rectification." The result is that successive impulses of current flow through the telephone receiver and all of these tiny impulses in any one group add their effects together and produce a motion out of the telephone diaphragm. The interval between one group and the next permits the motion of the telephone diaphragm to subside and this intermittent motion causes what is heard as a note in the receiver.

30. *Essentials of a radio or line radio system.*—The principal features required for a radio system, as just described, are equally necessary in a line radio system. These essentials are: At transmitting end—source of high frequency; modulating device. At receiving end—tuned circuit; rectifying device. The first of these four essentials, a source of high frequency, is needed for two reasons in pure radio communication, (*a*) the frequency must be high enough so that the waves radiate effectively, (*b*) the frequency must be higher than audible so that only the modulating signal or voice is heard at the receiving end. In line radio, however, only the second reason is applicable.

While not included in the bare essentials of the system, it is found desirable to use tuned circuits at the transmitting as well as the receiving end. The transmission of the high-frequency current or wave is facilitated at every possible point by the use of circuits tuned to the particular frequency used. Tuning carries with it the advantage that the system responds much more powerfully to the one particular frequency than to others. Thus several tuned systems may be used simultaneously without interfering with one another. As each system may carry independently a signal or voice, simultaneous or multiplex communication becomes possible.

The four essential features which a radio and a line radio system have in common are indicated in the following schematic diagram

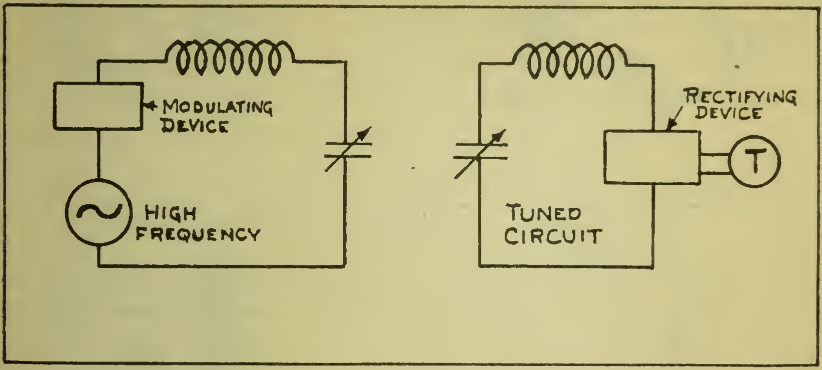

FIG. 14.—Radio or line radio transmitting and receiving circuit.

of the transmitting and receiving circuits. As compared with the simple wire communication systems described in Sections II and III, it may be seen from the diagram that the direct-current battery and modulating device (a key in the telegraphy and a microphone transmitter in telephony) are here replaced by a source of high-frequency current and a means for modulating it. At the receiving end, besides T, the telephone receiver of ordinary telephony, there are in addition two of the essential features of the radio or line radio method—the tuning arrangements and a rectifying device.

Figure 14 is a complete diagram of a pure radio system, either the capacity or inductance being used as the antenna at both transmitting and receiving ends. The connection between the two ends is merely the ether, through which the waves are radiated. Line radio differs from the pure radio system merely in that a conducting line replaces the ether. Means must be provided for connecting the transmitting and receiving circuits to the line. This may be done in several ways. Examples are shown in Figures 15 and 16, taken from Squier's original paper of 1911.

In these diagrams, which show the principle of two possible means of connecting the transmitting and receiving apparatus to the line, the four essential devices appear, the source of high frequency, the modulating device (in these diagrams simply the microphone transmitter), tuned circuits, and a rectifier connected across the condenser of receiving circuit. Besides the tuned transmitting and receiving circuits themselves, tuned combinations of capacity and inductance are utilized to couple these circuits to the line.

Except for the conducting lines and modes of coupling thereto, most of the subjects in the remainder of this pamphlet have to do

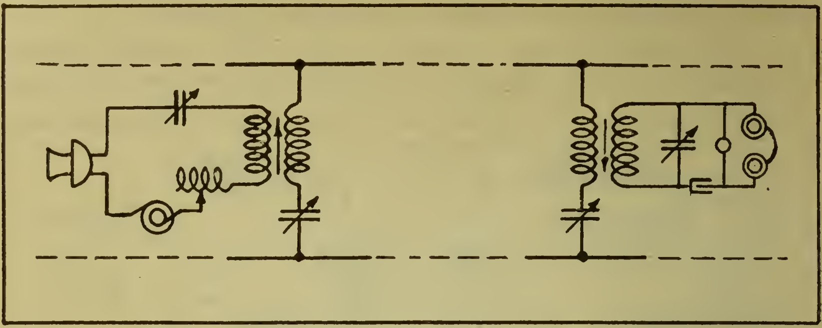

FIG. 15.—Line radio circuits connected across line in parallel.

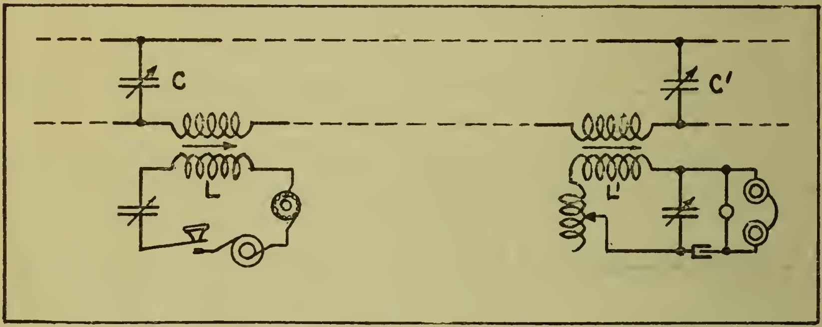

FIG. 16.—Line radio circuits connected across line in series.

with pure radio as well as line radio communication. The discussion henceforth will, however, deal explicitly with line radio only.

SECTION VII.

THE ELECTRON TUBE IN LINE RADIO COMMUNICATION.

31. *Electron flow.*—The development of line radio has been extraordinarily facilitated by the device called the electron tube and variously known under other names. First used as a detecting device or rectifier, it is now used also as a high-frequency generator, as a modulator, and also as an amplifier by means of which the currents

are more readily controlled and utilized. It is very satisfactory and stable in operation for these various purposes. The basic principles of action of the electron tube are now discussed. For further study, the student is referred to Radio Communication Pamphlets No. 1 and No. 40 (chapter 6).

The electron tube is a very simple device which looks more like an ordinary incandescent lamp bulb than anything else. While experimenting in the development of the incandescent lamp Edison made the discovery that an electric current could be made to flow in the empty space inside the bulb near the hot filament. If a metal plate

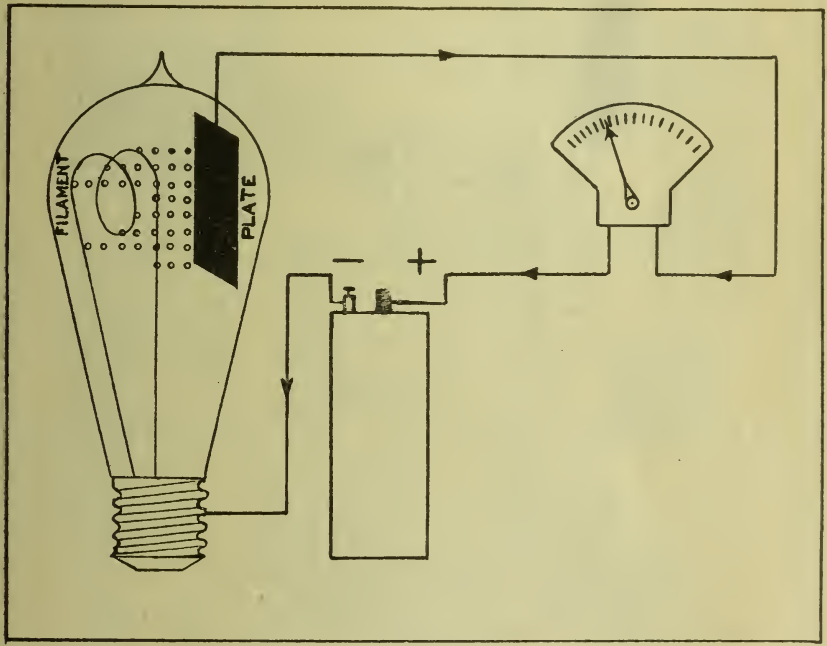

FIG. 17.—Use of electron flow from hot filament.

is placed inside of an incandescent lamp bulb near the filament (fig. 17) and if by means of a wire through the glass this metal plate is connected through a battery and an indicating instrument to the filament, a current will flow as indicated by the instrument. A current is flowing in the wire and also flowing across the empty space between the filament and the plate. By much patient research scientists have found out that this current in the lamp consists of the flow of a stream of very small electric particles called electrons. These electrons are shot out into the surrounding space in all directions by the hot filament. The electrons may be said to fill the bulb like a vapor. They move at random in all directions unless there is an electric force to make them move in some particular direction. The battery connected in the circuit outside the bulb supplies an electric force which acts between the filament and plate and makes the electrons move from the filament to the plate. If the battery is disconnected there is no current, and as many electrons as strike the plate fall off again into the bulb. The current depends on the number and speed of the electrons. The battery is what gives

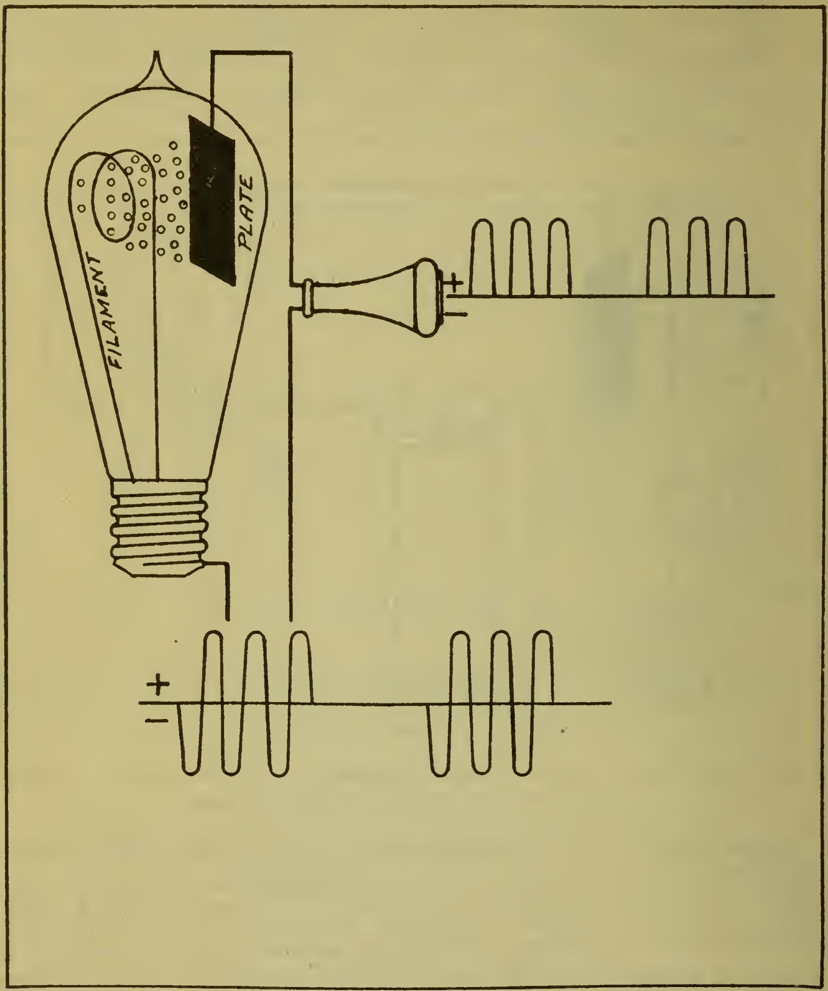

FIG. 18.—Use of electron flow apparatus as a rectifier.

them their speed in the direction filament to plate. The battery performs much the same action as a steam pump would if the bulb were a room into and out of which steam pipes were connected. If the pump were disconnected, there would be no flow of steam; and when the pump is connected, steam is made to flow into and out of the room and through the pipe.

32. *Rectifier action of tube.*—The point of all this is that the electron flow in the bulb has a rectifying or valve action. The electrons are emitted by the hot filament and can be made to flow toward the plate by a battery, provided the battery is connected in the proper direction. Each electron consists of negative electricity, and so a connection of the battery in one direction will cause the electrons

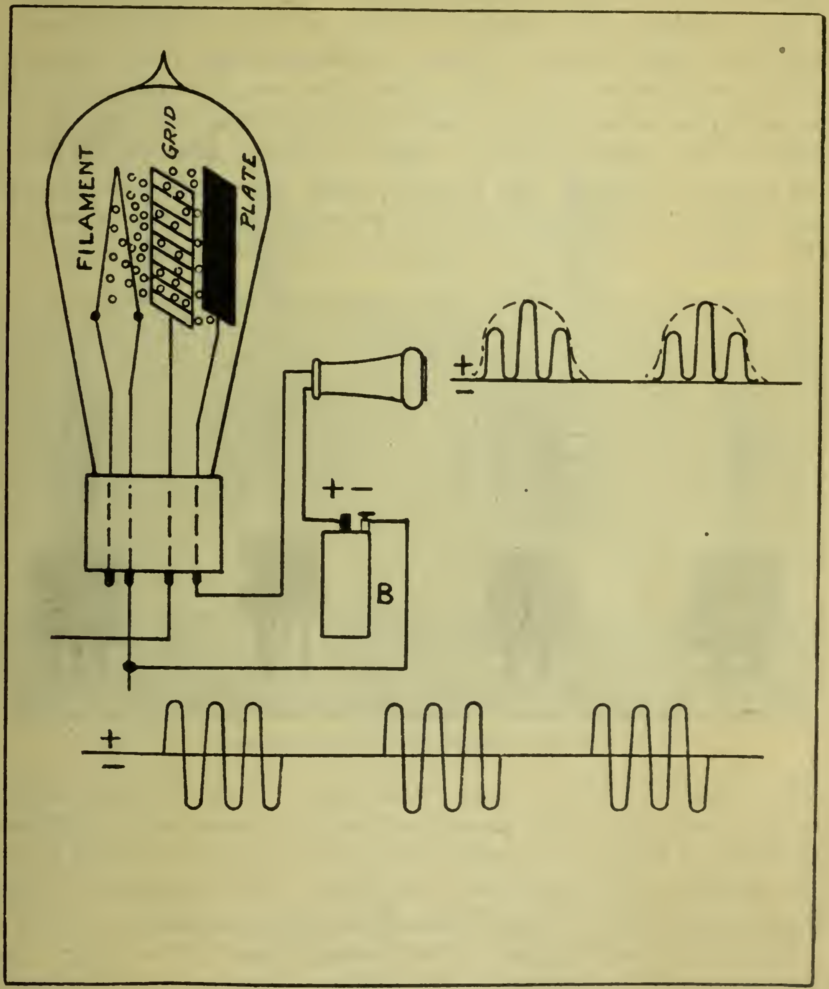

FIG. 19.—Electron tube containing grid.

to move toward the plate, while connection in the opposite direction will tend to prevent the flow of the electrons out from the filament to the plate. It should be clearly understood before going further that the rectifying action of the electron tube depends upon the fact that an electric force is produced in the tube by the battery which, if applied in one direction, causes an electric current from the filament to the plate, but that if this electric force is reversed no current flows. The device thus gives exactly the rectifying action needed in order to make the received signals in line radio produce sound in a telephone receiver. Suppose that the bulb shown in Figure 17 is connected to a line radio receiving circuit in place of the battery. Suppose also that the indicating instrument is replaced by a telephone receiver. This is shown in Figure 18. The pulses of current in the receiving circuit similar to those of Figure 13 produce electric force inside the bulb between the filament and plate which alternates in direction just as the pulses of current do. On account of the rectifying action, current can flow through the bulb only in one direction and consequently the pulses of electric force in one direction only are effective. As a result, pulses of current flow through the telephone receiver in groups, the pulses being all in one direction. This causes a note in the telephone receiver, as already explained.

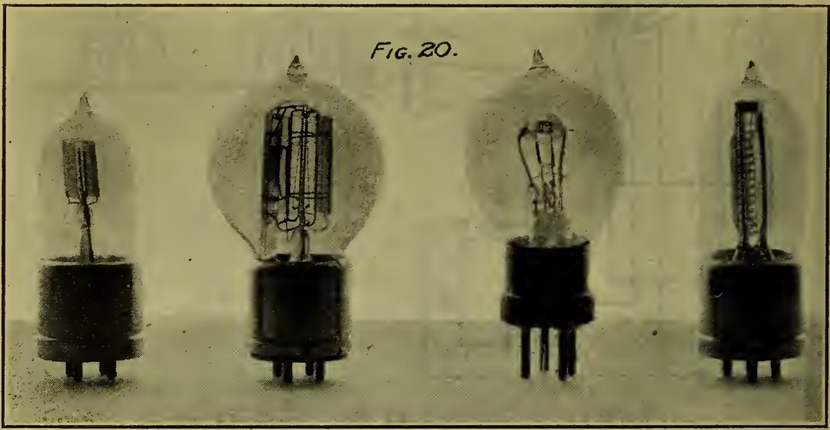

FIG. 20.—Various types of electron tubes.

33. *Action of the grid.*—An improvement in this electron device can be made which very greatly extends its power and usefulness. As shown in Figure 19, a grid of very fine wire can be placed in the tube between the filament and the plate. The importance of this improvement, due to L. De Forrest, will now be explained.

The grid is placed closer to the filament than to the plate. The electrons which are emitted by the filament can move freely between the grid wires. If by means of a battery or something else an electric force is established between the filament and the grid, this electric force causes electrons to move away from the filament toward the plate, and since the grid is placed much closer to the filament, the electric force makes the electrons move much faster than would the same electric force between the filament and plate. Very few of the electrons are taken by the grid, and a very small current thus goes through the wire connected to the grid. Thus a very small current to the grid is accompanied by the flow of a much larger current to the plate. Hence a larger current can be taken out of the tube than is put into it. A small electric force acts between filament and grid, causing a large electron flow from filament to plate. There results a relatively large flow of current in the apparatus connected outside

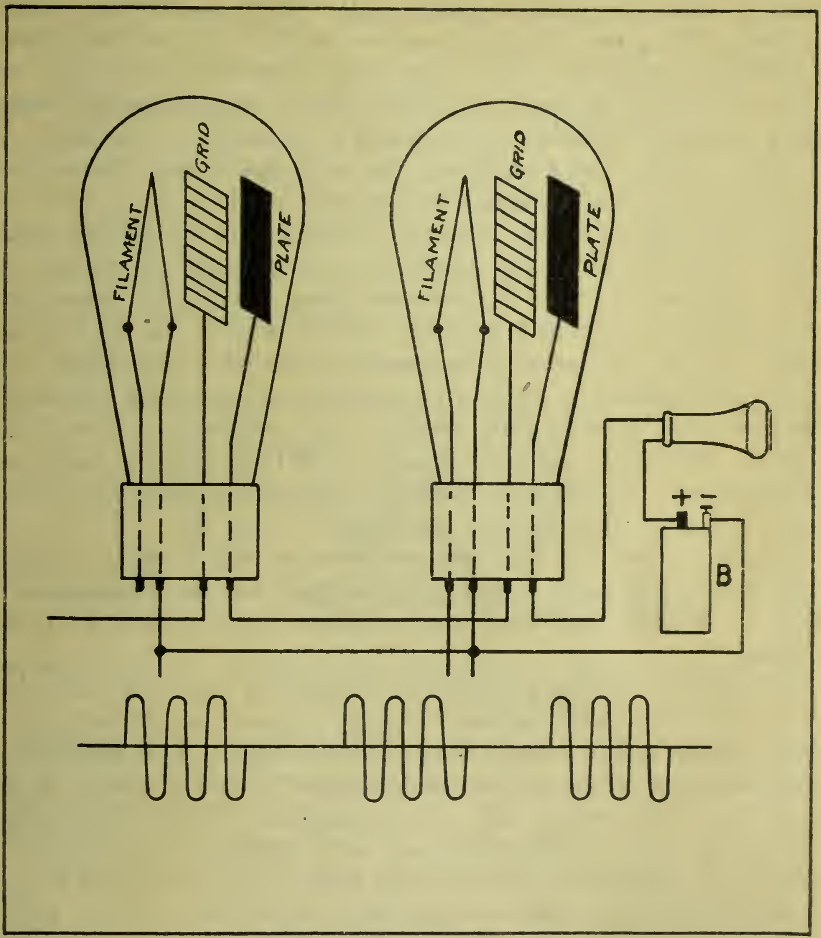

FIG. 21.—The principle of the amplifier.

the tube between the plate and filament. This device is commonly called a three-electrode electron tube, or simply an electron tube. It magnifies or amplifies electric currents. It accomplishes the control of a large amount of power by a small power. This is just the same thing that a gun does—pressing the trigger several times in a repeating pistol is like the action of the tube with successive pulses of electric force. The grid corresponds to the trigger and the plate to the gun barrel. A number of forms of electron tubes as used today are shown in Figure 20.

34. *Amplifiers.*—On account of the control of the plate current by a smaller grid current, the electron tube makes possible very wonderful feats. It is perfectly possible and quite easy to take the magnified output from an electron tube and pass it into a second electron tube, using that to make a still further amplification of the current. Using one tube after another in this way, we obtain what is called an amplifier. Two tubes joined together in this way are shown in Figure 21 and the process can be repeated several times using a number of tubes. The current is increased by each tube and handed on to the next without any change or distortion of the current even though it passes through several such steps.

The amplifier is of the greatest importance in radio, line radio, and in long-distance wire telephony. It reduces the amount of power that must be used in the transmitting apparatus because when an amplifier is used in a receiving station, signals can be received which are far too feeble to be received without an amplifier. By means of amplifiers to which are connected loud-speaking telephones, speeches may be made fully audible to all persons in a very large crowd. The large announcers used in railway stations make use of amplifiers. By means of amplifiers submarine vessels can receive radio messages when entirely submerged.

Amplifiers may be used with currents of either audio or radio frequencies, but must be specially designed for the frequencies to be used. Further information on amplifiers is given in R. C. P. 40, chapter 6.

35. *Electron tube as generator of alternating currents.*—The electron tube uses a small amount of power in the input circuit to produce a much larger amount in the output circuit. It is possible by suitable means to supply the small amount of power needed in the input from the output side of the amplifier. Thus once started the device can be self-excited and will continue indefinitely. It should be understood, however, that this is not a perpetual motion device, for energy must be supplied by means of a battery in the plate circuit of the tube. It does mean that the electron tube can be used to generate alternating currents as well as receive and amplify them. A simple circuit which illustrates this principle of self-oscillation is shown in Figure 22. The conventional symbols are used in this diagram: *D* represents the electron tube, $\sim$ being the grid, $\wedge$ the filament, and ▬— the plate.

The coil *A*, together with the condenser *C*, has a natural period of electrical vibration as explained above (Section VI). An accidental electrical disturbance, which is always present, contains this natural frequency and starts the circuit AC in very weak vibration. This communicates a weak alternating electromotive force to the grid of the tube which, due to the amplifying property of the electron tube, causes a much larger alternating electromotive force to act in the plate circuit and an alternating current to flow through the coils G and E. This current in coil E causes an alternating magnetic field around E which threads through coil A, thus inducing in A an alternating current which may be made larger than the original vibration by the proper amount of coupling. This causes a larger emf on the grid and consequently a still larger current in the coils G and E and so the current is increased up to the limit where the tube ceases to amplify further. So a continuous alternating current is produced, the frequency of which is determined roughly by the inductance and capacity of thte circuit AC and the amplitude by the design of the tube.

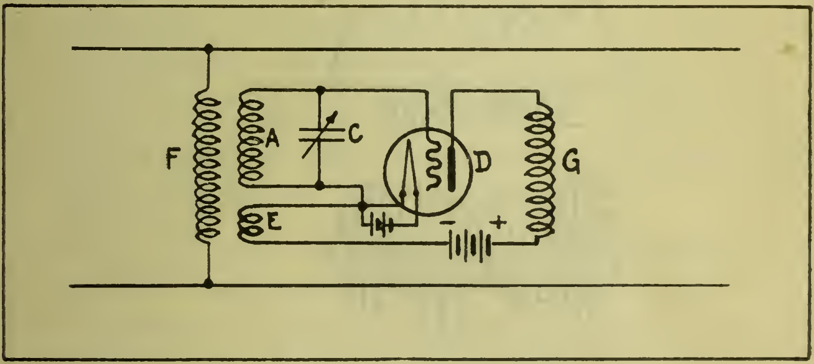

FIG. 22.—A simple self-oscillating circuit.

By means of the magnetic induction between coils F and A this alternating current is communicated to the line and transmitted to the receiving station.

This alternating current which is sent out on the line is of unvarying intensity and will not cause an ordinary detecting device to respond. It may, however, be started and stopped at an audible frequency and then dots and dashes sent as in ordinary telegraphy. This may be received on a crystal detector or electron tube used as a detector.

36. *Electron tube as a modulator.*—This alternating current may also be used to transmit speech. In order to do this, it is necessary to modulate or mold the wave. This is readily done by means of the electron tube. If in Figure 19 the telephone receiver is replaced by any kind of a generator of radio-frequency current, then if a person speaks into a telephone transmitter connected between grid and filament of the tube the variations caused by the sound of the person's

voice are impressed upon the radio currents which are being produced in the plate circuit. A modulated wave as in Figure 23 is produced; that is, the intensity of the radio-frequency current is varied to correspond to the wave produced in the transmitter by the voice. The solid lines represent the radio-frequency vibrations, and the dotted line shows how the intensity has been made to vary according to the sound wave shown above. Various circuits for producing this modulated wave may be used, and more detailed description is given in The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40, chapter 6.

This modulated wave is transmitted along the wires and at the receiving station is impressed on the grid of an electron tube acting as a detector. A receiver in the plate circuit of this tube then re-

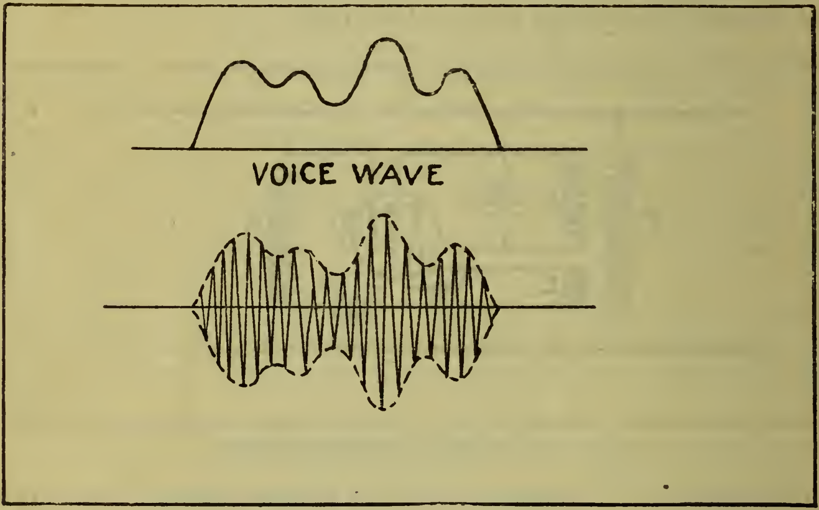

FIG. 23.—Voice waves carried by radio waves.

sponds to the frequency of the voice wave. This signal may be too weak to be heard, but may be amplified many times by use of electron-tube amplifiers.

SECTION VIII.

LINE RADIO METHOD.

37. *Advantages of line radio.*—Line radio has the advantage of radio and wire telephony without some of the disadvantages. In

radio it is possible to transmit at one time many different conversations provided they are at frequencies that are not too close together. These messages, however, may be "picked up" by anyone provided he tunes to that particular frequency. If metallic wires are used instead of ether as the means of transmission, the communications are private, and the person must not only be tuned to the particular frequency but also connected to the line in order to receive the message. The line is relatively free from interference from strays and from radio transmitting stations provided suitable transpositions are used. It has also been found that a break in the line does not stop the conversation, so that this method of communication is more reliable than either ordinary telephony or radio.

By suitable arrangements several two-way conversations may be carried on over one pair of wires without interference, and for distances of 100 miles or over the relative cost of line radio is less than ordinary telephony. It is as flexible as ordinary telephony, for equipment may be changed from one trunk line to another without loss in efficiency. The connections for line radio do not in the least interfere with the use of the lines for ordinary telephony, but the lines can be used for both simultaneously as well as for duplex telegraphy, so that line radio does not destroy the present method but simply multiplies the number of messages that can be sent on the existing lines.

Line radio, however, is not limited to the use of telephone lines, for any kind of metallic lines may be used. Trolley lines carrying direct or alternating current may be used and constant communication maintained with trolley cars or with other stations that may be connected to the line. High-tension power lines may also be used. In these cases the sending and receiving apparatus are connected through high-voltage condensers to the line. These condensers are of such capacity that they will pass the high-frequency currents to the line, but not the low frequency from the line. In order to keep in communication with moving railway trains the message is sent out on wires along the track. An antenna on the train can then pick up the message or send out messages that are received on the line. This may be done without the radiation of much energy, so that it is comparatively secret.

The military advantages of this method are many. It gives a method of using a single pair of wires for several messages and so eliminates the construction of many lines. It gives a practically noninterrupted method of communication under adverse circumstances. It allows continuous directions of troops even while being transported from one point to another. The equipment used may be at any time used for ordinary radio telephony or telegraphy.

38. *Frequencies used in line radio.*—In order to have two or more conversations at one time on a single pair of wires they must be at such frequencies that they do not interfere. When two alternating currents are near the same frequency they combine to form an alternating current that has a frequency equal to the difference of the two frequencies. So if their difference is less than 3,000 cycles per second, this "beat note" will be heard. So, in general, the carrier frequencies should be different by more than this amount. For example, if one carrier frequency is 100,000 cycles per second, all others should be above 103,000 or below 97,000. Also, the lowest frequency used must be above 3,000 cycles per second. The upper limit has not been definitely determined, but frequencies of the order of 600,000 cycles per second have been used satisfactorily. The frequency of the carrier wave should always be higher than that of the modulating wave.

The modern method of producing these frequencies is by the electron tube. As has been explained, any frequency desired can be maintained by suitable circuits and the amplitude of this wave may be modulated by means of voice currents produced in a telephone transmitter. The method of producing the high-frequency used by Major General Squier, who first operated line radio successfully, was a high-frequency alternator of special design capable of producing any frequency up to 100,000 cycles per second. Such an alternator is very expensive and difficult to operate, so that electron tubes which have been developed since have taken its place entirely. Any generator of high-frequency alternating currents may be used for the generation of these frequencies, but the electron tube generator is less difficult to operate and in every respect is the best generator to use.

39. *Tuning and multiplexing.*—The simultaneous transmission of several conversations over one pair of wires without mixing requires careful adjustments to be made. In Figures 15 and 16 is represented a single transmitting and receiving set connected to a pair of wires. Several of these sets may be connected to the same pair of wires if it is desired to carry on conversation between two stations without being heard by the other station. These two stations must be tuned to the same frequency; that is, the inductance and capacity of each station must be adjusted so that the circuits have the same frequency of vibration. Other stations are tuned to a different frequency, so each receiving station receives the message that is carried by a high-frequency wave having its own frequency. The two stations in order to maintain two-way conversation may use two different carrier frequencies, one for receiving and one for sending at each station. By suitable complex circuits, however, it is possible to use the same frequency for both directions, so tuning

makes it possible to carry on several conversations at one time, the limit to the number being set by the sharpness of tuning that is possible.

The Western Electric Co. has developed what is called a band filter to take the place of tuning. This filter is a combination of inductances and capacities so arranged that it offers a low impedance to a certain band of frequencies and a very high impedance to all others. Then if a transmitting set is connected through such a filter to the line only a definite band would be impressed on the line. Then if a receiving set is connected to the line through a similar filter, it will receive only the messages on carrier frequencies within that band, so it accomplishes the same results as does tuning.

Tuning of a circuit causes it to be very selective; that is, it picks out its own frequency and will not respond to frequencies very far on either side of its own. In telegraphy this is very desirable, but for telephone purposes it is not. When a high-frequency wave is modulated by means of audio frequency, it has what is called side bands; that is, the resulting alternating current consists of the carrier frequency, the carrier frequency plus the modulating frequency, and the carrier frequency minus the modulating frequency. So it is desirable to get on the wire a band of frequencies from the carrier wave minus 3,000 to the carrier wave plus 3,000. The band filter is much better suited to do this than is selective tuning, for, although tuning can be made to pass the frequencies desired, a tuned circuit always will transmit one frequency at a maximum and so produce distortion, while a band filter can be made to transmit all frequencies within its band in about the same ratio.

40. *Conducting lines—interference.*—Line radio may use the ordinary telephone or power lines, but for use of line radio alone other conductors may be as satisfactory. Most of a high-frequency current is carried on the surface of a conductor and if the same amount of copper is used in a solid wire and a hollow wire the hollow wire will have the lower resistance to the high-frequency current. To add strength, iron may be used as a core and copper used on the outside. The copper then will carry all the current. Aluminum wire is also very suitable for use of line radio. Galvanized-iron wire, however, offers a very high resistance and can not be used.

The circuit used may be either a single wire with ground return or a complete metallic circuit. The ground return circuit allows considerable interference. That is, outside sources of radio frequency, such as radio stations, static, etc., cause noises and disturbances. Such a circuit also picks up messages from neighboring lines and radiates its message to other lines. The use of a complete metallic circuit eliminates this to a large extent.

Care must be taken in selecting the frequency to be used in neighboring circuits. If two carrier waves are near the same frequency, there may be enough induction between the lines to produce beats between these carrier waves that are audible, or if the frequencies are the same one message may be superimposed on the other. This may be practically eliminated by suitable location of circuits and selection of frequencies. The induction between lines may be reduced by suitable transpositions, that is, the crossing of the lines at definite intervals so that the induction in one section is opposed by that in the next. There may also be beats produced between the carrier wave and radio stations. These may be eliminated by a suitable choice of frequencies, avoiding those of neighboring radio stations, and by use of transpositions. There is no more interference from strays in line radio than in ordinary telephony, which is much less than in radio telephony.

The selection of the frequencies to be used is a problem of the installation. It is not necessary that the frequency bands be regulated as in radio, but it is a problem that must be decided by the engineer of the particular system, who must take into account only his own demands and also avoid the use of frequencies used by high-power radio transmitting stations which may be near his lines.

A pair of wires in a cable may be used as well as open lines. The original work of Major General Squier was done using a pair of wires in a city telephone cable. The loss of energy is greater due to dielectric losses and eddy currents in the sheath and neighboring conductors. This decrease in energy may be compensated for by the use of amplifiers.

41. *Possibilities of line radio.*—Line radio as a method of communication depends on the use of amplifiers. The power put into the line is dissipated or "attenuated," due to resistance and reactance drop, radiation, leakage, and dielectric losses. That is, the received signal is many times smaller than the transmitted signal. This attenuation is much greater in the case of high-frequency current than in the case of low frequency and greater in cables than in open lines. So in order to hear the signal at the receiving end it is necessary to amplify the received signal. This may be done very efficiently by means of the electron tube amplifier, which may be installed in the circuit and will require very little attention.

It has been shown experimentally in comparison with radio that much less power is necessary from the sending circuit of line radio installation to produce the same signal than from an ordinary radio station. Also when the signal is amplified there is not as much noise associated with it and so it may be amplified more. The speech transmitted is free of distortion and has much better quality than that transmitted by ordinary wire telephony.

Line radio is comparatively a new field in the communication art, and for that reason there are many things that may be improved. The process so far has been to adapt old methods and equipments to the new field and use line radio as a device for increasing the usefulness of the old systems. As the field advances it becomes a problem to fit the conditions to it alone. This brings out the necessity of developing a type of conductor and line best suited for carrying high-frequency currents with minimum loss. Also there is need for suitable transmitting and receiving devices which will give little distortion and faithful reproduction of the speech.

SECTION IX.

TELEPHONY AND TELEGRAPHY BY MEANS OF LINE RADIO.

42. *Line radio telegraphy.*—Line radio adapts itself very readily to multiplex telegraphy. In this case for one station to send a message to another station it is only necessary for the circuits of both to be tuned to the same frequency or for both to have similar band filters.

The operator at the sending station, sending out continuous waves, opens and closes the circuit to form dots and dashes. These, however, would not be heard if the receiving station used an ordinary detector unless the frequency was audible. To send an audible frequency would interfere with the telephone messages that may be going over the same line and would not increase the use of the lines. To overcome this, messages are sent using high-frequency current and, at the receiving station, instead of a detector, another high-frequency generating circuit is used. The frequency of this generator is slightly different from that of the transmitting generator. The incoming signal combines with the local high-frequency current, and beats are formed that may be adjusted to an audible frequency. So the dots and dashes are heard in the phones in the plate circuit of the receiving tube, the frequency of the note heard being the difference between the two frequencies. This method of reception is very sensitive, and very sharp tuning is possible. Figure 24 shows an arrangement that may be used for line radio telegraphy.

The operator at the sending station opens and closes the key K and thus allows high-frequency currents to be impressed on the line from the oscillating circuit S, the operation of which is described above (Section VII). These high-frequency currents flow in the receiving coil, which is tuned to the same frequency as the sending coil. *R* is another oscillating circuit which is tuned to a frequency slightly different from *S* and has a telephone receiver in the plate circuit. The currents induced on the line from *S* combine with those generated in *R*, and an audible note results which is heard in the telephone *T*, and so the dots and dashes are distinguished.

The sending station may also be made audible to the receiving station if a chopper (device for opening and closing the circuit at an audible frequency) is inserted in that circuit. This is a special case of modulation of the sending station and may be received by methods used for the reception of line radio telephony.

Since for line radio telegraphy it is only necessary to send and receive one frequency, the tuning may be very sharp, or if a band filter is used, the width of the band passed may be very narrow.

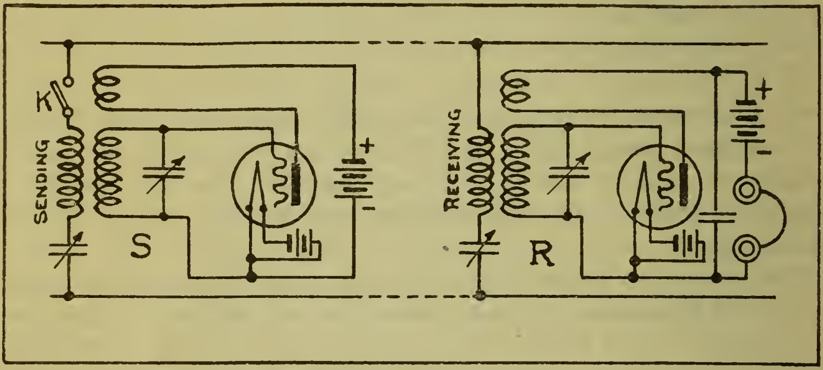

FIG. 24.—A line radio telegraph circuit.

This allows the bands to be close together, and more messages can be sent for a given range of frequencies than can be sent by line radio telephony.

Two-way messages may be sent on the same line and at the same frequency if complex phantom circuits are used.

43. *Line radio telephony.*—In line radio telephony, instead of starting and stopping the high-frequency current as in telegraphy, the amplitude of the current is varied or modulated according to the speech wave (see Section VII). It is then unnecessary to use an oscillating circuit to receive the message, for if an electron-tube detector is used the phones will respond to the speech wave. Figure 25 shows a circuit that may be used.

The sending station *S* is the same as in line radio telegraphy except that the key has been replaced by a microphone *M*. When the operator talks into this microphone, the resistance of the circuit is varied and so the amplitude of the high-frequency current is varied. The receiving circuit *R* is an electron tube arranged as a detector; that is, the high-frequency wave of varying amplitude induced in the circuit *L* causes a pulsating direct current to flow in the telephone *T*. Figure 23 shows diagrammatically the radio wave modulated by the voice wave. If such a wave is impressed on the grid of the rectifier tube, then there appears in the plate circuit of the tube a reproduction of only one-half the wave, say the upper half. This contains, then, a high-frequency pulsation and a voice-frequency pulsation. The high-frequency pulsation will not affect telephone receivers placed in the plate circuit and may be by-passed by means of a small condenser *C* placed across the phones. The voice frequency, however, is required to pass through the phones and causes variations in the diaphragm of the receiver which produce the original sound wave impressed on the transmitter. The voice wave may be so weak that when changed into sound waves

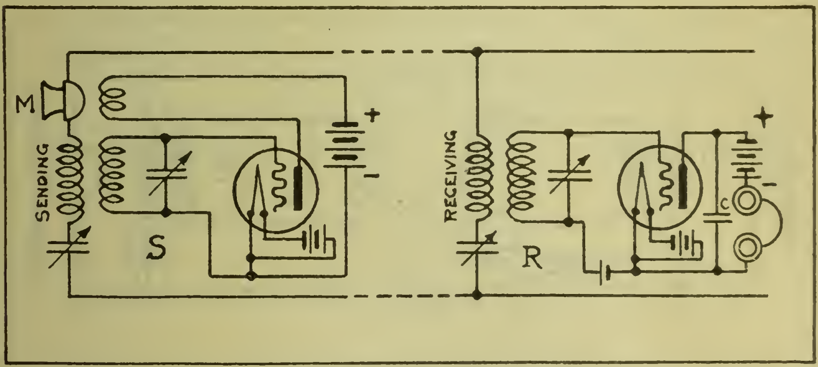

FIG. 25.—A line radio telephone circuit.

it can not be heard distinctly. In this case it may be amplified by use of an electron-tube amplifier. Instead of phones then in the plate circuit of the rectifying tube is put the primary of a transformer, the secondary of which is in the grid circuit of the amplifier. The phones are then in the plate circuit of the last amplifier tube. It is also possible to amplify the signal before rectification as well as after. (The circuits shown are the simpler circuits and are not suitable for sending much power. Other circuits that may be used are described in The Principles Underlying Radio Communication, chapter 6.)

Line radio telephony requires a wider band of frequencies for each message than does line radio telegraphy. When the carrier frequency is modulated there results not only the single frequency but also what are known as side frequencies. These are frequencies equal to the carrier frequency minus the modulating frequency and to the carrier frequency plus the modulating frequency. It is only necessary to transmit the carrier frequency and one side frequency so that the band filter may be so arranged that it suppresses one side frequency and the transmitted band is narrowed. By this method it has been found that it is possible to have conversations on adjacent carrier waves which have a frequency difference of only 3,000 cycles.

In transmission of line radio telephony the greater part of the energy sent is the carrier wave, which is not used in the production of speech. A system has been developed whereby this carrier wave is suppressed at the sending station and resupplied at the receiving station. All that is sent along the line, then, is one of the side bands. This reduces materially the amount of current sent along the line and consequently there is less loss in the line. This method also supplies high frequency only during the time that actual conversation is taking place. The circuits employed for this method of

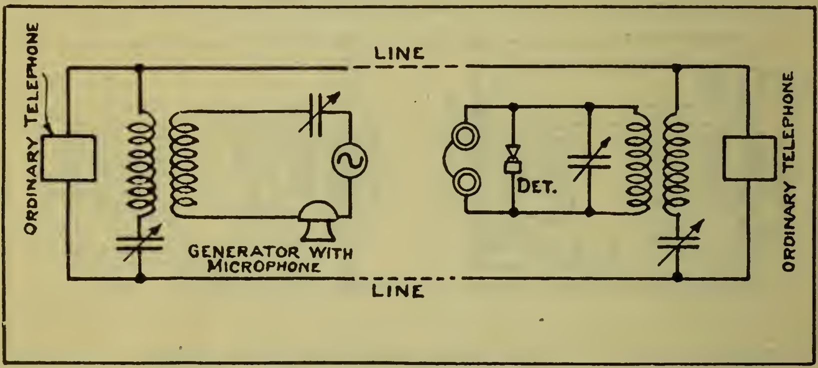

FIG. 26.—Line radio circuit superimposed on ordinary telephone circuit.

operation are complex and are described fully in the paper on Carrier Current Telephony and Telegraphy, by Colpitts and Blackwell.

44. *Methods of coupling to line.*—The methods of coupling to the line have been referred to at different places. Figures 15 and 16 show the methods used by Major General Squier in his original work on line radio. The circuits are tuned as in ordinary radio. The generating circuit and receiving circuit are tuned to the same frequency and by means of the condensers the line is also tuned to the same frequency. The coupling between the circuits and the line by this method is electromagnetic. That is, the magnetic lines in the transmitting coil thread through the coil in the line next to it and cause the same kind of current to flow in that coil. The position of the coils relative to each other may be changed. In actual operation the position of the coils and the value of the capacities in the line are adjusted for maximum signal.

Duplex operation of a telephone line was first accomplished by Major General Squier using one pair of lines for one conversation by ordinary telephony and one by line radio telephony. The method used by him is shown diagrammatically in Figure 26.

Other line radio stations using different frequencies may be bridged across the line and the number of simultaneous messages increased. Each line and the ground may also be used at the same time for duplex telegraph circuits. This method of coupling the line radio circuits requires wide spacing of the carrier frequencies. The band filter allows a much closer spacing of frequencies and consequently a larger number of simultaneous messages. A simple diagrammatic sketch of this method is given in Figure 27.

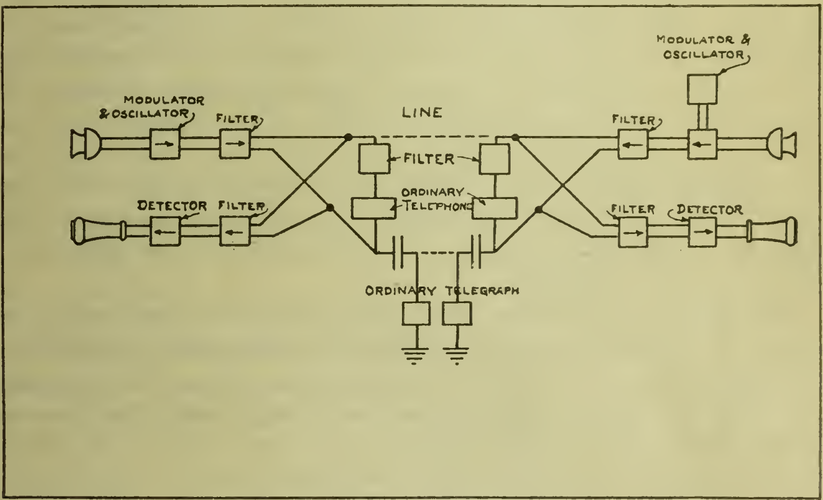

FIG. 27.—A multiplexed line.

This shows a two-way line radio circuit with ordinary telephone and telegraph circuits which may be duplex circuits. The line radio circuits can be multiplied many times by using different frequencies for the carrier waves and may be either telephone or telegraph, or both. By suitable phantom circuits each two-way line radio circuit may be on the same frequency. These circuits are complex and are described in the paper by Colpitts and Blackwell mentioned above.

45. *Other uses of line radio.*—Line radio has its principal application to commercial multiplex telephony and telegraphy, but, as has been mentioned before, its use is not limited to this field. For military use it has the advantage of being the most secret method of telephone communication. It is reliable, and communication between two points may be maintained even with a physical break in the line. It is not limited to use of telephone or telegraph lines but may be adapted easily to use on any existing lines, such as power lines,

without interference with what may already be on those lines. Messages are not limited to stay on the wires at all times but may be linked with ordinary radio telephony or telegraphy; that is, the message may be sent over a space where no wires exist by radio and then received, amplified, and transmitted over wires to a more distant point. This makes it possible to extend both the range of a radio station and the line radio station and to reach points with telephone where it is impossible to construct lines.

The use of this method for signaling to moving trains and trolley cars has already been mentioned. This gives a possibility of a train dispatcher being in constant communication with the engineer of a train.

The work of multiplex telephony and telegraphy using line radio has had a great development in this country and has been used for long-distance toll lines by the American Telephone & Telegraph Co., who has been responsible for much of its development as applied to the extension of existing telephone circuits. The Signal Corps has continued investigation on several phases of line radio especially as applied to military use. Some experiments have also been carried out that show that it is possible to use alternating current for submarine cable transmission, using the principles of line radio, but at very low frequencies.

This country has not been alone in the development and use of line radio. In Japan line radio communication using power lines has been in operation as well as the use of the telephone lines for multiplex transmission. In Germany the German federal post office has conducted experiments and has installed line radio circuits on several of the long-distance telephone and telegraph lines.

It is probable that this system will be used soon in all countries to extend the use of the long-distance telephone systems without the necessity of the construction of additional lines. The development of the method is being continued and it is impossible to say what advancements may be expected.

Section X.

HISTORY OF LINE RADIO.

46. *Early attempts at multiplexing.*—Many attempts have been made in the past to devise systems of multiplex telephony and telegraphy. Among the most notable early investigators seeking the solu-

tion of the problem were Grey (1886); Carty (1889); Pupin (1892); Hutin and Leblanc (1892); and Stone (1894). The dates following each name state the year in which articles were published or patents taken out by the authors. The schemes proposed by these inventors failed in the practical solution of the problem, although many were suggestive. Multiplexing based on these schemes was never attempted by the telephone companies. Ruhmer (1910) proposed a scheme in which high frequencies were transferred over the line and received by the use of a crystal detector. In his proposed scheme Ruhmer did not make use of the principles of resonance except at the receiving end for separating the different frequencies transmitted over the line. Ruhmer's schemes never got beyond the experimental stage.

47. *Work of Squier in 1910.*—Line radio was actually established as a successful means of communication by the work of Squier (Major General, Signal Corps, United States Army). Conceiving the idea of impressing high (radio) frequency oscillations on a wire and thus combining the engineering practice of wireless telephony and telegraphy with the engineering practice of wire telephony and telegraphy, he carried out in 1910 a long series of tests and experiments to prove the practicability of his idea. After showing by tests over a telephone line that his methods were highly practical, Squier put the new art on a scientific basis by making an extensive series of measurements of the phenomena arising from it.

The basic principles of the new art and the specification of patents relating thereto granted to Squier, together with the tabulated and plotted data resulting from his measurements, were published in a Professional Paper of the Signal Corps, United States Army (War Department Document 390), entitled "Multiplex Telephony and Telegraphy by Means of Electric Waves Guided by Wires." This original paper appeared in March, 1911. In June, 1911, it was read before the Chicago meeting of the American Institute of Electrical Engineers, the paper with resulting discussions then being published in the "Transactions" of that society. In this way the work attained wide publicity and was brought to the attention of all engineers interested in the two arts of electrical communication then existing.

48. *Résumé of Squier's publication.*—In addition to enunciating the basic principles of the new art and describing their successful application, Squier's original paper shows throughout that he brought the attitude of mind of the radio engineer to the problem of multiplexing wire communication. In Squier's original paper—

(*a*) The use of infra and ultra sound frequencies for line radio telephony was suggested.

(*b*) It was shown that the superimposing of the high-frequency oscillations on the circuit did not interfere with the simultaneous use of the ordinary telephone on that circuit.

(*c*) The method of generation of the radio-frequency oscillation was described.

(*d*) The description and electrical constants of the telephone line used in the experiments were given in detail.

(*e*) Various methods of modulating the radio-frequency output of the generator were shown.

(*f*) The various methods and the degrees of coupling that could be used were described and discussed.

(*g*) It was shown that the system could be grounded by inserting in the ground connection a capacity of value such that it would offer a very large impedance to disturbing low-frequency earth currents and low impedance to the high-frequency oscillations.

(*h*) The application of the three-electrode vacuum tube to the art was described.

(*i*) The use of a potentiometer to adjust the three-electrode vacuum tube to the sensitive receiving potential was shown.

(*j*) The fact that a ground return circuit as well as a complete metallic circuit could be employed was noted.

(*k*) The difference in action of soft iron core telephone receivers and telephone receivers having cores of permanent magnets was noted.

(*l*) The fact that the voltage on the line due to the impressed oscillations was low as compared with pure radio transmission voltage was observed and the simplifying effect this would have on the design of line radio apparatus was pointed out.

(*m*) It was noted that reflection of the waves would obtain at points on the line where a great change in the electrical property of the line occurs.

(*n*) The results of measurements of the electrical properties of the line at high frequencies were tabulated and plotted.

(*o*) The marked increase in current received if the line was tuned was shown. Measurements and graphs illustrating this were given.

(*p*) The effect of the frequency upon the attenuation of the current was measured.

(*q*) Many different circuits that could be utilized in line radio, including various methods of impressing the high-frequency oscillation on the line, were shown by diagrams.

(*r*) Specifications of the basic patents granted to him—United States Patents 980,356 to 980,359—are given in the appendix.

49. *Progress in recent years.*—Since 1911 much progress has been made in developing line radio communication. It has benefited equally with radio communication by the improvement in design of the electron tubes and by the improved design of circuits used in connection with it. So important is the electron tube in line radio that it can be said that it is this device which makes line radio commer-

cially practicable, since no other high-frequency generator of so low a first cost and so economical to operate is known, and the other operations necessary in line radio, such as generation, amplification, and detection, can be accomplished by the use of this device.

In recent years the American Telephone & Telegraph Co. have made important developments on the art and have put it into extensive commercial use. The engineers of this company have contributed materially to the development of the technique of high-frequency transmission over wires. They have made extensive researches, including the use of relays in line radio systems. They have developed the band filter and methods of using it to separate electrical currents of different frequencies. Methods of overcoming interference between circuits have also been devised. They have designed and developed the methods of "carrier suppression" and the harmonic generator used in this method. (Method described elsewhere in pamphlet.)

50. *Progress in foreign countries.*—The Canadian Independent Telephone Co. use line radio in many parts of their system. In addition to contributing toward the development of the technique of transmission, they have developed a system of duplex line radio telephony, using the same frequency at each end of the line. They are now perfecting circuits which will permit the same vacuum tube being used both as a generator and a receiver, and will impress the high-frequency output of the generator on the line only when sound waves affect the microphone.

This system is also being used in Japan and Germany. In both countries line radio telephony has been carried on over a line which at the same time was used as a high-tension power line. In Germany much work has been done in measuring the constants of various types of line at the frequencies used in line radio. A method of starting and stopping the high-frequency currents by means of voice control has been devised there.

SIGNAL CORPS PAMPHLETS.

(Corrected to December 1, 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. 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 (Types SCR–65 and 65–A).
6. Loop Radio Telegraph Set (Type SCR–77–A). (W. D. D. 1115.)
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.)
27. Sets, Radio Telephone and Telegraph, Type SCR–109–A and SCR–159. (W. D. D. 1111.)
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.)
41. Introduction to Line Radio Communication. (W. D. D. 1114.)

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and Type 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. (W. D. D. 1020.) (2d edition.)
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 (edition of 6–9–22). (W. D. D. 1112.)
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).

TRAINING REGULATIONS
(Signal Corps Subjects)
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WAR DEPARTMENT,
WASHINGTON, *April 15, 1925.*

The following publication, entitled "Loop Radio Telegraph Set, Type SCR–77–B," Radio Communication Pamphlet No. 43, is published for the information and guidance of all concerned.

[A. G. 062.1 (4–21–25).]

BY ORDER OF THE SECRETARY OF WAR:

JOHN L. HINES,
Major General,
Chief of Staff.

OFFICIAL:
ROBERT C. DAVIS,
Major General,
The Adjutant General.

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LOOP RADIO TELEGRAPH SET, TYPE SCR-77-B

SECTION I

PURPOSE OF SET—RANGES

1. *Purpose of set—ranges.*—The loop radiotelegraph set, type SCR-77-B, is a light portable vacuum tube transmitting and receiving set, designed to furnish radiotelegraph communication between units whose headquarters are usually from 3 to 5 miles apart. It will furnish reliable communication up to 3 miles. Under favorable conditions, such as open terrain, etc., this distance is increased to 5 miles. The wave-frequency band is from 4,100 kilocycles to 4,400 kilocycles (about 68-73 meters), and the set is so arranged that there are nine different wave-frequency settings available. It will be noted that the set will not operate with the SCR-77-A because of the different bands of wave frequencies.

SECTION II

GENERAL DESCRIPTION OF SET

2. *Special features of the set.*—The set as designed has a loop antenna, and is consequently very portable and can be quickly set up. This loop antenna is small and of low visibility, since its height when erected is only 4 feet. A moving unit furnished with this set can keep in constant communication within its transmitting range with other units furnished with a like set. The break-in feature enables the receiving station, which must also be an SCR-77-B set, to interrupt the transmitting station at any time. This feature greatly facilitates communication. There is no change in the adjustment needed to reverse the direction of communication. With the set properly adjusted so as to oscillate weakly when the key is up, the set causes no interference with other stations when receiving. It is then possible and desirable to operate all stations in a net on a common tuner setting.

3. *Carrying units of set—Weight and bulk.*—The whole set is assembled in five carrying units, each provided with a carrying strap. The loop antenna folds up and is carried in a bag, $28\frac{1}{2}$ inches long and $4\frac{1}{2}$ inches in diameter. When packed the total weight of both is 6 pounds. The transmitting and receiving apparatus is contained in an operating chest measuring $14\frac{5}{8}$ by $9\frac{15}{32}$ by $12\frac{9}{32}$ inches high and weighing $20\frac{1}{2}$ pounds complete. The 4-volt storage batteries are carried in a case measuring $5\frac{5}{32}$ by $10\frac{9}{16}$ by $8\frac{13}{16}$ inches high and weighing 27 pounds with the batteries in it. The equipment box has two separate compartments, in one of which are carried the dry batteries, and in the other the spare vacuum tubes and the telephone head sets. Its dimensions are 13 by $4\frac{5}{8}$ by $15\frac{5}{16}$ inches high, and when filled it weighs $17\frac{1}{2}$ pounds. The spare transmitting dry batteries are contained in a wooden case exactly like that provided for the batteries in use. The latter case is kept in the equipment box.

Section III

DETAILED DESCRIPTION OF THE SET

4. *The radio transmitter and receiver* (*type BC–9–A*).—The transmitting and receiving apparatus is assembled in one operating chest. Except for the head sets, the loop, and the plate batteries, the equipment is self-contained in the chest.

Three VT–1 vacuum tubes are used in the set, one of them serving as an oscillator. At the same time this oscillating tube also acts as a detector. The other two tubes are used as audio-frequency amplifiers. Associated with these tubes are various capacities, inductances, resistances, transformers, etc., necessary for their operation.

The back of the operating chest is provided with sockets for connecting the loop antenna. When the set is in use, the operating chest is placed on the equipment box and is provided with hooks to which clamps on the battery box can be fastened. All the controls necessary for sending and receiving are mounted on a panel, a view of which is shown in Figure 1. The legend used is as follows:

Figure 1

1. Fasteners to lock panel in place. 2. Direct-current milliammeter (0–10). 3. Telephone jacks. 4. Plate-current control; controls grid circuit potentiometer. 5. Tuner graduated from 0–10; controls a variable air condenser. 6. Battery switch; turns off and on the filament and potentiometer batteries. 7. Telegraph key. 8. Fine adjustment control for tuner. 9. Cord to plate

batteries. 10. Cord to filament battery. 11. Auxiliary binding posts for filament battery. 12. Auxiliary binding posts for plate batteries. 13. Oscillator filament resistance switch; shorts out resistance in series with oscillator tube filament when greater filament emission is necessary.

The panel is protected by a cover which is hinged at the lower end. When lowered it rests upon the projecting end of the equipment box, thus forming a shelf for the operator. The telegraph key is hinged and is to be pushed up against the panel when the front of the chest is closed. Electrical connections to the key are provided by knife contacts. The panel is locked in position when the handles of its

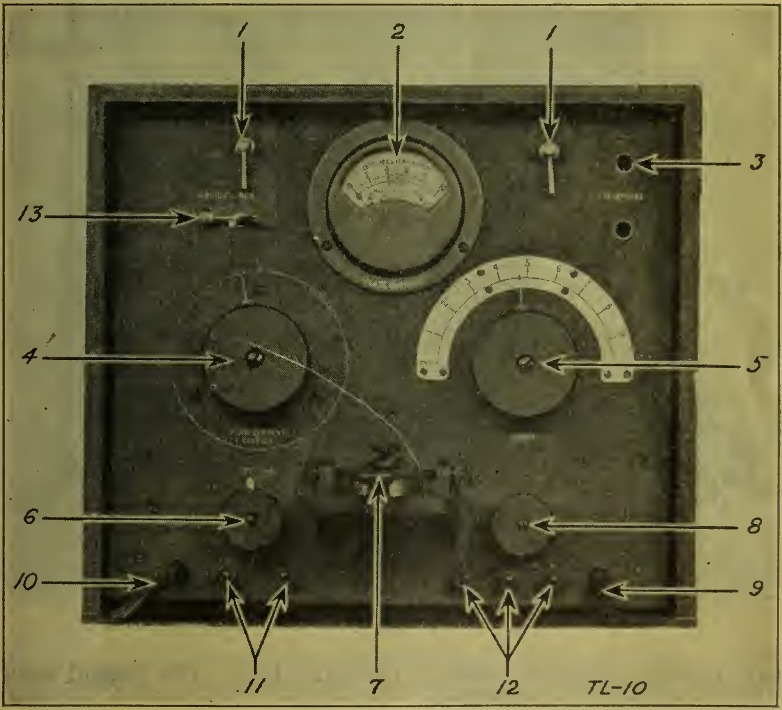


Fig. 1

fasteners are pointing downward. Turning the handles in either direction to the horizontal position unlocks the panel, which may then be swung forward, since it is hinged at the bottom.

The back of the box is a wooden panel, which has been specially treated so that it will not absorb moisture. Various pieces of apparatus are mounted on the inside of this panel, including a small single-leaf condenser used in calibrating the set. The adjustment of this condenser is made by means of a machine screw projecting through the wood panel, thus being made accessible on the outside of the chest.

The bakelite panel can be entirely removed from the box by swinging it forward and then lifting it from its bearings and disconnecting the three flexible leads connected to the floor of the box. Figure 2 shows the view when the panel is swung forward for the purpose of inserting vacuum tubes or dry batteries. Figure 3 shows a view of

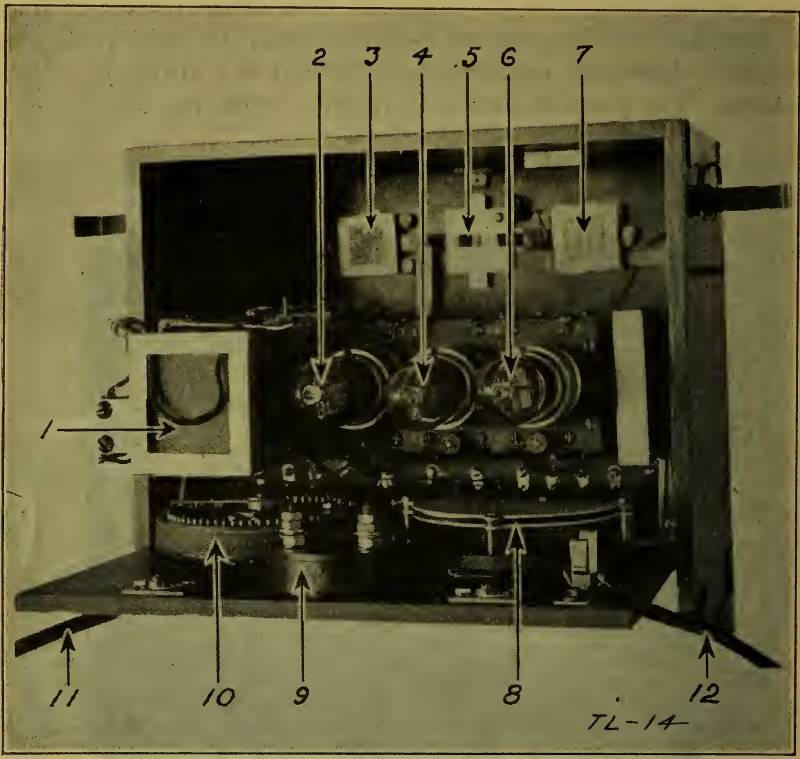


Fig. 2

the apparatus removed entirely from the box. The legend used in these two figures is as follows:

Figures 2 and 3

1. BA–2 battery for potentiometer. 2. VT–1 oscillator tube. 3. Grid oscillatory circuit condenser (720 mmf.). 4. First audio-frequency amplifier tube. 5. Single-leaf variable condenser used in calibrating set. 6. Second audio-frequency amplifier tube. 7. Plate oscillating circuit condenser (720 mmf.). 8. Variable air condenser (tuner). 9. 0—10, d. c. milliammeter in plate circuit of oscillator tube. 10. Potentiometer for varying grid-filament biasing potential of oscillator tube. 11. Filament circuit cord for storage battery. 12. Plate circuit cord to dry batteries (3-conductor). 13. One-to-one ratio transformer, coupling plate circuit of second audio-frequency amplifier tube to telephone head set. 14. Two 5,000-ohm resistances, forming part of potentiometer

circuit. 15. Filter-circuit inductances. 16. Filter-circuit condensers. 17. Switch controlling filament and potentiometer circuits. 18. Transformer (C–21), coupling oscillator tube plate circuit to first audio-frequency amplifier tube. 19. Stopping condenser (0.02 m. f.) prevents direct-current potential on oscillator tube plate from reaching grid. 20. Transformer (C–21), coupling first audio-frequency amplifier to second audio-frequency amplifier. 21. 100,000 ohms resistance in series with milliammeter. 22. By-pass condenser shunting 100,000 ohms resistance. 23. Compensating condenser shunting 120-volt battery.

It is to be noted that most of the apparatus is mounted on the tube shelf which rests on sponge rubber in order to minimize noise in the receiver due to shocks and vibration. Only three condensers and

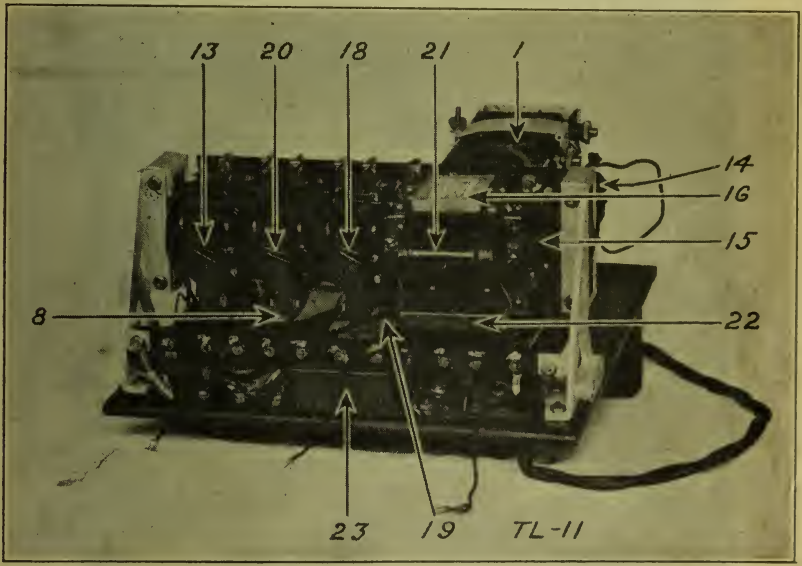


Fig. 3

their connecting straps are mounted inside the rear panel. If it ever becomes necessary to remove the rear panel, the three copper strip connections going to the floor of the box should be disconnected by removing the screw at the upper end of each one.

5. *The loop (type LP–2)*.—The tubing of which the loop is made is of an aluminum-bronze composition which can only be soldered with a special flux. The loop is made in a single turn and is provided with hinges so that it can be folded up to fit in its carrying case. The joints are provided with wing nuts to enable the loop to be firmly fastened together. The threads at the end of the bolts on which the wing nuts screw are scored so as to prevent the removal or loss of the nuts. Two slotted supports for the loop are provided

on the back of the operating chest, and into these the ends of the loop are made to fit firmly. The length of the loop is 48 inches, and its height from the support, 36 inches. The whole loop is given an extra heavy black nickel finish.

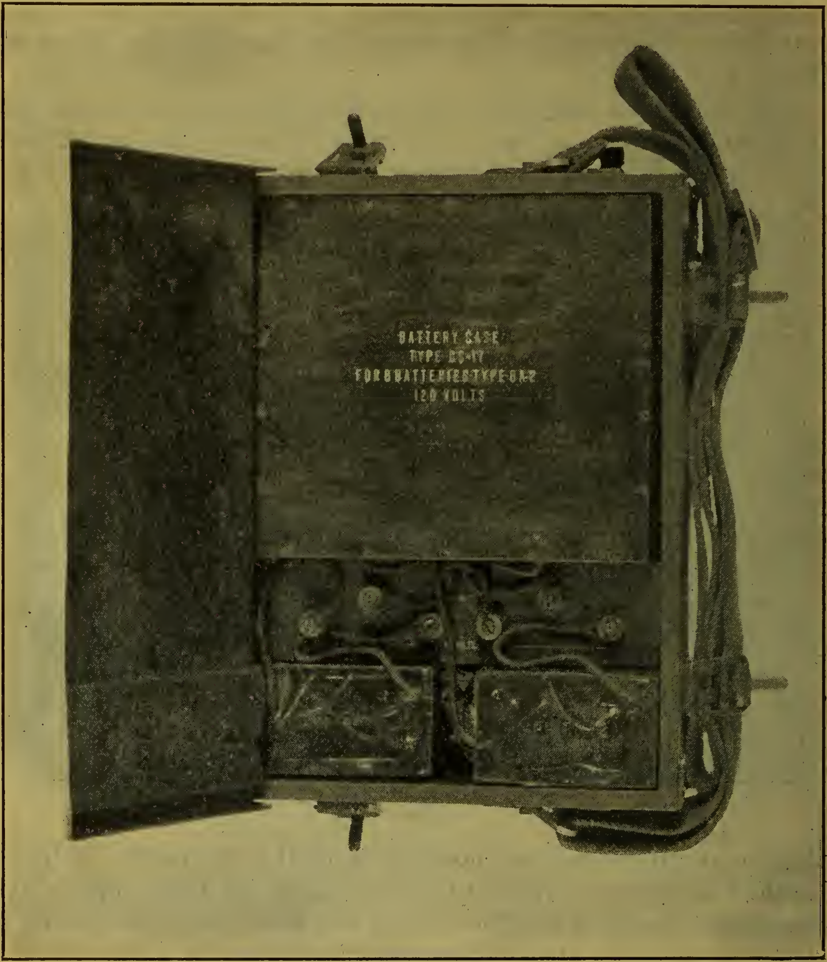


Fig. 4

If loop fittings come loose, it is better to repair by drilling and riveting than to attempt to resolder unless facilities of a repair shop with formula for special flux are available.

6. *The equipment box* (*type BE-48*).—This box carries auxiliary equipment and serves as a base upon which is fastened the operating chest when the set is in use. There are two main compartments in the box, one of which contains the dry batteries furnishing the plate potentials for the tubes. A view of the box showing this compart-

ment is given in Figure 4. The other main compartment, which is also furnished with a cover on the opposite side to the one shown in the illustration, carries three spare vacuum tubes and two telephone head sets. The box is fitted with clamps for the covers, means of fastening the operating chest to it, and a carrying strap. The leads from the batteries carried in the box are brought to a jack having tip, ring, and sleeve connections. Into this is plugged the telephone plug on the cord leading to the operating chest. The jack is inside of the equipment box, but a small recess is provided to allow the cover to be clamped down over the cord.

7. *Dry batteries used with the set.*—There are nine type BA–2 dry batteries used with the set. Six in series furnish plate potential for the oscillator tube; two in series furnish plate potential for the amplifier tubes; and one is used in the potentiometer circuit. The potentiometer battery is mounted within the operating chest; the two amplifier-tube batteries are carried in the equipment box as are also the six oscillator-tube batteries. The latter, however, are all assembled in a battery case (type CS–17), which therefore may be considered as a 120-volt battery. Figure 4 shows a view of this case, as well as the two amplifier tube batteries, both being mounted in the equipment box. The six type BA–2 batteries in the battery case have their terminals firmly soldered together and taped. The end leads project from the case. It is intended that when the 120-volt battery becomes exhausted in field service, the complete CS–17 battery case will be replaced by one containing fresh batteries. Fresh BA–2 batteries are installed in the case at the supply base or other designated point. An extra 120-volt unit in its case is carried with the set.

8. *Storage batteries used with the set.*—The filament current is furnished by a BB–41 lead-storage battery. This is a small battery having a rating of 16 ampere hours. The cell containers are made of hard rubber and are fitted with a nonspill plug. The battery case is made of steel and is fitted with a removable cover. Along the sides of this cover slots are provided so that the cover may be placed on the battery while it is in use. The batteries are $4\frac{5}{8}$ by $5\frac{5}{32}$ inches by $8\frac{11}{16}$ inches high and weigh approximately 11 pounds. The normal charging rate is $1\frac{2}{3}$ amperes. The normal discharge rate is 3.2 amperes for 5 hours, the final voltage being 3.5 volts.

There are three BB–41 storage batteries furnished with the set. It is intended that two of these, fully charged, shall be carried in the field in the case provided with the set, and that one shall be kept at the charging plant. Of the two carried with the set in the field, one is in use and one is a spare. For further information about storage batteries, see Training Pamphlet No. 8.

SECTION IV

INSTALLING THE SCR–77–B

9. *Preparing the equipment box.*—Place the battery case (CS–17) containing the 120-volt unit in its compartment, in the equipment box. Connect the terminals to the binding posts marked "— 120 volts +," being sure to observe the correct polarity and to make firm connections.

Place two BA–2 batteries in the smaller compartment on the same side of the equipment box. Connect the terminals of one to the left-hand pair of the binding posts, marked "— 20V+," and the terminals of the other to the right-hand pair marked in the same way. Observe the proper polarity and make clean, tight connections. Close and fasten the cover of this side of the equipment box. Place the box on a level spot of ground with its fasteners up.

10. *Preparing the operating chest.*—Place the operating chest on the top of the equipment box and fasten it in place by the catches provided. If the operating chest is not absolutely firm it will rock when the key is operated, causing an unsteady beat note. Open the cover of the operating chest, allowing it to rest upon the projecting end of the equipment box. Turn the " Off—On " switch to the " Off " position. Open the free side of the equipment box, remove the telephone head sets, and also the vacuum tubes, if these are not already in the operating chest. Plug in the plate battery cord (the one attached to the lower right side of the operating chest). Having run the cord through the slot provided in the cover of the equipment box, close and fasten it.

Turn the handles of the two fasteners at the top of the operating chest to a horizontal position and pull the panel forward. Place a BA–2 battery in its holder alongside of the vacuum tube. Connect its terminals to the binding posts alongside of the holder. Observe the correct polarity and make tight connections. Secure the battery in place by means of the clamp. Place a VT–1 vacuum tube in each of the three sockets. Close the front panel and lock it in place by turning the handles of the fasteners downward. Pull the top of the telegraph key downward to its operating position. Plug in a telephone head set.

Place the storage battery carrying case near the operating chest and connect to one of the storage batteries, the terminals of the cord extending from the left-hand side of the operating chest. Observe the correct polarity as marked. The cover of the battery should then be closed.

11. *Preparing the loop.*—Remove the loop from its case and unfold it. Jam the ends of the loop firmly into the sockets on the back of the operating chest and tighten up all wing nuts on the loop. The set is now ready for operation.

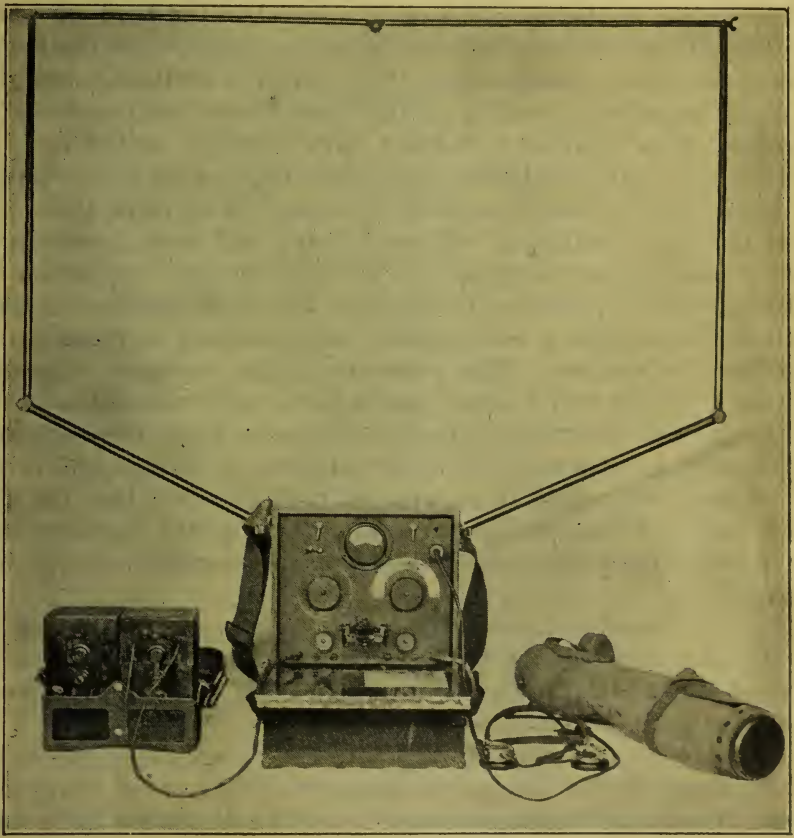


Fig. 5

Section V

OPERATION AND CARE OF SET

12. *Adjustment for reception.*—The filament circuit switch is turned to "On" in order to light the filaments and to complete the grid potentiometer battery circuit. The potentiometer adjustment is then turned slowly in a clockwise direction from the "Off position," thus causing the plate current to increase slowly until the circuit starts oscillating. If a click is heard in the head set when the loop is touched with the bare finger, and again when the finger is removed, the set is oscillating. If the circuit is oscillating strongly, a slight decrease in reading of the plate current milliammeter is obtained when the loop is touched, thus stopping oscillations. If the circuit is only oscillating weakly, the decrease of plate current obtained when the loop is touched is too small to be perceptible. As even this weak oscillation will be radiated and cause interference over a considerable distance, it is desirable that the oscillation be made as weak as possible. If necessary, the potentiometer can then be turned back while a weak signal is being received until the signal just begins to weaken. (This precaution is only necessary when one station is located near another station in the same net, and is therefore using the same tuner setting.) The set has now been adjusted for receiving. Turning the tuner adjustment slowly will bring the signals transmitted from other SCR–77–B sets within the distance range of the sets. Slight readjustment of the potentiometer is necessary from time to time as the storage battery is being discharged.

13. *Adjustment for transmission.*—The only operating adjustment of the set is that required for receiving, described in previous paragraph. After that has been obtained, in order to transmit, simply press the key.

14. *Oscillator tube filament resistance switch.*—A single-pole knife switch is mounted on the face of the panel. When closed the switch short-circuits the 0.5-ohm resistance in series with the oscillator tube filament. This has very slight effect on the receiving adjustment, but greatly increases the oscillator tube filament emission and the strength of the transmitted signal. The arrangement is particularly helpful when the storage battery is nearly discharged. However, with the filament resistance short-circuited, especially using a fully charged battery, the filament current is large and the tube filament life will be considerably shortened. The switch should therefore be closed only when it is necessary in working with a distant station.

15. *Break-in.*—In order to interrupt or break any message that he hears an operator sends a series of dots with the key. The operator transmitting at the distant station will hear these dots during the intervals when his own key is up and will immediately stop trans-

mitting in order to receive the message from the interrupting station. This feature facilitates the correction of errors or the transmission of a priority message.

16. *Operation of a single net.*—The satisfactory performance of this set in a tactical net requires that all sets be calibrated. The set of the net control station should be placed in operation, oscillating weakly with the key up. The tuner pointer should be placed on 5. The other sets should be operated one at a time in stand-by position (oscillating weakly with the key up), not less than 20 feet from and with their loops at right angles to that of the NCS set. Their screw-driver condensers should then be adjusted by means of the screw provided in the back of each set until zero beat is obtained as near as possible to the 5 mark on their scales. The tuner of the NCS set can then be placed on points 1 to 4 and 6 to 9 in turn and corresponding points marked with a pencil on the tuner dials of the other sets. To bring in the signals of the NCS at any particular setting it is only necessary to move the tuner pointer of the secondary station a little to the left of the corresponding marking on the tuner dial and to adjust it until a note of satisfactory pitch is obtained. These points should also be marked. Secondary stations can then interchange traffic satisfactorily on these markings with only slight readjustments of their tuner pointers to obtain pleasing beat notes. Traffic is carried on in accordance with net regulations as laid down in radio procedure, on a single tuner setting, only one message being transmitted at a time in a single net.

17. *Operation of a number of nets.*—When a number of nets are to operate at the same time, each net is assigned its individual tuner setting. To prevent internet interference and to provide for internet traffic, it is necessary that the net calibrations be adjusted. All sets to be used as net control stations should be brought together for calibration. The method used in the preceding paragraph is employed, a master set being chosen arbitrarily. It may be found by experience that some other than the first set chosen will be a more satisfactory master set. This would be true if the sets tuned in with their tuner pointers either all above or all below the tuner dial mark No. 5. Secondary stations are thereafter calibrated by their NCS in accordance with his adjusted markings. Nine nets can then operate in the same vicinity on their assigned tuner settings without interfering with each other and can engage in internet traffic. Care should be taken that nets operating on the same tuner mark are widely enough separated to prevent interference.

18. *Trial operation.*—After all the sets that may be required to work have been calibrated, it is well to try out intercommunication

between them while they are all in the same vicinity. Any faulty calibration can then be checked up and corrected without the confusion that would result if the sets were taken into the field before the faulty calibrations were discovered.

19. *Permanency and limits of calibration.*—The calibration of the set as described above is quite permanent and reliable. However, any heavy jar or shaking up of the set is liable to disarrange the adjustment. If the set is operated at a station where the surroundings or earth conditions are different from those under which the set was calibrated, the frequency of the set will probably be slightly changed. This is most apt to occur when the loop of the set is near some object. Under such circumstances, the position of the set should be changed, if practicable. In some cases it will be necessary to recalibrate the set in the position at which it is to be used. This should be done under the direction of the officer in charge of the set. In extended operations the calibration of the sets should be checked up at least every day by comparison with the master set. This may be done by the operator transmitting for a definite length of time with his tuner upon each position. The other stations should then, one at a time, make any correction of the markings on their scale that may be necessary.

20. *Troubles and remedies.*—If the set is inoperative after being installed, go over carefully all connections made in installing the set. Especially examine the loop joints to see that they are clean and bright and that they make good electrical contact. If the set is still inoperative, lower the operating chest panel and see if all of the filaments are lighted. If not, trace out the circuit for poor or broken connections. The tube socket contact springs sometimes make poor contacts with the contact pins of the tube, due to dirty contacts or weak-spring tension. Of course, a run-down storage battery may be the cause of the failure of the tubes to light up.

21. If no reading of the milliammeter can be obtained with the key up by adjusting the potentiometer, either the milliammeter or the C–21–A transformer primary may be open. The trouble may be due to faulty connection with the 120-volt B battery, or the battery may be run down. If the milliammeter is burned out or otherwise becomes open-circuited, it should be shunted until replaced or repaired. To shunt the meter, connect its two terminal posts together by a piece of wire.

22. If it is impossible to cause the meter to read as low as 0.5 milliamperes by adjustment of the plate current control knob, the difficulty is due either to reversed polarity of storage battery connections, a run-down or wrongly connected grid potentiometer battery, or an improperly calibrated milliammeter. The latter condition

may be deduced if the set receives properly under all conditions. This fault is not serious.

23. If the screw which controls the screw-driver condenser is forced too hard, its threads may be stripped or it may become disengaged from the movable leaf. Either condition will prevent the calibration of the set. If it becomes disengaged, the panel must be lowered so that one hand can be thrust back into the set in order to reengage the screw with the leaf.

In some instances this condenser is forced open so far that its movable leaf touches the strap connecting the two ratio condensers. This condition shorts the plate ratio condenser and prevents the set from oscillating. The leaf must be returned to its normal position. Sometimes it may first be necessary to reengage it with the screw.

24. When a storage battery runs down, the amplifying stages cease functioning before oscillations stop. The set will continue to transmit but will not receive. If no ringing sound is heard in the head set when either the panel or oscillator tube is tapped, the amplifying stages are not operating properly.

25. A small percentage of tubes will not oscillate with key up for any position of the potentiometer. In such a situation another tube should then be tried. Tubes which have a gas leak will ionize when the key is pressed. This is evidenced by a blue glow in the tube when the key is pressed.

26. If the set becomes noisy the following procedure is suggested as useful in locating the trouble: When the key is pressed the noise practically always stops, since this procedure shorts the primary of the first C–21 transformer. If the noise is still heard, it will be in the two-stage amplifier, the 40-volt amplifier plate battery, or the storage-battery circuit. If the noise largely disappears when the key is closed, the difficulty is due to irregularity of the oscillator plate current passing through the C–21 primary when receiving. In this case one side of the grid biasing BA–2 battery should be disconnected. If the noise is still heard, the grid potentiometer circuit is probably working normally. If the noise disappears when the oscillator tube socket plate terminal is connected to filament, the noise is then either in the tube, in the plate 1,000-mmf. radio-frequency bypass condenser, or in the 20,000-mmf. stopping condenser. Then, removing the special connection to filament, if the noise continues when the tube is removed from the socket, the noise is located in one of the two condensers mentioned. Several of the plate 1,000-mmf. condensers have been found to cause noise because of low insulation resistance due to corrosion. When the sets are working normally the most frequent source of noise is the oscillator tube. Often pressing the key momentarily will reduce this noise. Some tubes

are very noisy when jarred. All tubes developing unusual noise should, of course, be replaced. The discarded tube will probably work satisfactorily in one of the audio amplifier sockets.

27. *Unsteady notes.*—Sometimes the note received will vary in pitch or intensity either slowly or at a rate fast enough to be considered a vibration. The condition is caused by a shaking or vibrating loop on either the transmitting or receiving set. Either set may be rocking on its supports or a loop may be vibrating because of a high wind. If serious difficulty is experienced in the correct reception of signals, steps should be taken to correct the trouble either by sheltering the loop from the wind or by supporting the troublesome set more firmly.

28. *Potentiometer battery.*—When the set is not actually operating the switch controlling filament and potentiometer should be

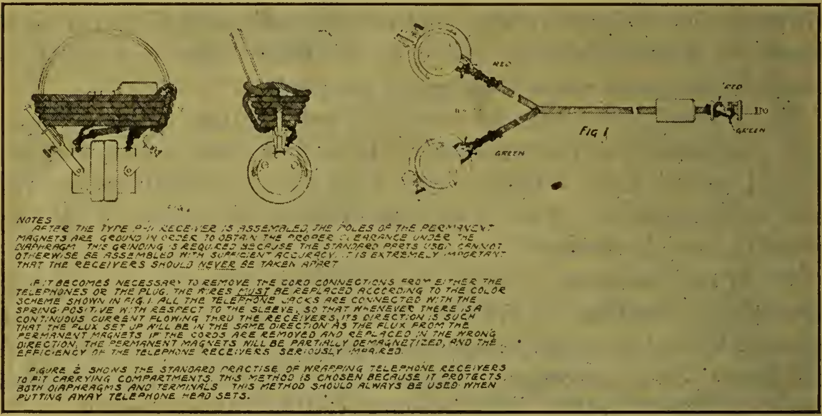


Fig. 6

turned to the "Off" position, even when the storage battery is disconnected. Otherwise about 1½ milliamperes of current will flow in the potentiometer circuit, tending to exhaust its battery. As an additional safeguard, when the set is turned in to the storage or the supply room, the positive lead of the potentiometer battery should always be disconnected from its terminal.

29. *General care of the set.*—The sets are made as rugged as is possible with this type of apparatus. However, they should not be subjected to any heavy jars or severe shaking, since this will break connections or injure the apparatus. The set should not be unnecessarily exposed to rain or dampness. If it becomes wet it should be thoroughly dried out but not exposed to intense direct heat. Care should be taken to keep all terminals bright and clean, including the joints of the loop. If the sets are stored they must be kept in a dry place. Instructions for the care of the head set are given in Figure 6.

Section VI

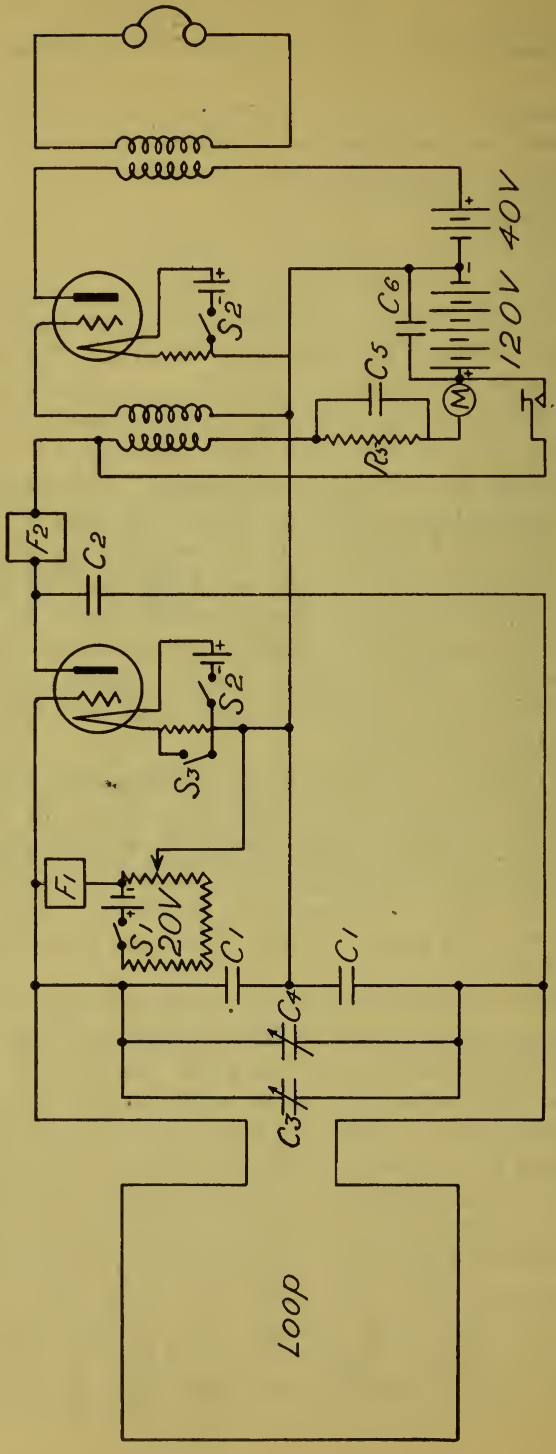
PRINCIPLES EMBODIED IN THE SET AND ITS CIRCUIT DIAGRAM

30. *Principles of operating.*—The SCR–77–B set uses three VT–1 vacuum tubes. One of these is connected as an oscillator, using a capacity coupling between the plate and the grid. The other two tubes are used as audio-frequency amplifiers to amplify the heterodyne note produced when receiving, as explained below. The oscillating circuit is so designed that when receiving it is oscillating weakly so that this tube will act as a detector. The set receiving the message is generating undamped waves continuously; i. e., not broken up into dots and dashes. The set transmitting the message emits strong, continuous waves, which are interrupted to form dots and dashes. As the two sets in communication have been so adjusted that their difference in frequencies of oscillation is equal to an audible frequency, the heterodyne effect produced by the two oscillations gives rise to an audio-frequency note when rectified by the detector in the receiving set.

31. *Simplified diagram of set and explanation of oscillatory circuit.*—A simplified diagram of the circuit is shown in Figure 7. The loop gives an inductance large enough to permit stable oscillations at the frequencies used by the set. Across this loop are the grid condenser and plate condenser each marked C_1, which supply the coupling between the plate and the grid necessary to build up and maintain oscillations.

32. A condenser of large capacity C_2 in the lead from the plate to the oscillating circuit prevents the 120-volt direct-current potential from passing through the loop to the grid. Because of its large capacity it offers little impedance to the radio-frequency oscillations. A very small single-leaf variable condenser, C_3, is connected across the loop to permit an adjustment of the frequency of the oscillating circuit. This is the screw-driver condenser used in calibrating the set. A variable air condenser, C_4, is also connected across the loop. This provides another adjustment of the oscillation frequency of the set and is controlled by the tuner knob on the front panel.

33. *Plate circuit.*—The plate voltage of the oscillator tube is supplied by a 120-volt battery, which is also connected to the filament. When the key is up for receiving, the plate current passes through



TL-12

Fig. 7

(For Legend See Fig 8)

a 100,000-ohm resistance. This greatly reduces the effective voltage on the plate, so that very weak oscillations will be obtained. The small plate current thus obtained passes through the C–21 trans-

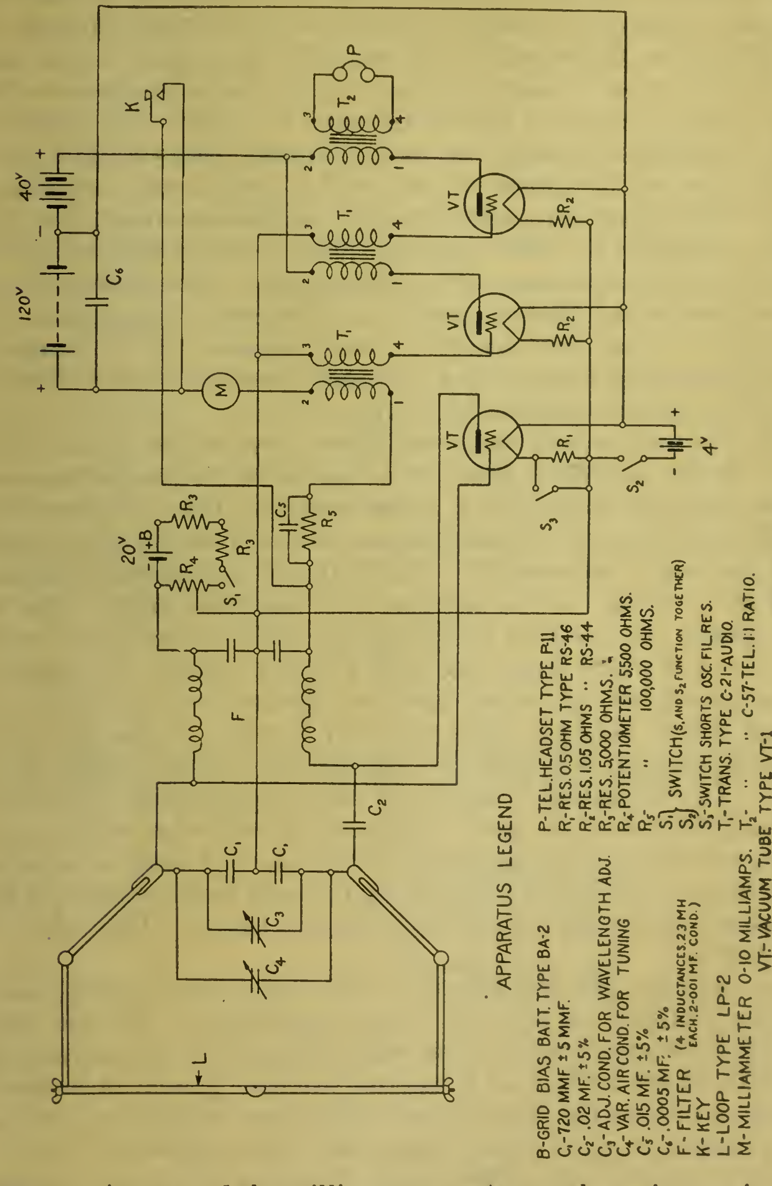


Fig. 8

former primary and the milliammeter. Across the resistance is connected condenser C_5, which acts as a fairly low impedance by-pass for the audio signal current. In transmitting, the key is pressed. short circuiting the branch circuit including the 100,000-ohm resistance, C–21 primary, and the milliammeter. The full plate voltage is then impressed on the plate. A large plate current (approximately 25 mils) is obtained, which gives rise to a radio-frequency loop current of large amplitude. The short circuiting of the C–21 primary avoids the passing of the large plate current through the winding, since this might in time cause the winding to become open circuited. It is necessary to short circuit the milliammeter when transmitting because of the low range of the meter. The plate current is supplied through two radio-frequency choke coils in series which prevent the direct current supply circuit from furnishing a short circuit path for radio-frequency oscillations around the plate ratio condenser C_1. The 0.001-mf. plate circuit condenser enables the choke coils to operate with maximum effect. The 0.0005-mf. condenser across the 120-volt battery is a frequency compensator. It operates to reduce the change in radio frequency due to change in circuit constants when the key is pressed, from the slightly different circuit constants when the key is up.

34. *The grid potentiometer and filter circuit.*—The grid and filament of the oscillating tube are connected by two radio-frequency choke coils in series and a potentiometer. The radio-frequency choke coils prevent the potentiometer circuit from short circuiting the grid ratio condensers C_1. The 0.001-mf. grid circuit condenser enables the choke coils to operate with maximum effect. The potentiometer consists of a 20-volt battery (BA–2) and three resistances, one of which is provided with a sliding contact. The negative biasing potential between the grid and filament is controlled by the potentiometer between values of 0 and 7 volts. A change in this biasing potential will produce a change in the plate current of the tube. The adjustment is needed so that the amplitude of the oscillation produced by the tube when receiving will be as weak as possible, and in order that the steady oscillations will cause a minimum interference with near-by stations on the same tuner setting. When transmitting, the potentiometer adjustment has very little effect on the power.

35. *Detection and amplification.*—The weak radio-frequency oscillations produced by the tube at the receiving set and the radio frequency arising from the radio wave produced by the transmitting set with which the first set is working are both present in the oscillating circuits of the receiving set. These two oscillations give rise to a composite wave whose amplitude varies periodically with a frequency equal to the difference in frequency of the two original oscillations. This difference of frequency has been adjusted, by the process of tuning, so as to be equal to an audio frequency. The composite wave is detected by the oscillating tube and, because of its

periodically varying amplitude, gives rise to an audio-frequency pulsation in the plate circuit of this tube. These audio-frequency pulsations, because of the high impedance of the condensers, can not follow this path to the filament and are therefore forced to follow the circuit through the filter inductance, the primary of the first audio-frequency transformer, the milliammeter, and the 120-volt battery to the filament. The functioning of the amplifier tubes is similar to that of an ordinary amplifier.

It should be noted that the plate circuits of the amplifier tubes receive the proper potential from a 40-volt battery (two type BA–2 batteries) and that the telephone receivers are in separate circuit from the tube, being coupled to the plate circuit of the last tube by a special one-to-one transformer. The direct current in the plate circuit is thereby prevented from passing through the head set or head sets.

36. *Filters.*—The two filters used in the SCR–77–B set are both alike and permit the ready passage of low-frequency currents, but offer high impedance to high-frequency currents. In each filter there is one condenser having a capacity of 1,000 mf. and two inductances in series having a value of approximately 23 microhenries each. Each inductance is made of 105 turns of No. 34 (0.0069 inch) "Beldenamel" copper wire, 69 threads to an inch, wound on a bakelite spool 0.316 inch in diameter.

SECTION VII

PARTS LISTS OF SET

37. Parts lists for this set will be published separately and should be obtained by applying to the Office of the Chief Signal Officer.

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