THE RADIO MANUAL

FOR RADIO ENGINEERS, INSPECTORS, STUDENTS, OPERATORS AND RADIO FANS

By

GEORGE E. STERLING

Radio Inspector, Radio Division, U. S. Department of Commerce
Member, Institute of Radio Engineers

Edited by

ROBERT S. KRUSE, B.S.

Formerly Technical Editor QST, Magazine of American Radio Relay League; Consultant for Development of Short Wave Devices, Technical Editor and Writer

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A Radio Station Aboard Ship (Frontispiece)

PREFACE

This work has been prepared to serve as a guide and text book to those who expect to enter the radio profession as an engineer, inspector, commercial or amateur operator.

The student in engineering will find in this work a detailed description with circuit diagrams of many commercial transmitting and receiving systems as employed in this country for radio communication, a knowledge of which is essential to those entering this field.

Sufficient subjects have been included whereby one may by diligent study qualify to pass the technical examinations required to secure a commercial, broadcast, or amateur operator's license. These examinations are conducted by the Radio Division, Department of Commerce, at the various offices throughout the United States.

Applicants for positions as radio inspectors and engineers in the Departmental and field service of the Federal government will find this volume of invaluable aid in preparing for the technical examinations required to secure such positions. These examinations are conducted by the U. S. Civil Service Commission.

The radio service man and the amateur experimenter will find many chapters of interesting study which, if carefully pursued, will increase their technical knowledge and will assist them in their desire to have a better understanding of radio phenomena.

An effort has been made to treat briefly the elements of electricity and magnetism an understanding of which is so essential to the preliminary study of radio phenomena. These subjects are explained clearly so that one with no previous knowledge of electricity may acquaint himself with the fundamental laws governing the same. Having once acquired this knowledge, the study of radio frequency phenomena becomes easier inasmuch as the operation of all radio apparatus is based upon fundamental electrical and magnetic principles.

The commercial operator who has already passed his examination for license and is desirous of increasing his knowledge of various radio systems will find in this book a complete description of the various types of commercial and broadcast apparatus generally employed on various ship and land stations. Circuit diagrams are shown together with maintenance and operating instructions. In addition, complete information is included in order to facilitate the location of defective parts and make the necessary repairs or replacements.

Radio Communication Laws of the United States and those of the International Radiotelegraphic Convention are contained within this volume. Regulations governing the issuance and renewal of operators' licenses are included, and other information as issued by the Federal Radio Commission pertaining to the operation of various classes of radio stations in the United States.

Rapid advancement has been made in the application of radio as an aid to the navigation of aircraft. The increased use of radio apparatus on aircraft to receive radio beacon signals and weather reports requires that the pilot have an understanding of the principles underlying radio communication in order that he may be skilled in the use of such apparatus in order to successfully operate the same and make repairs and adjustments in an emergency. In this book the pilot will find a complete description of the modern types of apparatus employed as an aid to navigation on aircraft as developed by the U. S. Bureau of Standards.

Throughout the whole book the reader will note that the author has consulted the work of prominent scientists and radio engineers well known for their specialty in that particular branch of radio engineering. For example, in the discussion of the stabilization of radio frequency amplifier circuits the author has used mostly verbatim the article of Dr. L. M. Hull, entitled "Anti-Regenerative Amplification," published in QST of January, 1924. Again, in the discussion of the duties of a control operator at a broadcasting station the author has used portions of an article entitled "Broadcast Control Operation" by Carl Dreher, Staff Engineer, National Broadcasting Company, as presented in the proceedings of the Institute of Radio Engineers, Volume 16, number 4. Throughout the whole work the author has consulted freely articles and papers published by the Radio Division, Department of Commerce, Bureau of Standards, QST, and the Proceedings of the Institute of Radio Engineers.

The author desires to acknowledge his indebtedness to the Western Electric Company, Radio Corporation of America, American Radio Relay League, The Edison Storage Battery Company, Electric Storage Battery Company, Electric Specialty Company, Crocker-Wheeler Electric Company, Weston Electrical Instrument Corporation, Federal Telegraph Company and various other commercial companies and departments of the Federal Government for loan of material used in the preparation of the manuscript.

PREFACE

The author also wishes to tender his grateful thanks to R. S. Kruse for his assistance and constructive criticism offered during the preparation of the work; to Carl Dreher for technical information supplied; and to Ralph Kingsley for his untiring energy in preparing the drawings used throughout the volume and to several of my colleagues who have assisted at various times when difficulties presented themselves.

G. E. S.

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CHAPTER I

ELEMENTARY ELECTRICITY AND MAGNETISM

1. **Introductory**—To understand the various applications of the vacuum tube in radio telegraphy and telephony it is essential that the student learn the electronic theory of electricity, as it is the only theory that adequately explains the action of the three-element vacuum tube. Therefore, the explanation of electricity in this chapter will be in terms of electrons.

2. **Electrons**—Matter of all kind is composed of atoms. Each atom contains many electrons which are considered negative electricity. If a negative charge of electricity were to be divided into many small charges, eventually a minute charge would be reached that could no longer be divided. This minute charge is an electron and is the natural unit of negative electricity.

Besides containing electrons, each atom also contains a certain amount of positive electricity. Normally the positive and negative electricity are just equal. However, if the atom is placed under a stress some of the electrons will be pulled away or escape from the atom, thus leaving it with a deficit of negative electricity as compared to the positive electricity. The atom is then considered to have a positive charge. If electrons have been added to the atom it would have been considered charged negatively. Accordingly then an unelectrified body contains a normal number of electrons, a positively charged body contains a deficit or lack of electrons, a negatively charged body an excess of electrons.

3. **Relation of Charged Bodies**—If a glass rod is rubbed vigorously with a piece of silk it will be found that it has acquired the power to pick up or attract small bits of paper. A hard rubber rod rubbed with wool will acquire the same property. By rubbing the rods they have become electrified. Consider the glass rod to have acquired a positive charge, and the rubber rod a negative charge of electricity.

The glass rod acquired a positive charge by rubbing electrons from it, thus leaving with less than its normal amount. The hard rubber rod acquired a negative charge by rubbing electrons on to it, thus increasing its normal amount of electrons.

Perform the following experiment by first cutting a small portion of the pith from a corn cob and moulding the same into a small ball. Suspend the light ball by a silk thread and then bring the positively charged glass rod near it and it will be found that the pith ball is attracted by the glass rod. Allow the glass rod to touch the pith ball. It will now be noticed that the rod repels the pith ball. When the pith ball touched the positively charged rod it acquired a positive charge by contact.

Immediately after acquiring the positive charge the pith ball was repelled by the positive charge on the glass rod. Now bring the negatively charged rubber rod near the positively charged pith ball. The pith ball is attracted toward the rubber rod. Allow the pith ball to touch the rubber rod and now note the reverse action that the pith ball is repelled. By touching the negatively charged rubber rod the pith ball acquired a negative charge by contact. From this experiment it is learned that in general positive and negative charges attract each other while two positives repel and two negatives repel.

The following experiment will explain why the bits of paper were picked up by the charged rod. Take a body *A*, as in figure

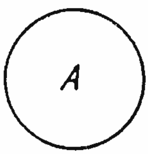

FIG. 1. Uncharged Body.

FIG. 2. Body A Charged by Electrostatic Induction from Charged Body B.

1, and bring near to it a body charged with electricity. Then testing with a charged pith ball it will be found that the body *A* has acquired a charge in this manner. As the charged body *B* is brought close to *A* it will be found that one side of *A* is positive and the other side negative. Remove the body *B* and the charge on *A* disappears. This is charging the body *A* by ELECTROSTATIC INDUCTION. It is easily explained by the fact that the electrons on *B* have repelled those near it on *A*, thus giving that side a deficit of electrons, a positive charge, and to the side to which the electrons have gone, an excess of electrons, a negative charge. Removing the body *B* allows the electrons to flow back in their proper place, thus discharging the body.

When the charged glass rod approached the bits of paper the electrons were drawn to the upper side of the paper and were then attracted to the rod carrying the paper with them.

4. **Potential**—Charging a body with negative electricity by adding electrons produces a stress within that body by action of the electrons repelling each other, trying to get as far away from each other as possible. Some of these electrons in their movement go to the surface of the body and gather especially on the points of the body. The more electrons that are added, the greater becomes the force by which the electrons try to escape. This force which tends to discharge a body is called POTENTIAL. The potential of a body depends upon the capacity of that body to hold electrons and the number of electrons that can be added. What has been said about adding electrons, charging negatively, is true of taking away electrons, charging positively.

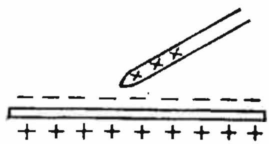

FIG. 3. Electrons Drawn to Upper Side of Paper by Charged Glass Rod.

The arrangement shown in Figure 4 will permit that body to hold more than its ordinary amount of electrons. The lines represent a conductor and the space between the lines a non-conductor. If the conductors are charged it will be seen that they attract and bind each other and hence the conductors are able to hold a greater number of electrons. This is called a condenser, and a common form is several sheets of copper foil separated by mica insulation.

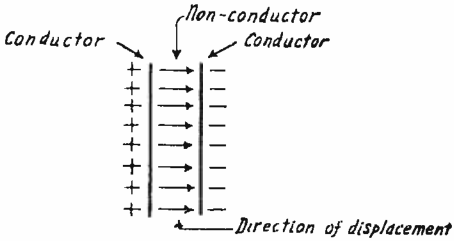

FIG. 4. A Charged Condenser.

5. **Electrons and Difference of Potential**—Consider a pair of bodies charged as shown in figure 5. Consider the pair *A* and *B*. *A* has an excess of electrons, thus it has a force trying to discharge the electrons—it has a NEGATIVE POTENTIAL. *B* has a deficit of electrons, thus it has a force trying to attract electrons—it has a POSITIVE POTENTIAL. Comparing *A* and *B*, there is a dif-

ference of potential equal to the potential of B plus the potential of A. If given a path, electrons would flow from A to B. A current would flow from B to A caused by the difference of potential of A and B.

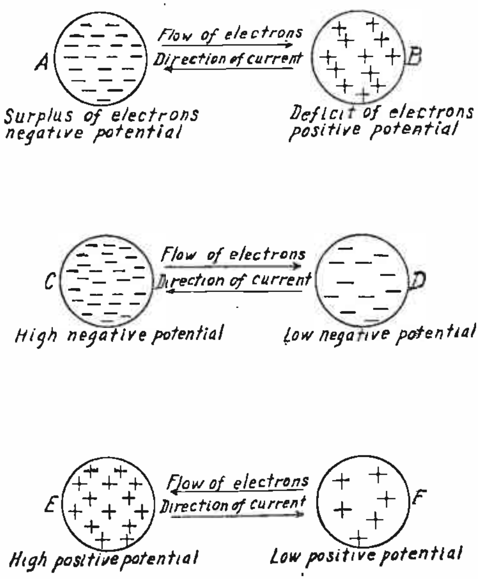

FIG. 5. Relation of Electrons and Direction of Current Flow.

Consider C and D. Both have a negative potential, but C has a larger negative potential than D as it has relatively more electrons than D. Hence, there is a difference of potential equal to potential C minus potential D. If given a path the electrons would flow from C to D. A current would flow from D to C, caused by the difference of potential of D and C.

Consider E and F. Both have a positive potential, but E has a larger positive potential than F, as it has relatively more electrons missing than F. Hence, there is a difference of potential equal to potential of E minus potential of F. If given a path the electrons would flow from F to E. A current would flow from E to F, caused by the difference of potential of E and F.

6. Direction of Current and Electron Flow—It is noted then that there is a current produced when there is a difference of potential, and that the current direction is taken as opposite to that of the direction of the flow of electrons. It is noted too that it is the flow of electrons which is the current. The direction of the current has unfortunately always been taken the wrong way.

The direction of the current flow is from higher to lower potential—from positive to negative. The thing that actually happens is that the movement of electrons takes place in the opposite direction from the negative to positive. This distinction between the direction of electron flow and the direction of current flow should be carefully noted.

7. **Electromotive Force**—The difference of potential between two bodies or between two points of the same body is measured in volts. Because a difference of potential will always cause a current to flow, provided a path is furnished, it is also called electromotive force (e.m.f.); the force of which makes the electrons move. Therefore, a volt is the unit of e.m.f.

8. **Current**—Current strength, that is, the number of electrons moving per second is measured in amperes.

9. **Conductors and Non-Conductors**—In order for a current to flow a path must be furnished for the electrons. A body that permits electrons to move about in it is called a conductor. A body in which all the electrons are not free to move is called a non-conductor. Other names for a non-conductor are insulator, or dielectric. Different bodies permit different degrees of freedom and hence there are various grades of conductivity. If the electrons are very free to move they find little opposition in their passage, i.e., they encounter little resistance. If the electrons are not free to move they find much opposition to their passage, i.e., they encounter a high resistance.

10. **Resistance**—The property of matter by which it opposes the passage of electrons is called resistance. The resistance of a column of pure mercury 106.3 centimeters long, weighing 14.4521 grams, at a temperature of 32 degrees Fahrenheit is one ohm. It is called an ohm because the first man to investigate resistance was Simon Ohm. Since the resistance of any metal rises when the metal is heated our "standard ohm" must always be measured at the same temperature and for this there has been chosen the temperature of 32 degrees Fahrenheit as stated above (zero degrees Centigrade).

The resistance of a conductor depends upon the kind of material in the conductor, the length of the conductor, the cross-sectional area, and to some extent upon the temperature of the conductor. To be exact, it increases directly with the length of the conductor and decreases with an increase of cross-sectional area. In radio it also increases with an increase of frequency.

11. **Production of an Electric Current**—From the foregoing discussion it is seen that a current will flow along a conductor if there is a difference of potential created. The current will be maintained if the difference of potential is maintained. Take a zinc rod and a copper rod and immerse them in sulphuric acid. Test the ends of the copper and zinc for charges and it will be found that the copper has a positive charge and the zinc a negative charge. Therefore, a difference of potential exists. Connect the copper and zinc by a wire and a current will flow. Disconnect the wire and test the copper and zinc again. The result will be the same. That is to say, this combination will maintain a difference of potential and hence will produce a steady current.

The sulphuric acid eats the zinc (chemical action) and gives it electrons, taking them away from the copper. Such an arrangement is called a cell. See figure 6. Two or more cells together are

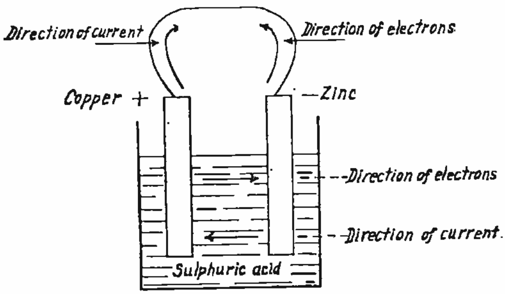

Fig. 6. Primary Cell.

called a battery. There are many combinations of materials that will give the same result. The combination always consists of two dissimilar metals and an acidic or basic solution. The voltage of such a cell is never more than 2 volts. Such cells are called primary cells. The difference between a primary cell and a storage battery lies in the fact that the primary cell cannot be renewed by passing an electric current through it while a storage battery can. Zinc is employed in all cells, other than storage cells, in common use. It is always the negative pole or terminal. The positive pole is usually copper or carbon.

12. **Series and Parallel Connections**—Cells may be connected in series or parallel. When connected in series the resultant voltage

is the sum of the voltage of each cell. When connected in parallel the resultant voltage is the same as that of any one cell. The rule is to connect cells so that the resistance inside the cells is equal to

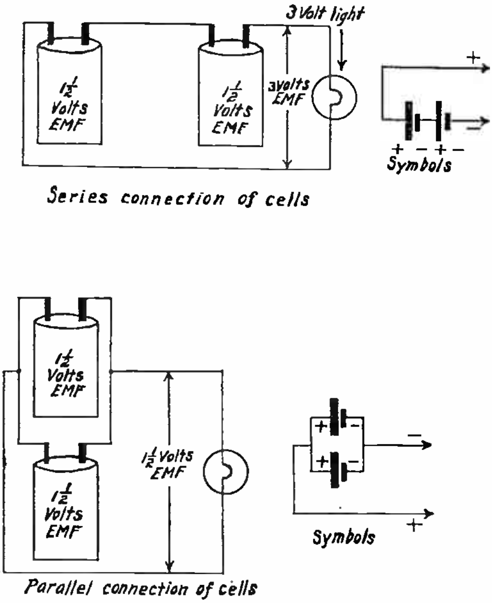

FIG. 7. Series and Parallel Connection of Cells.

that outside the cells. Using storage batteries this rule resolves itself into the following fact: The only time batteries are used in parallel is when current, taken all from one battery, would be so large as to damage the battery.

13. **Application of Ohm's Law**—The value of volts, amperes and ohms are so taken that the following statement, known as Ohm's law, is true: amperes = volts over resistance or the three forms of Ohm's law may be shown as follows:

Standard Units	Formulas	Examples
Amperes = $\frac{\text{Volts}}{\text{Ohms}}$	$I = \frac{E}{R}$	5 Amps. = $\frac{\text{10 Volts}}{\text{2 Ohms}}$
Volts = Ohms × Amperes	$IR = E$	5 Amps. × 2 Ohms = 10 Volts
Ohms = $\frac{\text{Volts}}{\text{Amperes}}$	$R = \frac{E}{I}$	2 Ohms = $\frac{\text{10 Volts}}{\text{5 Amps.}}$

14. **Resistances**—Resistances connected in series have a greater resistance than any one alone. Their total resistance is the sum of the separate resistances.

Formula

$$R = R_1 + R_2 \qquad \text{(resistances in series).}$$

Two resistances connected in parallel have a smaller total resistance than either of them. If they are of equal values, the total resistance is one half of the resistance of one. If there are three resistances of equal values the total resistance would be one third of the resistance of one.

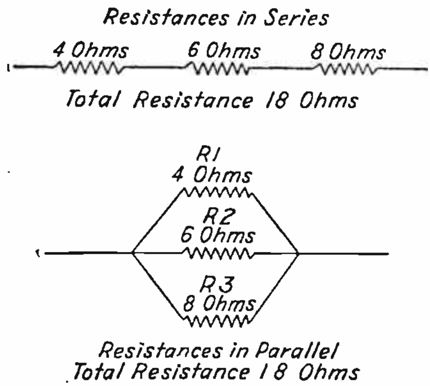

FIG. 8. Series and parallel connection of resistance.

When the resistances are of unequal values their total resistance is computed as follows:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

where R = the total resistance.

Example: Resistances of 4 ohms, 6 ohms and 8 ohms are placed in series. Their total resistance is $4 + 6 + 8 = 18$ ohms. Connected in parallel their total resistance is:

$$R = \frac{1}{\frac{1}{4} + \frac{1}{6} + \frac{1}{8}} = \frac{1}{\frac{13}{24}} = 1.8 \text{ ohms.}$$

It is now clear that two or more resistances in parallel will conduct an electric current more freely than one.

It should be remembered that Ohm's law is true for the whole or any part of an electrical circuit. However, it will be seen later that Ohm's law is not applicable to all radio circuits.

15. **Effects of Current**—The passage of current through a conductor can be determined by two principal effects:

1. Heating effect.
2. Magnetic effect.

When a current of electricity flows through a conductor, it encounters frictional resistance and a certain amount of energy is transformed into heat. The heat generated increases directly as the resistance; also the heat generated increases directly as the square of the current, and the time during which the current flows. This is expressed:

$$J = I^2 \times RT$$

(where J is the joule, I the current, R the resistance and T the time in seconds).

The joule is defined as that amount of energy which is expended during one second, by current of one ampere flowing through a resistance of one ohm. The joule per second is the practical unit of electrical power which has been named the watt.

Since power is the rate of doing work per unit of time, one watt per second would equal one joule. The power may be also expressed in the units of electromotive force and current strength. The power in watts in a given circuit in which direct current is flowing is equal to the product obtained by multiplying the current in amperes by the electromotive force in volts or:

$$\text{Watts} = I \times E.$$

The magnetic effect may be described as follows: Figure 9 shows a coil of wire wound around a soft iron bar and carrying a steady current furnished by the battery. While the current is flowing the bar will be found to have acquired the power to attract pieces of small steel or iron. If the current from the battery is broken the bar will not have the power of attraction for the iron or steel. Thus the current flowing through the solenoid has given it a new property called magnetism, and since it has this property only when the electric current flows it is called an "electromagnet."

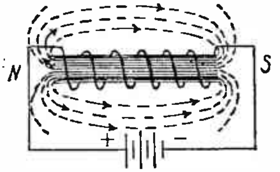

Fig. 9. Electro-Magnet.

If the soft iron bar is replaced by a bar of hard steel and the current is permitted to flow through the solenoid for a considerable length of time it will be found that the steel retains the property of attraction long after the circuit is broken from the battery. A piece of magnetized steel which retains its magnetism is called a "permanent magnet."

It will be found that the iron likewise has retained the property of attraction, but to a smaller degree than that of the hard steel. The steel is said to have a high degree of "retentivity," while the iron has but little retentivity.

The lines of force retained by a piece of iron after the magnetizing current has been turned off are called the "residual lines of force" and the iron is said to have "residual magnetism." Residual magnetism plays an important part in the operation of some types of generators which will be described later.

If a permanent magnet is dropped into a box of iron filings it will be noticed that there are two places on the steel magnet to which the iron filings cling most strongly. These places are near the ends of the bar and are called the "poles" of the magnet.

The poles always appear in pairs and are named north poles and south poles, because of the following fact: If the magnet is suspended in such a way that it is balanced and free to turn around

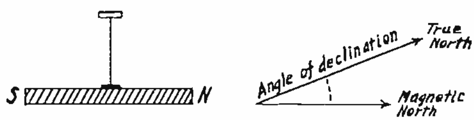

FIG. 10. Suspended Magnet Attracted by Earth's Magnetic Pole.

in a horizontal plane as in figure 10, it will be noted that the magnet will always come to rest pointing in an approximate north-south line. The same end or pole will always point northward; this is called the north or north seeking pole while the other end is called the south or south seeking pole.

The following experiment will indicate the power of attraction and repulsion of the poles of magnets. The north pole of the suspended magnet will be repelled when approached by the north pole of the other magnet; likewise, the south pole will be repelled when approached by another south pole, whereas if the north pole is approached by a south the suspended magnet will be attracted. Again if the south pole of the suspended magnet is approached by a north pole the suspended magnet will again be attracted. From this experiment it will be found that like poles repel; unlike poles attract. This clarifies somewhat a statement in the preceding paragraph wherein it was noted that the end of the magnet pointing toward the earth's north pole was the north seeking pole. It is commonly called the north pole of the magnet, but according to the theory of attraction and repulsion of the poles of the magnet a north pole could not be attracted by the earth's north magnetic pole.

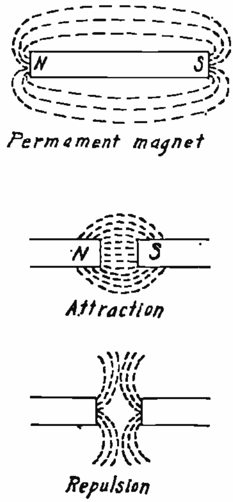

FIG. 11. Relation of Fields of a Magnet.

16. **Angle of Declination**—A magnet balanced upon a pivot and free to swing in a horizontal plane is called a compass. It takes a north and south direction. This is explained by saying that the earth has effective magnetic poles. These effective magnetic poles are near but do not exactly coincide with the geographical poles. Hence, there is an angle between true north and the direction which the compass points, magnetic north. This angle is called "angle of declination."

17. **Magnet Field**—If the field surrounding a magnet were to be examined it would be found to consist of definite closed lines. The lines are called the magnetic lines of force. The magnetic lines of force start at a north pole and pass through a south pole back to the north pole. See figure 11. They make various routes depending upon the magnetic substance near them but they always come back to their source. The space through which they pass is called the " magnetic field."

18. **Permeability**—Whether a body will be acted upon by a magnet depends upon its ability to carry magnetic lines of force. This property of carrying lines of force is called permeability. Different kinds of iron have different degrees of permeability. The magnetic strength of an electromagnet or solenoid varies as the product of the amperes passing through the conductor and the number of turns or commonly called the "ampere turns." For example 100 amperes through 50 turns of wire gives the same result as 20 amperes through 250 turns, for 100×50 and $20 \times 250 = 5000$.

The magnetic strength of such a coil is also dependent upon the permeability of the iron; that is to say, the iron, in effect, increases many times the lines of force.

19. Theory of Magnetism—The following experiments and results give the base for a theory of magnetism. Take a magnet and strike it. The magnetism gradually disappears.

Take a bar magnet, cut it into pieces. Each piece will be found to be a magnet, no matter how small it is.

Take a magnet and heat it. The magnet becomes very much weaker and eventually loses its magnetism.

Take a piece of steel and stroke it with a magnet. The steel will become a permanent magnet.

Now when it is remembered that heat is caused by rapid vibration of the small particles of which a body is composed and that the final division of the magnet is also these small particles, it is easy to draw the conclusion that these small particles are magnets. The small particles are called molecules and hence this is known as the "molecular theory of magnetism."

It is not thought that these molecules are magnets sometimes and at other times not magnets. It is thought that these molecules are magnets always. If iron molecules are always magnets, why is it that a piece of iron is not always a magnet?

Consider the diagram of figure 11*a*. The small lines represent the molecules. It is seen that if they are arranged in a disorderly way the lines of force emanating from one molecular magnet go to the nearest south pole of another molecular magnet and so on back to their origin without going outside of the iron bar. Hence, there are no magnetic lines of force outside of the iron bar. Therefore, it is not a magnet.

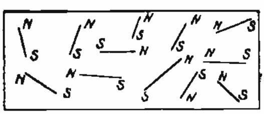

FIG. 11*a*. Arrangement of Molecules in Iron Bar Not Magnetized.

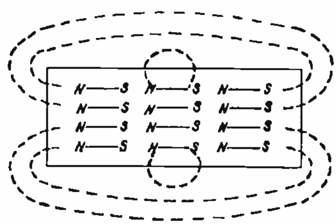

FIG. 11*b*. Arrangement of Molecules when Iron Bar is Magnetized.

If the iron bar is stroked by a magnet the molecules arrange themselves in an orderly manner as shown in figure 11*b*. The magnetic lines of force emanating from one molecular magnet pass to the next one and then to the next and to get back to their source must go outside of the iron for they cannot double back on themselves. Hence, the iron bar is now a magnet.

20. **Voltmeters and Ammeters**—The fact that an electric current is always surrounded by a magnetic field is used in the construction of voltmeters and ammeters. The simplest kind of an ammeter is made by placing a compass in the center of a coil of wire. The deflection of the needle is greater, the greater the strength of current.

Another type of ammeter and the one most commonly used is made by having the magnet stationary and the coil movable. The moving coil principle was developed by a French scientist named D'Arsonval and is spoken of as the D'Arsonval movement. Figure 12 shows the arrangement of this instrument.

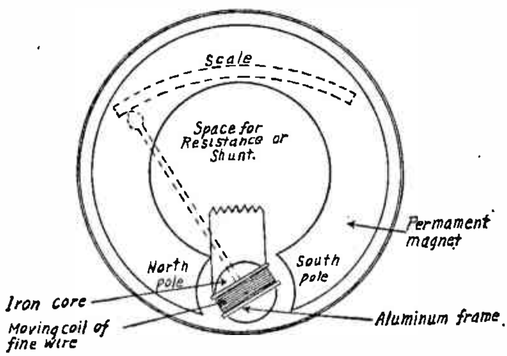

FIG. 12. Ammeter with D'Arsonval Movement.

Between the pole faces of a permanent magnet is placed an iron core, allowing a gap between it and the pole faces large enough to permit an aluminum frame to swing freely. On this frame is wound a coil of very fine wire, through which a certain percentage of the current to be measured passes. As this current passes through the coil, the latter becomes an electromagnet with north and south poles, which are immediately affected by the north and south poles of the permanent magnet. Obeying the magnetic law that like poles repel and unlike poles attract, the north end of the electromagnet is drawn toward the south pole of the permanent magnet and vice versa—which means that the aluminum frame is swung around and the pointer attached to the frame travels across the scale. Every meter of this type is in reality a millivoltmeter (millivolt—1/1000 of a volt) as the coil is built in such a way that a small current flowing through it causes the action described.

Permanent magnets can be weakened by jarring and age; hence, makers of really good meters use carefully aged tungsten steel magnets.

21. **Use of Shunt and Multiplier**—A voltmeter is always shunted (connected in parallel) across the load whose voltage is to be measured. It is made with an extremely high resistance sometimes connected externally or when possible within the meter case. This resistance takes only a small current.

The ammeter is always connected in series with the load. It has a low resistance. In some ammeters only a constant fractional part of the total current passes through the coil, the remainder being conducted by the shunt which is calibrated for the particular ammeter.

An example will describe how these resistances and shunts are calibrated.

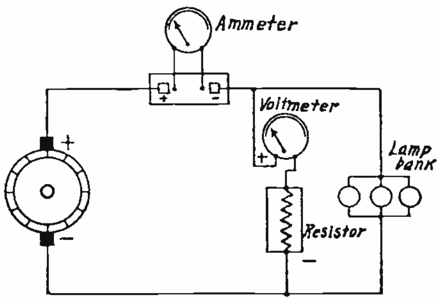

FIG. 13. Method of Connecting Voltmeter and Ammeter. Voltmeter Employing Resistor and Ammeter Employing Shunt.

If there are 10 feet of fine wire on the aluminum frame having a resistance of 1 ohm per foot, the total resistance is 10 ohms.

The frame is then set in position and it is found that 1/10 volt (100 millivolts) is necessary to send the pointer across the scale, i.e., the frame moves through approximately 10 degrees because of the magnetic pull exerted. Then according to Ohm's law $I = .100/10 = .010$ ampere, which is the amount of current used under .100 volt pressure to cause full scale deflection, and the balance must be used in resistance.

For an ammeter capable of measuring 5 amperes the current is permitted to flow through a shunt and just enough is permitted to flow through the coil to cause a full scale deflection. Suppose it is desired to construct a 5-ampere meter. The start is made with a small meter, for instance, a .01 ampere (1/100 ampere) meter. The maximum current that it is desired to measure is 5 amperes. This can be done by splitting the current so that only 1/100 of an ampere goes through the meter while 4.99 amperes go around through another path. Figure 13 shows such an arrangement. The resistance of the other path, called a shunt, must accordingly be 1/499 of the meter resistance.

22. **Telephone Receivers**—The telephone receiver is an application of the property of magnetism. The telephone receiver, as used for ordinary telephone work, consists of a case holding a permanent horseshoe magnet, two coils of wire and a soft iron diaphragm, the latter being clamped by its rim with its plane at right angles and close to but not touching the poles of the permanent magnet. The extensions on the permanent magnet are fitted with bobbins which are wound with many turns of fine wire. The diaphragm is left free to vibrate except at its rim. The distance from the pole pieces to the diaphragm is normally fifteen thousandths of an inch (.015 inch).

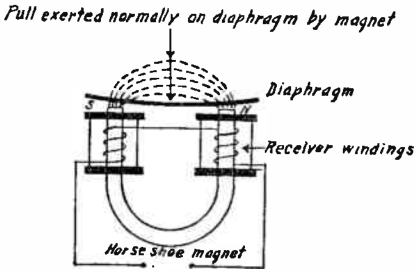

Fig. 13*a*. Construction of Telephone Receiver.

The action of the receiver is as follows: The permanent magnet attracts the diaphragm of the receiver, holding it under a steady attraction. If a varying or alternating current passes through the coils of the receiver, the strength of the magnet is varied. The pull on the diaphragm is therefore varied and if the changes in the current passing through the coils are rapid they will cause the diaphragm to vibrate accordingly.

Thus if the current passing through the coils is varied at the frequencies used in speech the diaphragm will vibrate accordingly reproducing the voice of the speaker.

The diaphragm is lacquered on one side and enameled on the other. The lacquered side should be toward the magnet. As the efficiency of a receiver depends greatly upon the smallest practical air gap which is considered with the vibrations of the diaphragm, the side nearer the magnet is covered with a coat of lacquer, which is much thinner than the coat of enamel on the other side. The lacquer and enamel serve to protect the diaphragm from rust. The pole pieces of the magnet are lacquered for the same purpose.

As the receiver has a permanent north and south pole, current flowing in a given direction will either increase or decrease the strength of both poles, at the same time the coils being connected so as to accomplish this.

The distinctive features of telephone receivers for radio work are lightness of the moving part and the employment of a great many turns of the wire around the magnet poles. The lightness of the moving parts enables them to follow and respond to rapid pulsations of current. The large number of turns of wire causes a relatively large magnetic field to be produced by a feeble current. The combined effect is to give a device which will respond to very feeble currents.

The resistance of the windings of each of a pair of receivers for radio work is seldom less than 500 ohms, the values of resistance being measured with direct current. For radio work the windings of the two receivers constituting a pair are almost always connected in series.

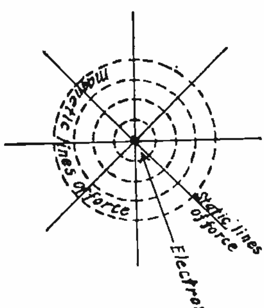

Fig. 14. Electron in Motion Produces Magnetic Lines of Force.

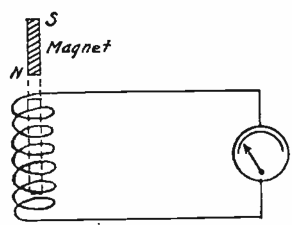

Fig. 15. Production of Current by Electro-Magnetic Induction.

23. **Induction**—A great discovery in electricity was the fact that a magnetic field in motion would cause a movement of electrons; that is, the production of current. The following experiment will illustrate this fact.

Take a coil of wire as in figure 15, drop a magnet end first through the coil. The needle of the milliammeter will move, indicating the presence of a current. It will quickly come to rest. Draw out the magnet. The needle moves again; but this time in the opposite direction. Reverse the magnet and repeat above. It will be noticed that the needle moves but in the opposite direction to its movement before the magnet was reversed. Use two magnets. The needle moves farther than with one magnet. Try moving the magnet faster and slower; the faster it moves the more the needle moves—i.e., the stronger the current. Notice that a current flows when and only when there is relative movement between the magnet and the coil. Try moving the coil instead of the magnet—the results are the same.

Substitute a piece of unmagnetized steel for the magnet. There is no current. The difference between the magnet and the steel is that the magnet is surrounded by magnetic lines of force. These experiments show that whenever a conductor is cut by magnetic lines of force there is a current produced. A current was produced by "electromagnetic induction."

Investigate further by having a current produce the magnetic lines of force and they in turn producing a current. Substitute an electromagnet for the magnet used in the previous experiment. Arrange a circuit as in figure 16. Press the key. The milliammeter

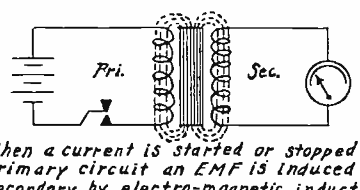

FIG. 16. Production of Current in a Secondary Circuit by Electro-Magnetic Induction.

needle moves in one direction and then comes to rest. Break the current by means of the key—the m.a. needle moves in the opposite direction and then comes to rest.

Insert an iron core in the coil of wire. The results are similar but the current induced is much stronger. In this experiment the conductor has been cut by magnetic lines of force. The circuit with the key is called the primary circuit—the other circuit, the secondary circuit, making the circuit in the primary allows a current to pass in it which sets up a magnetic field. This magnetic field building up from the wire outward cuts the secondary, thus causing a current. When the primary circuit is broken the magnetic field collapses, and the secondary is again cut by lines of force, but this time going in the opposite direction.

All these experiments produce current by electromagnetic induction. The facts of electromagnetic induction may be summed up in the following way:

Whenever variable magnetic lines of force cut a conductor, or a closed circuit made by a conductor, there is an e.m.f. created in the conductor whose direction is such as to oppose the e.m.f. that produced it. The value of this back e.m.f. is proportional to the rate of change of the lines of force.

24. **Self-Induction**—Consider the circuit shown in figure 17. Close the key and a current will flow through the circuit. This

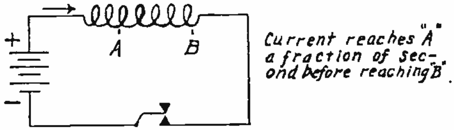

FIG. 17. Counter E.M.F. of Self-Induction.

current does not flow instantaneously so that it reaches a point *A* before it does *B*. The current passing through the turns of the coil sets up magnetic lines of force which cut the turns of wire producing an e.m.f. whose direction is such as to oppose the passage of the original current in the circuit. When the key is opened the lines of force collapse on the coil inducing an e.m.f. in the same direction as the original current and will try to keep the current flowing. Induction in the same circuit is called "self-induction."

25. **Mutual Induction**—Mutual induction is the interaction between two circuits by which a changing current in one sets up

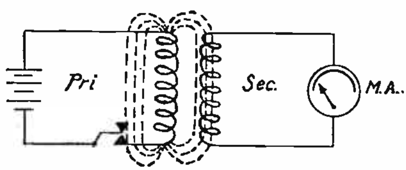

FIG. 18. Induced Current by Mutual Induction.

through electromagnetic induction a current in the other. Consider the circuit in figure 18. Whenever a current is started, stopped, or varied in the primary coil, the magnetic lines of force set up around it cut the winding of the secondary, inducing an e.m.f. in the secondary circuit. A transfer of electrical energy has taken place between two circuits which have no electrical conducting path between them. Induction between two separate circuits is called " mutual induction."

The mutual induction of two given circuits depends upon the size and construction of the circuits themselves, their distance apart, their relative positions in space, and the nature of the material between them. All these factors necessarily affect the magnetic flux interlinked with both circuits. The effects of mutual inductance fall off rapidly as the distance between two circuits is increased. Mutual inductance is measured in the same unit as self-inductance.

Mutual inductance is of particular importance in radio circuits. The phenomena of mutual inductance are the essential principles involved in the operation of many different types of electrical apparatus, of which some are considered in the following pages.

26. Inductance—Inductance is defined as that property of a circuit which opposes a change in the flow of current through it. Inductance is electrical inertia.

Opposition to a change in the flow of current depends upon the amount of self-inductance, or upon the amount of self-inductance and mutual inductance combined. Every circuit possesses self-inductance, but only a circuit a part of which is a primary coil possesses mutual inductance. The inductance of a circuit is, therefore, the amount of self-inductance it possesses plus any mutual inductance which it may also possess. The unit of inductance is the " henry."

A circuit has an inductance of 1 henry when a current changing at the rate of 1 ampere per second induces an e.m.f. of 1 volt.

At radio frequencies where small values of inductance are employed the unit is subdivided and expressed as follows:

1 milli-henry (m.h.) — .001 h.
1 micro-henry (μ. h.) — .000001 h.
1 centimeter (cm.) — .000000001 h.

In self-induction this e.m.f. is set up as a counter e.m.f in the circuit itself; in mutual induction, it is set up in the secondary circuit. In either case its effect is to oppose any change of flow of current through the circuit and is the measurement of opposition to that change. In any given conductor, the time it takes the current to build up to its maximum or to decrease to zero is influenced by the opposition to its increase or decrease in strength, that is, it is influenced by the inductance of the conductor. The greater the inductance, the longer the time required for the current to reach its maximum strength.

The inductance of a circuit conductor, coil or of any apparatus is a property of that thing just as resistance is one of its properties. The impressed voltage does not affect the inductance. A conductor has inductance whether current flows in it or not.

27. Practical Forms of Inductors—The most commonly employed inductance at radio frequencies consists of a single layer coil wound as an air core solenoid. Other forms consist of multi-layer coils either in the form of spider web or honeycomb coil, so called on account of their peculiar construction.

More recently there have appeared the toroidal and the binocular coil, so called from their shape. The extent of the magnetic field can be greatly restricted by altering the shape of the coil. By bending the coil into the shape of a "toroid" as *b*, figure 19, the field or magnetic flux is circulated around the center of the coil and confined to the limits of the coil.

Another scheme used to confine the magnetic field of a coil is what is called the "binocular coil." This form of coil is shown as *c*, figure 19. Here the coil is broken in two with the two halves placed side by side, the windings of each being connected in series. The flux passes through one half and returns through the other half. Both the toroid and the binocular type coils are used in modern radio receivers and their purpose is to confine the magnetic fields of the coils to prevent their reaction on earlier stages in the line of amplification.

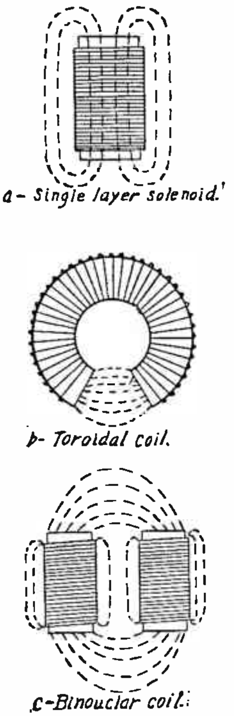

FIG. 19. Practical Forms of Inductance Coils Showing Electro-Magnetic Field Surrounding Each.

28. Iron Core Inductance—This form of inductor is made by winding many turns of wire on an iron core. The core may be of the open or closed type. An iron core inductance acts as an impedance to the flow of alternating or pulsating current. It is usually found in circuits of audio frequency. It ranges in value from 1 henry to 200 henrys in inductance. The use of such coils will be shown in later chapters.

29. Capacity Effects—When water is poured into a container the pressure in the container depends on how high the level of the water is raised; the pressure will be directly proportional to the quantity of water put into the container, and inversely proportional to its size and shape. The size and shape will qualify what might be called the capacity of the container. If the container is connected to a tank containing water, a discharge will flow into it until the levels or pressures are the same in both, and the greater the capacity of the container the more water will flow in to equalize the pressures.

30. Dielectric Current—Similarly, if a perfect insulating material, with no other conductors near it, is charged by connecting it by contact or by a wire to a source of e.m.f., a charge will flow into it until the two are at the same potential. A small sensitive indicator of current connected in figure 20 will show a sudden

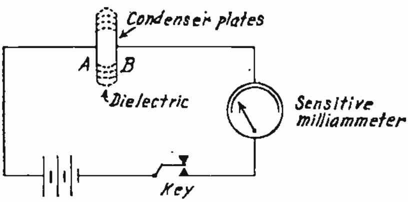

FIG. 20. Production of Displacement Current in a Condenser.

deflection each time the key is closed and will soon return to zero. The momentary flow of current is due to the production of an electric strain or displacement of electricity. This is resisted by a sort of elastic reaction of the insulator that may be called electric stress. On account of this reaction of the electric stress, the electric strain due to a steady applied e.m.f. reaches a steady value, and the current becomes zero. When the electric strain is allowed to diminish a current again exists in the opposite direction. A current of this kind, called a "displacement current," exists only when the electric strain or displacement is changing. When considering the existence of electric strain or displacement in an insulating material the material is called a "dielectric" and the displacement current is sometimes called a "dielectric current." The electric displacement is a movement of electrons with the positive electrons of each molecule of the substance gathered at one end and the negative at the other. A dielectric in such a strained condition possesses a charge of electricity and is sometimes called electricity in "electrostatic" form or electricity at rest.

31. **Condensers**—A condenser is constructed of several conductors placed parallel to each other and separated by an insulator called the dielectric. It usually takes the form of one metallic plate or set of plates joined together and separated from a similar plate or set of plates by a dielectric of glass, ebonite, paraffin, oil, mica or air.

The capacity of a condenser depends on:

(*a*) The area of the plates.
(*b*) The distance between the plates.
(*c*) The material of the dielectric.

If an experiment is made of the effects of glass and air as the dielectric of a condenser, it will be found that the glass increases the capacity 6 to 10 times as much as the air.

The "dielectric constant" of a substance is, therefore, its effect when used as a dielectric as compared with an air dielectric. The following table shows the dielectric constants of various materials used as insulators in condensers.

Material	Dielectric Constant
Air	1.0
Glass	4.0 to 10
Mica	4.0 to 8
Hard Rubber	2.0 to 4
Paraffin	2 to 3
Paper, dry	1.5 to 3
Paper (Treated as used in cables)	2.5 to 4
Moulded Insulating Material, Shellac base	4 to 7
Moulded Insulating Material, "Bakelite"	5 to 7.5
Transformer Oil	2.5
Water, distilled	81.0

A wide variation is seen in the values given for some substances. The different grades and kinds of different materials vary considerably in many of their physical properties, including their electrical properties. For instance photo glass as used for plates has a higher dielectric constant than that of plain window glass. Moulded insulating material known to the trade as bakelite has a much higher dielectric constant than other substitutes commonly spoken of as moulded "mud."

If the voltage applied is from a source of alternating current, the values of the dielectric constant may differ considerably from the values of direct current. This is particularly true if the alternating current has a very high frequency, such as used in radio communication.

Dielectric materials are not perfect insulators, but do have a very small conductivity. A charge in a condenser will be slowly dissipated if allowed to stand with its terminals disconnected. This is called the "leakage" of the condenser. A condenser of which the dielectric is moulded "mud" or paper which has not been treated will sometimes discharge due to leakage within a few minutes. The lower the degree of conducting the longer the charge will remain in the condenser.

The thinner the dielectric, everything else being equal, the greater the capacity. The breaking down potential for a dielectric depends on its thickness as well as on the material; consequently, the thickness of the dielectric which must be used in a condenser depends on the potential strain it will be required to stand as well as the material used in the dielectric. Thus, the dielectric strength is measured by the voltage which will break down the insulation of unit thickness of the material. The values vary according to the shape of the electrodes between which the dielectric is placed. Thus, when capacity is increased by decreasing the thickness of the dielectric for a given potential, there is a certain thickness for each dielectric that may be used and the best dielectric has not necessarily the highest dielectric strength.

The larger the capacity of a condenser the more charge is required to bring it to a given potential. Thus, the potential is directly proportional to the charge and inversely proportional to the capacity as in the water analogy, or in the symbols.

$$E = \frac{Q}{C} \quad \text{or} \quad C = \frac{Q}{E} \quad \text{or} \quad Q = C \times E,$$

E = potential,
Q = quantity or charge,
C = capacity.

Unit capacity would be that of a condenser which is raised to unit potential by unit charge. The practical unit of capacity is called the "farad." A condenser whose capacity is one farad would be raised to a potential of one volt by a charge of one coulomb. A farad is far too large a unit for ordinary purposes and the following sub-divisions are generally employed in practice as follows:

1. "μ fd." = .000001 farad,
*1 "$\mu\,\mu$ fd." = .000000000001 farad.

(* Sometimes written "pfd" mean pico farad, will probably replace micro-micro-farad.)

32. **Dielectric Hysteresis**—If a charged condenser is discharged and left undisturbed for, say, 30 seconds, a small second discharge can be obtained from it, and sometimes a third one. This is due to the fact that when charged the strain across the dielectric causes the charges to leave the plates and really settle on the surface of the dielectric, through which they are bound by electric lines of force, or ether strain in the dielectric. When the opposite sets of plates are suddenly discharged through a circuit joining them, such as a wire or a spark gap, the following electrons rushing around the circuit neutralize the positive and negative charges but some are still left straining across the dielectric, trying as it were to get across that way instead of taking the easier path that has suddenly been provided for them; the dielectric does not entirely recover from the strain when the discharge takes place. The charge which flowed out instantaneously upon discharge is called the "free charge." The charge which flows out the second or third time is called the "absorbed" or "residual charge." In condensers made with oil or well-selected mica for the dielectric, absorption is small. This absorption is manifest by heat in the dielectric and represents a loss of energy.

33. **Series and Parallel Connection of Condensers**—Condensers may be connected either in series or in parallel. If connected in parallel, the combined capacity is equal to the sum of their capacities, or:

$$C = C_1 + C_2 + C_3.$$

Connecting them in parallel is equivalent to adding the plate areas. If three condensers of similar construction each having a capacity of .004 μ fd. are connected in parallel, the resulting capacity would be .012 μ fd.

If condensers are connected in series the resulting capacity is less than one alone. If the condensers have equal values of capacity, their combined capacity is obtained by merely dividing the capacity of one by the number of condensers in series, but if they have unequal values, the resulting capacity is equal to the reciprocal of the sum of the reciprocals or,

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}.$$

If three condensers of .004 μ fd. are connected in series, the resulting capacity would be .0013 μ fd. If three condensers of

.002, .003, and .004 μ fd. were connected in series the resulting capacity would be .00092 μ fd.

The voltage that several equal condensers in series will safely stand is as many times greater than the voltage of one as there are

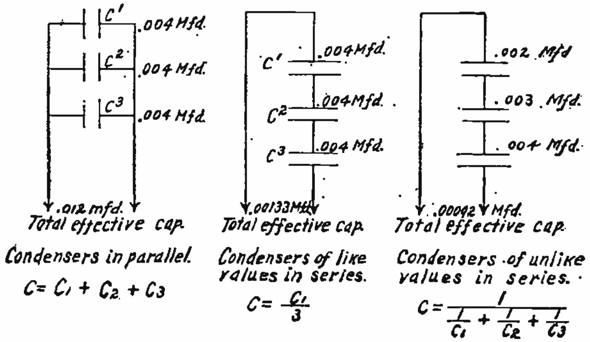

FIG. 21. Series and Parallel Connection of Condensers.

condensers in series. Advantage of this is often taken in building condensers for high voltages. Using this principle, a .004 μ fd. condenser to stand 20,000 volts can be made of twenty 1000-volt sections of .08 μ fd. each, all connected in series.

Transmitting condensers are sometimes protected by having a safety gap mounted on their terminals. The gap is so spaced that should the condenser be subjected to an excessive voltage a discharge will take place across the gap, thus lowering the potential of the condenser and preventing a rupture of the dielectric.

It has been shown that a condenser when first connected to a charging source has zero potential, and as the current flows, the potential rises until the voltage of the condenser is equal to the voltage of the charging circuit; the flow of current then stops. If the charging potential is decreased, the condenser will start to discharge and current will flow out in the opposite direction to which it was charged. The voltage of the condenser tends to set up a back pressure which tends to drive the charging current back. The effect of capacity in a circuit increases the time required to obtain a maximum flow of current through the circuit. Inductance in a circuit tends to prolong the flow of current while capacity tends to extinguish it or hold it back. The effects of counter e.m.f. of inductance and capacity produce a great effect on the flow of alternating current.

34. **Alternating Current**—An alternating current differs from

a direct or steady current due to the fact that it is changing in direction and strength.

From zero potential it starts to flow in one direction; reaching a maximum value it gradually returns to zero potential, only to flow again but in the opposite direction, reaching a maximum value in this direction and again returning to zero potential. This constitutes what is called one complete cycle. Each cycle is composed of two alternations. One alternation is the flow of current in one direction starting from zero rising to a maximum value and returning to zero again. The highest value of current reached during an alternation is called its amplitude. The number of complete cycles occurring during a second of time is called the frequency of the current. Thus a 500-cycle generator produces 1000 alternations of current per second. The process is conveniently pictured by what is commonly called a "sinewave" as shown in figure 22.

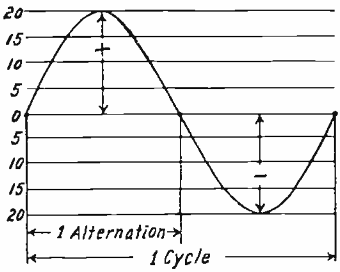

FIG. 22. Curve of One Complete Cycle of Alternating Current.

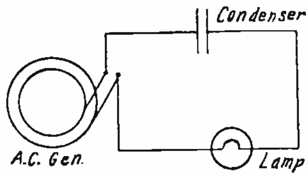

FIG. 23. Condenser in Series with A.C. Circuit.

It can be shown that the voltage and current curves of an alternating current may be irregular or distorted in form and if pictured graphically will show besides the fundamental, other frequencies which are multiples of the fundamental and are known as harmonics. If a harmonic is double the frequency of the fundamental it is known as the second harmonic; if three times, the third harmonic and so on. The fundamental is known as the 1st harmonic. Harmonic frequencies are quite common to radio frequency currents as will be shown later.

Alternating currents having a frequency below 10,000 cycles per second are called audio frequency currents and those above 10,000 cycles are called radio frequency currents.

An alternating current can flow in a condenser in the form of a dielectric current. An alternating e.m.f. in a circuit with a condenser will have the effect of allowing the current to flow through the condenser. Consider the arrangement as shown in figure 23. A very small lamp and a condenser of at least 20 micro-farads are connected in series with an alternating current generator. As long as the circuit is closed the lamp will be lighted indicating the passage of current.

If direct current was applied to this current the lamp would be lighted only momentarily such as when the circuit was closed or until the condenser was charged to the same e.m.f. as the applied e.m.f. With an alternating e.m.f. in the condenser circuit the alternating current is constantly flowing into and out of the condenser to keep the voltage between the plates equal to the instantaneous value of the applied e.m.f. The current is largest at those moments when the applied e.m.f. is changing most rapidly, it is zero at the moments when the e.m.f. is for a moment stationary at its maximum values.

35. **Impedance**—The flow of direct current through a given circuit is opposed only by the ohmic resistance, but the flow of alternating current is opposed by the counter e.m.f. of self-induction as well as ohmic resistance. The effect of self-induction in a direct current circuit is only momentary, the effects being observed only when the current is changing in value such as would occur when the circuit is closed or opened. Consider the circuit as shown in figure 24. The presence of the choke coil retards the

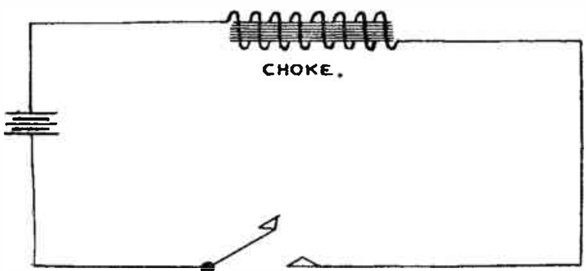

FIG. 24. Reactance Coil.

flow of current when the key is closed and tends to prolong it after the key is opened. If the battery were to be replaced by an alternating current generator there would be a constant opposition to the alternations of current, i.e., the counter e.m.f. self-induction of the choke would retard an alternation from reaching its maximum amplitude and would also tend to delay it from falling to zero. The counter e.m.f. of self-induction is called reactance and as it is a certain form of resistance it is convenient to measure it in ohms. The combined opposition of reactance and ohmic resistance is called impedance (expressed as Z) and it also is measured in ohms. However, the combined resistance, or impedance of a circuit in which there are values of reactance and ohmic resistance is not found by adding the values of each but expressed as follows:

$$\text{Impedance or } Z = \sqrt{R^2 + X^2}.$$

Where R = resistance of circuit in ohms.
X = reactance of circuit in ohms.

The counter e.m.f. occasioned by a circuit loaded with inductance is termed " inductive reactance." It is expressed:
Inductive reactance = $6.28 \times NL$.

N = frequency in cycles per second.
L = the inductance in henrys.

From the formula it can be seen that the higher the frequency the greater will be the inductive reactance. At radio frequencies (frequencies in excess of 100,000 cycles) the reactance of a given coil reaches high values.

The counter e.m.f. occasioned by a condenser in series with an alternating current is called capacity reactance. It is expressed:

$$\text{Capacity Reactance} = \frac{1}{6.28 \times NC}.$$

N = frequencies in cycles per second.
C = capacity of condenser in farads.

A condenser offers less obstruction to the flow if the alternations are rapid than if they are slow.

36. **Phase Displacement**—If an alternating current circuit is composed of resistance only the current and voltage sinusoids reach their maximum points at the same instant and simultaneously pass through zero. By introducing inductance in the circuit the current curve reaches the maximum at a time later than does the voltage curve, the interval of time depending on the value of the inductance and the frequency of the circuit. This difference in time is called phase displacement. Such a circuit is said to have a " lagging phase." See left hand drawing of figure 25.

If a condenser was placed in the same circuit and capacity reactance predominated the opposite condition would exist, that is, the current would "lead" the voltage, reaching its maximum at a

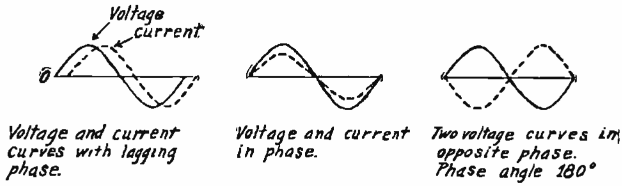

FIG. 25. Curves Showing Lagging and Leading Phases.

time before the latter. A circuit of this type is said to have a "leading phase."

Difference in phase is nothing more than difference in position in the cycle. Phase displacement is expressed in terms of the degrees of a circle, i.e., an alternating circuit current is said to have an angle of lag of a certain degree depending upon the constants of the circuit.

The effect of phase displacement on the power of the circuit is to reduce the value of power for the same value of current and voltage as compared to the power in a purely resistance circuit. Whenever an alternating current load contains reactance elements, then the product of E and I does not give the power put into that load. This product must be corrected by being multiplied by the "power factor" which is always smaller than one and is usually

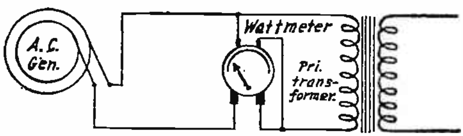

FIG. 26. Wattmeter Connections.

given in percent. Since one generally does not know the power factor it is therefore best to use a watt-meter which makes the multiplication and correction automatically.

37. **Single and Polyphase Alternating Current**—An alternating current having but one e.m.f. is known as a single phase current. An a.c. having two more e.m.f.'s differing by a fixed amount is called a polyphase current.

If three conductors were spaced on an armature 120 degrees apart and revolved between the poles of a U magnet there would be generated in the conductors three e.m.f.'s differing in phase by 120 degrees. If the three conductors are connected to an external circuit the system would be known as a three-phase circuit.

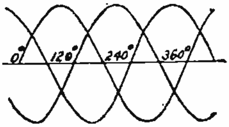

FIG. 27. Voltage Curve of Three-Phase Alternating Current.

38. Effective Value of Alternating E.M.F. and Current—In order to determine the effectiveness of an alternating current the root of the average square (r.m.s.) of the instantaneous values of current is taken and is expressed in terms of the strength of a given direct current which would produce the same power or heating effect.

Example: If 10 amperes of direct current pass through a resistance of 2 ohms the power of the current converted to heat will be I^2R or $10^2 \times 2 = 200$ watts.

If an alternating current is passed through the same resistance and is adjusted as to strength that 200 watts are consumed in heat there will be 10 amperes of alternating current flowing.

The effective value of alternating current is .707 of the maximum value per alternation. The maximum value of the current in figure 22 is 20 amperes. Its effective value is $20 \times .707 = 14.14$ amperes. The current rises and falls uniformly between the value of $+20$ amperes and -20 amperes, producing the same heating effect as a direct current of 14.14 amperes.

The maximum voltage per alternation of an a.c. circuit is 1.41 times the effective value. The maximum voltage per alternation in 110 volt a.c. circuits is then 155 volts.

Commercial alternating currents are usually of sine form at the generator although many things can happen after that to distort the wave form. Alternating current meters read in "effective value," or "direct current equivalent," so one needs no mathematics to determine the effective values of such currents.

39. Hot Wire and Thermo-Couple Ammeters—Radio frequency currents are measured by the heating effect of a piece of wire or strip of metal. Such instruments are called "thermal ammeters." They are divided into two classes called "hot-wire" and "thermo-couple" ammeters.

The hot-wire ammeter depends for its action upon the expansion of a metal wire when it is heated. Figure 28 illustrates the principle. The wire *AB* is connected with the radio frequency current. The resistance of the wire is such that it will stretch when heated by the r.f. current. The spring *S* exerts a pulling action on the slackened wire through the thread *T*. The resultant motion causes the needle *N* to move over the scale. The degree of movement depends upon the amount of current flowing in the wire *AB*. The scale is calibrated in amperes so that the position of the needle shows directly how large the current is.

The thermo-couple ammeter depends for its action on the e.m.f. produced by heating two dissimilar metals. The value of e.m.f depends on the combination of metals and ordinarily increases directly as the temperature is increased.

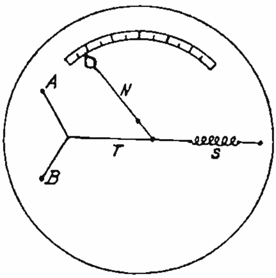

Fig. 28. Principle of Hot-Wire Ammeter.

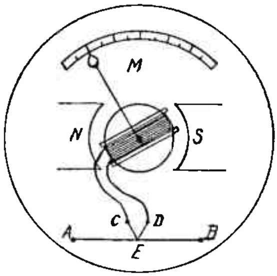

Fig. 29. Principle of Thermal Ammeter.

The theory of operation can be explained by referring to figure 29. The two dissimilar metals *C* and *D* make contact with the hot wire *AB,* in which the radio frequency current is flowing. The e.m.f. produced by the heat at the junction *E* is communicated to the direct current ammeter *M*. As previously explained, the heat due to given number of amperes of alternating current is the same as that of an equal number of amperes, direct current. A deflection of the needle of the ammeter indicates the effective value of current as alternating current meters of radio frequency variety read in "effective value" just as do ordinary 60-cycle or 500-cycle instruments.

40. **Skin Effect**—The resistance offered by a wire to radio frequency current is not the same as for a direct current. The resistance increases with frequency. Radio frequency currents are conducted only on the surface of the wire, hence, it is the surface area and not the cross-sectional area which is the most important in determining the resistance to currents of high frequency. Stranded wire or tubing, or metal strip is often used in connecting up radio apparatus, because the same amount of copper has much more surface in such shapes than when it is formed into solid wire. It should be remembered, however, that it is possible to carry this

to extremes. It is common for radio amateurs to use large strip copper where there are only small currents. There is no point in this and it needlessly complicates the apparatus.

41. Frequency Meters—The speed of induction motors, motor generators and other alternating current apparatus depends on the frequency of the supply circuit. Change in frequency is accompanied by a change in speed. Changes in frequency cause corresponding changes in the reactance of circuits, which may be a considerable disadvantage. A consideration of these facts leads one to appreciate the need for a reliable frequency meter.

Weston frequency meters are found on the switchboards of almost all radio transmitters of the spark type. They are employed in the power circuit of transformers at frequencies of the order of 500 and 1,000 cycles per second and are known as the resonant type of frequency meter, model 355, type 2.

The type 2 instrument is self contained, i.e., the reactors, resistors and condenser are contained within the instrument case.

Figure 30 illustrates diagrammatically the electrical circuits of the instrument. The vertical field coils designated as 1 are connected to the line through a resistor *R*, a condenser *C*, and two protecting reactors, *X*-1 and *X*-2. The horizontal field coils 2 having a reactor *X* in series with them, the coils and the reactor are shunted by the condenser *C*.

By referring to figure 30 it will be seen that the current which passes through the reactor *X* traverses field coils 2. This is a lagging current. It produces in coil 2 a magnetic field tending to hold the needle in a plane perpendicular to the coils. This lagging current also traverses coil 1.

The current which passes through the condenser *C* likewise traverses coils 1 but this is a leading current. The resultant of the lagging and leading currents in coils 1 produces a magnetic field tending to displace the needle from the normal position.

When the frequency is lower than normal the lagging component of the current in coils 1 preponderates because of the decrease in reactance of reactor *X* and the increase in reactance of condenser *C*. Therefore, the effect of the resultant current in coils 1 is to deflect the needle to the left of its normal position.

When the frequency is higher than normal the leading component of the current in coils 1 preponderates as the reactance of *X* is increased and that of *C* decreased. The resultant current now causes the needle to deflect to the right of its normal position.

At normal frequency the effect of the fundamental of the current passing through coils 2 is very greatly magnified by the circuits 2, *X*, *C*, becoming resonant.

Because of this the current passing through coils 2 is very large while what passing through coils 1 is only the small line current. Thus the action of coils 2 on the needle is so great and that of coils 1 so small that the needle remains in its normal position. The resonant feature enables a large torque to be obtained with a very small current being taken from the circuit.

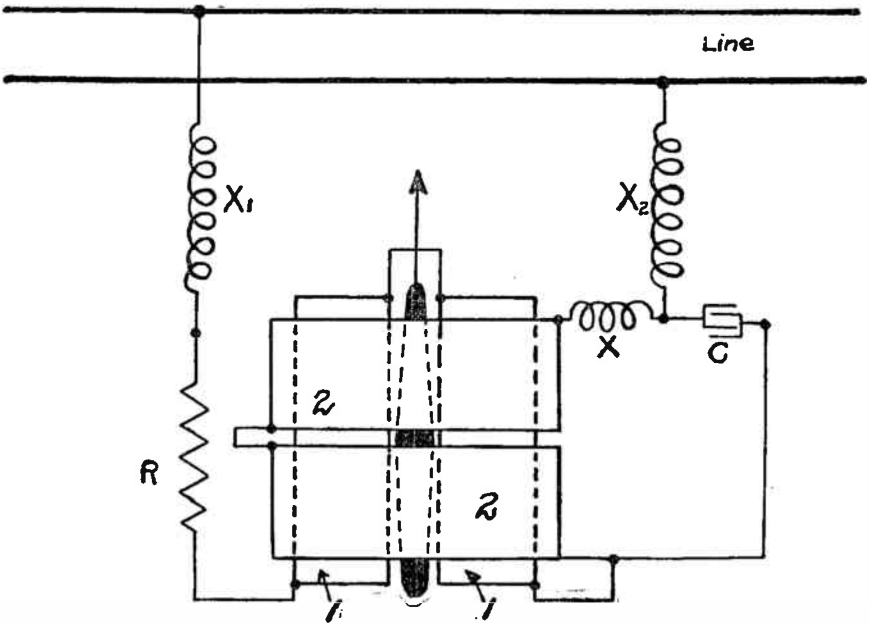

FIG. 30. Circuit of Frequency Meter.

Because the resonant circuit amplifies the effect of the fundamental only and the reactors *X*-1 and *X*-2 together with the resistor *R* prevent the passage of harmonics through the field coils 1, this instrument is not at all affected by distorted wave form, indicating with the same degree of accuracy on a sinusoidal wave form or on a wave having practically a rectangular form.

Model 355, type 2, instruments are designed for a normal voltage range from 110 to 220 volts, with an overload capacity, which allows the voltage to reach 350 volts without injuring the instrument. This renders the instrument suitable for use on radio telegraph sets when the open circuit is high but the operating voltage considerably lower.

42. **Resonance in Alternating Current Circuits**—By the proper selection of inductance and capacity values in an alternating current circuit the counter e.m.f.'s can be made to balance and the reactance therefore reduces to zero. The circuit then acts as if neither inductance nor capacity were present and the flow of current is governed solely by the ohmic resistance. When this condition exists the circuit is said to be a resonant circuit as the frequency of the circuit corresponds to the frequency of the current flowing in the circuit. The frequency at which this occurs is called the "resonance frequency." Every combination of capacity and inductance has its reactance equal to each other at some frequency or other, which is usually a frequency different from the one that it is desired to work at. Therefore, it is convenient to have either the inductance or the capacity or both variable so that the "resonant frequency" can be adjusted to that desired.

The inductive and capacity reactance will be equal in such a circuit if the following condition exists:

43. **Inductive Reactance** = Capacity Reactance, or

$$6.28NL = \frac{1}{6.28NC}.$$

44. **Reactance Coils**—Reactance coils consisting of several turns of insulated wire wound on an iron core are connected in series with alternating current circuits at commercial frequencies to either secure resonance at a certain frequency or to provide an inductive reactance whereby the current flowing in the circuit is retarded. The reactance of such coils is made variable by either providing taps on the windings connected to a suitable switch or the reactance value can be changed by moving the core in and out of the windings.

Reactance coils having air cores are employed in radio frequency circuits and are known as radio frequency choke coils. The reactance of such a coil is very high at such frequencies. They are used to prevent the flow of radio frequency currents in some branch of the circuit.

The reactance of a given coil at radio frequencies may be of such a high value that little or no current would flow unless a certain amount of capacity was inserted in the circuit in the form of a condenser. By making the values of both inductance and capacity variable the inductive reactance can be made to equal the capacity reactance and then the current will build up to large values. If a condenser of .00015 farad were connected in series with a 60-cycle alternator the capacitive reactance would be:

$$\text{Cap. Reactance} = \frac{1}{6.28 \times 60 \times .00015}$$
$$= 17.6 \text{ ohms approx.}$$

If resonance were desired in such a circuit it would be necessary to insert an inductance of .046 henry approx. as:

$$6.28NL = \frac{1}{6.28NC}.$$

Substituting,

$$6.28 \times 60 \times .046 = \frac{1}{6.28 \times 60 \times .00015}.$$

In order to transfer energy from one circuit to another by magnetic induction as is done in radio telegraphy and telephony the circuit to which energy is to be transferred must be in resonance with the first circuit.

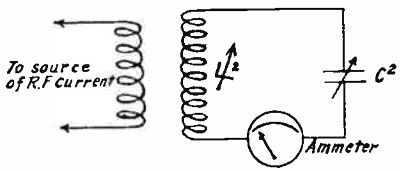

Fig. 31. Showing How Resonance is Obtained in an Alternating Current Circuit.

It can be adjusted to resonance by trying different values of inductance and capacity until the current indicating device of the second circuit shows a maximum deflection.

The process of adjusting the circuits to resonance is called "tuning." Figure 31 shows the arrangement of two radio frequency circuits electromagnetically coupled whereby they can be tuned to resonance by choosing different values of inductance or capacity.

45. Alternating Current Transformers—There are two kinds of alternating current transformers commonly employed in radio telegraphy and telephony. The purpose of one is to change or transform alternating current of low voltage and comparatively large current to alternating current of higher voltage and smaller current or vice versa.

The transformer which is used to produce a higher voltage is called a "step-up" transformer. A transformer used to produce a lower voltage than the input is called a "step-down" transformer.

The step-up transformer is employed to produce high voltages to charge condensers in a spark system for radio transmission. It is also used to produce high voltages for the plate supply of vacuum tube transmitters. The step-down transformer is used to operate the filaments of vacuum tubes.

46. **Construction**—An alternating current transformer consists of two windings so placed as to have appreciable mutual inductance. The winding or coil to which the input power is delivered is called the "primary" and the winding which delivers the "output" to the load circuit is called the secondary. These windings are placed over an iron core which is common to each and increases their mutual inductance.

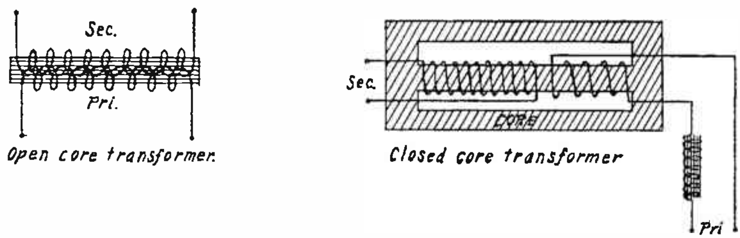

FIG. 32. Open and Closed Core Transformers.

In some transformers the path of the magnetic flux is partly through the air; such a transformer is called an "open-core" transformer. A transformer on which the magnetic flux is entirely through iron is called a "closed core" transformer. The two different types are shown in figure 32. A closed core transformer has a very small leakage flux. Very little flux exists in the air surrounding the core due to the complete path of high permeability offered by the closed core. Usually the primary consists of several coils or "pies" connected in series and placed directly over the center of the iron core with strips of wood to space the winding from the core in order to allow ventilation.

The secondary also consists of several pies connected in series and slipped over the primary with an insulating tube between them.

Transformers having air cores are employed at radio frequencies. The mutual inductance of such windings of an air-core

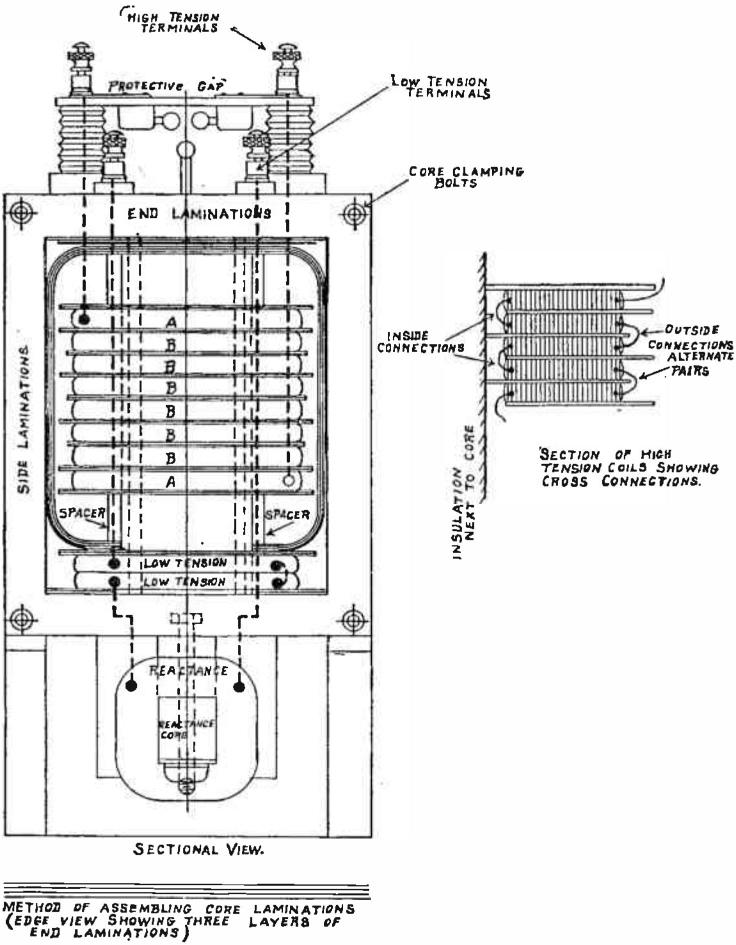

FIG. 33. Sectional View of Closed Core Transformer.

transformer is comparatively small. At low frequencies the efficiency of such transformers is very low. If such transformers were to be employed at high powers it would become very expensive.

The core of an alternating current transformer employed at 60 cycles is constructed of many thin sheets or laminations of silicon steel. By the use of silicon steel laminations the losses due to eddy currents are reduced and the transformer can be operated at higher flux densities than one which is not laminated.

47. **Ratio of Transformation**—If the primary of a step-up transformer has 100 turns and the secondary 1000 turns, the turn ratio is expressed as 1 to 10.

When an e.m.f. of 200 volts is applied to primary an e.m.f. of 2000 volts will be induced in the secondary, and if the primary current is 50 amperes, the secondary current will be 5 amperes. From this it can be seen that the larger the number of turns on the secondary as compared to the primary the larger will be the voltage induced in the secondary, and if the voltage is stepped up the current is reduced or will have a smaller value than that of the primary. The secondary of a step-down transformer, therefore, has fewer turns than the primary but the wire must be larger.

48. **Transformer Operation**—The primary circuit of the transformer is connected in series with a source of alternating current which magnetizes the iron core, periodically causing a varying flux to flow through the iron core in accordance with the alternations of current. The variable flux cuts the windings of the secondary, thereby inducing an e.m.f. in this winding, and if the secondary is a closed circuit a current will flow. The current will flow in the secondary in such a direction as to tend to cause a magnetic flux in the core in a direction opposite to the direction of the flux caused by the current flowing in the primary. The flux existing in the iron core must be of sufficient magnitude to induce in the primary winding a back e.m.f. of the same value as the terminal voltage. In order to maintain the flux constant, the current flowing in the primary winding must increase to a value such that the increase in the primary ampere-turns is sufficient to overcome the opposing magnetic effect of the secondary ampere-turns. This reduces the affective inductance of the primary to such a value that sufficient primary current is available in order to maintain a constant flux; when the load is on the secondary the effective inductance of the primary becomes quite small.

49. **Losses**—The principal losses in a power transformer are of two kinds, the "copper losses" and the "core or iron losses." The copper losses in the primary and secondary windings are equal to the current squared times the resistance. The "core losses" are

of two kinds, the first of which is the "eddy current" losses due to currents induced in the iron core. By the use of laminations in the core the eddy current loss is considerably reduced. Due to

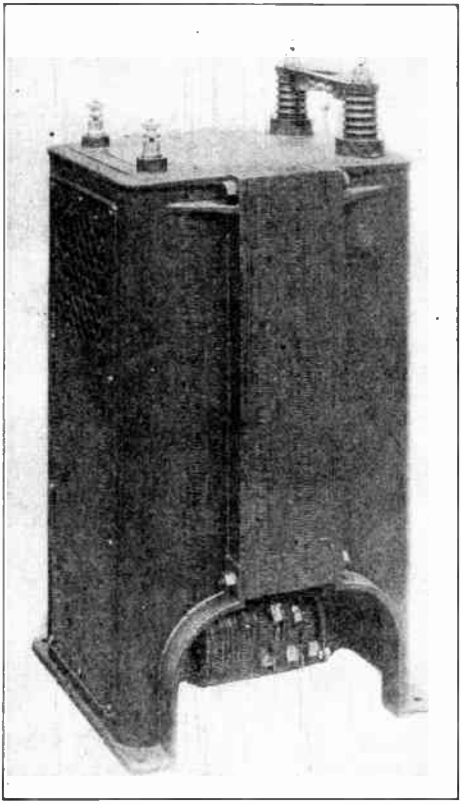

FIG. 33a. 2 KW. 500-Cycle Transformer. (American Transformer Co.)

the constant reversals of magnetism within the core considerable energy is expended in changing the positions of the molecules of the iron laminations. This expenditure of energy is known as the "hysteresis" loss. The core losses occur as long as a voltage is applied to the primary and are nearly the same whether the secondary is delivering a load current or not.

50. Cooling—The losses in a transformer represent electrical energy converted into heat. Some means must be provided for dissipating this heat, or the temperature of the transformer may rise, until it is destroyed. Radio transformers of small size are usually cooled by simply being exposed to the air. The exposed surface of the winding is sufficient to dissipate the heat. Large transformers are cooled by immersing the windings in oil.

51. **Reactance Regulator**—The low frequency power circuit of a radio spark transmitter is usually adjusted so that it is resonant at a frequency approximately 15 percent below the best operating frequency. This prevents the note of the transmitter from "mushing" when the key is closed. It is accomplished by connecting a reactance coil in series with the primary windings of the transformer. Such a reactance is either variable in steps or is of a fixed value and adjusted at the factory by the manufacturer.

52. **Method of Connection of Two-Phase and Three-Phase A.C. Transformers**[1]—Two-phase circuits nearly always have four wires and are equivalent to two single phase circuits in which the currents have the same frequency and always preserve a definite phase relation to each other. Both phases are used for motors, half the power being drawn from each phase so that the same

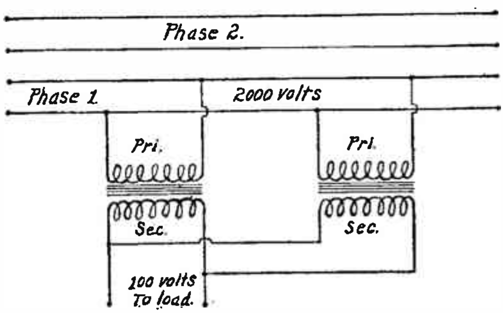

FIG. 34. Parallel Connections of Step-Down Transformers to Two-Phase Current.

transformer capacity must be connected to each phase. For lamps, the transformers are connected the same as to single-phase circuits, care being taken to divide the load between the two phases as nearly equal as possible. If two transformers are connected in parallel, both primaries must be connected to the same phase as in figure 34. If connected to different phases secondary currents will

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be out of phase and local currents will circulate through the secondary coils, resulting in waste of energy and unnecessary heating.

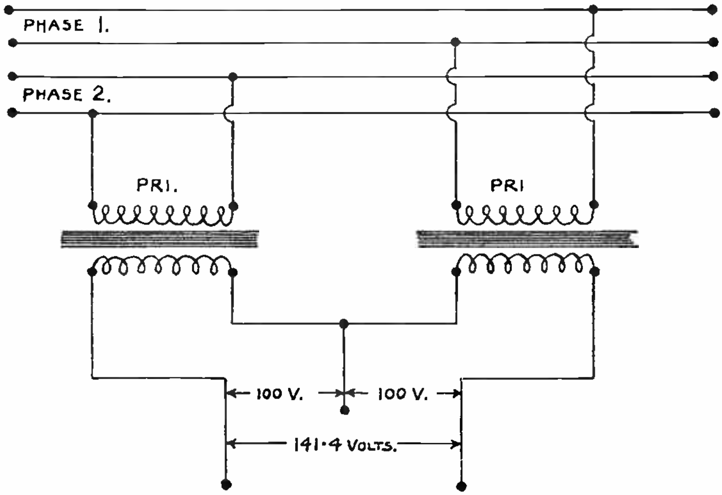


FIG. 34a. Two-Phase, Three-Wire System.

The secondaries of a pair of transformers may be connected in series with one primary connected to each phase of the line circuit, thus forming a two-phase, three-wire secondary system.

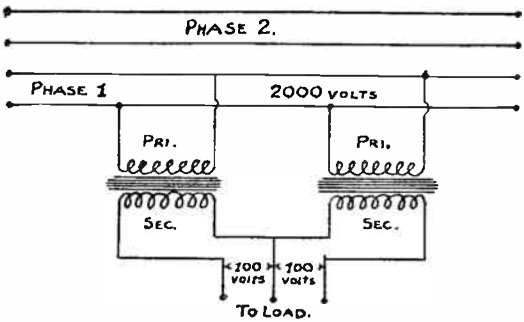


FIG. 34b. Secondaries in Series and Primaries Connected to Same Phase.

See figure 34a. This method is seldom used, since the voltages on the two sides of such a system are easily unbalanced.

The secondaries may be connected in series and both primaries connected to the same phase as in figure 34*b*, forming the regular three-wire secondary system. The voltage between the outside secondary wires is the sum of the voltages on the two sides.

53. **Three-Phase Circuits**—When three transformers are connected as in figure 35, two coils are in series across each phase. This is called a *Y* or star connection. When the primaries are connected *Y*, the secondaries are usually connected in the same way.

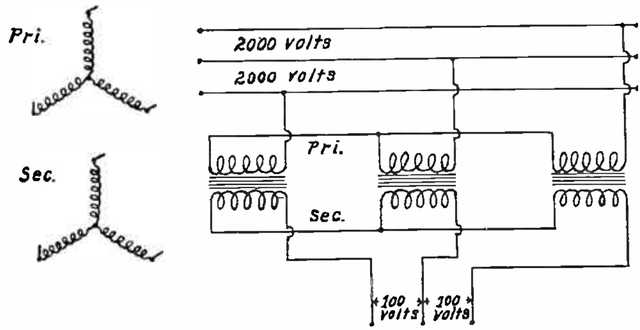


FIG. 35. "Y" or Star Connection of Three-Phase Transformers.

The terminals of the transformers may be connected, as in figure 36, thus forming a delta Δ or mesh connection.

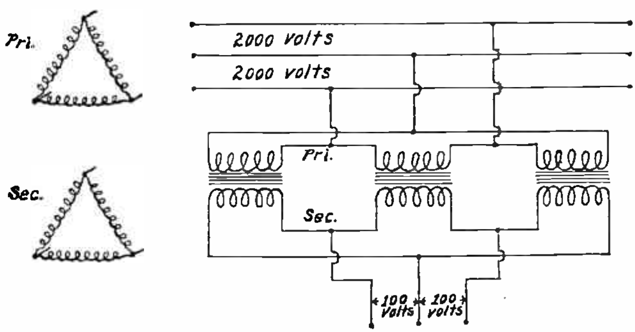


FIG. 36. Delta (Δ) or Mesh Connection of Three-Phase Transformers.

In special cases, the primaries may be connected delta and the secondaries *Y* of the same transformers. Figure 37 shows such connection, as employed in radio telephony for producing high voltages for the plate supply of rectifier tubes which after rectification and filtering is used as the d.c. supply to the other tubes of the transmitter.

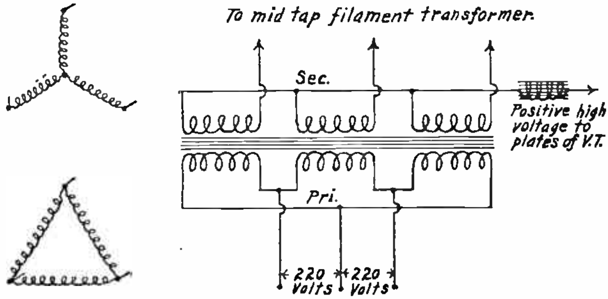


FIG. 37. Delta Connection of Primaries and Star Connection of Secondaries as Used for Plate Supply for Radio Transmitters.

54. Induction Coil—High voltages for charging the condensers of spark transmitters may be obtained from the secondary of an induction coil.

An induction coil is operated from direct current. It is limited in the amount of power that can be used. The vibrator on such coils requires very careful adjustments in order to produce a steady spark note. Such coils are still in use on vessels as the emergency apparatus and are operated from an auxiliary storage battery usually of 24 volts.

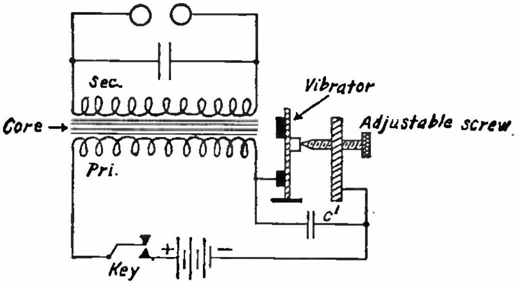


FIG. 38. Induction Coil.

55. Construction and Operation—The coil is constructed of two coils wound on an open core of soft laminated iron. The primary has few turns of large wire and the secondary many turns of fine wire. Connected in series with the primary is an adjustable vibrator fitted with a soft iron armature and so constructed that it can be attracted by the magnetic flux of the iron core. Each time the vibrator is attracted by the core it is thereby drawn away from the stationary contact through which the primary circuit is brought to another contact mounted on the vibrator itself. Thus the movement of the vibrator breaks the primary circuit, stopping the primary current. The magnetism of the core now collapses suddenly, thereby inducing a momentary current surge in the secondary. When the magnetism of the core has died out the vibrator is released and thereupon flies back again completing the primary circuit. The core then becomes remagnetized and the whole thing happens over again a considerable number of times per second. The frequency of operation depends upon the weight of the vibrator and the stiffness and length of the spring. An interrupted current flows through the primary as long as the key is closed. The changing primary current produces a variable magnetic flux which cuts the turns of the secondary and a current will flow due to the e.m.f. induced in the secondary windings. The current in the secondary flows in one direction as the current is made and as the current is broken it flows in the opposite direction. As the current breaks much faster than it makes, the induced e.m.f. is much higher on the break. This is caused by the self induction of the primary winding.

56. Radio Frequency Waves—Radio communication is the setting up of waves in the ether and the receiving of these waves at some point distant from the sending station. Consider the waves that are produced on the surface of a body of water as represented in figure 39. The straight line *C* represents the surface of water when it is at rest. The curves represent the surface of the water at some distant point. The tops of the curves are the crests or highest points reached by the waves. One complete wave extends from *C* to *C*-1 or from *B* to *B*-1. The distance from *C* to *C*-1 or from *B* to *B*-1 is called the wave length and in radio is always indicated by the Greek letter λ called lambda. A wave length then is the distance from any point on a wave to the corresponding point on the next wave.

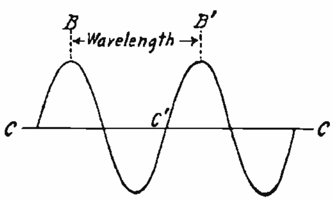


FIG. 39. Graphical Representation of Water Waves.

Water waves are carried along by water. Water is their medium. Radio waves are carried along by the medium called ether. Light and heat waves are also ether waves. The speed of all etherical waves is the same, viz.: 186,000 miles (300,000,000 meters) per second, but the wave length of each is different. In the water waves the wave length was found to be the distance from the crest of one wave to the crest of its successor. Radio waves are measured from one maximum of electric or magnetic force to the next maximum.

There is a definite relation between the length of a wave and its velocity. The following experiment will confirm this. Stand on the shore and estimate the length of the water waves as they pass by. Assume the distance from crest to crest of a wave to be 12 feet. The number of waves passing per second is 10 and is called the frequency of the waves. What is the velocity? If each wave is 12 feet long and 10 pass per second the velocity must be $12 \times 10 = 120$ feet per second. This is a general rule and can be expressed: $V =$ Number or frequency $\times$ Wave Length.

57. Wave Length—It has already been stated that radio waves travel 300,000,000 meters per second. The velocity never changes. Substituting in the formula stated above the wave length of the radio waves can always be determined if the frequency is known. The length of radio waves is always expressed in meters. Likewise if the wave length is known the frequency of the waves can be determined as follows:

$$F = \frac{V}{\lambda}, \qquad \lambda = \frac{V}{F}.$$

Example: What is the frequency if the wave length is 300 meters?

$$F = \frac{300{,}000{,}000}{300} = 1{,}000{,}000.$$

The frequency of radio waves is expressed in cycles per second. The frequency of the waves in the problem above is 1,000,000 cycles per second. With the development of short wave lengths (wave lengths less than 100 meters), by the amateur experimenters, the expression of frequencies in cycles of such waves necessitated the use of large numerals. It is more easily expressed in kilocycles or megacycles. 1 kilocycle = 1,000 cycles, 1 megacycle = 1,000,000 cycles. The frequency of 1,000,000 cycles can then be expressed as 1,000 kilocycles or 1 megacycle.

Referring again to figure 39, it will be noted that the waves are divided into two parts: One above the straight line and the other below it. In one part the water has moved upwards, in the other the water has moved downwards. This is true of all waves. The maximum value that the wave moves upward or downward is called the amplitude of the wave. It is the amplitude of a wave that determines how much energy the wave contains.

Radio waves are made up of two parts, i.e., electro-static lines of force and magnetic lines of force. Experiment shows that electro-static lines of force travel at right angles to the magnetic lines of force. The magnetic lines of force always travel parallel with the ground, sweeping back and forth; and the electro-static lines of force travel perpendicular to the ground, sweeping it up and down. Both the electro-static and the electro-magnetic lines of force reverse their direction every half wave length. One wave constitutes an electro-static field which travels first in one direction and then in the other. The same is true of the electro-magnetic wave.

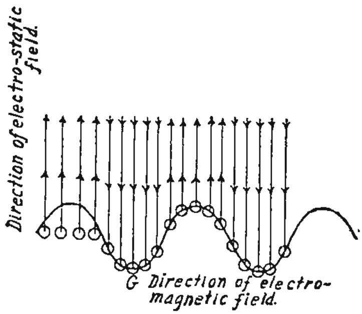


FIG. 40. Components of Radio Wave Showing Direction of Movement.

58. **Antenna System**—In order to produce electro-magnetic and electro-static waves in the antenna system and have them radiated into space it is necessary to excite the antenna by connecting it to a source of alternating current. A 60-cycle alternator such as produces house current would not do. In order to secure resonance in such a circuit, it would require an antenna of tremendous dimensions. The radiation from such an antenna would be negligible at a frequency of 60 cycles. The frequency of the alternating current in the antenna must be very high in order for the radiated waves to produce any distant effect in a receiving antenna circuit. The frequency of the alternating current necessary to produce radio waves is between 10,000 and 600,000,000 cycles, per second. The radiation from a vertical antenna of a single wire is illustrated in figure 41. It is called a Marconi antenna. Marconi made the first use of grounded antennas. The wires of an antenna are considered one plate of a condenser and the ground the other. If the antenna of figure

41 is connected to a source of radio frequency current the field of the antenna and earth is surrounded by lines of force, which die away when a discharge current flows, and are set up when the

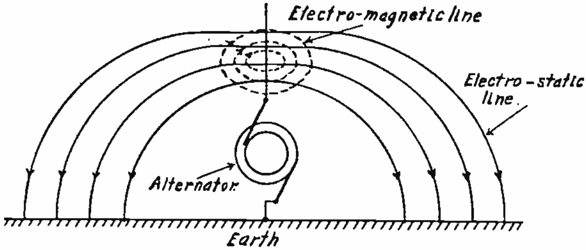


FIG. 41. Radio Waves Surrounding Grounded Antenna.

charging current flows; thus an increasing or decreasing electric strain is identified with a current in one direction or the other resulting in a wave motion.

As already stated the wave motion consists of an expanding static field which is accompanied by a magnetic field, both being radiated at right angles to each other and to the direction of propagation.

The natural or fundamental wave length of an antenna is determined by its height, length, the number of wires, and its geometrical shape.

The higher the antenna, the more the energy radiated. The natural wave length of the antenna is the wave length without any inductance coils or condensers in series with it. In order to operate the antenna at a wave length below the fundamental wave length it is necessary to employ a condenser in series with the antenna. The wave length of an antenna is increased by adding inductance at its base. Every antenna has a certain amount of distributed inductance and capacity. The inductance of the wires forms the distributed inductance. The distributed capacity is formed by the wires acting as one plate of a condenser and the ground the other. The capacity of the condenser thus formed is dependent upon the length and number of wires in the antenna and the distance between each wire, as well as the height of the antenna above the ground. When another capacity is connected in series with the capacity of the antenna the same effect is produced as two condensers in series. The capacity is thereby reduced. The fundamental wave length can be calculated directly from the dimensions but as such formulæ are too complicated for the average operator they will not be shown here. However, an approximation can be made as follows: For a simple vertical grounded antenna, the approximate fundamental wave length is 4.2 times the total length of the antenna in meters including lead in. When four wires are employed in the flat top the constant 4.4 should be used.

The various methods employed to excite an antenna will be shown in a later chapter devoted to short wave length transmission as used by amateurs.

59. **Damped Waves**—The waves as illustrated in figure 42 are called damped waves. It should be noted that the waves

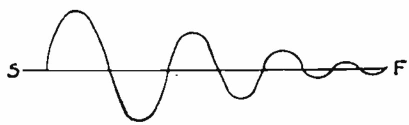


FIG. 42. Damped Waves.

diminish in amplitude, i.e., each succeeding wave has a smaller amplitude than the preceding one. All the waves from *S* to *F* comprise one wave train. A mechanical analogy will illustrate the production of a damped wave train. Hang a weight on a spring balance, pull the weight down and let it free. It will vibrate up and down and gradually come to rest. The moving weight will set up waves in the air which cannot be heard (sub-sonic), but these waves are of exactly the same character as the motion that produces them. The motion of the weight is gradually decreased due to friction and finally it comes to rest. The waves produced in the air by movement of the weight are exactly as shown in figure 42. They are of decaying amplitude. The radio waves produced by spark transmitters employed in connection with mobile radio telegraphy are also of decaying amplitude and are called damped waves. The production of such waves and their effect on a radio receiving antenna will be shown in a later chapter.

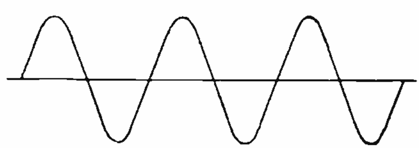


FIG. 43. Undamped Waves.

60. **Undamped Waves**—Waves in which the amplitude remain constant are called undamped or continuous waves (C.W.).

The following experiment will illustrate how a wave train of constant amplitude can be produced. The same spring balance and weight is used for this experiment. Pull the weight down and let it free. When it has gone up to its highest part and is starting downward again, tap it just hard enough for it to go down to the first, lowest position. Do this each time it starts downward. Its motion and hence the waves set up by it can be represented by figure 43. The amplitudes of all waves are the same. It is an undamped wave. In order to make it undamped or continuous it was necessary to add energy by tapping it at the proper time. Undamped waves have certain advantages over damped waves.

The production of undamped radio waves by both the vacuum tube and arc will be taken up in succeeding chapters.

CHAPTER 2

MOTORS AND GENERATORS

1. **The Alternating Current Generator**—The magneto such as is used for producing current for operating polarized telephone ringers is the simplest form of an alternating current generator.

Referring to figure 44, the following takes place: Magnetic lines of force are flowing across the field from the N. to the S. pole of the permanent magnet. To induce an e.m.f. in the rotary coil it must move through the lines of force, and in *A*, the maximum number of lines is passing through the coil. The number of lines does not change until the armature has passed beyond this position as shown in *B* and the voltage is zero. As the armature rotates a

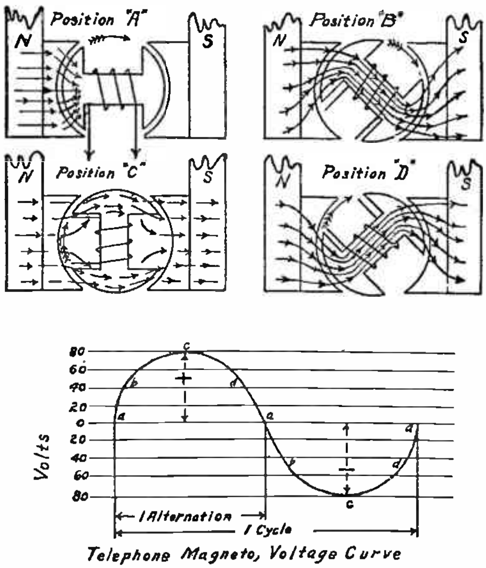


FIG. 44. Generation of Alternating Current by Telephone Magneto.

little beyond *B* the lines begin to change and voltage builds up until *C* is reached, when the remaining lines of force are shortened out of the coil and the rate of change of the lines is the greatest and the voltage will be at a maximum.

When the *D* position is reached the lines of force pass through the coil in the opposite direction and the voltage drops to zero. The induced e.m.f. in the rotating armature produces an alternating current, for while the armature is passing from the position *A* to the position *B*, a plus or positive current is generated if the North pole is on that side and from *C* to *D* a minus or negative current is generated because the wire there is subject to the influence of the South pole. The curve shown is a sine curve as explained in a previous paragraph on alternating current. A machine generating a single alternating current is called a "single phase" machine. Generators used exclusively for spark transmitters are generally single phase.

Commercial alternators do not depend on U magnets but have field poles; the poles carry coils on a frame, which are wound alternately in opposite directions so that the current flows about the turns in opposite directions, giving the poles alternately North and South polarity. The field poles are excited by being connected to a source of direct current which is controlled by a variable resistance so as to weaken or strengthen the field depending upon

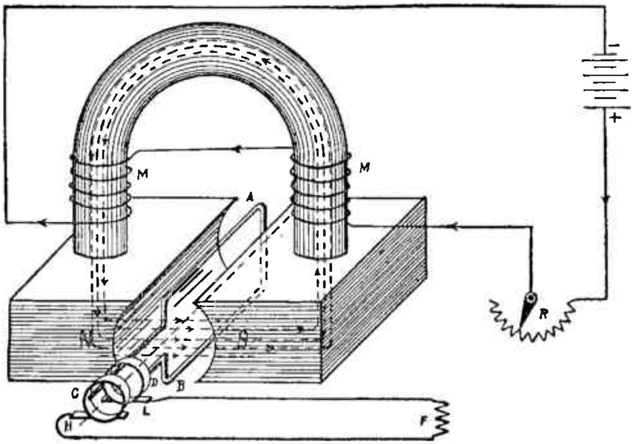


FIG. 45. Fundamental A.C. Generator.

the load on the generator. See figure 45. This variable resistance is called the field rheostat. The armature consists of several coils so connected that the voltage induced in one coil is added on to that of the next coil. In small machines the armature terminals are connected to the collector rings which rotate with the armature. Current is taken from the collector rings by means of carbon brushes which make continuous contact with the collector rings.

On the inductor type of alternator both the armature and field windings are stationary. The rotating element is called the inductor and controls the variable magnetic flux as will be shown later.

Modern generators of large capacity have a rotating field and slip rings. The armature is the stator.

2. **Inductor Type of Alternator**—The inductor type of alternator is employed considerably in connection with radio telegraphy. As mentioned before its field magnets and armature are both stationary. The rotating element called the inductor is constructed of a mass of iron with many teeth or pole pieces cut in the same. The passage of each tooth or pole piece by a field and armature coil generates a complete cycle of e.m.f. whereas with alternators of either the revolving armature type requires the passage of two poles to cause a cycle.

The principle of operation of an inductor type of alternator is shown in figure 46. A considerable gap separates the stationary

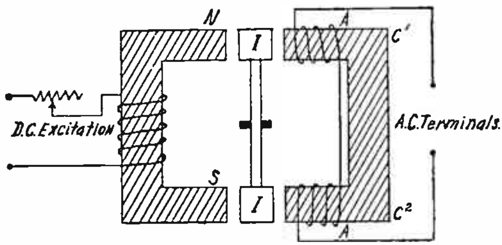


FIG. 46. Production of Alternating Current by Inductor Type of Alternator.

field and armature magnet. In this gap is the iron inductor *I*. It is free to revolve in a direction as to pass away from the reader and through the page. When the inductor is in the position shown between *N* and *C*1, and *S* and *C*2, there is a certain magnetic flux due to the direct current excitation furnished externally. When the inductor is not in the position shown there are long air gaps in the magnetic circuit which have a very much smaller permeability than the iron conductors. The flux is therefore considerably less. The increase and decrease of magnetic flux in the coils *AA* due to the rotation of I sets up an alternating e.m.f. because any change in the flux inclosed by a circuit sets up an e.m.f. in the circuit (see Electro-Magnetic Induction) in the one direction while the flux is increasing, and in the opposite while it is decreasing.

Inductor types of alternators are constructed to generate a frequency as high as 200,000 cycles per second. This high frequency is obtained by having 200,000 inductor teeth pass a given point every second. This result can be obtained only by having a great many teeth on the rotor and driving it at a very high speed. Inductor types of alternators used in spark systems of radio telegraphy are usually designed to generate a frequency of 500 cycles per second.

3. **Determination of Frequency**—The frequency of an alternator may be determined by the formula:

$$F = \frac{N \times S}{120}.$$

F = Frequency in cycles per *second.*
N = Number of field poles.
S = Speed of armature in revolutions per minute.

In commercial practice the frequency of the generator is increased by increasing the speed of the armature as the field poles are fixed.

The voltage of the generator may be increased by increasing the speed of the armature or by increasing the strength of the magnetic field of the field poles as already stated. Generally the latter procedure is employed as increasing the speed of the armature will increase the frequency whereas increasing the field strength makes no change in frequency.

4. **Direct Current Generator**—Since the current in a generator armature is always alternating it is necessary to employ a commutator to convert it into direct current. The function of the commutator is explained as follows: The coil in figure 47 is revolved in a uniform magnetic field producing an e.m.f. in the armature winding, as in the generation of alternating current. But if each end of the coil is connected to a half cylinder of metal on which rests a stationary brush $B+$ or $B-$, then as the loop is rotated the connection to the external circuit is reversed every half revolution, and the pulsations of current are always in the same direction. The brushes are adjusted so that contact is made

to the next metal segment when the current in the armature is zero and about to reverse.

In figure 47 the armature coil *A* — *B* is turning in the direction of the arrow and in the position shown the *A* side of the armature being under the North (+) side of the field magnet generates an e.m.f. in such a direction that the segment *D* has a positive polarity which makes contact with the positive brush *B* +. The current in the external circuit flows from the positive brush *B* + through the load back through the negative brush *B* — to the negative side of the armature coil. As the armature passes a quarter revolution the armature coil will be moving along the flux and not cutting it, so there will be no e.m.f. Each brush will be just in the act of passing from one segment to the other.

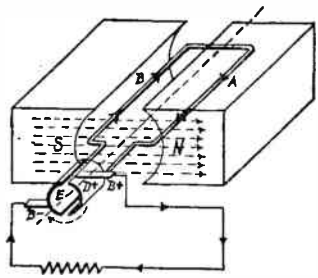


Fig. 47. Fundamental D.C. Generator.

After half a revolution of the *B* side of the armature coil, that *B* side of the armature coil that was under the South (—) pole of the field magnet is now under the North (+) pole and generates an e.m.f. which is opposite from its original direction but in the same direction as the *A* side when under this pole.

Thus the segment *E* is now positive polarity as it is making contact with the brush *B* + and the current again starts to flow from the brush *B* + through the load back to the brush *B* —. In the external circuit the current always flows in the same direction, though in the armature coil the current is alternating.

The voltage curve of such a generator is represented graphically in figure 48. Due to the variation in voltage such a current is

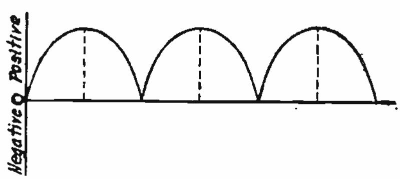


Fig. 48. Voltage Curve of Fundamental D.C. Generator.

said to be pulsating instead of alternating. The current is flowing in one direction all the time but is of an uneven value. In commercial generators enough armature coils are employed so as to deceive one into believing that a maximum e.m.f. is generated all the time. Each coil is connected to its own two segments and the coils are also so connected that the currents in each overlap so that the resultant current is of practically constant value. The commutator of such a machine consists of bars of copper, slightly wedge-shaped, separated by thin insulating sheets of mica, the whole assembled in the form of a cylinder held together by strong end clamp rings. The segments are insulated from the clamps by suitably shaped rings, usually of molded mica insulation. Connections leading to the armature conductors are soldered into slots in the segments, which commonly have lugs or "risers" for the purpose, extending upward at the end toward the armature.

Direct current generators on shipboard are usually driven by an upright steam engine coupled directly to the generator.

Excitation—An alternating current generator requires a source of direct current to excite the field windings. When the current for the field comes from an independent source the machine is said to be *separately excited.*

Direct current generators are so connected that excitation is secured from their own generated armature current.

5. **Shunt Wound Generator**—The circuit of a shunt wound generator is shown in figure 49, where the terminals of field wind-

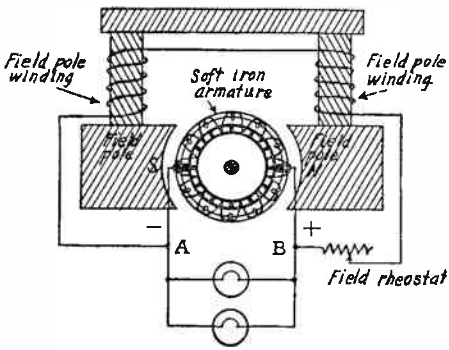


FIG. 49. Circuit of Shunt Wound Generator.

ings are connected across the armature terminals at points *A* and *B*. The shunt field poles are wound with many turns of fine insulated wire. The number of turns is governed by the magnetic flux required for the correct excitation of the machine. Only a small portion of the current generated by the machine flows through the high resistance shunt windings. (The strength of the current flowing through the field windings can be regulated by the resistance called the generator field rheostat.)

When the armature of this type of machine is first rotated it has to depend upon the residual magnetism of the field poles to generate its initial current. Residual magnetism as already explained is the magnetism resulting from the magnetic lines of force retained by soft iron after once being magnetized.

As the armature is rotated the residual lines of force cut the coils of the armature, generating therein a feeble current which flows through the shunt field windings, and increases the number of lines of force cutting the armature coils. This induces a stronger current in the armature conductors which continually adds to the strength of the field until the normal voltage of the generator is established. The complete process usually requires from 10 to 50 seconds. After the generator attains its normal speed, the voltage across its terminals may be raised or lowered by the generator field rheostat. Increasing the resistance of the field rheostat decreases the generator terminal voltage. Decreasing the resistance of the field rheostat allows more current to flow in the field windings and increases the generator terminal voltage.

6. Series Wound Generator—The field windings of a series wound generator are connected in series with the armature. All the current generated by the armature must pass through the field windings; therefore it is necessary to employ large wire in order to handle all the current without heating since the current is large. Thus the necessary ampere turns are secured by virtue of having a large number of amperes and comparatively few turns of wire. The current in passing through the field windings strengthens the weak field due to residual magnetism and the normal voltage of the generator is soon attained. Figure 50 shows the circuit of a series wound generator.

7. Compound Wound Generator—The field magnets of a compound wound generator are wound with two sets of coils, one set being connected in series with the armature and external circuit. The function of the series winding is to strengthen the magnetic field by the current taken through the external circuit, and thus automatically sustain the voltage under variations of a load. Figure 51 shows the circuit of a compound wound generator.

8. Voltage Characteristics of Shunt, Series and Compound Wound Generators—When shunt excitation is used, if the external load is increased, the potential difference at the armature terminals is reduced. The effect of the reduced terminal voltage is to reduce the current of the shunt field windings resulting in a weakened field. With an increased load the armature current increases as the shunt field current decreases; hence the terminal voltage falls off considerably.

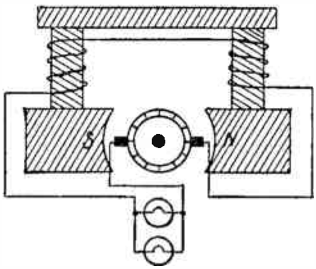


FIG. 50. Circuit of Series Wound Generator.

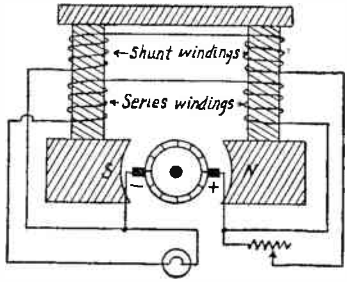


FIG. 51. Circuit of Compound Wound Generator.

With series excitation the condition is very different. When there is no load on the generator, only the weak residual magnetism of the iron pole pieces is available, and the terminal voltage is consequently very small. As the load increases larger values of current flow through the series field windings permitting a greater e.m.f. to be generated. The greater the current taken by the external circuit, the greater will be the voltage.

The compound wound generator gives a more constant voltage on circuits of varying load than is possible with a generator with either shunt or series windings. As the external load of a shunt generator is increased, the potential difference at the armature terminals will fall, but in the case of the compound wound generator, this fall of e.m.f. is counteracted by the series winding, the current which flows in it increasing with load and causing the terminal voltage to rise. The number of turns of each winding and the relative strength of current are proportioned so that a practically constant pressure is maintained under varying load.

Each type of generator has its special uses. For instance, the exciter for an a.c. generator of a radio set can be a shunt generator because the load does not change much. Incandescent lamps require a very steady voltage that is not changed when some of them are turned on or off. A compound generator meets this requirement.

9. **Regulation**—The relation of the voltage on no load to the

voltage on full load of a generator is called *regulation*. It is found by the formula:

$$\text{Regulation} = \left(\frac{V_0 - V_f}{V_f}\right) \times 100 \text{ percent.}$$

Where V_0 = voltage at no load,
V_f = voltage at full load.

A small percentage regulation means that the voltage remains very nearly constant when the load is charged. A high percentage means that the voltage drops considerably on load and the machine therefore has poor regulation. Example: Consider a spark transmitter whose a.c. alternator no load voltage is 300 volts. The key is closed and the voltage drops to 270 volts. Substituting in the above formula

$$\left(\frac{300 = 270}{270}\right) \times 100 \text{ percent} = 11 \text{ percent approx.}$$

10. **Failure of Generator Field to Build Up**—If the initial current generated due to residual magnetism does not excite the field poles in the direction of the residual magnetism, the field will not build up and will be noted by a low or no voltage reading of a voltmeter connected across the output terminals of the generator. The following test will indicate if the magnetism of the field poles is opposite to that of the residual magnetism. Connect a voltmeter across the output terminals and note voltage with *field circuit open.* This reading may be only a volt or two and is the voltage generated due to residual magnetism. Close the field circuit and take another reading of the voltmeter. If the voltage has decreased the connections to the field circuit are wrong and they should be reversed. After reversing field, start generator up again and if the fields are correct the machine should build up to normal voltage. Failure to generate may be due to other causes such as dirty brushes, or commutator, loose connections or loss of residual magnetism. Residual magnetism can sometimes be restored by permitting the current from a battery or other generator to flow through the field circuit for a few hours.

11. **Reversal of Polarity of Generator**—It sometimes happens especially on ships' generators that while the auxiliary batteries are on charge the generator is stopped by an engineer on duty without first removing the load from the machine. Unless the charging circuit is protected by circuit breakers the battery

will start to discharge through the generator resulting in a reversal of the residual magnetism. When the machine is again started the reversed residual magnetism reverses the polarity of the generator brushes, thus reversing the direction of the field current and making it agree with the new direction of the residual magnetism. This will allow the generator to build up, but the polarity will be reversed. The residual magnetism can be again reversed so that the generator will have its normal polarity by sending a current from another generator or a battery through the field in the proper direction. This is accomplished by connecting the positive terminal of the battery to what is now the new positive terminal of the generator and the negative of the battery to the negative of the generator. The brushes should be lifted or removed during this operation. A battery of 6 to 12 volts will sometimes accomplish the correct result. If the reversal does not take place immediately upon first test the battery should remain connected to the fields for an hour or two.

12. **Ground Indicators**—Ground indicators in the form of two lamps in series with the midpoint grounded are sometimes installed on switchboards. Figure 52 shows the connections of

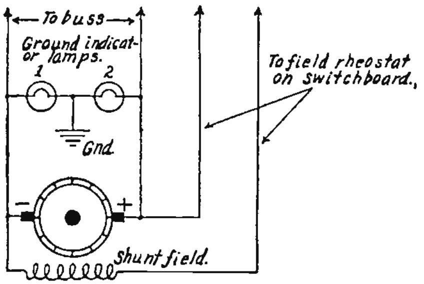


FIG. 52. Circuit of Ground Indicator on D.C. Generator.

such indicators. Normally the two lamps in series will light dimly. Should a ground occur on either leg of the circuit one of the lamps would light to full incandescency. For instance, assume the positive leg of the circuit in figure to become grounded; this will short circuit lamp number 2, and lamp number 1 would then be directly connected across the generator terminals and would be lighted to normal brilliancy.

13. **Electric Motors**—There is no essential difference between a motor and a generator. The structure of both is identical but the function is reversed. The motor converts electrical power

into mechanical power. Direct current motors are of three types, shunt, series and compound, so called from their winding characteristics. Motors operating from alternating current are of two types, the induction and the synchronous motor. There are special combination motors operating from either d.c. or a.c. This type is known as a universal motor. They are seldom employed in conjunction with radio and for that reason will not be treated here.

14. **D.C. Shunt Motor**—The fundamental operating principle of a motor is as follows: When a current is flowing through a conductor in a magnetic field there is a force that tends to push the conductor across the field. The conductor will move in a direction at right angles both to the direction of the field and to the direction of the current. For example: If the plane of a coil lying between the poles of a magnet is parallel to a magnetic field, and a current is passed through the coil, it will tend to turn or take up a position at a right angle to the magnetic field. If the current is reversed when it has reached this position, the coil will continue to revolve.

The action of the motor can be explained by the diagram in figure 53. The current flowing through the armature windings

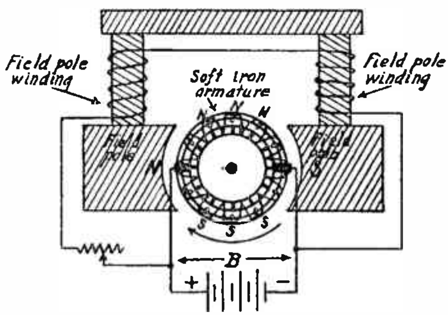


FIG. 53. Circuit of D.C. Shunt Motor.

from the battery *B* is in such a direction that the lower half of the armature coils is magnetized and has a South pole and the upper half a North pole. The upper half will then be attracted by the South field pole and repelled by the North field pole. The lower half will be attracted by the North field pole and repelled by the South field pole.

The action will be continuous, because, as the top of the armature moves toward the South field, the commutator acts to maintain the flow of current in the same direction as before, consequently the upper half of the armature is always a North pole and the bottom a South pole. Thus the armature is made to revolve when supplied with current.

Compare the circuits of the shunt wound generator in figure 49 and shunt wound motor in figure 53. They are fundamentally the same. If the shunt wound generator was charging batteries and the engine was shut off, the generator would continue running providing the battery circuit was large enough and had no circuit breakers. The ammeter in such circuit would show a current in the opposite direction. The battery is discharging and operating the generator as a motor exactly as described in the previous paragraph.

15. **Direction of Rotation**—If the connections from the battery were reversed at points *A* and *B* in figure 53, it would have no effect on the direction of rotation. The armature would still continue to rotate in the direction of the arrow. Reversing the connections from the battery would reverse the polarity of the flux in both the armature and the field poles. The North field pole would become a South field pole and South field pole would become a North field pole. Likewise the armature South pole would become a North pole and the South pole of the armature a North pole. The same power of attraction and repulsion between like and unlike poles would result with no change in direction of rotation. In order to change the direction of rotation the *flow of current must be changed in either the armature or field poles, but not in both.* For example: In figure 53 reverse the field poles only. The North pole is now a South pole and the South pole a North pole. The direction of armature current has not been changed, therefore the upper half is still a North pole and lower half a South pole. The North pole of the armature being attracted by the new South pole, rotation begins opposite to the arrow or counter clockwise, where before, as shown by the arrow, the direction of rotation was clockwise. The same thing would have happened if the armature windings had been reversed instead of the field windings. The general practice is to reverse the current in the armature, rather than in the fields.

16. **Counter Electromotive Force**—As soon as the armature of a motor starts to rotate, an e.m.f. is induced in the armature windings of such polarity as to oppose the e.m.f. that started the motion. The back pressure or voltage is known as counter electromotive force and governs the speed of a motor. The value of counter e.m.f. is proportional to the speed of the armature, the

number of armature wires and strength of the magnetic field. The faster the armature turns the greater the counter e.m.f. becomes. It cannot turn so fast that the counter e.m.f. is as great as the line voltage, because then the two would balance: there would be nothing to make the current flow through the armature, and consequently no pull to keep it turning. If the motor is placed on a load the speed falls off and consequently the value of the counter e.m.f. falls off. The current in the armature is increased as the back e.m.f. falls off and the motor automatically regains speed of sufficient value to drive the load.

The field magnets are always of the same strength, regardless of the load, because the current around them depends only on the line voltage and the resistance of the field coils. It is entirely independent of the current in the armature.

Thus the speed of a motor supplied with direct current at constant voltage varies directly with the counter electromotive force and in any given machine the stronger the field, the slower will be the speed of the armature. The strength of the field can be regulated externally by a variable resistance in series with the field windings. This variable resistance is called a motor field rheostat. If the resistance of the field rheostat is *decreased* more current flows through the field windings, thus increasing the field strength, consequently the *speed of the motor is reduced*. If the resistance of the motor field rheostat is *increased* the magnetic field is weakened resulting in an *increased speed of the motor* up to a *certain point,* or until the increased speed of the armature increases the counter e.m.f. to such an extent as to cut down the armature current. If the motor field rheostat accidently burns out or should any open circuit occur in the shunt field the armature will develop terrific speed. The centrifugal force becomes great enough to burst the windings of the armature, therefore requiring expensive repairs to the machine. If upon starting such a motor the circuit breakers trip, fuses blow or excessive current taken by the motor is noted, the machine should be stopped at once and investigation made to determine if the field circuit is properly connected and not open.

From the above it can be seen that the advantage of a shunt wound motor is that it is self regulating and maintains a fairly constant speed under varying load.

17. **Starting Resistance**—The resistance of a motor armature is small. If the line voltage was applied directly to the armature terminals excessive current would flow which might injure the commutator or burn out the armature windings. The counter

e.m.f. developed by rotation is what keeps the armature current from becoming excessive. When the motor is first connected to the line it is not rotating and there is no counter e.m.f. Some other way must be found to limit the amount of armature current until the machine can attain sufficient speed to generate the required amount of counter e.m.f. This is accomplished by connecting a variable resistance in series with the armature and gradually reducing it as the motor gains speed. A device whereby the resistance is regulated is called a starter. A diagram of a shunt wound motor with hand starter or starting box is shown in figure 54.

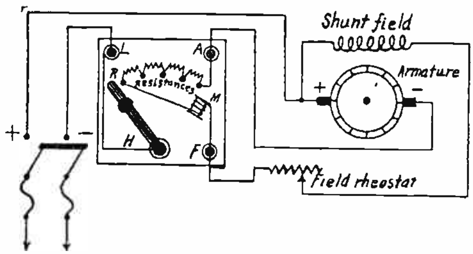


FIG. 54. Cutler-Hammer Hand Starting Box Connected to Shunt Wound Motor.

The action of a typical hand starter is as follows: As the handle *H* makes contact with the stud on the first resistance *R*, the armature circuit is completed with all the starting resistance in series, thus limiting the armature current, and the motor starts slowly. The motor field circuit is completed through the windings of the magnet *M* and the motor field rheostat. As the handle moves toward the full running position, the motor gains speed, likewise the value of counter e.m.f. is increased. When in full running position with all the resistance of the starting box cut out, the motor is generating a counter e.m.f. of such value as to permit the full line voltage to be applied directly to the terminals of the armature. No change has been made in the strength of the field magnets by the operation of the starter. The holding magnet *M* holds the handle in the full running position unless demagnetized by interruption of the d.c. supply or an open in the field circuit. Should the d.c. line be interrupted the handle flies back to the off position requiring the motor to be started in the normal manner. Should the handle fail to fall back excessive armature current would flow when the line voltage is restored, resulting in damage to the machine as explained previously. Should the field circuit develop an open circuit the magnet is again demagnetized, thus releasing the starting handle and preventing the motor from attaining an excessive speed.

If a motor is started too slowly the starting resistances will overheat and burn out. If started too rapidly the fuses in the d.c. line will melt, or excessive armature current will flow, tripping the circuit breakers. It should require about 15 seconds to start motors used in connection with radio transmitting apparatus.

18. **Automatic Motor Starters**—It is often desirable to install

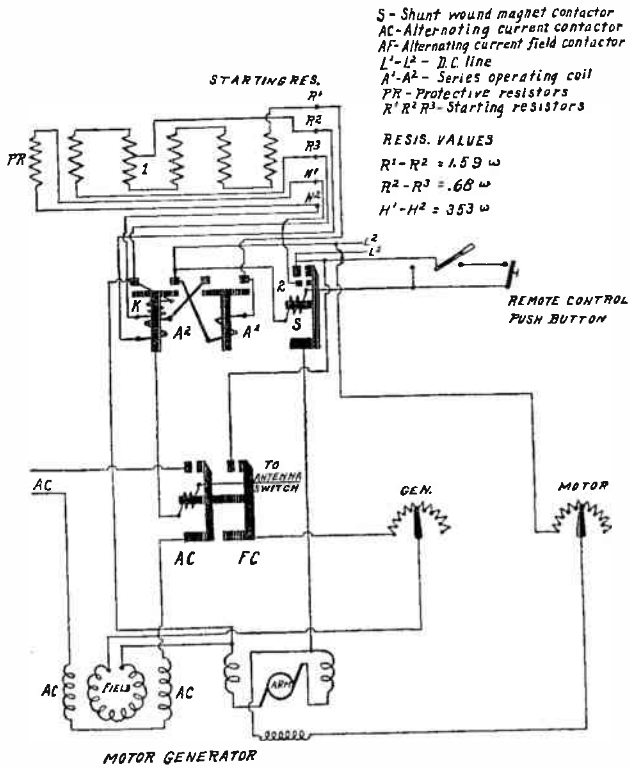


FIG. 55. Circuit of the Electric Controller and Mfg. Co. 2 KW. 120-Volt Automatic Starter.

the motor generator of a radio transmitting set at a point remote from the radio room in order that the noise from its operation will not interfere with the reception of radio signals. In instances of this kind automatic starters are employed, which are controlled from a distant point by pressing a small button or closing a small switch. The automatic starter solenoid and resistances sometimes are a part of the transmitter panel in the operating room and controlled by a start-stop switch mounted close to the antenna send-receive switch on the operating table. The motor generator is usually mounted in an iron box over the top of the engine room and accessible to the operator for care and maintenance.

The complete circuit of one type of the automatic starter of The Electric Controller and Manufacturing Company is shown in figure 55. This type of starter has been used extensively in connection with Navy Standard 2 K.W. spark transmitters, as installed on vessels of the United States Shipping Board and other privately operated vessels.

This push button automatic starter consists of: One type S counter-weighted shunt wound magnetic contactor for closing the main circuit; two type A series wound magnetic contactors for short circuiting the starting resistor; 1 resistor box; and 2 terminals used in wiring the apparatus.

The shunt wound contractor is of standard form, having a shunt wound coil which stands full line voltage continuously without protection and which when energized moves the main contact arm on to stationary contact, thus making circuit to the motor. The contactor has a magnetic blowout to aid in rupturing the arc when opening the circuit. The main arm of the contactor is provided with an auxiliary control circuit contact to make and break the circuit for the shunt holding coil of the last accelerating contactor. The main arm is also counter-weighted to prevent closure of the arm when the contactor is moved out of vertical position.

The series contactors are of the vertical plunger type and are so constructed that an excess of current through the series operating coil will not lift the plunger, in fact will keep the plunger in the open position until the current value has been reduced to such a value that will lift the plunger and contact disk into contact with the contact brushes, thus short circuiting out part of the starting resistance.

19. **The Construction** of this series contactor is shown in figure 56, in which *A* is the operating coil, connected in series with the motor; *B* is the cast iron case, making the magnetic circuit; *C* is the plunger carrying the contact disk, *D*, at the top, which in the closed position makes contact with the contact brushes *E*; *F* is the adjusting plug; *G* is the operating air gap; *H* is the lock-out air gap; and *I* is the shunt holding coil.

20. Operation of Series Magnetic Contactor—If current of a higher value than the operating value of the contactor is caused to flow through the series operating coil *A*, an upward pull is exerted on the plunger *C*, due to the flux in the operating air gap *G*, but

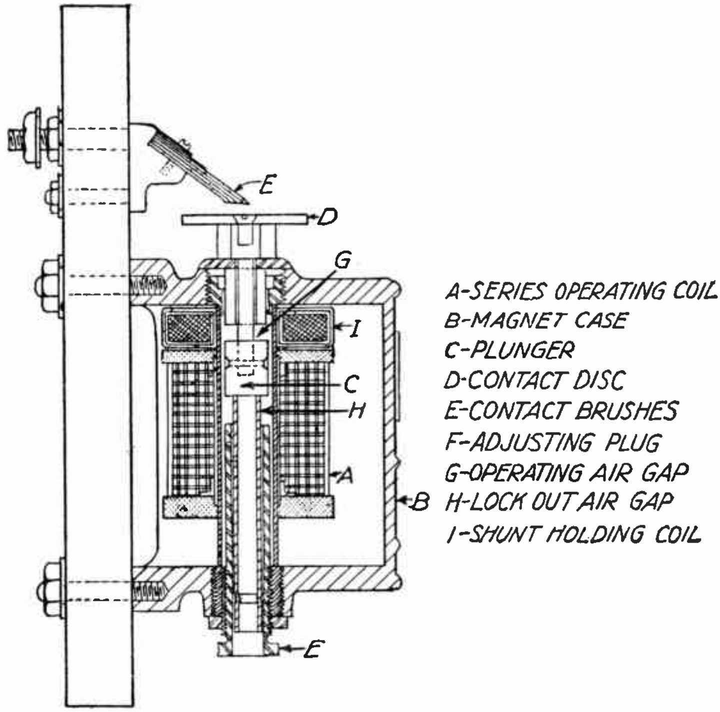


FIG. 56. Type A Series Magnetic Contactor Employed with Automatic Starter.

there is also a downward pull on the plunger due to the flux through the lock-out air gap *H*. This flux in air gap *H* is due to the fact that the steel stem extension on the lower part of the plunger *C* is over-saturated by the flux through air gap *G*. As the current is reduced the flux through air gaps *G* and *H* is reduced until the steel stem of plunger *C* can carry practically all of the flux in air gap *G*; at which time the downward pull at air gap *H* is greatly reduced and the upward pull at air gap *G* is sufficient to overcome the downward pull and the weight of the plunger, thus pulling the plunger to its closed position with contact D against the contact brushes E.

The value of current at which the plunger lifts can be increased by increasing the length of air gap H. This is done by screwing the adjusting plug F farther out of the case. Or the plunger can be made to lift at a lower value of current by screwing the adjusting plug farther into the case, thus decreasing the air gap H.

An increase of current through the series coil after the plunger has lifted only tends to hold the plunger more firmly in the closed position. A reduction of the current through the series coil to about 15 percent of the normal value, or an interruption of the current, will cause the plunger to drop to the open position.

A shunt holding coil K, figure 55, is provided on the last accelerating contactor of each starter. This coil is connected in series with a protecting resistor unit PR, and they receive full line voltage upon closure of the contactors. At the same instant the series coil is shorted out of circuit and the shunt coil will hold the contactor closed until its circuit is opened.

The resistor box contains the resistor units used for accelerating and the protective resistor unit for the shunt holding coil. The box is of sheet steel with asbestos board cover carrying necessary terminals.

The wiring diagram in figure 55 shows that when the remote control push button is closed the circuit is completed through the shunt wound magnetic contactor S, which moves the contactor arm establishing the circuit through the starting resistors R_1, R_2 and R_3, and the operating coil A, of the first series contactor. As soon as the current has dropped to a predetermined value this contactor closes, short circuiting the first step of the resistance at point 1 and closing the circuit of coil A_2 of the last accelerating contactor. When the current has again dropped to the proper value this contactor closes, shorting out all of the starting resistance and both series operating coils. The first accelerating contactor drops open but the last accelerating contactor is held closed by the shunt holding coil K, which is connected across the armature upon closure of the shunt contactor at point 2 and receives full line voltage upon closure of the last accelerating contactor. The motor continues to run until the shunt contactor is opened by de-energizing its coil. Opening the shunt contactor also opens the circuit to the shunt holding coil of the last accelerating contactor which opens.

The starter is adjusted to accelerate a direct current motor in the shortest possible time and yet keep the current peaks down to

50 percent over normal full load. If the motor is lightly loaded the time of acceleration may be very short, the accelerating contactor closing almost immediately after closure of the main contactor, but if the motor is heavily loaded, several seconds may elapse between closure of the series contactor.

With certain adjustments on the accelerating contactors it might be possible that these contactors will refuse to close if the circuit to the motor has been opened when the motor was running at maximum speed and immediately closed again, thus allowing the motor to continue to run with the starting resistance in circuit. If this is the case, the accelerating contactors will close immediately when the load is thrown on the motor by closing the alternating current circuit.

21. **D.C. Series Motor**—The field coils of a motor may be wound with thick wire and connected in series with the armature, so that the same current flows through both. It is then called a series motor.

The operating characteristics of a series motor are considerably different from those of a shunt motor. They do not run at a very constant speed, but run very much more slowly when heavily loaded. At the lower speeds they develop a large torque. They are used to advantage on street cars where high turning effort is wanted for starting a load. They are of no use in radio where a constant speed motor is required.

22. **Motor with Differential Field Winding**—It has been explained how the speed of a motor is increased or decreased by variation of magnetic field and any reduction of the field flux of a given machine will increase the speed of the motor. By the use of a differential field winding, as the external load is increased, the strength of the shunt field is decreased, resulting in restoring the machine to its normal speed. The manner in which this is accomplished is shown in figure 57, where the field winding of the motor is two distinct sets of coils. One is the normal shunt winding connected across the input terminals of the machine and the other a series winding connected in series with armature. The windings of the series coils are so arranged that any flux produced by the series windings is opposite in polarity to that of the shunt winding. A suddenly applied load will tend to slow the armature down, resulting in a reduction of the counter e.m.f., and an increased armature current will flow.

The increased armature current flowing through the series coil produces a magnetic flux opposite to that produced by the shunt field resulting in a differential and therefore weaker field which restores the motor to normal speed.

A field rheostat is connected in series with the shunt field of a differential field winding for variations of speed control.

By the use of a differential field winding, motors may be designed to give very close speed regulation and are, therefore, very desirable to drive a.c. generators for radio telegraphy.

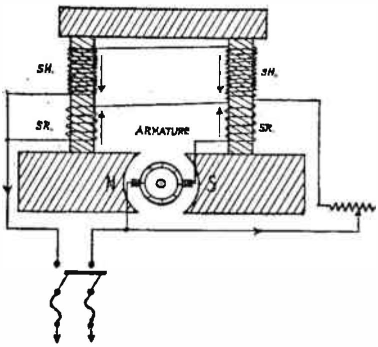


FIG. 57. Motor with Differential Field Winding.

23. Alternating Current Induction Motor—It has been explained how a current flowing through a coil produces a magnetic field. If a set of coils is arranged in the form of a two-phase or three-phase field and connected to an alternating current having two or more phases, it will be noticed that a compass needle placed within the field will start to spin around and will continue to do so as long as the coils are energized. The effect is as if the needle of the compass were under the magnetic influence of a magnet with its poles sliding along the face of the field.

The action of an induction motor can be explained by comparing it to a transformer in which the stator is the primary and the rotor is the secondary. Both have poles and these tend to repel each other. Because the stator field revolves it drives the rotor before it at a speed which is almost the same as the rotating field at no load but which is reduced by any load applied to the motor shaft, or any resistance put into the secondary (rotor circuit).

Speed Control—The speed of the rotor of an induction motor depends upon the construction of the stator and the frequency of the alternating current. In the simplest form there is no connection between rotor and external circuit. However, some types of induction motors have the rotor fitted with slip-rings to provide connection to an external resistance which controls the speed of the machine. This is usually accomplished by providing the rotor with a three-phase Y-connected winding and connecting a variable resistance, in series with each phase, as shown in figure 58. By means of the three-pronged arm, the resistance in series with each phase of the rotor winding can be varied from the full amount to zero, thus varying the speed from minimum to full speed.

The terms "squirrel cage rotor" and "wound rotor" are often used to describe rotors; the first means the simple kind with conductors of plain bars of metal and no slip-rings or other moving

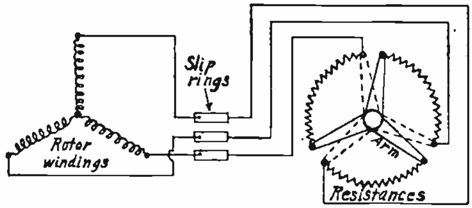


FIG. 58. Speed Control Connections of Three-Phase Induction Motor.

contacts, the second means the kind having coils like an armature and fitted with slip-rings.

An induction motor cannot be started on single-phase current but will operate on the same if started somehow. One way of starting an induction motor is by the use of a "phase splitter." The armature has two sets of coils, one having more inductance than the other. Due to difference in reactance of the two coils the currents flowing in the two are not in phase. The motor starts then as a sort of two-phase machine. After it gets up to speed the starting winding is disconnected either by a two-way switch having a starting and running position or by an automatic centrifugal cut-out in the motor.

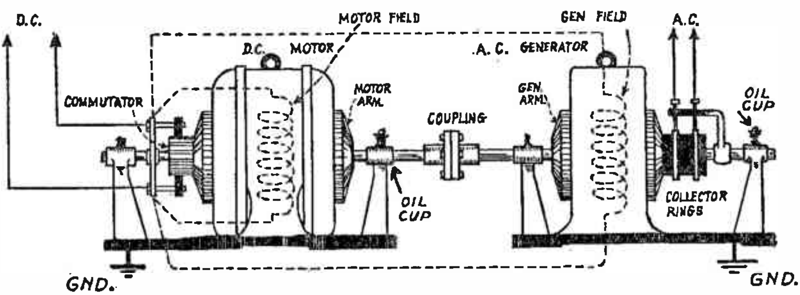


FIG. 59. General Construction of Motor Generator.

24. Motor-Generators—Direct current is the only available power supply on practically all ships. In order to operate the power transformer of a spark transmitter it generally is necessary to use an alternating current. Arc and tube transmitters require direct current voltages considerably higher than those provided by the ship's dynamo. When electric current is to be had, but not in the form needed, the change can be made easily by a motor-generator. This combination, as usually employed on shipboard, consists of a direct current motor and an alternating current generator coupled together on a common iron base. In the case of the arc or vacuum tube transmitter the combination may consist of a direct current motor and a direct current generator which provides d.c. voltages considerably higher than that available from the ship's dynamo. In broadcasting stations the combination may be an a.c. motor coupled to a d.c. generator. Such machines usually have four bearings,

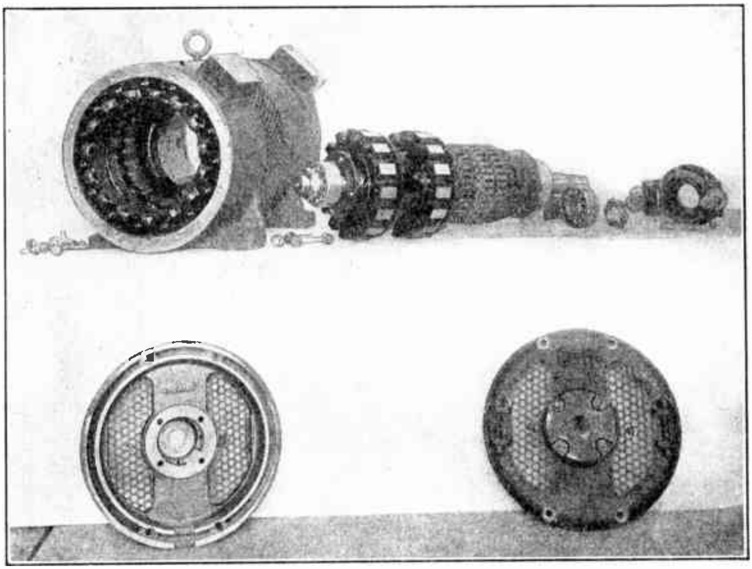


Fig. 60. Exploded View of Crocker-Wheeler 2 KW. Motor Generator with Inductor Type of Alternator.

two for the motor armature and two for the generator armature. In the case of a shipboard installation the field of the generator is excited from the direct current of the ship's dynamo. Field excitation is controlled by a generator field rheostat. Figure 59 shows the general construction of a motor generator. Motors and generators have been described. Each unit can be thought of by itself, without regard to the other. Some automatic starters employed in connection with motor generators have the wiring so arranged that the field of the alternator is not closed until the motor is in fully running position. This prevents the operator from putting

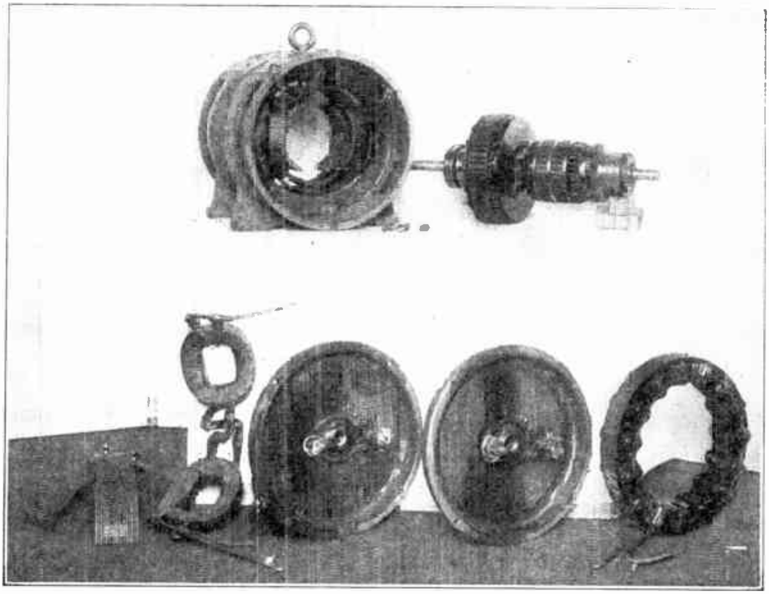


FIG. 61. Exploded View of Crocker-Wheeler 2 KW. Motor Generator with Alternator of "Wound Type."

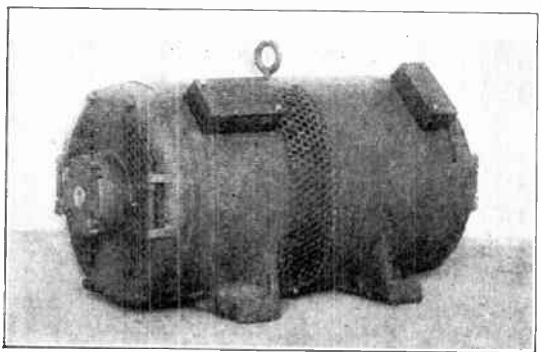


FIG. 62. Assembled Motor Generator.

a load on the machine until the motor gets up to normal speed. Various types of motor generators and their application to a particular transmitter will be described in the succeeding chapters.

25. **Rotary Converters**—If connections are made to a pair of collector rings from opposite sides of a two-pole d.c. armature, one can take off an alternating current. Since this armature is now able to supply either a.c. or d.c. from the same winding one naturally suspects that it might be possible to *feed in* a.c. at one end and take off d.c. at the other. This is actually possible and such a machine is called a "rotary converter."

The rotary converter shown in figure 63 has a single winding on one armature for both alternating and direct current. Direct current from an external source enters the armature *A* through

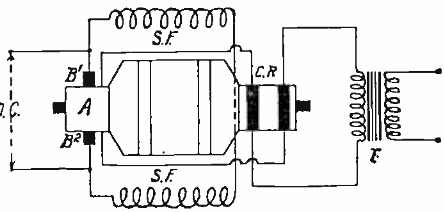


FIG. 63. Fundamental Circuit of Rotary Converter.

the brushes *B*1 and *B*2 and also flows through the shunt field *SF*, causing the armature to revolve in the usual way. Taps are taken off the commutator segments directly underneath the brushes and are connected to collector rings *CR* on the opposite ends of the shaft, the circuit continuing through the primary of an a.c. transformer *T*. The voltage of the alternating current will be a maximum when taps to the collector rings are underneath the brushes and minimum when midway between the brushes. As the armature revolves the current taken from the collector rings will flow in the opposite direction and therefore, as the armature revolves, an alternating current can be taken from the armature, the frequency of which varies with the speed. The a.c. voltage of the converter is increased by increasing the speed of the armature, but the frequency of the current increases simultaneously. When such a machine is run as a direct current motor and used to supply alternating current it is spoken of as an "inverted rotary converter."

26. **Dynamotor**—A dynamotor is employed to change direct current at one voltage to direct current at another voltage. This is very convenient on small yachts and pleasure craft where from

a small battery of low voltage a high voltage from 300 to 1000 volts can be produced to supply the plates of a vacuum tube transmitter. The dynamotor has two separate armature windings placed

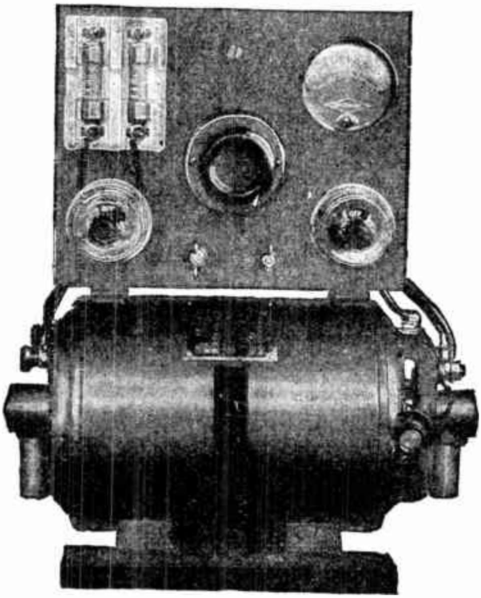


FIG. 64. Esco Dynamotor and Switchboard.

on a common rotor core. One acts as a motor, the other as a generator. There is but one frame and one set of field magnets. The two windings are connected to commutators at opposite ends of the

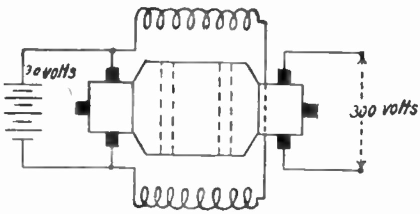


FIG. 64a. Fundamental Circuit of Dynamotor.

shaft. The ratio of voltage is fixed when the machine is built, so the output voltage depends on the voltage applied. The field coils receive current from the same source as the motor armature. Figure 64 shows the picture of such a machine and figure 64*a* the fundamental circuit.

27. Protective Devices—Some means must be provided in a radio transmitter to prevent the radio frequency currents from flowing back into the power leads and thence into the motor and generator windings resulting in damage to the same.

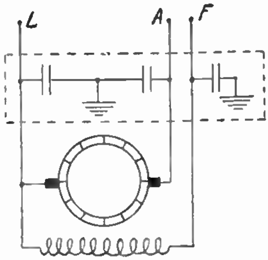


Fig. 65. Protective Condensers Connected across Motor Terminals.

The low voltage wires are usually run in metal conduit and the conduit connected to earth. In some installations lead-covered wires are provided and the lead sheathing of all wires is tied together and then grounded. The high frequency currents are induced in the surface of the conduit or lead-covering and are effectively grounded and thus no harm results to the power machinery.

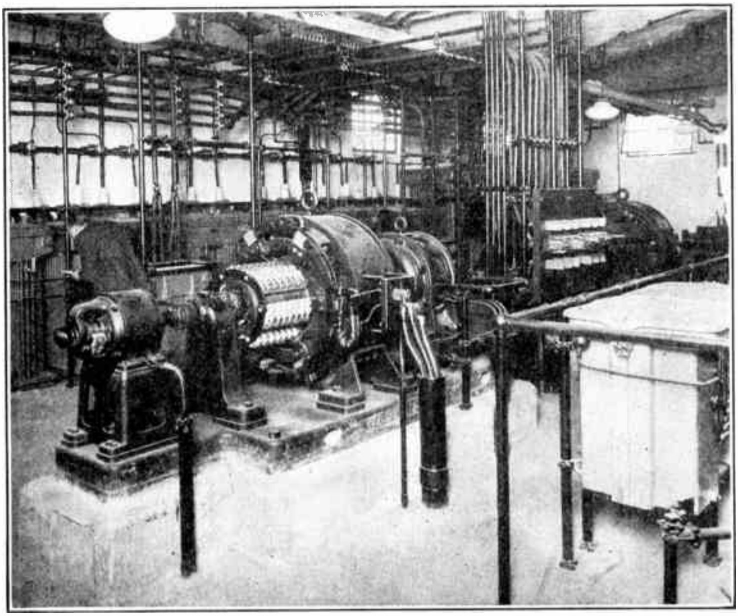


Fig. 65*a*. Power Plant of Modern Broadcasting Station (WJZ).

Protective devices are also used to protect the power machinery in the form of two condensers in series and connected across the power leads with the mid tap of the condensers grounded.

The high capacity condensers offer a path of low impedance to the induced radio frequency currents and they are thus conducted to ground.

These condensers are usually of 1/2 or 1 μ fd. capacity each and are connected in the following circuits:

(1) In shunt to motor armature.
(2) In shunt to motor field windings.
(3) In shunt to generator armature.
(4) In shunt to generator field windings.
(5) In shunt to d.c. feeders entering radio room.

Protective condensers of a motor generator are usually made up as a unit and mounted directly on the frame of the machine. Each terminal of the machine is connected to a condenser and the other terminal of the condenser is connected to the frame of the machine which is grounded by a lead connected to the transmitter ground.

In the succeeding chapters the care necessary for each particular machine supplied with the radio transmitting apparatus is taken up in detail and for that reason the general care and maintenance of motor generators will not be taken up in this chapter.

CHAPTER 3

STORAGE BATTERIES AND CHARGING CIRCUITS

1. **Auxiliary Power Requirements**—Under the United States Radio Law of July 23, 1912, known as the Ship Act, an auxiliary power supply is required to operate the radio transmitter in an emergency. This power supply must be independent of the vessel's main power plant and be of sufficient capacity to enable the transmitting set to be operated for at least four hours to send messages over a distance of at least one hundred nautical miles day or night.

On American vessels subject to this Act, the independent power is in most cases a set of storage batteries of sufficient capacity to operate the main transmitter over a period of time in excess of that required by law. This requirement of the law is complied with in other instances by the installation of an auxiliary generator driven by a gasoline engine. The auxiliary power plant is automatically started and stopped by a system of relays and contactors.

It is the purpose of this chapter to describe the construction, operation and maintenance of the different types of auxiliary power equipment.

2. **Storage Batteries**—Under the heading of Elementary Electricity we have seen how the primary battery created a difference of potential by immersing two dissimilar metals in an acid or alkaline solution. The difference of potential caused a current to flow in a completed metallic circuit. Such a battery will furnish current until all the chemical action possible has taken place. The battery has then become "dead." To produce another flow of current it is necessary to obtain new plates and new electrolyte.

In a secondary or storage battery, neither the plates nor the electrolyte need be renewed. The storage battery differs from the primary battery in that when it has given out all the energy which the chemicals enable it to supply, instead of requiring new elements, the cell can be completely regenerated or brought back to the original condition by passing a current into it in a direction opposite to that in which the flow took place on discharge. The charging current simply reverses the chemical action and restores the plates to the same composition as before the discharge.

A storage battery does not act as a storage place for electricity as its name implies, but the chemical action that takes place when the battery is charged changes the composition of the active materials of the plates so that when they are connected together by a conductor, sufficient difference of potential exists to cause a current to flow. The current flow, or discharge of the battery, reverses the chemical action that took place when the battery was charged until finally the character of the plates is such that no difference of potential exists and the battery is discharged.

3. **The Edison Cell**—The Edison storage battery differs in electrical characteristics, chemical action and mechanical construction from any other battery.

4. **Electrolyte**—The potash electrolyte is composed of pure distilled water combined with a 21 percent solution of *potassium hydrate* mixed with a small portion of *lithium hydrate*. It has a specific gravity of approximately 1.200 at 60 degrees F. after being thoroughly mixed by charging. This reading should be taken one hour after discontinuance of charge to allow for dissipation of gases.

The specific gravity of the cells changes but little with charge and discharge and therefore is of no value in determining the charged or discharged condition of the cell. However, throughout the useful life of the cell the electrolyte gradually weakens and for this reason specific gravity readings are of value to determine when a renewal of solution is necessary. The low limit of specific gravity is 1.160 and is usually accompanied by a temporary loss of capacity and sluggishness.

5. **Plate Construction**—The *positive plate* is made up of many perforated steel tubes into which has been packed, under heavy pressure, alternate layers of nickel hydrate, the positive active material and nickel flake. Each tube is reinforced by eight seamless steel rings. The *negative plate* is composed of a steel grid supporting many perforated nickel-plated steel pockets. Iron oxide, the negative active material, is loaded into these pockets, which in turn are secured to the grids by means of hydraulic pressure of 120 tons.

6. **Chemical Action**—The fundamental principle of the Edison storage battery is the oxidation and reduction of metals in an electrolyte which neither combines with nor dissolves either the metals or their oxides. Although the electrolyte is decomposed by charge and discharge, it is reformed again in equal quantities and therefore its density and conductivity remain the same over a long period of time. The active materials of the plates are insoluble in the electrolyte, therefore, no chemical decomposition takes place therein.

The chemical reactions in charging are (1) the oxidation from a

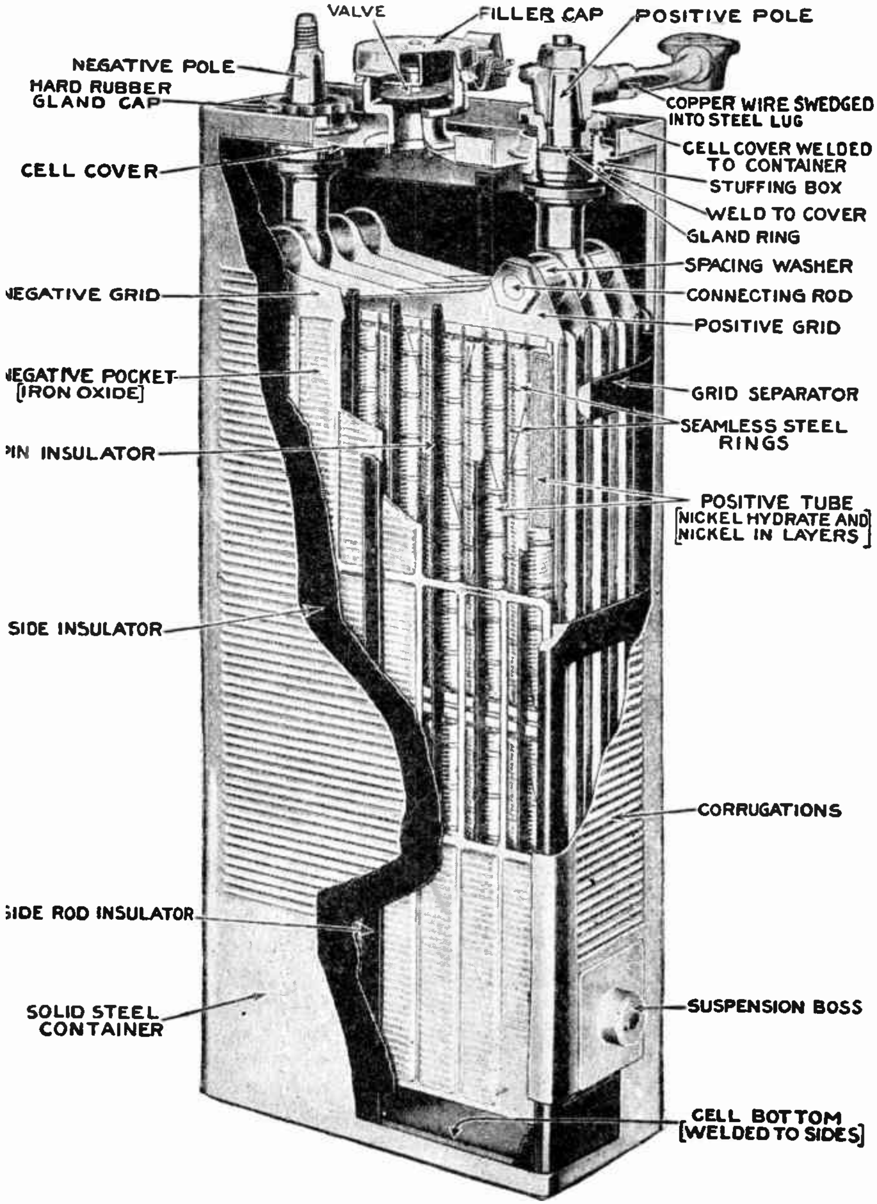


Fig. 66. Sectional View of Edison Storage Battery.

lower to a higher oxide of nickel in the positive plate and (2) the reduction from iron oxide to metallic iron in the negative plate. The oxidation and reduction are performed by the oxygen and hydrogen set free at the respective poles by the electrolytic decomposition of water during the charge.

The discharge of the cell is simply the reversal of the above reactions, the hydrogen reducing the higher oxide of nickel to a lower oxide, and the oxygen oxidizing the iron to iron oxide.

7. **Container**—The container is made of high grade steel which is oxy-acetylene welded. Each battery consists of two or more cells connected together by nickel-plated copper connectors fitted with a tapered steel lug which fits the terminal post of each cell. Each lug is held in place by a hexagonal nut. Each cell fits into a specially constructed wooden tray so arranged that the containers which are conductors will not short-circuit the battery.

The Polarity of the Positive Terminal of an Edison battery is designated by a red bushing and a plus sign (+), stamped on top of the container. The negative terminal is indicated by a black bushing with no sign on the container.

A *filler cap* of special construction is provided in the center of the cell to enable watering and to allow for the escape of gas. It is of such construction that the cell can be tipped to an angle of 45 degrees without spilling the electrolyte.

8. **Voltage**—The fully charged voltage of an Edison cell when discharging at the 5-hour rate is approximately 1.4 volts per cell.

The average discharge voltage at the 5-hour rate is 1.2 volts per cell.

The discharged voltage at the 5-hour rate is 1.0 volt per cell.

9. **Installation**—The Edison battery may be installed in any part of the vessel; however, in most marine installations the battery is located either in a special room adjoining the radio operating room or in a well-ventilated box placed on the boat deck. In several installations the battery has been placed in one corner of the operating room and carefully housed in with screens for ventilation.

The Edison battery requires no lead-lined compartment and gives off no noxious fumes during charge. A dry location is preferable, if too warm; excessive evaporation of electrolyte may result. The battery box need not be lined but should be absolutely water proof to prevent salt spray and other impurities from striking the cells.

Edison batteries are generally shipped fully charged. This is indicated by a red label accompanying the battery and indicates they are ready for immediate use.

A green label indicates that the cells are not charged and that they require an overcharge at the normal rate before being placed in service.

10. **Height of Solution**—Upon receipt of the battery the height of the solution should be tested by use of the glass tube shipped for that purpose.

One half inch is the proper height of the solution above the top of the plates for all types of Edison batteries in marine use except the high type cells. The proper height of the solution in the high type cells is 3 inches above the top of the plates for the A type and 2 1/4 inches for the B type.

11. **Testing Height of Solution**—Insert tube until the tops of the plates are touched, close the upper end with the finger and

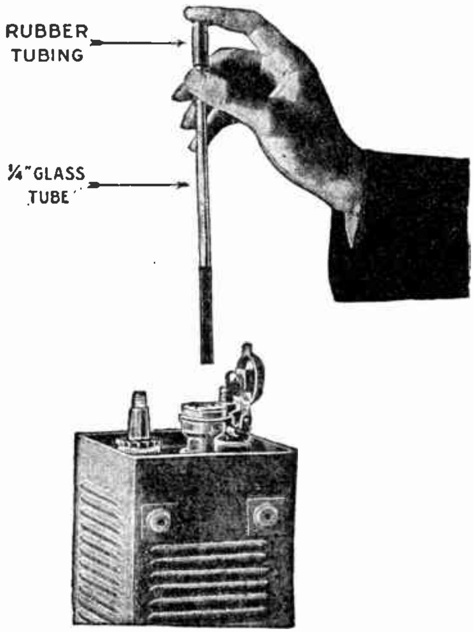


FIG. 67. Testing Height of Solution.

withdraw the tube. The height of the liquid in the tube indicates the height of the solution above the top of the plates.

A glass tube reasonably walled, about 8 inches long and not less than 3/16 inch inside diameter with ends cut straight and smooth, may be used for this test in event none is supplied. A short length of rubber tube forced over one end and projecting about 1/8 inch will prove a good finger grip.

12. **Refilling Battery**—If the plates are visible above the top of the solution of the packing case or surrounding materials show a rusty stain, it is an indication of spilled electrolyte and thus loss must be replaced preferably with Edison storage battery "Standard Refill Solution" or lacking this, with "Standard Renewal Solution." Lacking either of these, pure distilled water should be added until the solution is brought to the proper height.

When the level of the solution is only a small amount below the proper height, fill with pure distilled water.

13. **Maintenance of Edison Battery**—The Edison battery requires a minimum of attention; however, by observing a few simple precautions the operator can be assured of maximum capacity from the battery in time of emergency or disaster.

1. To charge, the positive of the charging source should be connected to the positive terminal of the battery. No great damage will result to an Edison battery if it is left discharged or if charging polarity is reversed, except to temporarily reduce the capacity of the battery.

2. If battery is in compartment or box, open cover of same before charging.

3. Make sure solution is at the proper level.

4. The correct charging voltage should be 1.85 times the number of cells in series.

5. It is well to remember that a marine battery of 90 or more cells is broken up into two banks of 45 cells or more, each bank for charging. This is accomplished by a 3- or 4-pole double throw switch on the charging panel.

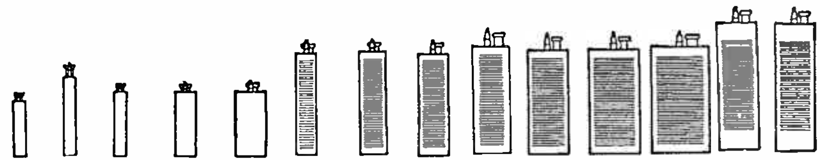
Do not exceed charging rate as specified under electrical data, for the type of battery in use. It is not advisable to charge at less than normal rate. In an emergency, charging may be done at a higher rate providing there is no frothing and temperature does not exceed 115 degrees Fahr. 80 to 90 degrees is the normal temperature for maximum efficiency.

Frothing indicates too rapid charging or too high level of solution.

6. Never put lead battery acid into an Edison battery or use utensils that have been used with acid.

Operators on vessels using both Edison and lead cells should

General Data and Tray Dimensions of Edison Storage Batteries. (¼-in. Positive Tubes.)



Type (Letters denote size of Plates, Figures number of Positive Plates) Prices on Application	N2	B1H†	B2	B4	B6	A4	A5	A6	A7	A8	A10	A12	A8H†	A6HW‡
Rated Capacity, Ampere-Hours.....	11.25	18.75	37.5	75	112.5	150	187.5	225	262.5	300	375	450	300	225
Discharge Rate (8-hour) Amperes..	1.41	2.34	4.69	9.38	14.06	18.75	23.44	28.13	32.81	37.5	46.88	56.25	37.5	28.13
" " (5-hour) " ..	2.25	3.75	7.5	15.	22.5	30.	37.5	45.	52.5	60.	75.	90.	60.	45.
Average Discharge Voltage (8-hrs.)	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
" " " (5-hrs.)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Normal Charge Rate (7-hours)......	2.25	3.75	7.5	15.	22.5	30.	37.5	45.	52.5	60.	75.	90.	60.	45.
Weight of Cell, Complete, pounds..	1.67	5.2	4.5	7.8	11.3	13.8	16.7	19.4	22.6	26.8	33.3	40.6	30.4	28.4
" per Cell, in Trays, pounds	1.94	5.6	5.1	8.5	12.1	14.9	17.5	20.8	24.6	29.0	36.2	43.9	32.1	32.2
Amount Renewal Solution per cell (lbs.)........	.34	2.0	1.1	1.9	2.7	3.2	3.8	4.3	5.22	6.4	8.1	9.9	8.7	10.13
Over-all Tray Dimensions, in Inches														
Width of Standard Tray..........	3½	6⅛	6⅛	6⅛	6⅛	6⅛	6⅛	6⅛	6⅛	6⅛	7¾	9	6⅛	6⅛
*Height over-all (Filler Cap closed)	7½	11⅜	9⅝	9⅝	9⅝	14⅜	14⅜	14⅜	14⅜	14¾	14¾	15½	17½	17½
*Height over-all (Filler Cap open)..	8½	12⅜	10⅝	10⅝	10⅞	16	16	16	16	16⅜	16⅜	17	19⅛	19⅛
Lenght of Trays: 1-cell Tray......	2¾	3⅛	3⅛	4¼	5⅜	4⅝	5¼	5¾	6¼	7¼	7½	7½	7¼	7¼
2-cell Tray......	4½	5	5	7⅜	9⅝	7¾	9	10	11	12⅞	13½	13½	12⅞	12⅞
3-cell Tray......	6¼	6⅞	6⅞	10½	13⅞	10⅞	12¾	14¼	15¾	18⅜	19½	19½	18⅜	18⅜
4-cell Tray......	8	8⅞	8⅞	13⅝	18⅛	14	16⅜	18½	20⅞	24⅛	25⅞	25⅞	24⅛	24⅛
5-cell Tray......	9¾	10¾	10¾	16¾	22⅜	17⅛	20	22¾	25⅝	29¾	32¼	32¼	29¾	29¾
6-cell Tray......	11⅞	12¾	12¾	19⅞	26⅝	20¼	23⅝	27¾	30⅜	36	....	....	36	36
7-cell Tray......	13⅝	14⅝	14⅝	23	31¼	23¼	28½	32	35½	41⅝	....	....	41⅝	41⅝
8-cell Tray......	15⅜	16½	16½	26	35⅝	27¼	32¼	36¼	40¼	47⅛	....	....	47⅛	47⅛
9-cell Tray......	17⅛	18½	18½	29¾	39⅞	30⅜	36	41⅛	45	53⅝	....	....	53⅝	53⅝
10-cell Tray......	18⅞	20⅜	20⅜	32⅛	44⅛	33¼	40⅛	45⅛	50⅛	....	....	....	....	....
11-cell Tray......	21	22¼	22¼	36	....	36⅜	43⅞	....	....	....	....	....	....	....
12-cell Tray......	22¾	24⅜	24⅜	39	....	40⅛	....	....	....	....	....	....	....	....

†The "H" Type has an extra high container allowing for an excess of electrolyte (about 50 or 60 per cent) and permitting longer intervals between "filling." All above types can be furnished with the extra high container if desired. They are designated respectively as B2H, B4H, etc., and have the same electrical characteristics as B2, B4, etc. The difference in height is about 2¾ inches on the Type "A" and 1¾ inches on the Type "B"—the other dimensions remain identical.

‡The "HW" type has an extra high and an extra wide container, allowing for a still greater excess of electrolyte and permitting still longer intervals between filling. Practically all of the above "A" type cells can be furnished with the extra high and extra wide container if desired. They are designated respectively as A-4HW, A-6HW, etc., and have the same electrical characteristics as A-4, A-6, etc. The height of the container is the same as that of the "H" type and the width is the same as that of the next larger type, e.g., the container of the A-4HW and the A-6H is identical in size as is the container of the A-6HW and the A-8H. The other dimensions remain identical.

*Over-all heights are given for bottomless trays. Add ⅜-inch to height and ¼-inch to length for trays with bottoms.

FIG. 68. Data and Tray Dimensions of Edison Battery.

take special precautions not to use the hydrometer syringe of the lead batteries to fill Edison batteries.

7. Never add anything to the electrolyte of battery to prevent freezing. It is nearly impossible to freeze the alkaline solution and no permanent injury is caused by the severest cold.

8. Keep cells clean and vent caps free from crystals or potash salts which are liable to accumulate on cells.

9. Cell tops of marine batteries have a coating of brownish wax (rosin vaseline compound). If this is removed it should be replaced either with rosin vaseline or liquid vaseline.

10. Batteries should be removed from box or compartment from time to time and inspection of cells and compartment made. Make sure no water has accumulated in box or compartment. Remove all dirt and other foreign substances that may have accumulated which may in time short-circuit and damage battery.

11. It is very seldom that a battery is totally discharged in marine service and may become sluggish due to lack of work. If this condition is noted the battery should be completely discharged to zero at normal rate and then short-circuited for one or two hours. Follow this by an overcharge. If the condition is pronounced, this procedure should be repeated; 15 hours at the normal rate is considered an overcharge for the marine batteries, providing they have been discharged and short-circuited to zero voltage.

12. *On charge, and immediately following charge, all storage batteries give off hydrogen gas. Inasmuch as this gas is explosive in the presence of a spark or open flame, extreme care should be taken:*

- (*a*) *that no spark or open flame be permitted near the battery or its compartment.*
- (*b*) *that if battery be put in any other container or cabinet, such container or cabinet be adequately ventilated to allow a rapid dissipation of gas.*
- (*c*) *that all connections be kept tight to eliminate the chance of sparking due to loose connections.*

14. **Charging a Storage Battery**—In order to charge a storage battery it is necessary to connect the positive terminal of the battery to the positive terminal of the charging source, and the negative terminal of the battery to the negative terminal of the charging source.

The voltage of the charging source must always exceed the maximum voltage of the storage battery because the voltage of the battery exerts a back e.m.f. on the charging voltage. If the back e.m.f. of the battery is greater than the charging voltage, no charging current will flow.

A variable resistance is usually connected in series with the charging circuit to regulate the amount of current flowing into the

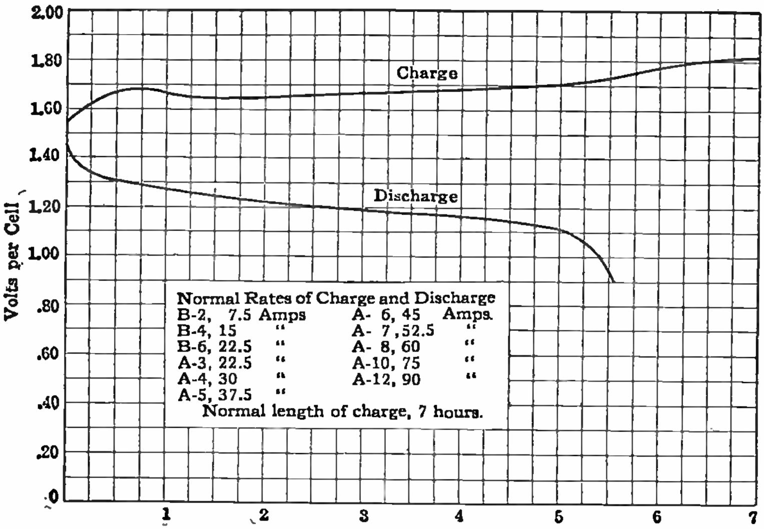


FIG. 69. Characteristic Curve of Charge and Discharge of Edison Battery.

battery. The correct resistance to be inserted in such a charging circuit can be computed from Ohm's law. Assume it is desired to charge a 5-cell A-8 Edison battery by the constant current method from a d.c. line whose voltage is 110. The charging rate as specified by the electrical data accompanying the battery is 60 amperes. Inasmuch as a voltage of 1.85 per cell is required to maintain normal rate at the end of charge the 5 cells in series will require 5×1.85 volts or 9.25 volts at the end of charge. Inasmuch as a voltage of approximately 1.5 per cell is required to obtain normal rate at the beginning of charge the 5 cells in series will require 5×1.5 or 7.50 volts at the beginning of charge.

Ohm's law is modified to read:

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

E = supply voltage,

e = battery voltage,

I = normal charging rate,

$R_1 = \frac{110 - 7.50}{60}$—resistance in ohms to obtain normal rate at beginning of charge.

$R_2 = \frac{110 - 9.25}{60}$—resistance in ohms to obtain normal rate at end of charge.

It will, therefore, be seen that in order to maintain normal rate throughout the entire charging period a resistance will be required which will be variable between the limits of R_1 and R_2. A lamp bank provides a convenient method of adjusting the correct charging rate to a battery. A bank of this type is shown in figure 70. In order to increase the charging rate it would be necessary to increase the number of lamps connected in parallel. To decrease the

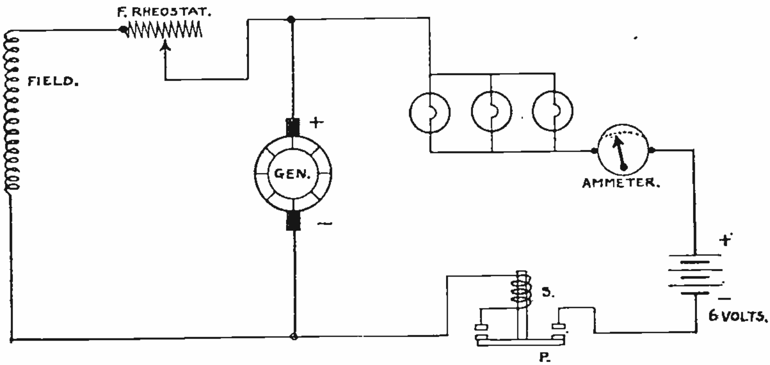


FIG. 70. Charging Circuit with Lamp Bank Resistance and Underload Circuit Breaker.

charging rate the number of lamps in parallel should also be decreased. If lamps of high or low voltage are employed the charging rate would increase or decrease respectively. More recently there are procurable resistance coils which can be conveniently screwed into a lamp socket. This type of resistance has sufficient current carrying capacity to replace several lamps which would otherwise be necessary in order to secure the same charging rate.

A protective device in the form of an underload current breaker is usually employed in charging circuits. In event the charging voltage is cut off or drops below that of the battery, the circuit is interrupted, preventing the battery from discharging through the generator, which usually results in a reversal of the residual magnetism of the field poles, and consequently the output of the generator.

Referring to figure 70 the solenoid *S* is connected in series with the charging current. The magnetic flux created by this current holds the plunger *P* in position to complete the circuit. Should the generator be shut down while charging, the solenoid *S* would be immediately demagnetized and the plunger would drop out, thus interrupting the battery charging circuit.

15. **Determination of Polarity**—The polarity of the charging voltage may be determined by four different ways:

1. By a direct current voltmeter of the movable coil type.
2. By an electrochemical polarity indicator.
3. By the use of a raw potato.
4. By dipping the terminals of the charging mains in a glass of plain or salt water.

Direct current voltmeters of the movable coil type have the correct polarity marked on the binding posts.

If connected properly to a source of direct current the needle will move in the correct direction on the scale indicating the voltage of the mains but if connected improperly the needle will move off the scale in a direction to the left of the zero position. The wire connected to the positive terminal of the voltmeter is the positive terminal of the mains and the other, of course, the negative terminal.

Chemical polarity indicators are composed of a chemical composition within a glass tube provided with terminals; when connected to a source of direct current the positive terminal turns blue.

Sticking the wires momentarily into a raw potato with about an inch or two separation, provides a path for a small current to flow which decomposes the starch of the potato causing that portion of it surrounding the positive terminal to turn blue.

When the terminals are dipped in a glass of plain or salt water, bubbles will appear at the negative terminal.

16. **Charging a Battery when the Voltage Exceeds that of the Generator**—It has already been stated that in order to charge a battery the charging voltage must exceed that of the battery. The majority of batteries employed aboard ships as an auxiliary power supply have a total voltage of 120 volts or more. Usually the Edison batteries in such installations have 90 or more

cells, whereas the lead plate batteries have 60 cells. In order to charge such batteries from the ship's dynamo, which usually generates 110 volts, the battery is split into two banks and the two banks are charged in parallel. When placed on discharge they are connected in series. This is accomplished by either a three-pole or four-pole double-throw switch. The three-pole double-throw switch is employed on the charging panels built by the Smith-Meeker Engineering Company for Edison battery installations. The four-pole double-throw switches are employed with all types of lead plate battery charging panels.

17. **Lead Plate-Sulphuric Acid Battery**—In general, the lead plate-sulphuric acid cell consists of lead plates immersed in a dilute sulphuric acid solution. If two plates were immersed in a dilute acid and then connected to a charging current it would soon be noted that the character of the plates had changed. The plate through which the current entered the solution, called the positive plate, would be brown in color due to the formation of the chemical peroxide of lead on its surface. The other plate or the one by which the current left the solution would become light gray by the formation of pure lead on its surface. Now if the charg-

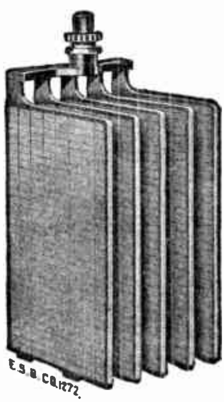


FIG. 71. Negative Plates of Lead Battery.

FIG. 72. Positive Plates of Lead Battery.

ing current be disconnected and a voltmeter be connected in the external circuit, it will be found that the cell will have become a source of voltage and current, and that this current will flow in the reverse direction from the charging current.

18. **Cell Construction**—The average commercial cell is made by "pasting" the active elements into lead grids. After the grids are cast, they are pasted with oxides of lead made into a paste of special composition which sets, in drying, like cement. The plates then go through an electrochemical process which converts the material of the positive plate into brown peroxide of lead and that of the negative plate into gray, spongy lead.

Both the positive and negative plates are provided with an extension or "lug" and they are so assembled that all the positive lugs come at one side of the container and all the negative lugs at the other, thus enabling each set to be burned together with a connecting strap, giving one positive and one negative pole. The burning is done by a hydrogen flame, which melts the metal of both lugs and strap into an integral union. There is always one more negative plate than positive, the outside plates of the grids being negative. The straps are made of hard lead alloy and are provided with posts to which the cell connections are made.

19. **Separators**—To prevent contact between adjacent plates, separators made of light pieces of wood, vulcanite or other material are placed between them. The wood separators used in one type of battery are grooved on the side which goes against the positive plate to allow for circulation of the electrolyte and the escape of the gas generated when charging. To prevent the highly oxidized positive plate from charring the wood, and also to check the washing away of the positive material, due to vibration and the gassing on charge, a thin sheet of perforated hard rubber is placed between the positive plate and the wood separator.

20. **Electrolyte**—The electrolyte for the cell is a dilute sulphuric acid. Sulphuric acid is usually sold and shipped in the concentrated form. It is an oily, syrupy liquid, and much heavier than water. In purchasing the acid for this purpose care must be taken to specify that it be free from iron and other impurities. To prepare this acid for use in one of the cells, one part of acid is added to about four parts of water. *Never add water to the acid,* since the chemical action of this combination is quite violent and there is danger of the steam from the water throwing acid on the hands or clothes of the operator. The acid must be slowly added to the water while constantly stirring the mixture. This process must be carried on in a clean glass, earthenware or lead container. If placed in an ordinary metal container, chemical action will start at

once between the acid and the metal and the electrolyte will become contaminated.

21. **Use of Pure Water**—Only approved water should be used to mix with the acid and to replace that lost by evaporation. Distilled (but not merely boiled) water is approved. Water taken from wells, springs or rivers is often satisfactory, but should not be used unless approved. Never transport or store water in any metallic vessel (lead excepted) and keep receptacle clean and covered, to keep out impurities. Glass, earthenware, rubber or wooden receptacles that have not been used for any other purpose are satisfactory. If water is drawn from a tap, it should be allowed to run a few minutes before using it.

22. **Containers**—The jar or container for portable batteries is usually of a hard-rubber compound; but larger batteries, which are used in a fixed position, are generally contained in glass or lead-lined tanks. The plates rest on stiff ribs or ridges in the bottom of the jar or container, allowing space for the accumulation of sediment.

23. **Hydrometer**—In mixing the electrolyte the correct proportion of water and acid can be exactly determined by test with the hydrometer. The hydrometer is a small glass tube closed at both ends and weighted at one of them. The hydrometer floats in the fluid and displaces the fluid more or less as the fluid is more or less dense. Thus, the density of the fluid can be read at the point where the "water line" of the fluid meets the graduated scale of the tube. The density of pure distilled water in terms of specific gravity scale is 1.000 at 70 degrees Fahrenheit. The specific gravity of the concentrated sulphuric acid is far above this and the water and the acid must be properly combined until the specific gravity of the combination is of the correct value for the particular type of battery. Since the temperature of the electrolyte has its effect upon the density of the electrolyte, the readings must be taken at approximately 70 degrees Fahrenheit, or else corrections for temperature must be applied. The general rule is to add .001 to the hydrometer reading for each 3 degrees above 70 degrees F., and to subtract .001 for each 3 degrees below 70.

24. **Baume Hydrometer**—Some foreign countries do not use the specific gravity hydrometer in taking the density of the electrolyte. The Baume hydrometer is the same as the specific gravity hydrometer except that the scale readings are calculated from different constants.

For liquids heavier than water:

$$\text{Sp. Gravity} = \frac{145}{145 - \text{Baume degrees}},$$

$$\text{Baume degrees} = 145 - \frac{145}{\text{Sp. Gr.}}.$$

Example: What is the Sp. Gr. of the electrolyte of a cell that shows a Baume reading of 29 degrees?

$$\text{Sp. Gr.} = \frac{145}{145 - 29} = \text{Sp. Gr.} = 1.250.$$

The specific gravity of a lead plate sulphuric acid cell increases with charge and decreases with discharge; therefore, the gravity readings are of considerable value in determining the charged or discharged condition of the cell.

25. **Voltage Characteristics**—The voltage of a lead cell is dependent upon the amount of dissimilarity in chemical action between the two plates. It is therefore dependent on the state of the solution and the active material of the plates. It is also dependent on state of charge and whether battery is on charge, or open circuit or on discharge. It is independent of the size of the plates or their number connected in parallel and of the distance between the plates in the liquid. The open-circuit voltage of a lead-acid cell is approximately 2 volts. The open-circuit voltage, however, does not indicate the state of charge. When the lead cell is being discharged at its normal rate, usually given by the manufacturer on the name plate, the voltage at its terminals gradually falls from approximately the open-circuit value to about 1.7 volts, at which point practically the complete capacity of the battery has been delivered. It is not desirable to continue the discharge beyond this point, except when the cell is delivering current at much more than the normal rate; for example, at 10 times the normal rate of discharge it is permissible to continue the discharge until the voltage of the cell has fallen to about 1.4 volts per cell. The average voltage which the cell can maintain during discharge varies with the rate of discharge and the construction of the cell. The average voltage will be about 1.95 volts when discharging at the normal rate. As the cell discharges the specific gravity of the electrolyte decreases. For many types of portable batteries the cell is considered discharged when the specific gravity has fallen to 1.140.

26. **Unit of Capacity**—The capacity of a storage battery is rated in ampere-hours. The ampere-hour is the unit employed to

express the equivalent quantity of current represented by current of one ampere flowing through a given circuit for an hour of time. The ampere-hour capacity of a cell depends for the most part upon the amount of active surface of the plates exposed to the solution. It is therefore proportional to the area and the number of plates.

27. **Ratings**—The normal discharge rate of a battery is usually obtained by dividing the total ampere-hour capacity of the battery by the normal continuous discharge rate. If the battery is discharged at the normal discharge rate it will give its normal ampere-hour capacity by the time it reaches its discharge voltage limit. If discharged at less than its normal discharge rate it will give more ampere-hour capacity and if discharged at more than its normal discharge rate it will give less ampere-hour capacity. A battery of 210 ampere-hour capacity with a normal discharge rate of 21 amperes can be expected to last for 10 hours if discharged at its normal rate. If discharged at only 7 amperes it will last more than 30 hours, whereas if it were discharged at 30 amperes it would reach its discharge voltage limit within less than 7 hours.

28. **The Ampere-Hour Meter**—This instrument is of particular advantage in denoting the state of charge or discharge of a battery. It is in the form of a small motor connected in series with the charge and discharge of the battery and operates a pointer which moves over a dial calibrated in ampere-hours. The speed at which the motor operates depends upon the amount of current entering or leaving the battery. It is so constructed that a revolution counter connected to the motor records directly in ampere-hours the quantity of electricity passing through the meter. When the battery is fully charged the pointer on the dial reads zero. As the battery is discharged the pointer moves in a clockwise direction toward the full scale reading. A red pointer on the meter is usually placed at the number corresponding to the capacity of the battery with which the meter is employed. When the rotating pointer reaches this point it is an indication that the full ampere-hour capacity of the battery has been utilized and it should be placed on charge. As the battery charges the pointer moves in a counter-clockwise position and just before reaching the zero or fully charged position the pointer makes contact with a projection that operates a set of contacts which causes the underload circuit breaker to trip, disconnecting the battery from the charging source. This type of meter runs slower on charge than on discharge so as to allow some necessary overcharge.

29. Discharge Voltage Limits—The discharge of a battery must be stopped when it has reached the discharge voltage limit which depends—upon the type of cell, the concentration of the acid, and the rate of discharge. The discharge voltage limit when given on the battery name plate is for the normal discharge rate.

A battery discharged at a high rate can be carried to a lower voltage limit than a battery discharged at a long low rate. During high rates of discharge the chemical reactions in the cell are very rapid, forming sulphate in the outer layers of the active material of the plates, making it difficult for the acid to reach the interior portions of the plates and increasing the internal resistance of the cell, causing the voltage to drop quickly. It may be allowed to drop lower than during either a long low or an intermittent rate discharge, since at a low rate the acid reaches the interior portions of the plates, reduces them to sulphate, and when the voltage limit is reached there is very little capacity left in the plates. In a short or high discharge to the voltage limit only a fraction of the capacity of the cell is withdrawn, although the voltage is carried lower than during a long low discharge, when the cell is more nearly exhausted.

30. Chemical Action During Charge and Discharge—When a cell is fully charged the negative plate is lead sponge, Pb, and the positive plate is lead peroxide, PbO_2, the specific gravity of the electrolyte (sulphuric acid, H_2SO_4, and water, H_2O) is at its maximum between 1.210 and 1.220 (marine radio batteries, Sp. Gr. higher for some other types), temperature 70 or 80 degrees F. Chemical energy is stored in the cell in this condition.

If the cell is put on discharge the H_2SO_4 of the acid is divided into H_2 and SO_4. The H_2 passes in the direction of the current to the positive plate, and combines with some of the oxygen of the lead peroxide and forms H_2O; the SO_4 combining with the liberated Pb of the positive plate to form lead sulphate. The SO_4 also forms lead sulphate, as the negative or lead sponge, Pb, plate. As the discharge progresses both plates are finally reduced so that they contain considerable lead sulphate, $PbSO_4$. The water formed has diluted the acid lowering the specific gravity of the electrolyte; when the plates are entirely sulphated current will cease, since the plates are identical, and any electric cell requires two dissimilar plates in the electrolyte. In common practice, however, the discharge is always stopped before the plates have become entirely reduced to lead sulphate. The lead sulphate that has formed by the acid in contact with the plates is more bulky than the lead sponge or lead peroxide just as copper sulphate on copper, or iron rust on iron, is more bulky than the amount of copper or iron eaten away. The lead sulphate, on account of its increased volume, fills the pores of the active material until finally near the end of discharge, the circulation of acid in the pores of the plates is retarded due to the increased bulk of the lead sulphate. Since the acid cannot get into the plates to maintain the normal action, the cell becomes less active, as indicated by the drop in voltage.

To charge the cells direct current is passed through the cells in a direction opposite to that of discharge. This current passing through the cells in the reverse direction will reverse the action which took place in the cells during discharge. It will be remembered that during discharge the acid of the electrolyte went into and combined with the active material, filling its pores with sulphate and causing the electrolyte to become weaker. Reversing the current through this sulphate in the plates restores the active material to its original condition and returns the acid to the electrolyte. Thus, during charge the lead sulphate, $PbSO_4$, on the positive plate is converted into lead peroxide, PbO_2, while the lead sulphate on the negative plate is converted into sponge lead, Pb, and the electrolyte gradually becomes stronger as the SO_4 from the plates combines with hydrogen to form acid, H_2SO_4, until no more sulphate remains and all the acid has been returned to the electrolyte. It will then be of the same strength as before the discharge and the same acid will be ready to be used over again during the next discharge.

Since there is no loss of acid, none should be added to the electrolyte.

31. **Object of Charging**—The acid absorbed by the plates during discharge is, during charge, driven from the plates by the charging current and restored to the electrolyte. This is the whole object of charging.

32. **Charging Methods and Gassing**—A battery can be charged at as high a rate as desired until it starts gassing. When fully discharged, but not overdischarged, it can absorb current at the highest rate. As the charge progresses, the plates can no longer absorb current at the same rate and the excess current goes to form gas. In a battery which is charged or nearly charged, the plates can absorb current without excessive gassing only at a low rate, and a high charge rate will be almost entirely used in forming gas, resulting in high temperature and wear on the plates.

33. **Overcharge**—Persistent overcharging not only tends to wash out the positive active material, but also acts on the positive grids, sometimes giving them a scaly appearance.

34. **Injurious Effects of Local Action**—There is another chemical action which takes place in any battery, termed "local action." This is going on all the time whether or not the battery is in use, and during all states of the charge. The lower the state of charge, the more injurious are the effects of local action, and the higher the density of the electrolyte used the more vigorous its action. The temperature of the electrolyte also has an effect on the local action—the higher the temperature the greater the effect. In addition to causing a battery to lose its charge, local action produces a lead sulphate of a different composition from that produced by electro-chemical action. The lead sulphate produced by local action is of a much harder texture than that produced by normal electro-chemical action and has a whitish crystalline appearance. It also has a high resistance and is insoluble in sulphuric acid. On account of the nature of this material, if allowed to accumulate on the active material to any appreciable extent, it will cause an increase in the internal resistance of the battery and a reduction in its capacity. This sulphate also tends to cause the plates to bend and buckle if allowed to go unchecked, because it continues to increase in volume as long as there is any sulphuric acid in the electrolyte. This is more noticeable where the sulphate has once gained foothold. In such cases the ordinary amount of charging will not bring the density of the electrolyte up to the proper specific gravity, and as the natural tendency of the repair personnel will be to add electrolyte, a trouble which has already gained headway will be aggravated.

35. **Treatment to Remove Sulphate Produced by Local Action**—If this injurious sulphate is not allowed to get too great a headway, it may be removed by long low-rate chargings. This method requires considerable time and is expensive, but is the only practicable one that can be employed without removing the elements and scraping them. Scraping the plates is objectionable, because in so doing a quantity of the active material is unavoidably removed with the sulphate, which naturally reduces the capacity of the battery. This sulphate forms not only on the surface of the plates, but also in the active material beneath the surface. The only proper course to follow is to take the necessary precautions to prevent as far as possible the formation of this sulphate to any appreciable extent. This can be done by remembering that local action is dependent upon the state of charge, the density, and the temperature of the electrolyte, the lower the state of charge and the higher the density and temperature the more injurious the effects. The local action thus far discussed is a natural conse-

quence under the conditions mentioned, even though the electrolyte is pure, but if impurities are introduced, a multiplicity of chemical actions will be set up which will have a disastrous effect on the plates.

36. **Buckled Plates**—Buckled plates are plates which have been bent and warped out of shape. Lead, like most all material, will expand under the action of heat, but it has a very low elastic limit, and once expanded, it will remain in that condition. If the temperature is kept below 110 degrees F. there will be no trouble from this source. Most buckled plates are caused by continued overdischarge or lack of charge.

37. **Height of Electrolyte**—The height of the electrolyte should be kept at the correct height above the tops of plates at all times. This height varies with different makes and types of batteries, but in general it should be kept as high as will allow the battery to be charged without overflowing; that is, without causing the electrolyte to run out at the filling tubes while charging.

38. **Maximum Gravity and Equalizing Charge**—By maximum gravity charge is meant, as the term implies, charging the battery until the density of the electrolyte reaches its maximum specific gravity. The object of the maximum gravity charge is to offset the effects of local action and to bring all the cells into step with each other in regard to state of charge. Instructions for carrying out maximum gravity and equalizing charge are usually given by the manufacturer.

39. **Trickle or Floating Charge**—A method of charging a battery held ready for emergency work or a battery out of service is what is known as a "trickle or floating charge." With this method a small charging current is passed *continually* through the battery. This low rate of charge will keep batteries in good condition with minimum attention. The only precautions to be observed are that reasonably good ventilation is provided and that water is added at sufficiently frequent intervals to prevent the plates from becoming uncovered. If the system is designed to keep the battery fully charged automatically, its operation should be checked periodically until it is certain that the system is not giving too much nor too little charge. If the cells gas continually, the battery is receiving too much charge. If the gravity continues to drop, the battery is not receiving enough charge.

For a battery which is on trickle charge 24 hours every day, if the adjustment is correct the voltage directly at the battery terminals will be between 2.10 and 2.30 volts per cell and should average very close to 2.15 volts per cell. If it is continually below

2.10, the charging is insufficient. If continually above 2.20 it is excessive. (These values are correct for batteries whose full charge gravity is 1.200–1.22—but not for other batteries.)

There is a wide-spread impression that a lead and acid battery held ready for emergency should be given periodical cycles of discharge and charge in order to maintain its normal capacity. If such a battery is kept on a trickle or floating charge, at the required rate, when not in use, it will be fully charged and capable of delivering its maximum capacity at the normal discharge rate during an emergency.

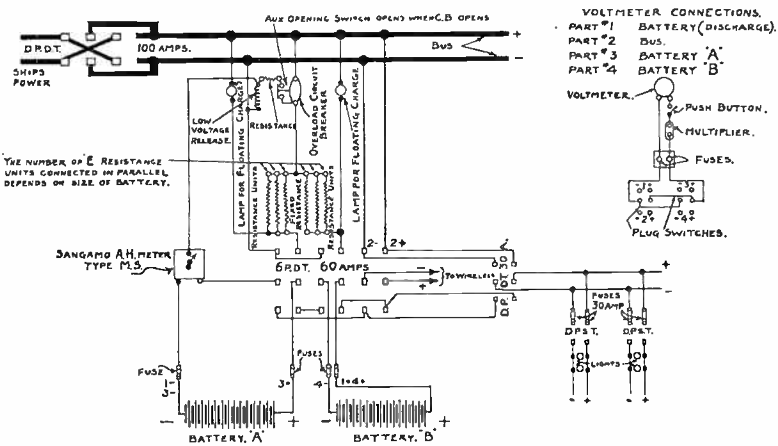


FIG. 73. Diagram of Exide Storage Battery Company's Switchboard.

40. Exide Storage Battery Switchboard—The ship's power circuit is connected through the large upper double-pole double-throw switch which is so connected that in case of the reversal of the polarity of the ship's power the same relation between the power bus and the battery can be obtained by reversing the switch. The circuit breaker is equipped with overload, low-voltage release, and automatic trip operated by the ampere-hour meter.

41. Operation—First determine that the power bus switch is closed in the proper direction by observing whether the voltmeter reads when the plug switch is in the lower left-hand receptacle. If it does not read, reverse the power bus switch, then ascertain that the two halves of the battery are also properly connected by taking readings in the upper and lower right-hand receptacle. The voltmeter circuit is normally open and a push button switch is provided on the switchboard for closing the circuit when it is desired to take a voltage reading. This precaution is taken to prevent inductive effects incidental to the operation of the radio outfit damaging the meter.

42. **To Charge the Battery**—Close the circuit breakers at the time, holding up the plunger of the low voltage release coil, and then close the 6-P.D.T. switch to the left. This will place the respective halves of the battery on charge through the charging resistances on the back of the board. The red pointer on the ampere-hour meter should be set at the numbering corresponding to the capacity of the battery in use. The black hand of the ampere-hour meter indicates the state of discharge of the battery at any time. As soon as the charge is started the black hand will begin to move towards zero and the charge should be completed when it reaches zero. When the black hand reaches zero it makes a contact which opens the circuit breaker by means of the automatic trip, thus automatically cutting off the charge. For the equalizing charge; or if for some other reason the battery requires an overcharge, it is necessary to remove the cover from the ampere-hour meter, or, by the use of a key furnished with the same, and turn the black hand to the proper point. (As determined by reference to the battery instructions.)

If when the battery is charging the ship's power circuit fails, the low voltage release will open the circuit breaker, preventing the battery from discharging back into the bus. The battery can be used for supplying current in such an emergency as described under "Discharging the Battery."

43. **To Float the Battery**—With the 6-P.D.T. switch closed to the left and the circuit breaker open, the charging circuit through the resistance units will be open, but the battery will be receiving a floating charge through the two lamps mounted in the upper corners of the switchboard. This is intended to be the normal condition of operation; i.e., battery fully charged and floating, with circuit breaker open, and 6-P.D.T. switch closed to the left, the radio circuit is connected direct to the bus. When the battery is floating or charging, the lights cannot be operated from it, and the lower double-pole double-throw switch should then be closed to the left. The feeder switches for the various light circuits can be opened or closed, as desired.

44. **To Discharge the Battery**—With the circuit breaker open, close the 6-P.D.T. switch to the right. With the battery discharging the lights can be operated from either the bus or the bat-

tery by closing the small lower double-pole double-throw switch to the left or right, respectively.

Whenever the ship's dynamo is shut down care should be taken to open the radio circuit switch on the ship's switchboard.

45. Operating Exide Batteries in Emergency Radio Service on Ships—Keep the battery and surrounding parts dry and

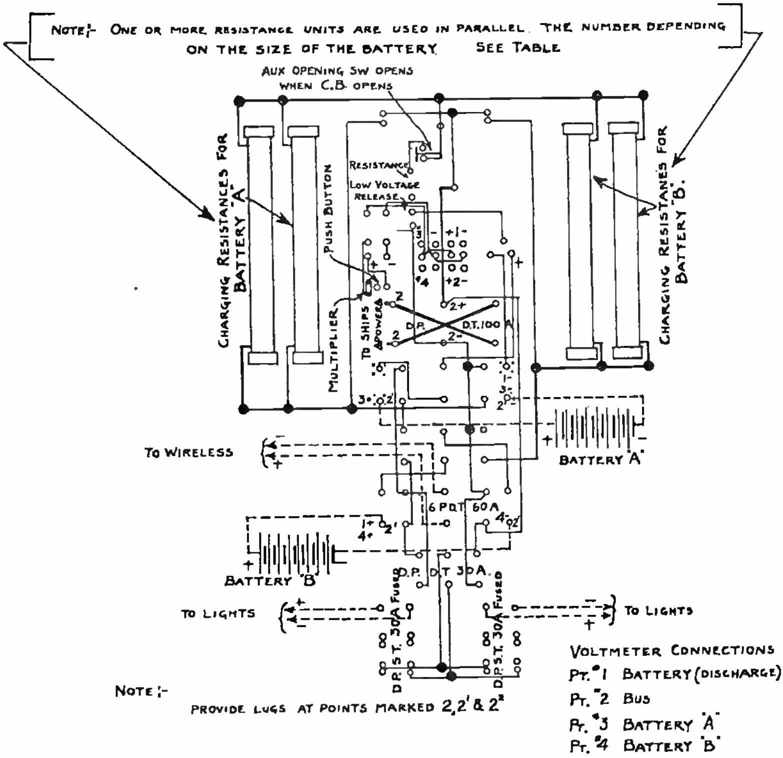


FIG. 74. Back View of Wiring of Exide Storage Battery Switchboard.

clean. If electrolyte is spilled or if wood trays (or compartments) are damp with acid, apply a solution of cooking soda and water, then rinse with water and dry; do not allow soda solution to get into cells. Soda solution or ammonia will neutralize the effect of acid on clothing, cement, etc.

46. Replacing Evaporation—Do not allow the surface of the electrolyte to get below the top of the separators; keep it above by adding sufficient suitable water to each cell as often as necessary. Do not fill higher than 1/2 inch above the top of the plates. In cold weather the time to add water is at the beginning of a charge, so that gassing will insure thorough mixing and any danger of the water freezing be avoided. It will never be necessary to add new electrolyte, unless some should be spilled. Never transport or store water in any metallic vessel (lead excepted) and keep receptacle clean and covered, to keep out impurities. Glass, earthenware, rubber or wooden receptacles that have not been used for any other purpose are satisfactory. Only suitable water should be used for replacing evaporation. Distilled water is suitable. Rain water is usually satisfactory, if obtained on a clean roof in a clear atmosphere, but care should be taken to allow the rain to flush the roof before catching the water.

47. **Pilot Cell**—The specific gravity of all cells in series on discharge and charge falls and rises together, so that the gravity reading of the electrolyte of one cell, known as the "pilot cell," will indicate the state of discharge or charge of the series as a whole. As the battery is divided into two parallel series for charge, a pilot cell in each half is necessary.

48. **Discharging**—The system is laid out with the idea that the battery is to be discharged only in emergencies.

49. **Discharge Limits**—In emergency, little if any permanent harm will result if the battery is discharged to the full amount that it will give (provided that it is immediately recharged) but overdischarging *as a constant practice will soon result in permanent damage.*

50. **Floating**—The battery is to be floated at all times, except when charging or discharging. When floating, both lamps on battery, switchboard will burn dimly. If either lamp goes out, immediately replace it with another of proper rating.

In order to check the generator polarity and to guard against the battery becoming accidentally discharged through the reversal of the generator, read the voltmeter frequently with the voltmeter plug in opening marked "Bus." If the polarity has changed, throw over the switch marked "Reversing Switch."

The system is designed to keep the battery fully charged and its operation should be checked every week or so until it is certain that the system gives neither too much nor too little charge. With proper adjustment, the specific gravity of the pilot cell will remain practically constant (within 5 to 10 points if level of electrolyte is kept the same height) and the cells will not be gassing. If the cells gas continually, the battery is receiving too much charge. If the gravity continues to drop, the battery is not receiving enough charge. Adjust the charging current if necessary by changing the floating lamps, using higher wattage to increase rate or lower wattage to decrease. Make another check after a week or so, repeating until it is certain that the system gives neither too much nor too little charge. The adjustment can then be considered correct and will only require occasional checking.

51. **Charging**—After discharges of any kind totaling one-tenth capacity or more, immediately put the battery on charge and combine the charging until the black hand of the ampere-hour meter has returned to zero. Once each month, preferably during fair weather, charge the battery. Move the black hand of the ampere-hour meter back, halfway to the red hand, and charge until the "pilot cell gravity" and the voltage of each side have remained constant for one hour and all cells have been gassing or bubbling freely for the same length of time. This means that, under normal conditions, the charge will be of about two hours' duration. When charging, keep the bus voltage at 110 volts as, if it is low, the charging rate will be reduced and the time required to charge correspondingly increased. For example, a bus voltage of 100 volts reduces the charge rate one-third and therefore increases the time 50 percent; a 90-volt reduces the rate two-thirds and triples the time.

Raise the covers of the battery box during this charge and *never bring a lighted match or other exposed flame near the battery as this might cause an explosion.* Keep the vent plugs in the cells. Do not remove them during charge except to take specific gravity or temperature readings. After the charge, reset the black hand of the ampere-hour meter to zero.

52. **Specific Gravity of Electrolyte**—The normal specific gravity of the electrolyte should, with the cells fully charged, be between 1.260 and 1.295 for all marine types with the exception of type MVS, for which it should be between 1.200 and 1.220.

It will never be necessary to add new electrolyte, except in connection with replacing actual loss of electrolyte due to spillage or similar causes. Before adjusting low gravity by adding acid, first make sure charging will not raise the gravity. To do this, continue charge until specific gravity shows no rise, and then for five more hours. Never make a gravity adjustment on a cell which does not gas on charge. To adjust low gravity, add new electrolyte of 1.300 specific gravity instead of water when replacing evaporation until the gravity at the end of an equalizing charge is up to 1.260 (1.200 for type MVS). Then stop adding electrolyte and replace all further loss from evaporation with suitable water. Do not adjust higher than 1.260 (1.200 for type MVS) and do not add electrolyte of higher gravity than 1.300 directly to the cells.

53. **Impurities**—Impurities in the electrolyte will cause a cell to work irregularly. Should it be known that any impurity has gotten into a cell, it should be removed at once. In case removal is delayed and any considerable amount of foreign matter becomes dissolved in the electrolyte, this solution should be replaced with new immediately, thoroughly flushing the cell with water before putting in the new electrolyte.

54. **Broken Jar**—If a jar should become broken, do not allow the plates to dry. If there is no extra jar on hand, remove the cell (either with or without its jar) from the circuit, immerse it in a wooden bucket filled with water and keep it covered with water until ready to reinstall it.

55. **Indications of Trouble**—The chief indications of trouble in a cell are:

(*a*) Falling off in gravity or voltage relative to rest of the cells.

(*b*) Lack of gassing on charge.

If a battery seems to be in trouble, the first thing to do is to give it a charge. Then take a gravity reading of each cell. If all the cells gas evenly on the charge and the gravity of them goes above 1.225 (1.180 for type MVS), most likely all the battery needed was the charge; otherwise, record all gravities less than this, resume charge and continue until three consecutive half-hourly readings of the gravity of all these cells show no increase for any of them. Then make gravity adjustment on those which are still below this and which are gassing. Before making an adjustment, determine whether the jar is cracked by adding water to the proper height and allowing cell or jar to stand several hours, noting whether level falls. If a jar is changed, charge it. If a cell will not gas on above charging, investigate for impurities.

If in doubt as to whether the electrolyte contains impurities, a half pint sample should be submitted for test. The Electric Storage Battery Company will analyze and report on, free of charge, samples received at its works (Allegheny Ave. and 19th St., Philadelphia, Pa.) with transportation charges prepaid; provided the battery in question is an Exide.

56. **Mathews Auxiliary Power Plant**[1]—Models 3F and 5F—The model 3F is of 3-kilowatt capacity and is equipped with a

[1] Manufactured by Mathews Engineering Co., Sandusky, Ohio.

2-cylinder gasoline engine as its prime mover. The model 5F is of 5-kilowatt capacity and is powered with a 4-cylinder gasoline engine. These two models are of the same bore and stroke and of the same general construction and type except for appearance and dimensions. The switchboards for both plants are the same.

Since the operation of the two models is identical these instructions will cover the care and operation of both sizes and plants.

57. **Automatic Features**—The object of the automatic features on the model 3F and 5F switchboards is—

1. To give the operator a plan which requires the very least amount of personal attention.
2. To give the storage batteries proper protection and care. This is accomplished mainly by the ampere-hour meter and the overload relay. Briefly the operation is as follows: When approximately 15 percent of the battery capacity has been used, the ampere-hour needle reaches the "start" point, thus putting the plant into operation, recharging the batteries and automatically shutting down when "full" point is reached.

The second important automatic feature is the overload relay. Batteries should never be subjected to a load greater than their normal rate of discharge for any continued period of time. The switchboard is equipped with an overload relay which starts the plant automatically whenever a load is turned on. The plant will continue to run and the heavy load will be taken directly from the generator as long as this heavy load continues, even though the ampere-hour meter needle may be at the "full" point.

Always remember that once the plant is started it will continue to operate until the meter needle reaches "full" point and even then the plant will continue to operate if there is a heavy load on the line. When, however, the meter needle is at "full" point and the heavy load is reduced to an amount which the batteries can carry without the aid of the plant, the plant will automatically stop.

58. **Protective Features**—The Mathews full atuomatic switchboard is provided with the necessary protective features so that the battery cannot become completely discharged. The first protective feature is the time element (described more fully in a later paragraph) which will permit the batteries to crank the plant only for a definite period of time. If the plant fails to start for any reason whatsoever, the circuit breaker prevents the batteries from "motoring" the generator indefinitely in an effort to start the engine.

The second protective feature is the "empty" point on the ampere-hour meter. Should the meter needle ever go below the "start" point, either through failure of the plant to start automatically or in case the hand might be moved back manually, it is arranged so that when approximately 50 percent of the battery capacity has been used the meter needle will make contact at the "empty" point. It will then trip the circuit breaker and prevent further discharge of the batteries until personal attention is given to the plant and the battery is brought back to full charge.

59. **Switchboard**—The control instruments of the Mathews plant are mounted on a special composition panel. The complete theoretical diagram of the Mathews control, as shown in figure 75, is of much importance because a study of this diagram will make the operation of the plant easily understood.

60. **Method of Operation**—Referring to figure 75, the com-

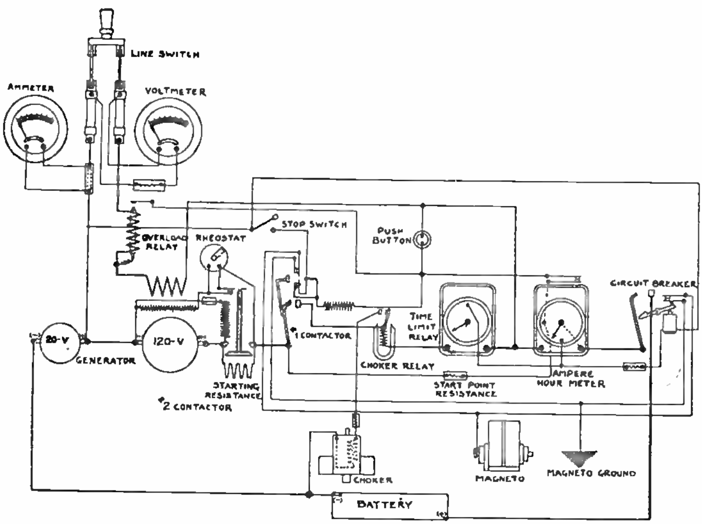


FIG. 75. Theoretical Wiring of Model 3F and 5F Mathew's Power Plant.

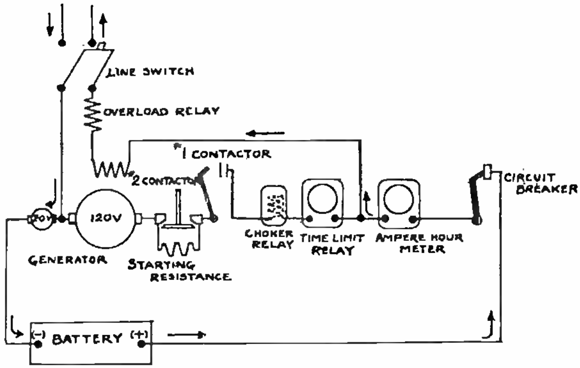
plete theoretical wiring diagram, applying to both model 3F and model 5F, starting at the positive battery connection, it will be noted that this line goes first to the circuit breaker. When the circuit breaker is open, therefore, the entire plant and the load is entirely disconnected from the battery. On normal operation the circuit breaker must always be closed.

From the circuit breaker the main line may be followed successively through the ampere-hour meter, the time limit relay and the choker relay, up to No. 1 contactor. Here, again, the circuit is broken by the opening of this contactor. It is by means of No. 1 contactor that the generator is automatically connected or disconnected, as demanded by conditions. From the No. 1 contactor, the main line runs to No. 2 contactor. Observe, however, that the circuit is not entirely broken at this point, as a path or circuit is provided around No. 2 contactor through the starting resistance. From this point the main circuit leads directly to the positive terminal of the 120-volt generator. Leaving the 120-volt generator at the negative terminal the circuit runs to positive 20-volt generator, through this generator to the generator negative 20-volt terminal, and thence to the negative battery connection, completing the circuit.

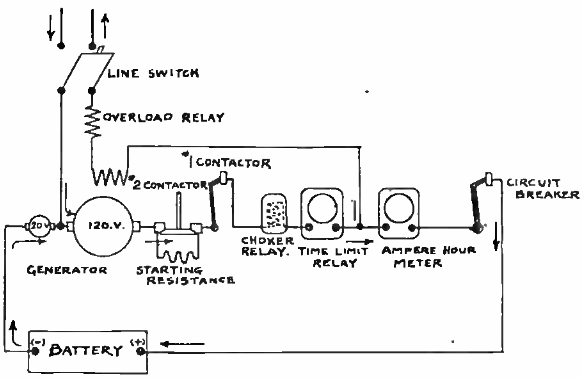
The circuit just traced out is that of the main "battery-generator." To trace the "load" circuit, note that the main line is tapped between the ampere-hour meter and the time limit relay. Starting at this junction, the load line runs through the generator series field, through the overload relay, to the positive terminal of the line switch. Returning through the lamps or appliances on the line to the negative terminal of the line switch, the load current passes through the ammeter shunt to the positive 20-volt generator connection. From this point the load circuit is complete either to the negative 120-volt generator terminal (in case the plant is running) or (if the plant is stopped) to the negative battery connection through the 20-volt generator. It is thus seen that the load may be carried either by the battery or direct from the 120-volt generator, depending on whether the plant is running or idle. To make this point perfectly clear, refer to figure 76. This cut shows, by means of arrows, the flow of load current when the plant is stopped and running.

In the above description, as well as in the cut, reference is made to the 120-volt and 20-volt generators. Actually these two machines are combined into one generator, having a commutator at either end of the armature. The purpose of the double commutator machine is to provide two voltages, one at 120 volts, for the lamps and appliances, the other 20 volts higher, or 140 volts, for charging the battery. In this way it is possible to provide the higher voltage necessary to charge the battery and at the same time maintain the lamp voltage constant at 120 volts, regardless of whether the plant is running or stopped. Figure 76 clearly illustrates how this is accomplished.

Referring again to figure 76, the control circuits may be readily traced out. As already explained, the starting and stopping of the plant is effected by the closing and opening of No. 1 contactor.



MAIN CIRCUIT - PLANT IDLE



MAIN CIRCUIT - PLANT RUNNING.

FIG. 76. Circuit of Plant—Running and Idle.

This contactor is controlled automatically either by the "start" point of the ampere-hour meter or by the contacts of the overload relay. The closing of either of these contacts energizes the coil of No. 1 contactor, closing it and automatically starting the plant. The same thing may be accomplished manually by pressing the push button.

61. **The Circuit Breaker**—The purpose of the circuit breaker is to break the connection between the generator and the battery in order to prevent overdischarging the battery, as previously explained, in case of engine trouble. The circuit breaker may also be tripped by hand if desired, by pressing the latch. This disconnects the battery from the plant and should be done whenever any electrical repairs or adjustments are made on the switchboard. The circuit breaker is engaged again by pressing in the contact arm handle. In case the latch does not engage with the contact arm, when the latter is pressed in, raise the latch with the fingers until it engages, holding the arm in position. The circuit breaker is operated automatically from the time limit relay, and also from the "empty" point on the ampere-hour meter. As already explained, it is not advisable to continue cranking over two minutes. At the end of two minutes the hand of the time limit relay makes contact at the cutout point, marked *O* on the dial. This point will be found to be in series with the circuit breaker coil, and on energizing this coil, the latch is tripped, the main circuit is broken and automatic cranking stops.

CHAPTER 4

THEORY AND APPLICATION OF THE VACUUM TUBE

Construction—The vacuum tube as employed in radio consists of a glass vessel similar in shape to the ordinary house lamp but exhausted to a higher degree of vacuum. Within the glass tube are three important elements known as the filament, grid and plate. They are insulated from each other and electrical con-

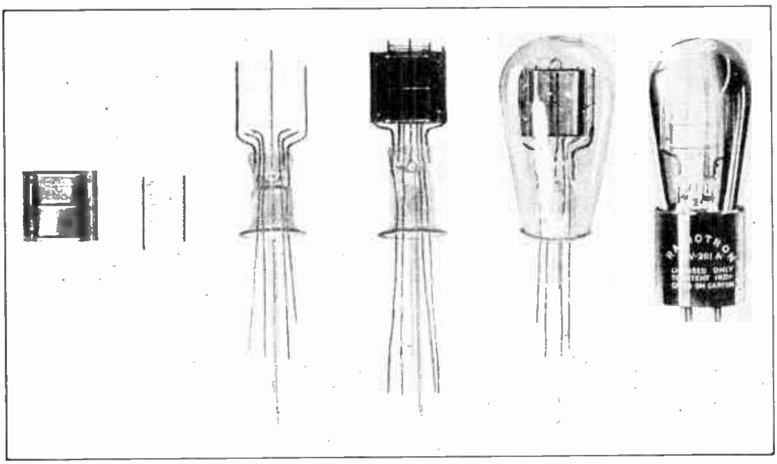


FIG. 77. A Vacuum Tube in Various Stages of Assembly.

nections to each are made by bringing out leads through the glass stem of the tube to the composition base upon which terminal pins are mounted. The base of the tube is constructed to fit into a device called the socket. The socket is provided with contacts that engage the terminal pins when the tube is placed in it. Binding posts on the socket make electrical connection to the contacts and provide means of connecting the elements to an external circuit. Two binding posts are provided for the filament and one each for the grid and plate.

1. **Thermionic Electronic Emission**—All substances are made of electrons. Electrons as described in the first chapter are

negative particles of electricity. Consider a piece of metal. These small negative particles move about in the metal taking zigzag paths in all directions. Their velocity of motion depends upon the temperature, increasing with temperature. If the metal is heated the electrons attain sufficient velocity to fly off the surface, exactly as the components of water when it is boiled. The heated filament in the vacuum tube is in this manner a source of electrons. A little study further will show that special types of filaments will give off many electrons without requiring much power for heating.

The filaments are usually constructed of tungsten wire. The number of electrons thrown off by such a filament will be greatly increased if certain chemicals are added to the tungsten wire at the time of manufacture. Such chemicals as thorium, barium and strontium are used for this purpose and are either drawn with the wire or cemented upon it. Vacuum tubes having thorium drawn with the tungsten wire are known as thoriated filaments. Those having a coating of barium and strontium are called oxide or coated filaments. Tubes having thoriated oxide filaments operate at much lower temperature than those having plain tungsten and but little light is thrown off. They are sometimes called dull emitters. Variable resistances to regulate the current are usually connected in series with the filament circuits.

Just as water will boil more enthusiastically if the generated steam is pumped away and a vacuum maintained, so will more electrons come off the filament if the free ones are constantly drained away by the attraction of a positively charged plate. The plate is constructed of nickel and surrounds the filament and insulated from it. A positive charge is placed on the plate, by connecting it to the positive terminal of a "B" battery or d.c. supply. The filament of the tube is usually heated by connecting it to a battery called the "A" battery or by a.c. from the lighting circuit by use of a stepdown transformer. The negative terminal of the "B" battery is connected to one terminal of the "A" battery. The positively charged plate attracts the free negative electrons and they are transported through the space between filament and plate. This stream of electrons from filament to plate furnishes a connecting

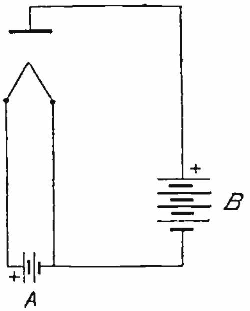


FIG. 78. Connections of "A" and "B" Battery to Vacuum Tube.

medium or path for a current which flows from the "B" battery to the plate, from plate to filament and filament to "B."

It should be noted that the direction of current flow is opposite to that of electron flow. This is in accord with the adopted theory that the direction of an electric current is from the point of positive to the point of negative potential as explained and illustrated in the first chapter.

If the plate potential was made negative, that is, if the connections to the "B" battery are reversed, the electrons would be repelled and little or no current would flow. If the battery "B" were replaced by an alternating current generator, the electrons would be attracted during the positive alternation and current would flow only during this half cycle. On the negative alternation the electrons would be repelled. Thus the tube acts as a rectifier allowing its current to flow in one direction and not in the other. Vacuum tubes as rectifiers have an important application in radio circuits as will be described later.

2. **Use of A.C. Vacuum Tubes**—Although alternating current has been used successfully in operating the amplifier and oscillator tubes of transmitters it is only of late that this method has achieved success with receiving tubes. The chief drawback has been the a.c. hum caused by grid-and-plate effect. If the grid return is made to the negative *B* and one side of the filament as in usual practice, the a.c. component of the filament voltage from the step-down transformer will act on the grid and plate of the tubes exactly as a signal voltage, thus producing a loud 120-cycle hum. By connecting the grid return to the mid-point on a potentiometer this hum can be balanced out on the amplifier tubes. However, this is not adaptable to the detector with grid condenser and leak operation, as it is susceptible to any stray low frequency electric disturbances. In order to eliminate the hum from the detector tube, a heater-cathode method is employed. As already explained, heating the filament is necessary in order to cause it to emit electrons. With the heater-cathode method electrons are emitted by another strip of metal placed close to the filament and heated by it. Such a vacuum tube has five prongs, the two filament connections, the cathode, plate and grid. The grid return is made to the cathode and is therefore not subject to the a.c. reversals of current, thus eliminating the hum.

3. **Action of the Grid**—Between the plate and the filament is the wire grid. The grid is much closer to the filament than the plate and hence a charge on the grid has much more effect on the flow of electrons than would a similar charge on the plate. A

small negative charge on the grid would repel the electrons and hence oppose their flow to the positive plate. On the other hand a positive charge on the grid would assist the flow of the electrons and more current will flow through the tube. Thus the grid acts as a valve to regulate the flow of current in the tube.

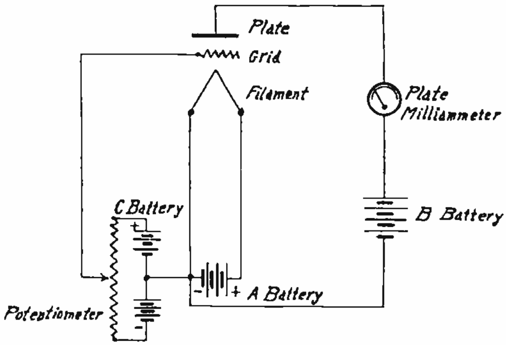


FIG. 79. Arrangement for Varying Grid Potential.

In the arrangement of figure 79 it is possible to demonstrate how small variations of grid potential are sufficient to produce large changes in the plate current. Referring to figure 79 it is possible to vary the potential on the grid by the potentiometer connected across the terminals of the battery "C." If the grid is made negative in respect to the filament electrons will be repelled by the grid resulting in a decrease of plate current as indicated by the milliammeter connected in the plate circuit. By varying the potentiometer the grid potential may be made sufficiently negative to stop the flow of plate current entirely. On the other hand by making the grid positive, electrons are attracted by both the positive grid and plate resulting in more electrons being drawn to the plate which will be manifest by an increased plate current.

4. Characteristic Curve—By plotting the different values of grid voltage against plate current the characteristic curve of the plate current is secured. Figure 80 shows such a curve. Characteristic curves may be also secured by plotting grid voltage against grid current; also plate voltage against plate current with a fixed grid potential. The values obtained by these methods are very useful when combined with values of the apparatus to be used with the tubes.

A study of curve *A* in figure 80 will show that with a fixed plate voltage, as the grid voltage is made positive, the plate current gradually increases. A limit is finally reached whereby an increase in grid voltage produces no increase in plate current.

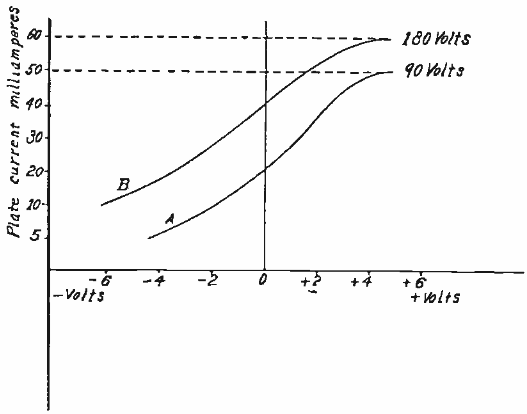


FIG. 80. Characteristic Curves of a Vacuum Tube.

Thus a limiting value or saturation point is attained by the plate current. A positive potential on the grid assists the attainment of this saturation point caused by the grid absorbing more electrons. This absorption causes a small grid current to flow from grid to filament, filament to battery "C," battery "C" to grid. The total electron flow is the sum of plate and grid current. The only way in which the plate current can be further increased is by either increasing the filament temperature or by increasing the plate voltage (curve *B*).

5. **Detector Action**—The three electrode vacuum tube may be used as a detector of radio frequency currents by employing the properties of the tube when worked at the curved portion of the plate-current grid voltage curve or by the properties of the tube when worked at the curved portion of the curve showing the relation of grid voltage and grid current.

The first method consists of establishing a normal grid voltage of sufficient value to operate the tube at that part of the characteristic curve whereby the radio frequency voltages communicated to the grid cause unequal changes in the plate current. Figure 81 shows the connections necessary to employ this method of detection. The antenna is connected directly to the inductance. The circuit is tuned to resonance with the desired transmitting station by the condenser C-1. The battery " A " heats the filament of the tube. The " B " battery and telephone receivers are connected across the plate and filament of the tube. The direct current of the " B " battery flows through the telephone receivers. The con-

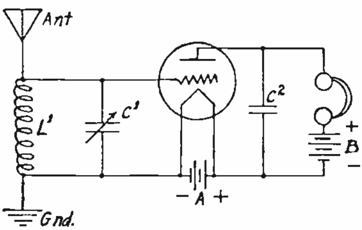


FIG. 81. Vacuum Tube Detector Circuit.

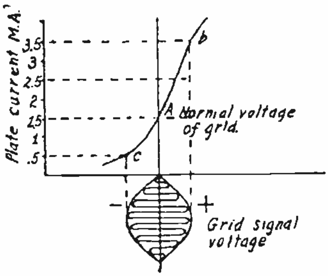


FIG. 82. Curve Showing Operation of Vacuum Tube as a Detector.

denser C-2 by-passes the radio frequency components that are present in the plate circuit. The circuit is tuned to incoming signals and the radio frequency voltages built up across the tuning condenser C-1 are impressed on the grid of the tube. For a positive alternation the plate current increases to the point b and on the negative alternation of the same amplitude the plate current is decreased to c, as shown in figure 82. Thus the average plate current is increased during the duration of a signal voltage. The fluctuations of plate current occur at radio frequencies corresponding to the frequency of the incoming signal. Due to the high inductance of the windings in the telephone receiver the radio frequency variations of plate current cannot flow through them, but are by-passed by the capacity of the windings and the condenser C-2. Only the average value of plate current flows through the receivers causing the diaphragm to vibrate at an audio frequency dependent upon the number of wave trains per second.

This method of detection is sometimes employed using a " C " battery to place a high negative voltage on the grid. The " C " battery of 3 or 4 volts is connected in series with the grid with the negative terminal next the grid. The positive terminal is connected to the tuned circuit. The high negative potential permits the tube to be worked on the lower bend of the characteristic curve. However, there is no change in the action other than the effect of each wave train which reduces the plate current more than it is increased. As before, the plate current is varied at a radio frequency rate resulting in an audio frequency vibration of the diaphragm of the telephones for each wave train.

6. **Condenser and Grid Leak**—The rectifying action of the tube with condenser and leak requires a positive bias on the grid for best results. Figure 83 shows the arrangement of apparatus employing this form of detection. One side of the grid leak resistance is connected to the positive side of the "A" battery through the inductance *L*-1. The action would be the same if the resistance was connected directly between grid and positive filament. In some circuits this is absolutely necessary since there is no other circuit back to the filament. The flow of steady grid current through this resistance places a positive bias on the grid of a few tenths of a volt with respect to the negative end of the filament. The rectifying action is accomplished by operating the tube on the curved portion of the grid current curve and the straight portion of the plate current curve. The action is as follows: During the positive alternation of the radio frequency oscillation the plates of the condenser *C*-2 connected to the tuned circuit *L*-1 *C*-1 become positive—the other plates become negative robbing the grid of some of its electrons; thus the grid becomes positive and electrons pass to it from the filament.

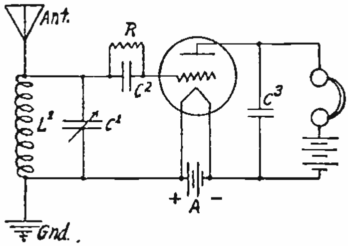


FIG. 83. Vacuum Tube Circuit Employing Grid Leak and Condenser.

During the negative alternation of the radio frequency oscillation, the plates of the condenser *C*-2 connected to the tuned circuit *L*-1 *C*-1 become negative—the other side becomes positive and hence the grid becomes negative. No electrons are added but none are thrown off as the grid is not heated. The net result of the whole oscillation is to lower the potential of the grid. The effect of each oscillation then is to decrease the potential of the grid (by adding electrons). This effect is cumulative so that each wave in a wave train adds to the effect of the preceding wave. The result of the passage of the wave train is that the grid potential is reduced. The reduction of the grid potential causes a reduction of the plate current. This occurs every time a wave train passes and hence there is a pulsating current of wave train frequency through the telephones. Wave train frequency is audio frequency, so the signal is heard. (See figure 84.) The grid leak does not allow the escape of the electrons from the grid while the

L-1 *C* circuit is oscillating. In the comparatively long time between wave trains, electrons on the grid escape through the grid leak and the grid regains its normal potential.

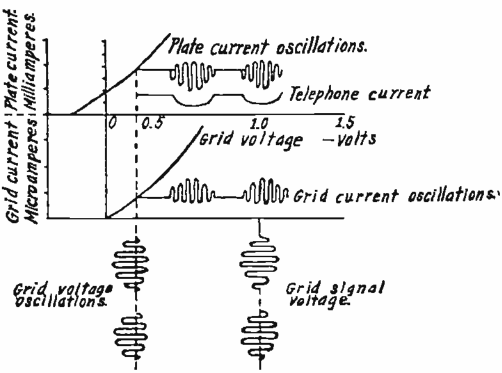


FIG. 84. Action of Vacuum Tube as Detector with Grid Leak and Condenser.

If strong signals are to be received or if static is strong, the value of the grid leak resistance cannot be too high or the charges will not leak off between wave trains, but for weak signals the leak resistance can be made much higher. The usual value of the grid condenser is .00025 mfd. and of resistance 2 to 5 megohms for strong signals and up to 10 megohms or more for weak signals.

7. **Vacuum Tubes as Amplifiers**—It was shown in the preceding paragraph that a vacuum tube acts as a detector or rectifier because an alternating voltage applied to the grid circuit produced unsymmetrical oscillations in the plate current. At the same time it is acting as a detector it is also acting as an amplifier—that is, oscillations of greater power are produced in the plate circuit for a given alternating voltage in the grid circuit than would be produced by the same voltage applied directly to the plate circuit.

The small voltages acting in the grid circuit simply act as a valve to control large values of current in the plate circuit furnished by the "B" battery.

To use the valve as an amplifier it is desirable to have the grid voltage of such value that on the positive alternation of the oscillation the plate current is increased as much as it is decreased during the negative alternation, otherwise distorted amplification will result. In order to secure undistorted amplification it is necessary to operate the tube on the straight portion of its plate-current grid-voltage curve. Sometimes a "C" battery is necessary in order to fix the normal grid voltage at the center of the straight portion of

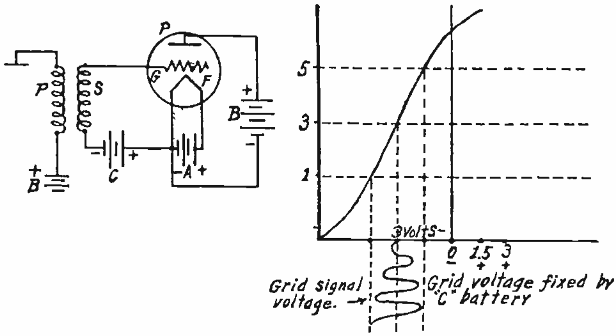


Fig. 85. Curve Showing Condition Necessary for Undistorted Amplification in Vacuum Tube.

the characteristic curve. The addition of the "C" battery also increases the life of the "B" battery but does not necessarily give more amplification.

Vacuum tubes are employed to amplify both radio and audio frequency oscillations.

8. **Audio Frequency Amplification**—There are several uses for audio frequency amplification in its application to radio. One of the most important of these is at a broadcasting station. Here a device called the microphone receives the sound waves from the voice or musical instruments and converts them into audio frequency currents. These audio frequency currents are too feeble to properly impress themselves upon the radio frequency currents which transport them through space in the form of waves; therefore the feeble audio frequency currents must be amplified by an audio frequency amplifier of special construction called a speech amplifier.

At a radio receiving station the audio frequency signals produced in the plate circuit of the detector tube can be heard by connecting a pair of telephones in series with the plate circuit. However, if it is desired to increase the strength of these signals whereby they are more easily distinguishable it becomes necessary to employ an audio frequency amplifier.

An audio frequency amplifier increases the power output of a receiver whereby it is possible to enjoy the program from a broadcasting station on a loud speaking device such as a horn or cone designed for that purpose.

9. **Characteristics Required of Audio Frequency Amplifier**—Sound waves vibrate at the rate of approximately 30 to 15,000 cycles per second. The average human ear cannot hear vibrations below 16 cycles nor above 15,000 cycles. In radio broadcasting it has been found that a band from 30 to 7,000 cycles is ample for excellent transmission. Therefore it can be seen that an audio frequency amplifier employed either as a speech amplifier at the transmitting station or as an audio frequency amplifier at the receiving station must have certain characteristics whereby all these frequencies can be reproduced without distortion. (See curve, figure 85-*a*.)

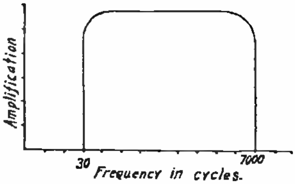


FIG. 85*a*. Characteristic Curve of Ideal Amplifier.

Audio frequency amplifiers designed for radio telegraph code reception do not require such frequency characteristics. An amplifier designed to give maximum amplification from 60 to 1,000 cycles is sufficient for this class of service.

10. **Amplifying Systems**—There are three principal methods of coupling vacuum tubes in an amplifying system. They are known as transformer coupled, resistance coupled and impedance coupled. The schematic circuits of each are shown in figure 86. These methods of coupling are also applicable to a radio frequency amplifier, the only change being in the sizes of the inductances and capacities employed. Each method has its advantages and disadvantages.

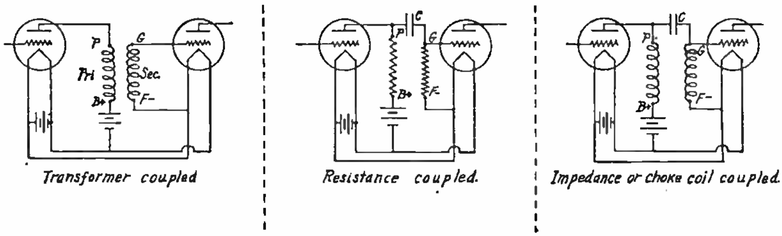


FIG. 86. Methods Used to Couple Vacuum Tubes in an Amplifier.

When a number of tubes are connected together in an amplifying system it is spoken of as a cascade or multi-stage amplifier.

If two tubes are employed in this way it is called a two-step amplifier, three tubes a three-step amplifier, and so on.

Of the three forms of coupling the transformer coupling is by far the most commonly employed primarily for the reason that two stages of transformer coupling may equal or exceed in amplification that secured by a three-stage resistance or impedance coupled amplifier. Transformer coupling is subject to distortion which may result in large values of amplification at high frequencies and very small values at the lower frequencies. However, with the improved design by certain manufacturers of audio frequency transformers there are procurable on the market several different types which produce even values of amplification of practically all audio frequencies employed in radio broadcasting.

Resistance and impedance coupled amplifiers of proper design amplify all audio frequencies to the same degree. Of the two methods the resistance coupled is the least efficient. Larger values of "B" battery are required on the plate of each tube to compensate for the voltage drop through the coupling resistors. The amplification per tube is less than the amplification constant of the tube (explained in a later paragraph) and is somewhat below that procurable by either of the other two methods.

The most general type of amplifier coupling employed at broadcasting stations to amplify the feeble currents from the microphone is the impedance coupled amplifier. The use of impedances in the plate circuit permits smaller "B" battery voltages to be used. Usually the inductances of the plate and grid coils are very high, thus permitting the voltage ratio to remain high throughout the greater part of the audio frequency band. The d.c. resistance is relatively low; therefore it is not necessary to employ higher plate voltages than are used with transformers. The gain per stage in amplification cannot exceed the amplification constant of the tube but does exceed somewhat that of the resistance coupled amplifier.

11. **Amplification Constant**—Resistance and impedance coupled amplifiers are limited in amplification per stage by what is known as the amplification constant of the tube. Amplification constant (expressed by the small Greek letter "mu," μ) is an expression of the ability of a vacuum tube to amplify voltages. For example, the plate current of a tube may be 4.5 milliamperes at 40 volts with a normal grid voltage of .4 volt. If the grid voltage is increased to 1.4 volts the plate current will rise to 5.9 milliamperes or slightly over 1.4 milliamperes per volt change. Now if on the other hand the grid voltage is left unchanged at .4 volt and the plate voltage is increased to 60 volts the plate current will be

increased to 8.5 milliamperes, a change of .2 milliampere per volt. Thus it can be seen that a volt added to the grid makes 7 times as much charge in the plate current as a volt added to the plate voltage would. This number, which represents the relative effects of grid voltage and plate voltage upon plate current, is called the amplification constant of the tube. A tube having a high amplification constant is known as a " high mu " tube.

Thus a resistance or impedance coupled amplifier of three stages employing tubes having an amplification constant of 7 would have an over-all gain of approximately 6^3 or 196. However, with transformer coupling there is obtained a voltage step-up which is approximately equal to the turn ratio and for example in the case of a 1 to 3 transformer an over-all amplification for a single stage of 3 times 7, the tube constant, or about 21. The over-all gain obtained from two stages of amplification would be 21 squared or 441. Thus more amplification is obtained with two tubes employing transformer coupling than can be obtained with three tubes of the same type in a resistance or impedance coupled amplifier.

12. **Plate Impedance**—There is another electrical characteristic of the vacuum tube that has to be taken into consideration when figuring on its amount of amplification available from an amplifying system. This characteristic is known as plate impedance. The plate impedance is the opposition offered to the flow of an alternating current in the output or plate circuit of the tube. Its value determines the maximum power output which can be obtained from a tube. Its value varies with the voltages on the filament, grid and plate.

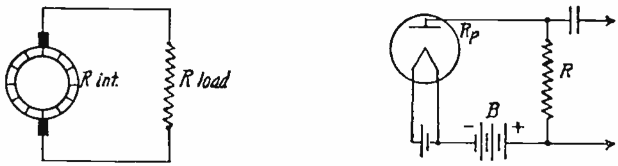


FIG. 87. The Output Rule—Showing that when Load Resistance is Equal to Internal Resistance Maximum Output is Obtained.

In considering the power output of a vacuum tube the resistance of the load to which it is coupled has considerable bearing. This can be easily explained by applying the rule governing the output of a direct current generator connected to a load. Referring to figure 87, the direct current generator is connected to the load marked R-load. The armature of the machine has a certain resistance which is indicated by R_{int} (internal resistance). When the load resistance (R-load) is equal to the internal resistance (R_{int}) the generator will give its maximum output. If the load resistance is higher the current drops off and the generator does less work outside.

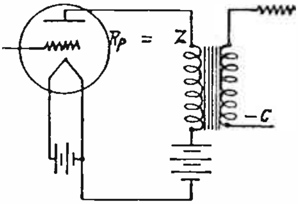


FIG. 87*a*. Output Rule Applied to Transformer Coupled Amplifier.

Now if the same rule is applied to a vacuum tube amplifier it will be found that the tube gives the most output when the load resistance R is equal to the plate impedance R_p. However, the application of this rule may result in serious frequency distortion when a tube having an extremely high plate impedance is connected to a transformer of high impedance. (Explained very clearly by Kruse in QST, April, 1927, Radiotron CX-340-UX-240.)

13. **Mutual Conductance**—The value of mutual conductance of a vacuum tube is an expression giving the degree of merit of the tube as an amplifier, detector, oscillator, etc. It is always desirable to have the mutual conductance as large as possible. The amplification constant is dependent upon the structure of the grid and its position relative to the other electrodes while the plate impedance depends upon the amplification constant and the surface areas of filament and plate.

As the usual practice is to vary the plate current by varying the grid potential the mutual conductance gives a measure of this effect. If the amplification constant and plate impedance are known the mutual conductance can be found by the equation:

$$\text{Mutual conductance in micromhos} = \frac{\text{Amplification constant}}{\text{Plate impedance}},$$

or

$$g = \frac{\mu}{r_p}.$$

Thus it can be seen that a tube having a high "mu" and low plate impedance will have considerable merit as an amplifier.

14. **Transformer Coupling**—Audio frequency amplifying transformers are usually of the closed core type having a primary and secondary winding insulated from each other. By winding the secondary with more turns than the primary, the voltages communicated to the grid of the tube to which the secondary is

connected can be considerably increased resulting in greater amplification per tube than is possible with either resistance or impedance coupling. The turn ratio of audio frequency transformers is of the order of 1 to 3, 1 to 6, 2 to 5; usually not running higher than 1 to 10.

Figure 88 illustrates the connections of a two-stage audio frequency amplifier arranged to amplify the audio frequency fluctuations of plate current produced in the detector tube plate circuit of a radio receiver.

Referring to figure 88 the plate of the detector tube is connected to the terminal marked *P* on the primary of the first transformer. The terminal marked *B* + is connected to the positive 45-volt terminal of the 90-volt "B" battery as this is the usual value for best operation of the detector tube. The secondary terminal marked *G* of the transformer is connected to the grid of the first amplifying tube. The other secondary terminal marked *F* — is connected to the negative three-volt terminal of the "C" battery, so as to operate the tube on the steepest part of its characteristic curve as well as to conserve "B" battery.

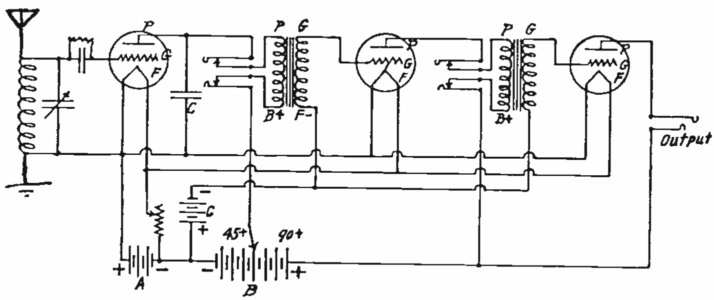


FIG. 88. Detector and Two-Stage Transformer Coupled Audio Frequency Amplifier.

Note: The correct value of bias voltage for a particular tube is usually furnished by the manufacturer.

The plate circuit of the second tube is connected to the primary of the second transformer as in the first, but the *B* + is connected to the positive 90-volt terminal of the "B" battery as this is the usual voltage employed to operate the first amplifier tube with transformer coupling. The secondary of the transformer is connected to the grid of the second amplifying tube with the filament return connected to the negative "C" battery. The plate circuit of the last tube is connected in series with loud speaker and 90-volt "B" battery.

Jacks are frequently provided in the plate circuit of each tube so that the loud speaker or telephones may be plugged in either the detector circuit, first stage amplifier, or the last stage.

The condenser *C* is connected directly across the plate and filament circuit to by-pass the radio frequency currents present in the detector plate circuit, otherwise they would be choked out by the reactance of the primary winding of the first transformer. The addition of the condenser serves to increase the strength of the signals and prevents distortion.

15. **Operation**—If no signal is heard there is only the steady plate current through the primary of the transformers, therefore no magnetic flux surrounds the windings and there is no e.m.f. induced in the secondary windings. When the grid of the detector tube is actuated by a signal voltage it produces fluctuations of an audio frequency in the primary circuit of the first transformer. The fluctuating current flowing in the primary produces a magnetic flux which cuts the windings of the secondary, producing an alternating e.m.f. therein which is communicated to the grid of the first amplifying tube. The alternating e.m.f. on the grid produces symmetrical variations of plate current in this tube. The plate circuit of the second tube in turn transfers the amplified fluctuations to the grid of the third tube where another gain in amplification is secured.

The amplification is gained by the small expenditures of grid power in each tube acting as a relay which controls the power available from the "B" battery. The alternating grid voltage on each successive tube is always higher than that of the preceding one, resulting in large variation of plate current, and a larger e.m.f. is built upon the secondary of each transformer as the energy is transferred from one tube to the next.

16. **Distortion in Audio Frequency Transformers**—There are two principal forms of distortion in an audio frequency amplifier. They are known as frequency and harmonic distortion.

The first, frequency distortion, usually is the result of the distributed capacity of the windings making it resonant at some frequency of the order of seven to fifteen thousand cycles. This results in tremendous amplification at these frequencies producing unnatural tones in the loud speaker or phones and often causes the tubes to oscillate at an audio frequency.

The quality of reproduction from a transformer subject to this form of distortion can sometimes be improved by connecting a high resistance or condenser across the grid and filament terminals of the secondary windings.

Frequency distortion in the form of loss of the lower frequencies may be caused by insufficient primary of transformer or insuffi-

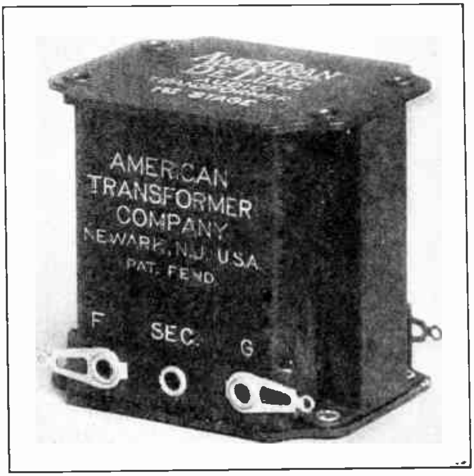


Fig. 89. An Audio Transformer Capable of High Fidelity of Reproduction.

cient turns in the choke of an impedance coupling, the effect in both cases being that the impedance is not sufficiently matched to the tube plate to constitute a successful load, hence the tube is unable to put power into it.

Harmonic distortion is the creation of frequencies that are multiples of the fundamentals. A 500-cycle tone may be fed into the amplifier and at the output there will be not only the 500-cycle tone but perhaps its second harmonic, a 1000-cycle tone, or perhaps even other such frequencies which are multiples of the original tone. This form of distortion may be caused by the saturation of the iron core. By employing a good grade of iron in the core and by proper design of the transformer this form of distortion can be made negligible. Harmonics are also created when a tube is overloaded.

17. **Resistance Coupling**—A resistance coupled amplifier consists of an arrangement of vacuum tubes so connected that the signal to be amplified is fed into the grid circuit of the first tube

transferred from the plate circuit of this tube by means of resistance and capacity coupling, on to the grid circuit of the next tube, and so on to the output of the last amplifier, to which the loud speaker is connected.

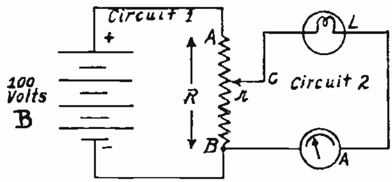


FIG. 90. Theory of Resistance Coupling.

Before considering the circuit of such an amplifier it would be well to consider the theory of coupling energy from one circuit to another by means of a resistance. Referring to figure 90 the resistance R is a voltage divider, also known as a potentiometer. The resistance R is connected in series with the battery B in circuit. Current flows through the circuit BR producing a drop in potential along the resistance. There is also another circuit consisting of a lamp and ammeter in series (circuit 2). If circuit 2 is connected across a small portion of R in circuit 1, the lamp in circuit 2 will light and the ammeter will record the current drawn from circuit 1. Circuit 2 is coupled to circuit 1, for there is a transfer of energy from 1 to 2. The circuits are coupled together by means of the coupling resistance R, which is common to both circuits. The total voltage across the AB is equal to battery, i.e., 100 volts. This value is obtained when the movable contact C has been moved to A. The lamp L will then light the brightest and the ammeter will read its highest value of current. As the contact is moved towards B, the voltage drops between B and the contact decreases as indicated by the brilliancy of the light and decreased reading of A. When the contact is at B the potential difference is zero and the light will go out. The potential difference between B and the movable contact is proportional to the amount of resistance between them. As long as there is a difference of potential between B and the movable contact a current will flow through the circuit LAr.

Applying this theory to the resistance coupled amplifier shown in figure 91 the action is as follows: The voltages acting in the plate circuit of the first tube are coupled to the grid of the second tube by the resistance R_p which is common to both circuits. The condenser C is not essential as far as the coupling is concerned but is necessary to prevent the positive potential of the " B " battery from reaching the grid of the tube. A positive bias on the grid

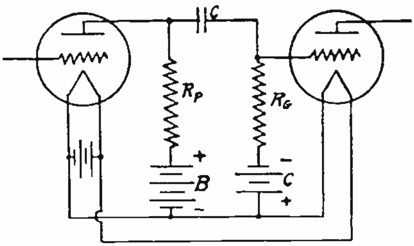


FIG. 91. Simple Resistance Coupled Amplifier.

will start a grid current resulting in reduced amplification and serious distortion. It offers a low impedance path to the alternating signal voltages. The resistance R_G allows the negative electrons to leak off from the grid. It also permits the application of the proper " C " battery bias required for best amplification.

On account of certain losses in the coupling circuit the total voltage developed in the plate circuit of the first tube is not available for the grid of the second tube. One of these losses is represented by the voltage used up in the plate coupling resistance R_p. This resistance usually has a d.c. resistance of 100,000 to 250,000 ohms, the value depending upon the type of tube and " B " battery voltage employed. The plate voltage applied divides across the coupling resistance and the tube in the ratio of resistance of one to the resistance of the circuit. The total impedance of the tube circuit compared to the coupling resistance is small and as a result most of the " B " battery goes to waste in the coupling resistance R_p. The " B " battery voltage employed in the resistance amplifier must therefore be kept high as it is impossible to reduce the value of plate resistance without reducing the voltage available for the grid of the second tube which means reduced amplification.

The insulation resistance of the stopping condenser C must be kept high, otherwise a positive bias will be introduced from the " B " battery to the grid of the next tube. A positive bias will start a grid current resulting in reduced amplification and distortion. Condenser C usually has a capacity of .05 to 1 mfd. depending upon the stage of amplification in which it is used. If too small its impedance to low frequencies is tremendous and the bass notes are lost. If too high the time required to charge and discharge becomes so great that serious distortion is produced on strong signals.

The value of R_G depends upon the tubes employed and the power to be handled. Satisfactory results are usually obtained by the use of a 1 megohm (1 million ohms) leak on the first stage, a 1/2 megohm leak on the second stage and a 1/4 megohm leak on the third stage. If the value of R_G is made too low the input to the tube is reduced resulting in a loss of amplification.

On account of the losses in a resistance coupled amplifier it can never exceed the amplification constant per tube and usually is about 80 percent of this value. It does, however, have a uniform frequency amplifying characteristic as the coupling resistance has practically the same reactance value throughout the audio frequency band. The stopping condenser is the only reactive device in the coupling circuit and by choosing the correct value a nearly flat amplification curve can be secured with a slight falling off at the very low frequencies occasioned by the reactance of the stopping condenser at these frequencies.

18. **Impedance Coupling**—The most general type of amplifier coupling device employed at broadcasting stations for the amplification of the feeble microphone currents is the impedance coupled amplifier. It has the advantage of a very uniform frequency amplifying characteristic. Like the resistance coupled amplifier it is limited in amplification per stage by the amplification constant of the tube. The gain per stage, however, is somewhat higher than that secured with a resistance amplifier of the same number of tubes.

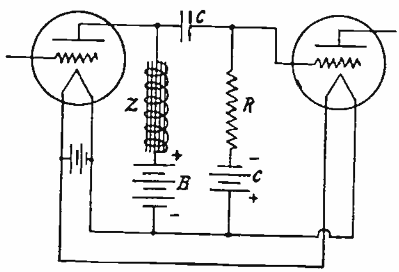


FIG. 92. Impedance-Resistance Amplifier.

The circuit shown in figure 92 shows the arrangement of an impedance coupled amplifier as commonly employed for radio reception. The impedance coil *Z* prevents the flow of alternating current through the " B " battery and must therefore have a high enough inductance to choke back the low as well as the high frequencies. The condenser C performs the same functions as in the resistance coupled amplifier, that is, passes the variations of plate voltage to the grid of the second tube and prevents the " B " battery from applying a positive bias to this grid. The resistance R supplies negative bias to the grid of the tube and also permits the negative electrons accumulated on the grid during a positive swing of signal voltage to leak off, this preventing the tube from blocking.

The values of C and R are of the same values as employed in resistance coupling. The value of impedance Z is made as high as practically possible in order to make the voltage ratio high. Its d.c. resistance is relatively low and therefore it is not necessary to employ such high values of " B " battery as are necessary with resistance coupled amplifiers.

In some types of impedance amplifiers the grid leak resistance is replaced by another impedance coil similar to the plate impedance, thereby making what is sometimes called a " double impedance " or " impedance-impedance " coupling to distinguish from the impedance-resistance type previously discussed. The impedance of this coil to alternating signal voltages is high but its direct current resistance is low. This permits the grid charges accumulated on strong positive swings of the signal voltage to easily leak back to the filament. In the case of a resistance connected in this branch of the circuit it is necessary it keeps its value very high in order that the grid may receive the full value of signal potential impressed across it. If too high the grid becomes blocked or free. This causes the amplifier to block or " motor-boat." The choke coil has a relatively low direct current resistance and a high

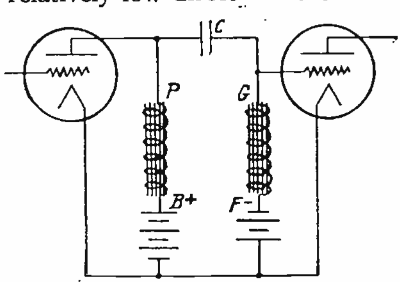


FIG. 93. Impedance-Impedance or Double Impedance Amplifier.

impedance to alternating currents at audio frequencies and thus permits the grid charges to leak away easily so that blocking or motor-boating does not occur on strong signals. An arrangement of this circuit is shown in figure 93.

Another arrangement consists of winding the plate and grid impedances on the same iron core. The ratio of the windings is 1 to 1. The highest voltage that can be communicated to grid of a tube employing straight resistance or impedance coupling is the voltage drop in the external plate circuit of the preceding tube. This is always less than the voltage directly in the plate circuit. By placing the windings on a common core the arrangement has the advantages of a gain in voltage by virtue of the mutual inductance between the plate and grid coils. The two windings are so arranged that the capacity between them is small. A coupling or stopping condenser is connected between the two windings at their high potential ends. The system has many of the advantages of ordinary impedance coupled amplifiers, with additional advantage of giving higher voltage ratio.

19. **Radio Frequency Amplification**—Amplification of the radio frequency currents before detection is called radio frequency amplification. Enormous gain in the amplification of weak signals can be accomplished by this method which generally means an increased range of reception. This may be explained as follows: The telephone current produced by a detector circuit rectifying signals from a spark or radio telephone transmitter is closely proportional to the square of the radio frequency voltage which acts on it. From this it can be seen that even a small amount of radio frequency amplification means a considerable increase in the rectified current of the detector. Assume an amplifier capable of amplifying either the radio or audio frequency currents 7 times. Employing it as a radio frequency amplifier will give an output of 7 squared or 49 times, whereas if it is employed as an audio frequency amplifier it can only amplify the detected signal 7 times. Thus there is much to be gained by such a method of amplification. It will also be shown how selectivity is gained by the use of cascade radio frequency amplifier of several tuned circuits.

The diagrams in figure 94 illustrate the most common methods of coupling radio frequency amplifiers which are, untuned r.f. transformers, tuned r.f. transformers and the variometer method.

The untuned method usually consists of a transformer having a primary and secondary winding of 1 to 1 ratio. It usually has an air core but when employed for amplification of frequencies of approximately 30 or 40 kilocycles, the core may consist of thin laminations of iron which tend to make the transformer tune broadly, i.e., accept a wide band of frequencies. In order that such transformers function over a wide band of frequencies the coupling is made close and frequently resistance is kept high by winding the transformer with fine wire or even resistance wire. The dis-

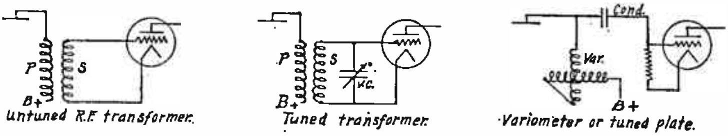


FIG. 94. Methods Used to Couple Vacuum Tubes in Radio Frequency Amplifiers.

tributed capacity of the windings produces a resonant circuit which results in small amplification at frequencies other than the resonant frequency. In order to employ such transformers to cover the broadcast band of frequencies corresponding to the band 200–600 meters, it is necessary to use in successive stages unlike transformers having different frequency characteristics so as to secure a fair degree of uniform amplification.

Tuned radio frequency is a very desirable method of coupling several tubes in a cascade amplifier. One of the greatest advantages is the gain in selectivity; the tuned circuits being very efficient at the frequency to which they are tuned and inefficient at all other frequencies. The more tuned circuits there are the greater becomes the selectivity. Very soon, however, practical limits are reached and the whole system becomes unstable. A brief study of the action of a tuned r.f. amplifier will show the reason for this instability which usually results in self-oscillations and reduced amplification.

Figure 95 shows the connections of a single stage of tuned r.f.

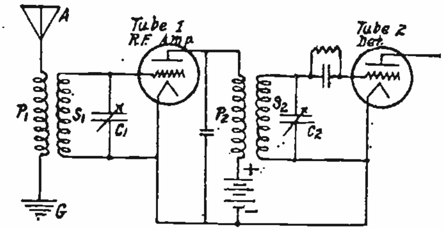


FIG. 95. Theoretical Circuit of Tuned Radio Frequency Amplifier.

preceding the detector tube. The antenna circuit transfers its energy to the secondary circuit by the coupling existing between the primary and secondary of the first r.f. transformer. The secondary circuit S_1 impresses on the grid of the tube 1 the signal of a frequency to which it is tuned. A magnified current is produced in the plate circuit of this tube which is transferred into the second tube by the second r.f. transformer. The secondary S_2 being tuned to resonance at the desired frequency accepts it and passes it on to the grid of the second tube where it is detected. As the condenser C_2 tunes the circuit to resonance it will be noticed that a whistle is produced which seriously interferes with the desired signal. In other words, the amplifier has become instable and the first tube has started generating self-sustained oscillations. These oscillations or radio frequency currents are generated regardless of the presence of the signal and continue as long as the secondary of the second r.f. transformer is tuned to the same or approximate frequency as the first r.f. transformer. Before proceeding to the means of preventing this effect we must explain the effect.

Self-sustained oscillations arise in one way by energy being re-transferred from the plate circuit to the grid of the same tube by electrostatic capacity existing between these two elements. Although of small value this internal capacity has a tremendous effect on the vacuum tube as a r.f. amplifier. The manner in which this re-transfer of energy takes place can be explained by referring to figure 95. The primary P_2 is magnetically coupled to the secondary S_2. A coil such as P_2 when closely coupled to a tuned circuit such as S_2, C_2 will undergo a change in its apparent inductance to a given frequency as the tuning of the circuit S_2, C_2 is varied. Suppose that the frequency of the current through the primary winding is that corresponding to 300 meters or 1,000 kilocycles per second. As the tuning of the secondary is gradually varied from 200 to 600 meters the inductive reactance of the primary to the 300-meter current will rise continuously until the secondary tuning arrives at 300 meters where the reactance will reach a peak value. As the secondary wavelength is increased beyond this value, the reactance of the primary to the 300-meter current will again drop off. If resonance is approached from either side the rise in inductive reactance of coil P_2 will build up a voltage on the plate and grid inter-electrode capacity (the small capacity existing between plate and grid elements within the tube) tending to force a current back into the input circuit (grid circuit) which aids the current already there, and correspondingly larger variations of plate current are produced. The amplitude of the voltages and currents will be built up until the losses in the circuit due to expenditure of power are equal to the total input. This process of feeding back power from the plate circuit to the input circuit is known as *regeneration*. Regeneration is very desirable in the circuit, providing it is under control, as it means increased output, but in this particular case it is not yet under control and as the secondary circuit is tuned to resonance or approximate resonance the amount of power becomes so great that it more than equals the power lost in the resistance of the input circuit and the tube will be capable of supplying all its own losses and will then start to generate self-sustained oscillations. The frequency of these oscillations will be approximately that to which the *S*-1, *C*-1 circuit is tuned. It is therefore clear that unless this feed-back is under control it will be impossible to secure maximum amplification, as at any time the circuits are resonated self oscillations will start causing severe distortion in reception and rendering the receiver almost useless. Self oscillations are most likely to occur at the lower wavelengths (higher frequencies) as the small value of inter-electrode capacity offers a low reactance path to currents of these frequencies resulting in greater feed back.

Self oscillations are also caused by energy being re-transferred from one circuit to another by the electrostatic and electromagnetic coupling existing between the different coils and wiring of the circuits. In the circuit of figure 95 the field surrounding coil *S*-2 will react somewhat on the coil *S*-1 and undesired feed-back will occur.

The methods used in eliminating oscillations may be classified into three groups. In one group an attempt is made to damp out the oscillations by making the amplification less efficient. In another group there are special arrangements to balance out whatever intercouplings do exist. In another group it is aimed to reduce to a minimum all stray magnetic and electrostatic intercouplings.

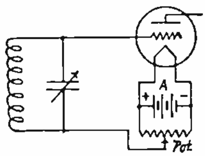


FIG. 96. Controlling Regeneration by Potentiometer Method.

20. "Losser" Methods—A grid potentiometer connected as in figure 96 is a "losser" method and comes under the first group mentioned above. When the movable slider of the potentiometer is adjusted so that the grid is sufficiently positive, the grid attracts enough electrons so that oscillation cannot take place. Making the grid positive decreases the amount of signal voltage as the grid to filament path provided by the electrons moving to the positive grid acts somewhat as a leak or short circuiting path. It also means increased "B" battery consumption as well as distortion produced by the changing grid-filament resistance of the tube.

Another losser method is shown in figure 97 in which a series resistance is connected directly in the grid circuit. This resistance, usually of 30 to 50 ohms, tends to damp out the amplitude of the signal oscillations and accordingly the variations of plate current are never sufficient to produce a feed-back that could start self oscillation.

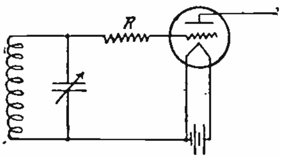


FIG. 97. Losser Method with Series Grid Resistance.

Regeneration can also be controlled by a rheostat in the filament circuit of the radio frequency tube. By proper adjustments of resistance the tube can be kept just under the oscillation point. This constitutes a losser method as it is usually necessary to operate the tube below its normal filament voltage to stop oscillations which means reduced amplification.

Still another method is by reducing the coupling between primary and secondary. This can be done by limiting the number of turns on the primary or by increasing the distance between the coils. The disadvantage of this method lies in the marked decrease in the transfer of energy from one stage to the next with an increase of wavelength. This disadvantage has been eliminated in one commercial amplifier by placing a portion of the plate coil on the condenser shaft so that it rotates inside the grid coil of the succeeding stage in such a manner that the rotating portion of the plate coil opposes the coupling from the fixed portion of the low waves (higher frequencies where the amplifier is most unstable) and adds to the coupling at the high waves rotating with the condenser through its 180 degrees of revolution. The circuit arrangement is shown in figure 98.

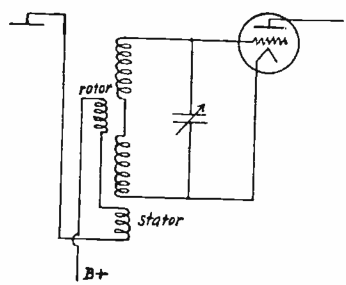


FIG. 98. Hassel's Method of Variable Coupling.

21. Feed-Back Prevention and Compensation—The second class of methods of control strikes at the source of the regenerative feed-back and involves either the prevention of current flow through the plate-grid capacity or the compensation of the effects upon the input circuit of this current flow. This class of methods falls into two groups. In the first group as exemplified by the Hazeltine "Neutrodyne" circuit, the degree of compensation is progressive, increasing as a suitable variation is made in the compensating element, so that over-compensation is possible, with a corresponding reduction in the amount of amplification. In the second, of which the Rice circuit is an example, the compensation can be increased only to a critical or maximum value which just eliminates the reaction through the plate-grid capacity and then is reduced again, during a progressive change in the compensating element.

22. Reversed Tickler—The simplest method of the first group is shown in figure 99. It is known as the reversed feed-

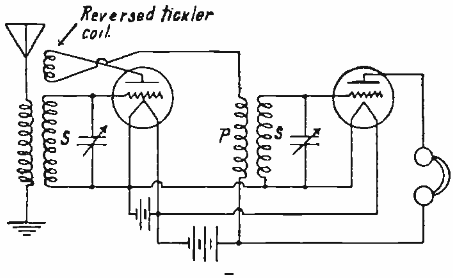


FIG. 99. Miner's Reversed Feed-Back Circuit.

back or reversed tickler circuit. It consists merely of the addition to inter-electrode coupling between plate and grid circuits of an additional magnetic coupling through the tickler coil. The connections to this coil are made opposite (reversed) with respect to those of the feed-back coil in the Armstrong circuit, so that this magnetic coupling tends to suppress regeneration instead of aid it, thus directly opposing the coupling through the plate-grid capacity. It was used commercially in the Tuska "Superdyne." An inherent disadvantage of this form of control is that it involves balancing an inductance against capacity and hence the degree of compensation varies quite rapidly with the wavelength of the received signal.

23. Hazeltine's Neutrodyne Method—The second circuit of this group is the development of Prof. Hazeltine and named by him "neutrodyne," a method of neutralizing capacity coupling in triode (three electrodes) amplifiers. It suggests the "neutralization of a 'force,' the tendency of the triode to oscillate."

The circuit is shown in figure 100. The neutralizing capacity C_N is connected from the grid to the high potential terminal of coil L which is so coupled to the transformer T-2 that the voltage across

L is just opposite in phase and bears a constant ratio to the voltage across T-2 regardless of the wavelength to which T-2 is tuned. By proper choice of C_N the current through C_1 can be made to introduce into T_1 a voltage which opposes and just balances that produced by the current through C_1.

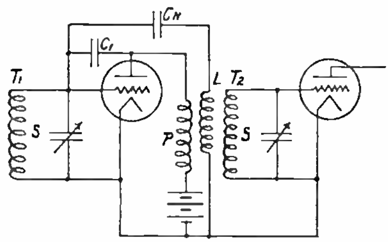


FIG. 100. Hazeltine's Capacity Coupling Method of Neutralization.

In practically applying the arrangements of figure 100 to amplifiers, the coil L may be used wholly for neutralization purposes; but it is convenient to use it also as one winding of an amplifying transformer, thus making a third coil unnecessary. Figure 101 shows how this may be accomplished in a conventional neutrodyne circuit employing a tuned two-stage radio frequency amplifier and detector with capacity coupling neutralization of the forms just described. As shown by Prof. Hazeltine, the neutralizing capacities are in part inherent, existing between the coils and condensers of adjacent stages, and in part added by condensers. These condensers are of very small capacity and are conveniently made in the form of an insulated wire inside a metal tube. The secondary

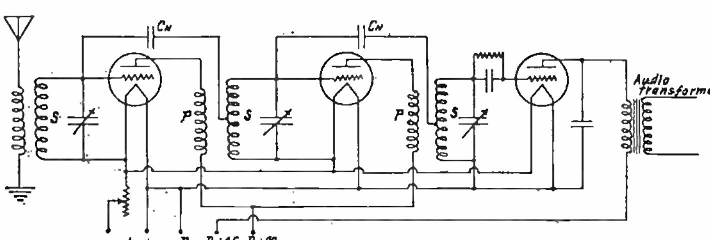


FIG. 101. Conventional Neutrodyne Circuit.

coils of the transformers are preferably wound outside the primaries and so screen away some of the coupling capacity otherwise existing between the primary coil of one stage and the secondary circuit of the preceding stage. This screening effect is advantageous, as it reduces the capacity to be neutralized. The coils of different transformers are arranged to have no magnetic coupling.

The adjustment of each neutralizing capacity is made experimentally by tuning in some strong signal and then turning out the filament of the tube whose capacity is to be adjusted, but leaving the tube in the socket. If the neutralizing capacity is not correct, the circuits on each side of the tube will have capacity coupling, which will transmit the signal. This method of adjustment was devised by Mr. H. A. Wheeler.

If the radio frequency amplifier circuit is adjusted by this method no regeneration exists, as radio frequency variations in the voltage of the plate with respect to the filament produce no radio frequency variations of the voltage of the grid with respect to the filament. If the capacity of the condenser C_N is increased beyond the point necessary to completely eliminate the incoming signal, the voltage induced on the grid will tend to destroy any amplification resulting from the use of a tube.

It is not necessarily desirable to completely neutralize the effect of regeneration as has been described. Stronger signals will be obtained with the same number of tubes if the capacity of C_N is increased only to the point where the amplifier ceases to produce radio frequency oscillations. The regeneration remaining will also tend to increase the selectivity of the system. If too much regeneration remains distortion may result from excessive selectivity or other reasons.

24. History—Historically the first application of the principle just described was in eliminating capacity coupling between the primary and secondary circuits of a radio receiver (SE-1420 described in a later chapter in this book) designed by Prof. Hazeltine for the U. S. Navy and developed in the Washington Navy Yard in 1918. This receiver was to have a wide range in wavelength (about 250 to 7,500 meters) and emphasis was laid on the necessity of preventing interference from short wavelengths when receiving signals of long wavelengths, such interference frequently taking place through capacity coupling. The first steps were the more obvious ones of arranging the circuits so that exposed parts were at or near ground potential and of enclosing the primary and secondary apparatus in separate metal compartments. However, the primary tuning coil and the secondary coupling coil had to be electrostatically exposed to one another in order to obtain the necessary magnetic coupling.

The arrangement adopted in the SE-1420 is illustrated in figure 101a. The large coil is the primary tuning coil; L_1 is the coupling coil; and L_2 wound outside of L_1 is the neutralizing coil. The inherent capacities from the high potential end of L_1 to various parts of the primary coil are represented by C_1' and C_1''; the corresponding neutralizing capacities are C_2' and C_2''. These various capacities have a constant ratio, on account of the similar exposure of L_1 and L_2 to the primary coil. Hence it is necessary only to give the proper number of turns relative to L_1 in order to satisfy the relation for a balance which is:

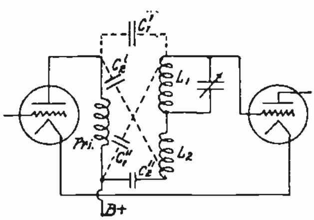


FIG. 101*a*. Arrangement of Neutralization of Capacity Coupling between Primary and Secondary Circuits in Navy Radio Receiver SE-1420 Developed by Hazeltine.

$$\frac{N_1}{N_2} = \frac{C_2'}{C_1'} = \frac{C_2''}{C_1''}.$$

Since L_2 is outside of L_1 it also has a direct screening action, making C_1' C_1'' smaller than they otherwise would be, and smaller than C_2' C_2''. Hence L_2 requires fewer turns than L_1. The proper number of turns N_2 was determined experimentally by putting the coils at right angles (so as to eliminate magnetic coupling) and adjusting N_2 until no signal was transmitted.

While studying the theoretical limitations of amplifier circuits in 1918, Prof. Hazeltine realized that a most serious limitation was the tendency to oscillate by reason of regeneration through the coupling capacity between the grid and plate. The higher the amplification attempted, as by reducing capacities and losses and by increasing the secondary turns, the greater would be the regenerative effect. It then occurred to him that the principle of capacity coupling neutralization previously worked out for the SE-1420 receiver would be applicable. It proved very successful and is considered one of the greatest contributions made to the operations of tuned radio frequency amplifiers.

25. **Wheatstone Bridge Circuits**—The second group of methods in which overcompensation is impossible makes use of the properties of the alternating current Wheatstone bridge: If a bridge be arranged with four arms, which may be capacities, inductances or resistances, and the bridge is properly balanced, then an alternating voltage impressed between either pair of opposite

points of the bridge can produce no voltage drop between the other pair of opposite points of the bridge.

Figure 102 illustrates an application of the principle in the Rice circuit. The filament terminal of the tube, instead of being connected to the lower end of the input circuit T_1, is connected to an

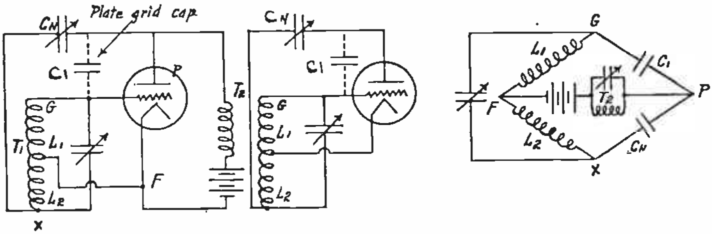


FIG. 102. Rice Circuit Employing Wheatstone Bridge Circuit for Stabilizing a Radio Frequency Amplifier.

intermediate point which divides the inductance of this circuit into two parts, L_1 and L_2. The lower terminal of the input circuit is connected through a small fixed condenser C_N to the plate. The terminals G and X of the input circuit and terminals P and F of the output circuit are two pairs of opposite points of a Wheatstone bridge leaving two inductive arms and two capacitive arms. The inductive arms are L_1 and L_2, which serve also as elements of the tuned input circuit T_1. The capacitive arms are C_N and C_1. The bridge is balanced for a given magnitude of capacity C_1 by placing the filament tap that inductance L_1 bears the ratio to L_2 that capacity C_N bears to C_1. Thus if C_N is made equal to C_1 the filament connection can be brought permanently to the center of the inductance coil T_1. It is best in constructing this circuit to connect the filament lead permanently near the center of the coil and vary C_N until a balance is reached. C_N can then be locked. The proper value of C_N will seldom be greater than 15 micro-microfarads. When the bridge is balanced in this way T_1 is electrically isolated from T_2 since all retroactive currents through C_1 are exactly compensated in T_1 by opposing currents through C_N. This permanent compensation is independent of the wavelengths and of the tuning circuits T_1 and T_2 when the bridge is balanced. It is also independent of the internal resistance and amplification factor of the tube. The amplifying action of the tube is the same as before. When a received signal is brought into T_1 the resulting voltage across the L_1 portion of the coil is impressed on the grid and a magnified copy of the currents in T_1 is maintained by the tube in

T_2. The tube is now a true one-way repeater, however, and no reaction by these currents upon T_1 is possible.

A second compensated circuit of this type is shown in figure 103. Here the arms of the Wheatstone bridge are all capacitive. C_N is an external fixed condenser, forming the arm adjacent to C_1. L is a radio frequency choke coil and provides a metallic grid

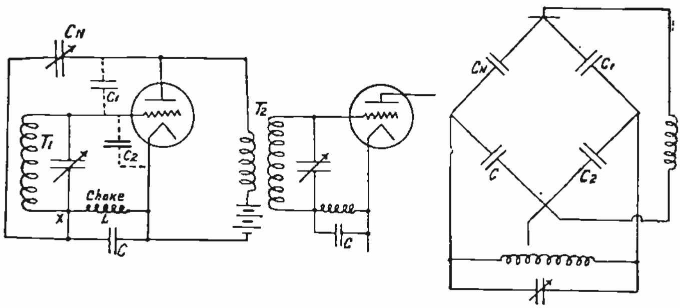


FIG. 103. Bridge Circuit with Capacitive Arms.

return path. The condenser C in shunt to it serves as another arm of the bridge adjacent to C_2. C_2 may be an external condenser but it is convenient to use for C_2 merely the internal capacity of the tube between grid and filament, hitherto unmentioned. Thus the only extra circuit elements that are necessary are the fixed coil L and the condenser C which can be adjusted and then set.

Similar other combinations of inductance with capacity and resistance with capacity in the four arms of the bridge are possible, all of which permit a balance which is independent of the frequency. Those previously shown are typical and perhaps the most practicable.

In the group of methods which aims to reduce stray fields several principles are utilized. To reduce electrostatic coupling the different coils of the radio frequency transformers may be placed at such angles as to reduce the coupling to zero. This method is employed in neutrodyne circuits.

The different radio frequency stages may be placed in separate screened compartments. This method of shielding has proved very successful in several radio broadcasting receivers.

The geometric form of the winding will also greatly influence both fields. Thus a toroidal coil has a much smaller external magnetic field than a single cylindrical coil. Similarly the " figure eight " coil has a reduced external field. Many variations of these principles are employed in radio receivers, all of which have the advantage of retaining selectivity and sensitivity while still eliminating self-oscillation.

26. **The Shield-grid Tube**—The four-electrode tube provides another and entirely different method of attacking the r.f. amplifier problem. Being internally shielded it has little or no inherent feed-back " through the tube," hence needs only screening between the circuits leading to and from the tube to secure non-oscillating performance. This sort of tube is a special subject in itself and will be treated later in the chapter.

27. **Variometer or Tuned Plate Coupling**—The tuned impedance as a method of coupling in radio frequency amplifiers consists of a variable impedance in the output circuit of each amplifier tube, this impedance usually taking the form of a variometer, or coil shunted by a variable condenser. Theoretically this method of coupling permits large values of amplification at a given wavelength, due to the comparatively high peak value when the plate circuits are tuned to the given wavelength. Practically, however, it is practically impossible to tune several such stages to resonance without producing oscillation. This method of coupling between radio frequency stages is not used at present to any extent whatever and no further discussion will be made of this method.

28. **Use of Regenerative Amplification**—The principle of regeneration can be applied directly to a vacuum tube detector circuit and will result in enormous increase of signal strength due to the amplifying action produced. To secure this amplification it is necessary to provide a feed-back which will be in phase with the voltage acting on the grid. This is the reverse of the method described in tuned r.f. amplification, where it was shown that a voltage opposite in phase was fed back to counteract the effects of regeneration in order to stabilize the amplifier. The circuit of a regenerative detector circuit is shown in figure 104. The explanation of the amplifying action is as follows: Oscillations in the tuned secondary circuit are applied to the grid through the condenser C' and produce corresponding variations in the direct current of the plate circuit, the energy of which is supplied by the battery B. This plate current flows through the tickler coil L_3, and by means of the mutual inductance between L_3 and L_2 some of the energy of the plate oscillations is transferred back to the grid circuit so that it is in step with the original voltage and adds to it. The increased voltage produces amplified grid oscillations which, by means of the grid, produce larger variations in the plate current, thus still further reinforcing the oscillations of the system.

Simultaneously with this amplification the regular detecting action goes on; the condenser *C* is charged in the usual way, but accumulates a charge which is proportional, not to the original signal strength, but to the final amplitude of the oscillations in the grid current. The result is a current in the telephone much greater than would have been obtained from the original oscillations in the circuit.

The connections between L_2 and L_3 must be so made that their mutual inductance is of proper sign to produce an e.m.f., which

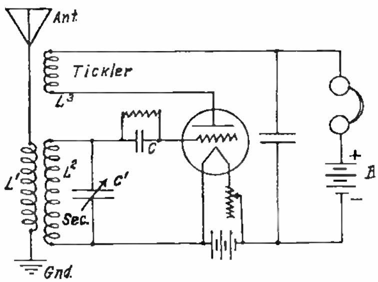


FIG. 104. Regenerative Detector Circuit.

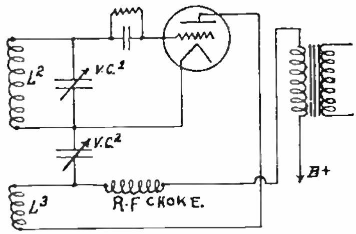


FIG. 105. Capacitive Control of Regeneration.

will aid the oscillations instead of opposing them. Various modifications of this method are used. The plate coil L_3 may be tuned by a variable condenser; or a variometer may be connected in the plate circuit in place of the coil L_3. When a tuned plate or variometer method of regeneration is used the feed-back to the grid occurs through the inter-electrode capacity of the tube and by stray capacities or magnetic coupling between grid and plate circuits.

Another method of controlling regeneration is shown in figure 105. This method employs a combination of both inductance and capacity in series; the value of the latter being variable. It is employed considerably in short wave receivers and provides an easy and smooth control of regeneration. The radio frequency choke coil in series with the plate inductance L_3 and primary of the transformer prevents the radio frequency currents from being by-passed by the distributed capacity of the windings and allows them to be controlled by the variable condenser V.C.$_2$, which controls the amount of feed-back. Besides this any of the usual regeneration methods may be converted into " resistance control " by employing a fixed tickler inductance and capacity with a variable resistance in shunt to the same.

29. The Vacuum Tube Oscillator—It has been stated in previous paragraphs that the vacuum tube would produce self-sustained oscillations dependent upon the feed back from plate to grid circuit. In the cases previously discussed a certain amount of feed back or regeneration was desirable and in one case (C.W. detector) this was carried to the point where the tube would oscillate. However, there are several other very important ways in which a vacuum tube can be utilized if it can be made to oscillate, i.e., become a generator of radio frequency currents.

Referring to figure 104—if the tickler coil L_3 is coupled very close to L_2 the greater will be the regenerative action. If the coupling is increased still further a "plop" will be heard in the phones which indicates that the tube is oscillating. The same thing has occurred as in the radio frequency amplifier; the energy fed back from the plate to the grid current is more than enough to supply the losses in the grid circuit and the tube becomes capable of producing self-sustained oscillations. The direct current furnished by the "B" battery is converted into alternating current of a definite radio frequency. The frequency of the oscillations is dependent upon the values of L_2C_1 in the tuned grid circuit. There are numerous circuits in which a vacuum tube may be connected so as to produce radio frequency currents. The only requirement for sustained oscillations is that the r.f. voltage induced in the grid circuit must vary the plate current through an amplitude which supplies to the external or coupling circuits power sufficient to maintain this r.f. voltage in the grid circuit.

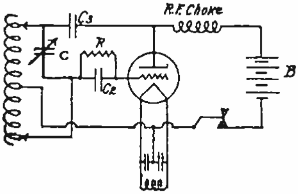


Fig. 105*a*. Vacuum Tube Radio Frequency Oscillator Circuit.

The circuit shown in figure 105-*a* is one which is used quite extensively for transmitting purposes. The method by which it generates radio frequency oscillations is explained as follows:

When the key is closed the plate voltage is applied to the current from the high voltage battery *B* which starts a feeble oscillatory current in coil and condenser circuit *LC*. The plate circuit is directly coupled to the oscillatory circuit inductance by the condenser C_3. The grid also is coupled directly to the opposite end of the inductance by the condenser C_2. The oscillatory currents flowing in the *LC* circuit produce a voltage drop across the inductance on account of its reactance to radio frequency currents. The voltage drop is communicated to the grid by the condenser C_2. This alternating voltage on the grid varies the plate current at a radio frequency rate which changes the internal plate impedance of the tube. Changing the plate impedance establishes a radio frequency voltage between filament and plate. This voltage is impressed on the oscillatory circuit through the condenser C_3 and is in step with the original voltage which means that the original alternating grid voltage is increased in amplitude. The increased grid voltage will produce still greater variations of plate current and correspondingly higher radio frequency voltage between the filament and plate. The building up process continues until the vacuum tube cannot supply enough power to the oscillatory circuit

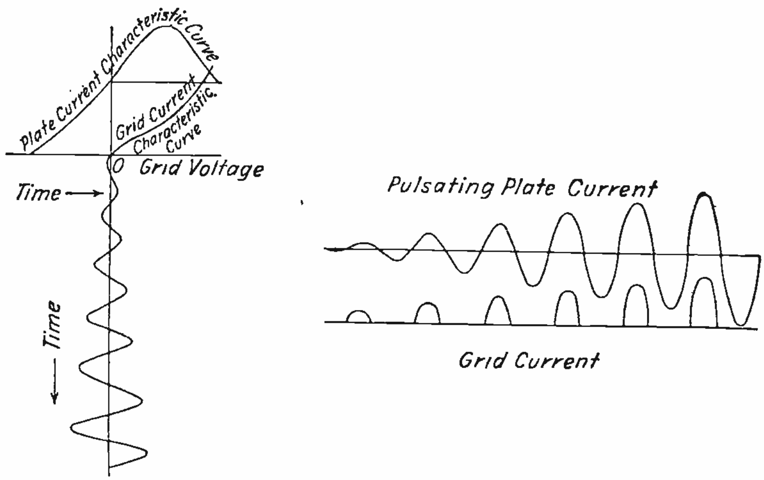


FIG. 106. Characteristic Curve of Vacuum Tube Employed as a Generator of Sustained Oscillations.

to increase further the amplitude of the oscillations. A glance at figure 106 will show that as the grid voltage increases it gradually increases the pulsating plate current. The grid finally builds up to a voltage that will no longer increase the plate current due to the fact that the plate current cannot pass beyond the saturation point and, as it flows only in one direction, it cannot pass beyond the zero line. Thus the oscillations are maintained at a constant amplitude. The oscillations generated by such a system are known as undamped, sustained or continuous oscillations. The frequency of oscillation is dependent upon the values of L and C.

The radio frequency choke coil prevents the radio frequency currents in the plate circuit from flowing back to the filament through the "B" battery. The condenser C_3, sometimes called the plate blocking condenser, prevents the "B" battery from being short circuited by the inductance L and also provides a low impedance path for the r.f. currents to the oscillatory circuit. The resistance R is used to place a negative bias on the grid with respect to the filament.

There are other circuits employed in conjunction with a vacuum tube for generation of radio frequency currents. They will be discussed in the next chapter.

30. **Harmonic Frequencies**—The sinusoidal voltage impressed on the grid of the generator circuit does not make equal changes of plate current during a cycle on account of the curvature of the characteristic plate current as shown in figure 106. This causes the current wave in the plate circuit to depart somewhat from the sinusoid and become distorted resulting in a generation of frequencies other than the natural period of the oscillatory circuit. Assume that the circuit in figure 105 is oscillating at a fundamental frequency of 500 kilocycles (600 meters). If a wavemeter is coupled closely to the inductance L and tuned to 1,000 kilocycles (299.8 meters) a deflection of the current indicating device on the wavemeter will be noted. This frequency which is twice that of the fundamental (one-half the wavelength) is the second harmonic. Likewise there will be found other frequencies at three and four times the fundamental (one-third and one-fourth wavelengths) and upward. It is impossible to obtain a reading on the current indicating device of the wavemeter at these high frequencies, but with an oscillating receiver capable of tuning over a wide band it is possible to identify them. The 2d, 3d, 4th, 6th, 8th, etc., are even harmonics. The 3d, 5th, 7th, etc., are the odd harmonics.

EXAMPLES OF HARMONIC FREQUENCIES.

Fundamental or 1st Harmonic Frequency K/cys.	2d Harmonic Frequency K/cys.	3d Harmonic Frequency K/cys.
1000 (299.8 m.[1])	2000 (149.9 m.)	3000 (99.9 m.)
350 (856.6 m.)	700 (428.5 m.)	1050 (285.5 m.)
210 (1428 m.)	420 (713.9 m.)	630 (475.9 m.)

[1] M-wavelength in meters.

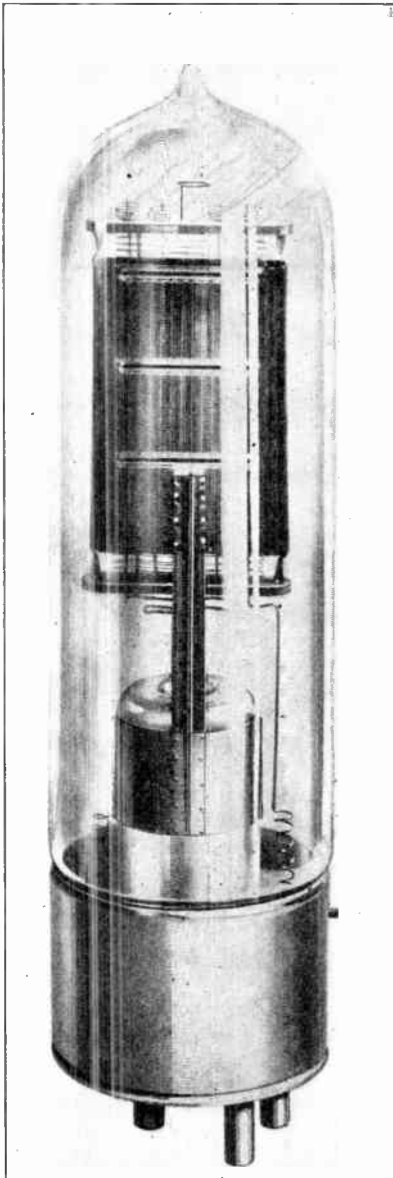


FIG. 107. Western Electric 50-Watt Power Tube.

It should be noted that harmonics are not generated by such an oscillator at frequencies below the fundamental (wavelengths higher than 600 in the example previously cited). However, it is possible to be listening in at a frequency of one-half the fundamental (twice the wavelength) at which a station is transmitting and still hear signals from such a station. This usually occurs when the detector tube in the receiver is itself oscillating. Although the detector tube may not be oscillating other tubes in the set may be oscillating feebly. The second harmonic of the tube oscillating in the receiver is "heterodyning" or beating with the fundamental frequency of the transmitter making the signals audible to the listener.

Elimination of Harmonic Frequency—Harmonic frequencies emitted by a transmitting station besides being a waste of power, cause interference at times to other services occupying frequency bands in which the harmonics fall, therefore, every means of preventing their radiation is resorted to, such as inductive coupling, tank circuits, with loose capacitive coupling to the antenna, master oscillator—power amplifier circuits and impedance circuits in the plate leads tuned to the interfering harmonic frequency. It is almost impossible to prevent radiation of harmonics, but by the methods just mentioned they can be greatly reduced in magnitude thus reducing the range of their interference considerably.

31. Method of Power Rating of Vacuum Tubes—Vacuum tubes used as oscillators or amplifiers in this country are rated by their output. In foreign countries they are usually rated by their input. The power input in watts to a tube is computed by multiplying the plate voltage by the effective plate current during an oscillation. The energy used in heating the filament is not considered. Example: The 203-A radiotron rated as a 50-watt tube when operated at 1,000 volts d.c. plate voltage shows a plate current of 125 milliamperes (.125 of an ampere).

Watts equal $E \times I$,
" " $1000 \times .125$,
" " 125.

The usual power output in watts of this tube if it were connected to an antenna circuit for radiation would be the antenna current squared times the resistance of the antenna circuit. *Example:* The antenna current with this tube may read two amperes. The resistance of the antenna circuit may be 12 1/2 ohms. The power expended in the output circuit is:

$$\text{Watts equal } I^2 \times R,$$
$$\text{" " } 4 \times 12\tfrac{1}{2},$$
$$\text{" " } 50.$$

To find the efficiency of converting the direct current power into alternating current power it is only necessary to divide the watts expended in the output by the watts expended in the plate circuit. Example:

$$\text{Conversion efficiency equal } \frac{\text{watts output}}{\text{watts input}},$$
$$\text{" " " } \frac{50}{125},$$
$$\text{" " " } .4 \text{ or } 40\%.$$

Thus 75 watts were lost in converting the d.c. power into a.c. power. It will be found that this power was expended in the grid current and in heating the plate of the tube. The example given is very conservative. Considerably greater efficiencies are very generally obtained.

32. **Reduction of Grid Current by Grid Bias**—The grid current may be considerably reduced by connecting a "C" battery in the grid circuit. The grid voltage is made negative in respect to the filament, thus reducing the grid current and hence the power dissipated by the grid. Another method by which the grid is made negative in respect to the filament thus decreasing the grid current is by inserting in the grid lead a condenser shunted by a resistance. The condenser offers a low impedance path for the grid radio frequency currents. The resistance is connected to the negative terminal of the high voltage plate supply and the voltage drop across this resistance places the correct negative bias on the grid of the tube.

33. **Safe Plate Dissipation**—It has been shown that a considerable amount of power was lost by heating the plate of the tube. The power lost in this way is called plate dissipation and is rated in watts. The electrical data accompanying each power tube shows what the value of this dissipation should be. The tube should always be operated at a high enough efficiency so that the difference between the input and the output does not exceed the rated safe continuous plate dissipation.

Example: A UV—203-A Radiatron has a power rating of 50 watts. Its safe plate dissipation is 100 watts. Operating at normal load the watts input would be:

Plate Voltage	1000
" Current	.125
Watts Input	125
" Output	50
" Dissipated	75

If the grid leak resistance is of the correct value and current carrying capacity the power expended in the grid-filament circuit can be omitted and the 75 watts considered as the plate dissipation. The normal plate dissipation has been shown as 100 watts for this type of tube, therefore the tube is being operated 25 watts lower than its maximum rating. Operating the tube at more than its normal safe plate dissipation without an attendant increase in power output may result in damage such as reduced electronic emission. If operated over a period of time the excessive heating of the plate may liberate gases from the metal which will be manifest by a milky white smoke within the tube. The tube is then said to be " soft " and is of no further use in this condition.

34. **Water Cooled Power Tubes**—If some means such as water cooling is used to carry away the heat energy dissipated by the plate, the output may be materially increased. The majority of power tubes from 1 K.W. upward are water cooled. Figure 108 shows a water cooled tube used in radio broadcasting. Water cooling is accomplished by placing a water jacket around the plate of the tube to which a rubber hose is attached. A motor-driven pump supplies a constant stream of fresh water through the hose to the bottom of the water jacket. An outlet is provided at the top of the jacket for the return path of the water. The fresh water and rubber hose provide the insulation between the plate and other low potential parts of the circuit.

Filament Construction of Power Tubes—The power tubes manufactured by the General Electric Company for the Radio Corporation of America have either a tungsten or thoriated tungsten filament. The thoriated or XL type of filaments provide a high filament emission at a low operating temperature combined with low power consumption and long life. The power tubes manufactured by the Western Electric Company have either a tungsten or oxide coated platinum filament. The use of an oxide filament provides ample filament emission at cherry red temperature. For maximum tube life filaments should always be operated at the lowest voltage consistent with satisfactory operation of the transmitter. In case of all tubes equipped with thoriated filaments, the end of the useful life of the tube is usually reached before the filament burns out. A tube may have lost its emission and be useless even though the filament lights and it is not otherwise defective.

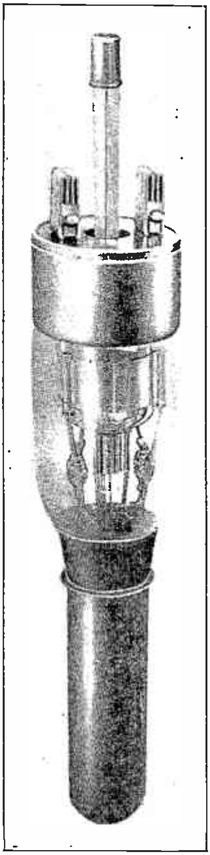


FIG. 108. Western Electric 5-K.W. Water-Cooled Power Tube.

Reception of Undamped Oscillations—In order to receive undamped oscillations some method must be employed whereby they are broken up into audio frequency groups, otherwise they will not be detected by either a crystal or vacuum tube detector and no response will be heard in the telephone. The diaphragm of the telephone is unable to vibrate at such high frequencies and, even though it did, no sound would be heard by the operator as the vibrations would be above audibility. The manner by which these undamped oscillations are made audible is known as the heterodyne method of reception. This method consists of combining with the received radio frequency wave another locally generated radio frequency wave of the same amplitude but of a different frequency. The two frequencies acting upon each other produce what is known as a "beat" frequency which is the numerical difference between the two frequencies. The principle of beat frequencies can be explained by the phenomenon which is produced when two keys close together on a piano are struck simultaneously. Due to the fact that the frequencies of the two keys are nearly the same the listener will hear a periodic increase and decrease in the intensity of the sound as the waves from one key add to, then neutralize the waves from the other.

If the undamped wave of a distant radio telegraph station transmitting at a frequency of 500,000 cycles (599.6 meters) is combined with another locally generated undamped wave of the same amplitude but of a frequency of 501,000 cycles and the combination passed to a detector there will result an audio frequency alternating current of 1,000 cycles per second. Likewise if the locally generated frequency was 499,000 cycles there would be produced after detection a beat frequency of 1,000 cycles. Thus it can be seen that a beat frequency is produced whenever the local generated frequency is tuned above or below the received signal. If the beat frequency is not more than 16,000 cycles it will produce an audio response in the telephones of the detector circuit. If of more than 16,000 cycles the beat frequency will be detected but will be beyond the limits of average audibility.

In other words a beat frequency is produced whenever the received waves are heterodyned by a local oscillator of different frequency. The beat frequency produced may be either an audio or a radio frequency depending upon the numerical difference of the two frequencies.

If the local generated frequency is tuned to exactly the same frequency as the received signals there is, of course, no beat frequency and the condition of "zero beat" is said to exist. This means of receiving has also been termed "homodyne" method. It is sometimes employed in the reception of modulated waves. Extreme care must be exercised by the operator to keep the two frequencies in tune. The slightest change in the capacity of the tuning circuit such as by the hand of the operator brought close to the tuning elements will result in the production of a beat frequency making the signals unintelligible.

35. Autodyne Method of Reception—The autodyne or self-heterodyne method makes use of the regenerative detector circuit wherein the feed-back is increased until the oscillations are produced as has been explained earlier in the chapter. The frequency of the oscillations are determined by the tuned grid circuit. By slightly detuning the grid circuit the frequency of oscillation is changed without tuning the received signal and there is produced a beat frequency corresponding to the difference between the frequency of oscillation and the signal frequency. The amount of detuning required to produce a beat frequency is not large and makes but slight decrease in the amplitude of the received signals. Autodyne reception of undamped waves is employed very successfully from 3/4 to 20,000 meters.

As explained by S. Ballantine,[1] the merit of the system of autodyne reception of undamped waves depends upon the stability of the oscillations in the circuit. With tickler coil arrangement, the sensitivity is closely proportional to the rate at which the average

[1] Radio Telephony for Amateurs, by S. Ballantine.

plate current changes with a slight change in the tickler coupling. This will depend to a large extent upon the stability of the oscillating state, and as a general rule it can be said that anything that can be done to make the oscillations less stable will increase the intensity of the beat note. For this reason the feed back should not be increased much above the point at which oscillation starts.

36. **Heterodyne Method of Reception**—The heterodyne (other power) method requires a local external oscillator so arranged that the radio frequency currents generated by it are coupled to the grid or plate circuit of the detector tube. The use of the separate source of oscillations has the advantage over the autodyne method that the beat frequency can be produced without changing the tuning adjustments of the receiving circuit. Figure 109 illustrates a simple receiving circuit connected so as to receive undamped waves by the separate heterodyne method. The filament return of the detector circuit has a few turns placed in an inductive relation to the grid coil of the oscillator (indicated in diagram as "pick up" coil) so as to couple some of the energy of the oscillator to the detector circuit.

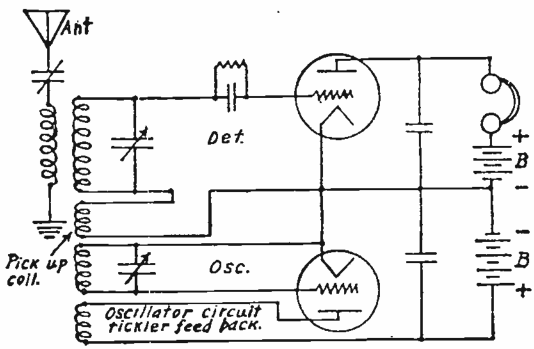


FIG. 109. Simple Heterodyne Circuit.

The most valuable feature of the heterodyne method of reception is the gain in signal strength and selectivity.

In both the autodyne and heterodyne methods the amplitude of the beat frequency, correspondingly the telephone response, is directly proportional to the amplitude of the incoming oscillations. The relation of direct proportionality for beat reception is in contrast to the detection of spark or modulated signals where the response is proportional to the square of the signal strength. Employment of beat reception insures equal amplification of weak and strong c.w. signals, whereas the employment of ordinary detection of spark or modulated waves produces a gain in the strength of the strong signals and a reduction in that of the weak signals. When it is considered that the signals from a continuous wave transmitter decrease inversely as the square of the distance the advantages of continuous waves is quite apparent.

Interference is minimized because even slight differences in frequency of the waves from other sources result in notes either of different pitch or completely inaudible. By suitable adjustments of the oscillator the beat frequency can be made to equal that corresponding to the resonant frequency of the transformer employed in the audio frequency amplification system thus permitting high amplification of that particular frequency with an attenuation of other frequencies resulting in a gain of selectivity. It is sometimes easier to copy a weak signal through interference such as "static" by employment of the beat method of reception. Assume the static discharges produce a signal voltage three times as strong as that of the signal which it is desired to receive. By employment of the beat method of reception in which the response is directly proportional to signal voltage the static discharges will be three times as strong as the desired signal. However, if the ordinary method of detection is used wherein the response is proportional to the square of the signal voltage the static discharges will be nine times as strong as the signal.

37. **Double-Detection Receivers**—It has already been explained how and why radio frequency amplifiers become increasingly unstable as the wavelength at which they are operated is decreased. A long wave radio frequency amplifier is much more stable and amplifies somewhat more. Realizing these facts Maj. E. H. Armstrong conceived the idea of employing a high wavelength (low frequency) amplifier of fixed tune and by the principle of beat frequencies changing the incoming high frequency (low wavelength) to that suitable for the amplifier.

Figure 110 shows the schematic arrangement of a superheterodyne. It will be noted there are two detectors, and for this reason the system is sometimes called the double detection method of reception. The second oscillator shown is only necessary when it is desired to receive continuous wave signals. Due to the large values of amplification possible with a superheterodyne it is only necessary to employ a loop or short length single wire antenna as the pick-up device. Increasing the length of the outside antenna will give an increased signal strength but at the same time increasing the noise level as well as decreasing the selectivity. Regarding the decrease in selectivity this will be especially notice-

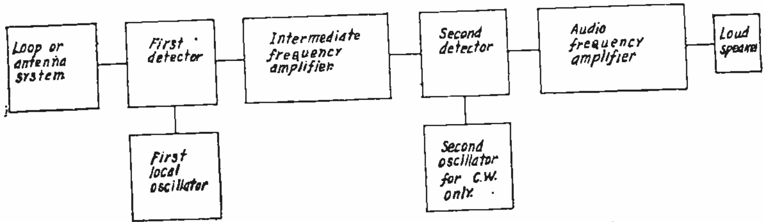


FIG. 110. Schematic of Double-Detection Receiver.

able when operating a "super" in an area surrounded by several local stations.

The Frequency Changer—The frequency changer of a superheterodyne consists of the first detector and local oscillator. The detector may be operated by the "C" battery method or by the use of a grid leak and condenser. The frequency of the oscillator is always controlled by a variable condenser.

The purpose of the oscillator in the superheterodyne is to provide a source of local radio frequency energy differing in value from the incoming signal frequency by the frequency to which the intermediate amplifier is tuned. The oscillator circuit employed should have a reasonable uniform output over the whole band of frequencies at which the super is operated, should be free from harmonics and have an oscillator condenser which can be operated without trouble from body capacity.

If the oscillator output is not uniform the receiver will be more sensitive at one end than at the other. Again if the output is too great, distortion in the form of a loud hissing or rushing sound will be heard with the signal. This is especially objectionable when it is desired to receive speech or music. If the oscillator emits harmonics it will be noted that a station may be heard, at several different settings of the oscillator condenser.

The operation of a superheterodyne oscillator seems to mystify the average broadcast listener, especially the fact that it is possible to bring in a station at more than one setting of the oscillator dial. Some listeners seem to think it is a fault of the transmitter. The reason can be explained as follows: Normally there are two places relatively close together on the oscillator dial at which the station may be heard. Consider the intermediate frequency amplifier designed to amplify at a frequency of 40 kilocycles (40,000 cycles

6,663 meters). In order to receive a signal from a transmitter operating on 1,000 kilocycles (299.8 meters) it would be necessary to tune the oscillator to 40 kilocycles above or below 1,000 kilocycles, that is, 1,040 or 960 kilocycles, either of which when combined with the incoming frequency and detected will produce a 40 kilocycle beat frequency. Thus it can be seen that if the oscillator is tuned to either 1,040 or 960 kilocycles the station will be heard. In order to explain why the station can be heard at other settings of the dial it is necessary to consider the harmonic frequencies generated by the oscillator. As already described a vacuum tube oscillator will generate besides the fundamental frequency other frequencies which are multiples of the fundamental. In this particular case consider the wavelength dial as set at the point where the 1,000 kilocycle station is heard. Now readjust the oscillator dial as if to receive a higher wavelength station until at some point on the dial the station operating on the 1,000 kilocycles is heard. This will probably occur when the movable plates of the condenser are almost in, that is, at nearly maximum capacity. If the frequency of the oscillator were to be measured at this point it will probably be 520 kilocycles. Now the second harmonic of 520 kilocycles is 1,040 kilocycles and it corresponds to the frequency at which it was necessary to set the oscillator originally in order to produce a beat frequency of 40 kilocycles. It is then obvious that the second harmonic of the oscillator is combining with the incoming frequency to produce the beat frequency which the intermediate amplifier accepts for amplification. If the oscillator were to be tuned to a still higher wavelength another point on the dial will be noted where the station is heard again. This frequency when measured will be 480 kilocycles the second harmonic of which is 960 kilocycles. This frequency corresponds to the other original setting of the oscillator necessary to produce the correct beat frequency. It is not always necessary to leave the wavelength dial set to note the effect just described. As the two dials are tuned together while searching for some particular station, the oscillator might arrive at some frequency whereby its harmonics may produce the desired beat frequency with a local station and although the wavelength dial may be considerably off from the frequency of the station its signals will be heard. This usually indicates a high resistance tuned input circuit and is aggravated somewhat when the superheterodyne receiver is operated on an outside antenna.

In figure 111 are shown two of the most popular types of oscillator circuits. The coupling coil is employed to transfer energy from the oscillator to the first detector. This coil is generally placed in the grid circuit of the first detector, next to the grid, or in the grid return to the filament although it can be placed in the plate circuit. The writer has found by experiment that the best

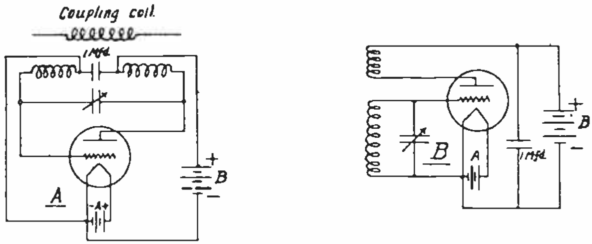


FIG. 111. Oscillation Circuits Used with Double-Detection (Superheterodyne) Receivers.

results are secured by placing it in the filament return circuit. By devising a means of loosening the coupling as the wavelength is decreased a considerable gain in sensitivity at the shorter wavelengths results. This is especially so when the oscillator circuit *B* is employed.

The oscillator circuit of *A* in figure 111 consists of a split winding of two equal sections, the tuning condenser being connected to the outside terminals of the coil, in parallel with the grid and plate of the oscillator tube. The high capacity condenser connected across the low potential ends of the coil serves to by-pass all high frequency currents around the plate battery.

This circuit has the advantage of having a fairly uniform output throughout the broadcast frequency range. It has several disadvantages, the main one of which its its body capacity effect. It will be noted that the rotary plates of the tuning condenser have to be connected either directly to the grid or the plate of the tube. If the rotary plates are connected to the plates of the tube, the trouble from body capacity will be decreased but not eliminated. If a variable condenser in which the shaft is not a part of the circuit is used, the body capacity effect can be entirely eliminated. The position occupied by the tuning condenser subjects it to the full plate voltage and should it become short circuited the plate battery will be run down and if the negative " B " is connected to the positive " A " battery all the tubes in the set will burn out. This may be averted by connecting a fixed condenser of .005 mfd. capacity or higher in series with the oscillator condenser. The capacity of the latter compared to the former is so great as to have but little if any effect on the tuning and acting as a blocking condenser in case of a short circuit.

The circuit of *B* is the familiar regenerative detector circuit except that the plate or tickler coil is fixed. The coil is coupled close to the grid coil so that the tube oscillates throughout the entire broadcast frequency range. The variable condenser across the grid coil controls the frequency of oscillation, the rotary plates being connected to the low potential end of the coil the circuit is free from the effects of body capacity. The output of this circuit is not quite so uniform as that of *A*. Both circuits will produce harmonics in about the same amount.

The frequency changer circuit as employed in the Western Electric Double-Detection Receiver type 4-C is shown in figure 112.

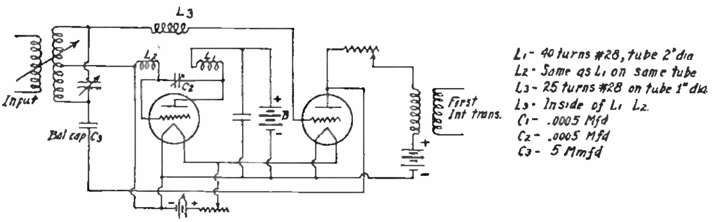


FIG. 112. Frequency Changer Employed in Western Electric Type 4-C Double-Detection Receiver.

The small condenser marked Bal.Cap. helps to stabilize the first detector at the same time providing a limited amount of regeneration in the circuit. The coupling coil is in the grid circuit of the first detector.

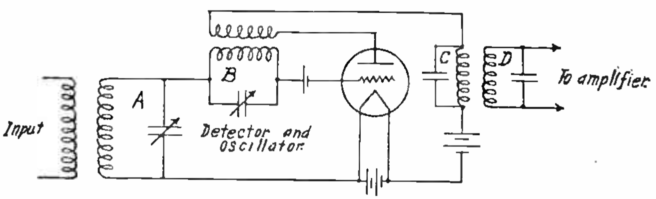


FIG. 113. Fundamental Circuit of the Oscillator and Detector of Second Harmonic "Superheterodyne."

In the earlier type of superheterodynes the first detector was made to function as both detector and oscillator. The general arrangement is illustrated by figure 113. In this circuit *A* is tuned to the incoming signal, circuit *B* is tuned to one-half of the incoming frequency plus or minus one-half of the intermediate frequency and the circuits *C* and *D* are both tuned to the intermediate frequency. There are created in the circuit a number of harmonics. The second harmonic combines to produce beats with the incoming signals of the desired intermediate frequency. On account of the fact that circuits *A* and *B* are tuned to frequencies differing by approximately 100 percent a change in the tuning of one has no appreciable effect on the tuning of the other.

Due to the variety of harmonics created stations repeated at several different places on the dial. The system is rarely used at this date except for reception of telegraph signals at wavelengths below 30 meters where it is most useful.

The Ultradyne—" Ultradyne " is the name that has been applied by Mr. Robert LeCault to a special form of double-detection receiver devised by him and first described in Radio News.

In the Ultradyne, figure 114, the first detector does not receive its supply from the " B " battery but instead operates with an alternating current plate supply. This alternating current is of radio frequency and is supplied by an oscillator of the usual type.

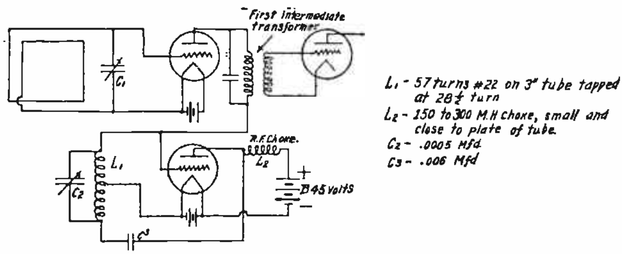


FIG. 114. Fundamental Circuit of Frequency Changer of Ultradyne.

The incoming frequency and the oscillator frequency are combined in the plate circuit of the first tube and by plate rectification a beat frequency is produced. As reported by many experimenters the circuit is especially sensitive to weak signals.

38. The Intermediate Frequency Amplifier—The intermediate frequency amplifying transformers as used in superheterodynes consist of the condenser-tuned air-core transformers, fixed air-core transformers, or fixed iron-core transformers.

At short wavelengths condenser-tuned air-core transformers are entirely satisfactory. At long wavelengths, such as 10,000 meters they will tune too sharp resulting in serious distortion. An analysis of the transmitted wave of a radio broadcasting transmitter will show that besides the carrier frequency there is present a band of frequencies twice as wide as the highest modulating frequency obtained from the microphone. Thus if the highest frequency obtained from the microphone is 7,000 cycles the band occupied by the radiated wave is 14,000 cycles wide. In other words, the carrier frequency is modulated 7,000 cycles each side of its assigned frequency. Assume the carrier frequency of a broadcasting station to be 1,000 kilocycles or 1,000,000 cycles. When modulated the space occupied by the transmission will extend up to 1,007,000 cycles and down to 993,000 cycles. Converted to wavelength these side band frequencies correspond to 297.7 and 302 meters. The band occupied for transmission extends then from 297.7 to 302 meters, a total width of 4.3 meters. The width of the band necessary to transmit modulated frequencies extending to 7,000 cycles is always 14,000 cycles (14 kilocycles) but the width expressed in meters will depend upon the wavelength of the carrier. Assume the air-core condenser-tuned transformers were to be used at an intermediate frequency of 10,000 meters or 29.98 kilocycles. In order to amplify the modulated frequencies up to 7,000 cycles would require that the transformers accept a band of frequencies extending from 36.98 to 22.98 kilocycles or when converted a wavelength band 6,800 meters wide. Therefore it can be seen that a sharply tuned transformer would not do as the side bands would be cut off and distortion would result. At 1,500 meters or less the desired characteristics could be realized as the wavelength band necessary to include all the side band frequencies would be only 20 meters wide. However at such frequencies the whole system may be unstable and it will be necessary to prevent oscillation by one of the methods previously discussed.

Fixed air-core transformers may be tuned by the distributed capacity of the coils. The distributed capacity of the winding and their inductance form a circuit which is resonant to a given band of frequencies. Although tuning somewhat broader than condenser-tuned air-core transformers they are used to best advantage when operated at a high frequency or low wavelength. When special constructional details are employed to reduce the distributed capacity of the windings they may be operated at 40 to 60 kilocycles with success.

Iron-core transformers possess the ideal characteristics desired in an intermediate transformer. The iron-core helps to broaden the tuning thus permitting the advantageous use of a low intermediate frequency which means high amplification with stability. However, if tuned too broad the curve overlaps into the audio frequency band (below 10,000 cycles) and the transformer will be noisy. This is illustrated by the curve *B* of figure 115.

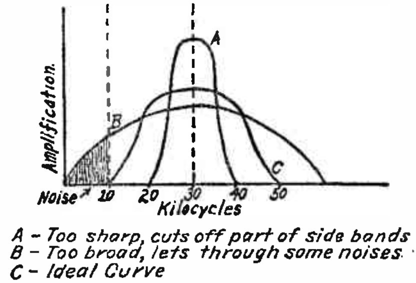


FIG. 115. Frequency Amplification Characteristics of Intermediate Frequency Amplifier.

Sometimes it is convenient to provide a condenser-tuned transformer in the first or last stage of an intermediate frequency amplifier employing iron-core transformers in order to sharpen the tuning. This arrangement is known as the "filter circuit." It is designed to be resonant at the intermediate frequency of the amplifier.

The second detector usually employs the standard grid leak and condenser. The grid condenser should have a value of .0005 to .001 mfd. to permit the easy passage of the low intermediate frequency currents.

The audio frequency amplifier may consist of any of the standard systems of amplification such as transformer, impedance or

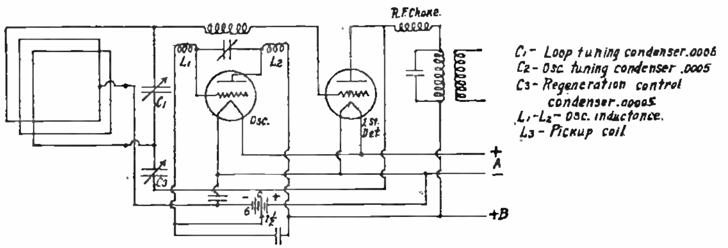


FIG. 116. Regeneration with Tapped Loop.

resistance coupling. The addition of a stage tuned radio frequency amplification ahead of the first detector gives somewhat increased gain in signal strength at the same time increasing the selectivity of the tuner and prevents the energy from the oscillator from being radiated. Regeneration in the first detector circuit can be accomplished by providing the loop or coupling coil with a center tap and connecting the plate of the detector tube to the loop or coil by a .00005 mfd. condenser as in figure 116. If the primary of the first intermediate frequency amplifier is tuned by a condenser the energy that should be fed back by the .00005 condenser will be by-passed and no regeneration will result. The

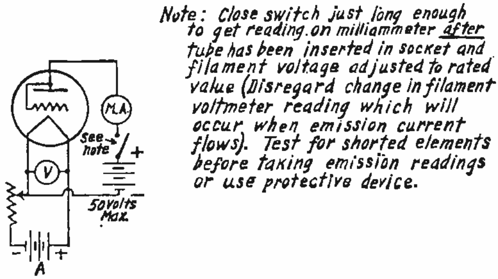


FIG. 117. Emission Test Circuit.

remedy for this condition is a radio frequency choke in the lead from the plate of the detector tube next to the primary terminal of the first intermediate transformer.

39. Reactivation of Thoriated Tungsten Filament Receiving and Rectifying Tubes—The filament condition of a tube may be most readily judged by an emission test using the circuit shown in figure 117. The voltages specified should not be exceeded. Higher voltages will permanently damage the vacuum and may even result in a burnout. If the emission is above the minimum value specified below, the tube is in good condition and does not need reactivation. If equipment for reading emission is not available a simple test for the two most widely used tube types can be made on the customary tube test set which measures plate current. This circuit is shown in figure 118.

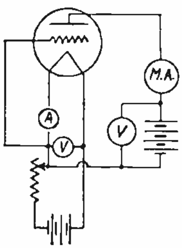


FIG. 118. Plate Current Test Circuit (Zero Grid Voltage).

For UX-199 or CX-299 tubes, set the plate voltage at 45 volts with the grid connected to the negative filament, set the filament voltage at 3 volts and read the plate current. *Momentarily* increase the filament voltage to 3.5 and read the plate current. If the plate current increases more than .2 milliampere, the filament is not fully active and the tube may be improved by the reactivation process.

For UX-201-A or CX-201-A tubes, the same value of the plate voltage (45) is used but the plate current is read with the filament voltage set at 4 and 6. An increase of more than .2 milliampere in the plate current indicates that the tube may be improved by reactivation.

If the tube will not return to normal after reactivation treatment it is proof that the tube has either served its normal life or has been so heavily overloaded that the thorium content has been exhausted or the vacuum impaired.

TABLE OF EMISSION CURRENT AND REACTIVATION VOLTAGE.

Type No.	Filament Voltage	Plate Voltage	Minimum Emission	Maximum Reactivation Voltage	Maximum Flashing Voltage
UX-199 or CX-299 . . .	3.3	50	6 m.a.	4.0	12
UX-120, CX-220	3.3	50	15 m.a.	4.0	12
UX-201-A, CX-301-A .	5.0	50	25 m.a.	7.0	18
UX-200-A, CX-300-A .	5.0	50	12 m.a.	7.0	18
UX-171, CX-371	5.0	50	50 m.a.	7.0	18
UX-210, CX-310	6.0[1]	100	100 m.a.	10.0	—
UX-213, CX-313	4.0[1]	100'	50 per anode	7.0	—
UX-216B, CX-316B . .	6.0[1]	125	100	10.0	

If the tube will not return to normal after reactivation treatment, it is proof that the tube has either served its normal life or has been so heavily overloaded that the thorium content has been exhausted or the vacuum impaired.

Methods of Reactivation—The following methods will generally restore the emission, that is reactivate, tubes which have been overloaded and also, at times, will reactivate, for short additional usage, tubes that have dropped in emission at the end of normal life. The exact process which gives the best results depends upon the nature and extent of the overload to which the tube has been subjected.

Tubes which have been subjected to only a slight overload may be reactivated by a very simple process. This consists in

[1] Emission of these tubes read at voltages below rated values.

Note: In taking emission readings the current may begin to fall off. Test should not be continued long enough to cause this to happen.

burning the filament, with the plate voltage disconnected, at the voltage listed in the table under the heading "Reactivation Voltage." This process speeds up the "boiling out" of the thorium from the body of the wire while at the same time the surface evaporation is very slow when plate voltage is not applied. The length of time required to reactivate a tube by the treatment is one-half to one and one-half hours, depending largely upon the length of time and extent to which the tube has been subjected to excessive voltage. At the end of thirty minutes burning, test the tube as explained above. If the emission shows improvement continue the treatment until test shows the tube to be above minimum passing limit.

Tubes which have been badly overloaded may not improve under this process, and a "flashing" voltage must be used, as outlined below:

First burn the filament for 10 to 20 seconds at the voltage shown in the table under the heading "Flashing Voltage." Then burn the filament under the process described above, using the voltage listed as "Reactivation Voltage." Read the emission at the end of 30 minutes and if not restored, continue to burn the filament up to 2 hours, taking readings every 30 minutes. If two hours treatment does not restore the emission or greatly improve it, it is proof the tube cannot be reactivated.

No plate voltage is ever applied during reactivation.

The applied voltages should always be controlled by a suitable voltmeter.

A small percentage of tubes reactivated by the use of flashing voltages may be expected to burn out during treatment.

Rapid reactivation, sometimes within ten minutes, can be accomplished by the use of voltages higher than those recommended above. This process very materially shortens the tube life and such reactivation is generally not permanent. Futhermore, the use of higher voltages greatly increases the percentage of tubes that burn out and the filament is frequently poorer at the end of the treatment than at some earlier period. Reactivation by the "while you wait" process cannot be recommended.

Reactivation Equipment—Alternating current from the lighting supply is most convenient and can be stepped down to the proper voltage by a toy or bell ringing transformer, such as G.E. Type No. 236093, which is provided with two-volt taps from 4 to 22 volts. The circuit diagram is shown in figure 119. As a.c.

voltmeters require considerable current they should not be left permanently in circuit parallel with the tubes.

If alternating current is not available d.c. supplied by storage batteries may be used. The flashing voltage may be obtained from

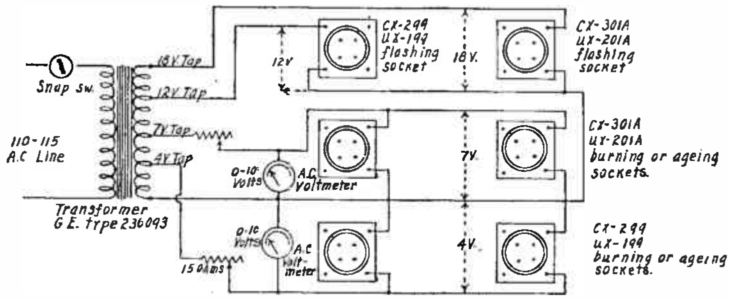


FIG. 119. Alternating Current Reactivating Apparatus and Circuit.

a storage " B " battery of the larger sizes. Only one tube should be flashed at a time on a " B " storage battery and the battery must be left fully charged. See figure 120.

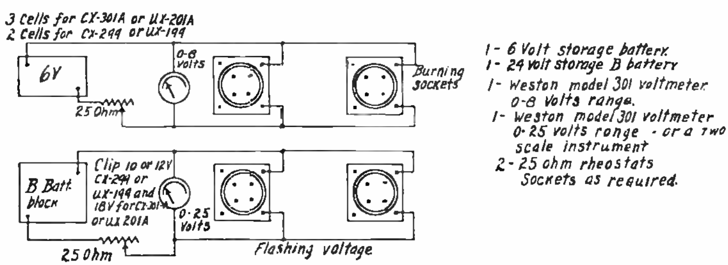


FIG. 120. Direct Current Reactivating Apparatus and Circuit.

Normal Operation Precautions—If it is necessary to reactivate tubes each month or at frequent intervals, it is proof that the tubes are being overloaded, and in such cases better service will be obtained if the following precautions are observed:

1. Do not burn filament at voltages in excess of the rated filament terminal voltage: Keep the filament rheostat set as low as possible, or use a reliable voltmeter.

2. Do not use high plate voltages unless " C " batteries are provided. With types C-299, CX-299, UV-199, UX-199 and CX-

301-A, UV-201-A and UX-201-A better life is obtained, and "B" battery current drain lessened when a voltage of 67 1/2 volts or less is used in the plate circuit in case no "C" battery is provided.

3. Be careful when changing battery connections to see that battery polarities are not reversed. If the leads connecting filament heating (A) or grid biasing (C) battery are reversed, signals and music may still be heard, but they will be faint and distorted. Such a reversed condition often causes the operator to turn the filament to a high setting, thus injuring the tubes without appreciably improving results. Always check battery connections after making any change.

4. If an insensitive tube and a tube in perfect condition are operated from the same rheostat, there will be a tendency to overload the good tube in order to obtain operation from the poorer one. The poor tube should be reactivated or replaced. Here also the use of a reliable filament voltmeter will save overloading the tubes.

5. When using C-299, CX-299, CX-220, UV-199, UX-199, UX-120 types and a filament voltmeter is not available, the operation of the set may be checked as follows: Connect *only two* fresh dry cells in series for use as the filament heating (A) battery. The rheostats may now be turned on full and if the set and tubes are operating correctly, satisfactory reception will be obtained. If results are not satisfactory check over batteries, battery connections, antenna connections and tubes. When the trouble is located, satisfactory reception will be obtained with two fresh cells.

40. General Comment—Many of the standard types of tube rejuvenators use excessive voltage with the frequent result that the tube is permanently damaged or has its useful life shortened. This is especially true with C-299, CX-299, CX-220, UV-199, UX-199 and UX-120 tubes. With these tubes the second burning voltage should not exceed 4.0 volts.

The voltages specified in the table are the maximum which should be used. The use of a voltmeter to set the applied voltages to the proper values is essential to obtain proper results.

Tubes which have internal shorts between elements cannot be reactivated and it may be convenient to check for such conditions with a pair of phones and a dry cell. When the tube is not lighted there should be an open circuit between the grid and all other elements, between the plate and all other elements, and a closed circuit through the filament.

Tubes in which the vacuum is impaired cannot be reactivated. This is usually indicated by a filament current reading above rated value. If considerable air is present in the tube, the filament will not light up at all unless the filament voltage is raised well above normal, in which case the filament may burn out.

Cunningham tubes type C-11, CX-12, CX-12 and CX-200 and Radiotron tubes type WD-11, WX-12, UX-112 do not use thoriated tungsten filament and cannot be reactivated.

41. Testing Tube UX-300A or CX-300A Detector Tubes—The UX-200A or CX-300A tube is designed only for service as a detector and differs from other types in that it contains an alkali vapor. The formation of the vapor occurs during the first three minutes after the tube is lighted, during which period the tube characteristics change rapidly causing variations in readings of plate current and performance of the tube when operating in the radio receiving set. As soon as the tube has warmed up, or at the end of about three minutes, the readings become uniform and no further changes occur. As a result of this action, readings taken during the period of change are variable, and of no value. However, since the change does not usually begin until the tube has been in the socket about one minute, it is possible to make a quick test immediately after it has been placed in the socket, otherwise, the readings should be taken at the end of three minutes.

Tests on the UX-300A or CX-300A should be made at a plate voltage of 45 volts and no higher voltage should be used. Since it is designed for detector service only, a thorough test of the tube requires considerable equipment. Plate current readings, such as taken in the ordinary test sets, *indicate only the condition of the filament and cannot be depended upon as a test of detector sensitivity*. For that reason the best practical test of the tube is a check of the operation obtained under actual service conditions in a receiver, a weak incoming signal being preferable. Quick tests made during the first minute will usually suffice, but if any doubt as to the satisfactory performance of the tube arises, it should be allowed to burn the full three minutes before completing the test.

A plate current reading obtained with this tube when used in a receiver set with a grid condenser and grid leak is quite different from that obtained in a test set. Under usual conditions the plate current is approximately 1.0 m.a., varying only slightly from this value whether the grid return is connected to the negative or to the positive filament. The difference in readings as compared with those obtained in a test set is due to the fact that the grid current furnished by this tube is sufficient to establish a voltage drop in the grid leak equivalent to the use of the grid biasing voltage of 2 or 2 1/2 volts.

Under service conditions a hiss is frequently produced at the time the changes in plate current above noted are occurring. If a milliammeter is placed in a detector plate circuit, it will be noted that the initial reading is perhaps 1.0 milliampere remaining at this value during the first minute, while during the second minute the plate current gradually increases to 2.0 or 3.0 m.a. It is during this change that the hiss sometimes occurs. The plate current then returns to a value close to the initial reading and the tube thereafter will operate quietly.

There are several reasons for not testing this tube at voltages higher than 45, the first being that it does not represent the operating conditions, and secondly that grid biasing voltages are often applied when testing at the higher voltages. Because of the high amplification constant of the tube the plate current will be practically blocked at 90 volts plate, if the ordinary voltage of minus 4 1/2 volts is applied to the grid the reading obtained being a fraction of a milliampere.

When a test of the filament conditions or for shorted elements only is desired, the readings obtained from the ordinary type of two meter test sets will be found satisfactory. Sample readings obtained on this test are given below:

Plate Voltage 45 Filament 5.0

Grid return first to minus F then to plus F

	Average Plate Current. Grid to − F	Average Plate Current to + F
UX-300A, CX-300A (Cold under 1 min.)	1.6 m.a.	6.1 m.a.
UX-300A, CX-300A (Hot after 3 min.)	2.1 m.a.	6.2 m.a.

42. Reactivation of Power Tubes—In case of severe overload resulting in overheating of the tube the electron emission may decrease and oscillations may not start when the key is closed. Unless the overload has liberated a large amount of gas the activity of an XL filament may be restored by operating the filament at a voltage about 20 per cent above normal for ten minutes. The plate and grid voltages should be disconnected during the process of reactivation. If the emission fails to return to normal the tube may be flashed and "aged." This process consists of operating the filament of the tube at a voltage about 50 percent above normal for one-half of a minute and then reducing the operating voltage to about 20 percent above normal from two to fifteen minutes. The plate and grid voltages are disconnected during the process. If the emission has not been brought back at the end of two minutes the aging process may be continued. However, if the emission does not return at the end of ten or fifteen minutes of ageing further attempt at reactivation may be considered useless. At the conclusion of each ageing process the normal grid and plate voltages should be applied and test made to see if the tube will oscillate. Extreme care must be exercised during the process or the filament will be ruined permanently. A table is shown on the following page giving the best values for flashing and ageing for the standard tubes in use.

Note: Reactivation is applicable only to those tubes having thoriated filaments.

TABLE OF BEST FLASHING AND AGEING VALUES FOR POWER TUBE REACTIVATION.

Type of Tube	Normal Filament Voltage	Flashing Voltage	Flashing Time	Ageing Voltage	Ageing Time
UV-203-A	10	20	30 Sec.	12	2 Mins.+
UV-204-A	11	22	30 Sec.	13	2 Mins.+
UX-210	7.5	15	30 Sec.	9	2 Mins.+
UV-211	10	20	30 Sec.	12	2 Mins.+
UX-213	5	10	30 Sec.	6	2 Mins.+
UX-216-B	7.5	15	30 Sec.	9	2 Mins.+
UX-852	10	20	30 Sec.	12	2 Mins.+

43. The UX-222 Screen Grid Tube—The UX-222 (CX-322) is a distinct departure from the conventional type of the three-element radio tube. The usual characteristic and performance obtained from this tube are made possible by the introduction of a second grid, which extends between the usual grid and the plate and is carried over outside the plate. Thus the plate is completely shielded or screened from the control grid by the second grid.

When operated as a four-element tube a voltage of approximately 22 to 45 volts is applied to the screen grid, and a higher voltage (90 to 135 volts) is applied to the plate.

Filament—The filament is rated at 3.3 volts with a current consumption of .132 ampere. When used as a 3.3-volt tube from a 6-volt battery connect a 20 to 30 ohm rheostat in series with one side of the filament. If parallel with 5-volt tubes; connect a fixed resistance of 15 ohms in series with the filament of the tube. It may be then connected in parallel with other 5-volt tubes, operating from a common rheostat. If placed in the negative lead a tap at 10 ohms will provide 1.3 negative bias for the control grid.

The input or control grid connection is brought out at the top of the bulb. The connection to the screen grid is made to the regular grid connection on a standard socket.

There are several ways in which this four-element tube may be utilized in radio receiving and transmitting circuits the most advantageous of which is as a radio frequency amplifier. When so used the most important advantage gained is elimination of all feed-back through coupling between grid and plate, due to low capacity, these elements, the interelectrode capacity having a maximum of .025 microfarad. It is possible to obtain a voltage amplification of 25 to 50 per stage in the broadcast range as compared with the usual range of 5 to 12 per stage with three-element tubes.

In the operating range the plate current does not vary appreciably with changes in plate voltage, this being due also to the screening effect of the second grid. As a result the amplitude of the plate current change, caused by a signal voltage impressed on the grid is scarcely affected by an increase in load resistance. Thus it is of advantage to use a very high resistance or impedance in the plate circuit, in order to obtain high voltage amplification.

The voltage amplification depends only upon two factors:

1. The mutual conductance (g) of the tube, which determines the amplitude of the plate current change, resulting from a signal voltage impressed on the control grid and—

2. The load impedance. The voltage across the output load is directly proportional to the load impedance since the amplitude of the signal current, with moderate loads, remains unchanged with an increase in impedance. This is unlike the condition with three-element tubes, where an increase in load resistance results in a decrease in the amplitude of the signal current.

At low rate frequencies 50 to 100 kilocycles, it is possible to build up a very high load impedance by using a tuned plate circuit, and a voltage amplification of 200 per stage is obtainable. At broadcast frequencies it is not possible to obtain a sufficiently high load impedance to realize maximum voltage amplification, and the values quoted above represent average results (25 to 50 per stage).

The desired high load impedance may be obtained by the use of a tuned plate circuit, but it may be preferable to use a transformer connection with a ratio of 1.1 or slightly lower so that low frequency disturbances do not reach the grid of the succeeding tubes and to facilitate the use of ganged condensers for uni-control.

Although the internal shielding prevents feed-back through the

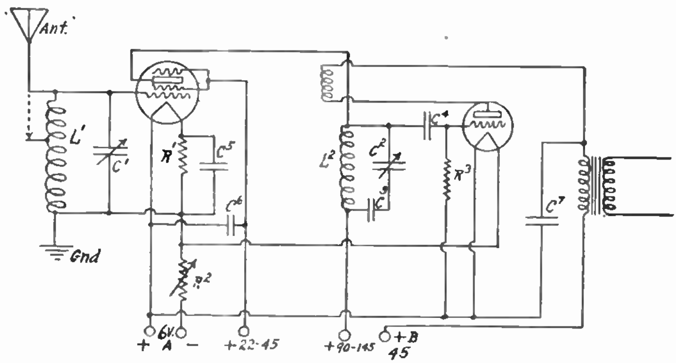


FIG. 121. Typical Screen Grid Tuned Plate R.F. Amplifier Circuit.

tube inter-electrode capacities, this is only one source of coupling between stages, and it is also necessary to shield the input circuit from the output circuit. The tube itself should be shielded, especially if the voltage amplification is high, by placing a metal cap over the tube, extending to the base, and connection must be provided at the top. This shield may be constructed of lead or tin foil and encircled around the shape of the tube.

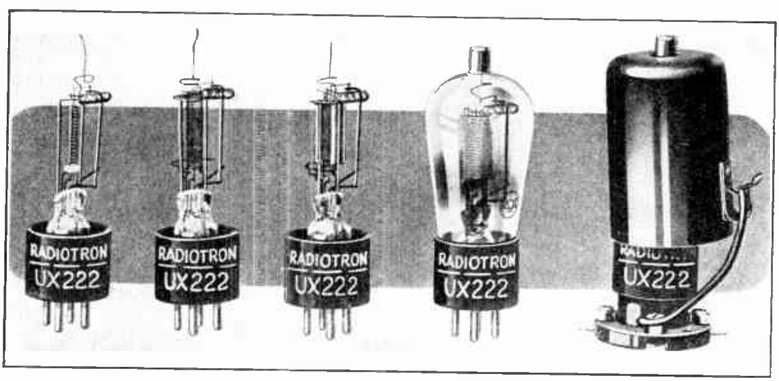


FIG. 122. UX-222 Screen Grid Tube in Various Stages of Assembly.

The UX-222 as an Oscillator—One of the greatest difficulties in making V.T. oscillators operate at a constant frequency is that the tuned circuit does not entirely fix the frequency. One of the reasons for this is that the tube capacities such as plate-grid capacity permits feed-back or grid excitation through the tube. The forcible removal of this feed-back by the introduction of the shield grid permits the control of feedback by external means that are under better control with a possibility of smoother and steadier operation. The output of the 222 is of course small and at this time permits of only experimental work. However in the end it may lead to transmitting oscillators which are somewhat more free from the undesired effects spoken of.

Reverse-Current Effect—One type of oscillator possible with the 222 tube does not use the ordinary principle of feed-back from plate to grid but instead takes advantage of reverse-current effect caused by secondary emission from the plate. The electrons passing from the grid strike the plate with sufficient violence to cause it to emit secondary electrons. If the grid is made positive with respect to the plate these secondary electrons will be attracted by this positive element. If the electrons striking the plate have sufficient velocity, the number of secondary electrons emitted will be large enough to cause electrons to flow out of this conductor instead of into it, thus reversing the direction of current. The device will then have the falling characteristic of the arc. As the plate potential is increased the current is decreased. A vacuum

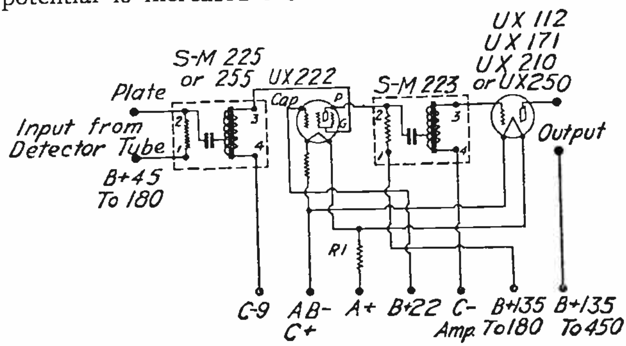


FIG. 123. Use of UX-222 Tube as First Stage Audio Amplifier with Space Charge Connection Followed by Silver-Marshall 223 Hi-Mu Transformer.

tube having this negative resistance characteristic can be used for the production of continuous waves. The tube and the circuit can be connected in several ways and have the advantage of being able to use untapped coils without ticklers and tuned by a single condenser. The 222 tube at present confines this use to laboratory work as its output is in very small power.

As an Audio Frequency Amplifier—The tube may be used as an audio frequency amplifier with resistance or transformer coupling. The screen grid voltage should be lowered to compensate for the voltage drop in the load unless a high plate voltage is available. With this connection a voltage amplification of 35 per stage may be readily obtained with perfectly flat frequency characteristic down to 50 cycles and below.

A.C. Screen Grid Tubes—Since the appearance of the UX-222 similar tubes have been marketed by many manufacturers and in addition the C.E. Co. of Providence, R. I., has marketed a tube known as the AC-22 in which the filament is operated on alternating current. The necessary electron emission is not obtained from the filament but from an "emitter" close to and heated by the filament. The rest of the structure and the general performance are similar to that of the UX-222.

Other A.C. Tubes—While almost any vacuum tube may be operated with a.c. filament supply when used in a transmitter or last audio stage (see figure 267*a*) there have recently appeared tubes designed for a.c. filament supply throughout the receiver. Typical of these are the UX-227 which (like the AC-22) uses the filament as a heater for a little "thimble" emitter and the UX-226 in which the filament is short and thick so that the voltage variations across it and the heat fluctuations during the cycle are not serious except in the detector socket where it is necessary to use a d.c. tube or one of the 227 type. The 226 type is connected like a d.c. tube except that plate and grid returns are not to one end of the filament but to a center-tapped resistance placed across the filament. The 227 type has the returns made to the "thimble," the a.c. filament having no connection with the r.f. circuits.

Double-ended a.c. tubes have long been built by Kellog and others. They are of the thimble type as are the Arcturus tubes. The latter have a thimble surrounding a filament but unlike other thimble tubes the "emitter" is connected to one end of the filament. The design of the tube has been so worked out that the a.c. hum which one would expect does not follow.

CHAPTER 5

FUNDAMENTAL CIRCUITS EMPLOYED IN VACUUM TUBE TRANSMITTERS

1. **Grid Excitation**—As described in the discussion of generation of radio frequency oscillations, some means must be provided for feed-back or coupling from plate to grid in order to maintain oscillations. It may be accomplished by one of two methods. Either inductive or capacitive coupling may be used. In commercial practice these methods are known as Hartley, Meissner or Colpitts circuits. They may feed direct to the antenna or feed through one or more stages of a radio frequency amplifier known as the "power amplifier." The first two named make use of the inductive grid feed-back, whereas the Colpitts circuit depends upon capacitive feed-back. The grids of the power amplifier tubes may be coupled to the oscillating (exciter) circuits in any one of a wide variety of ways.

2. **The Hartley Circuit**—Figures 124 and 125 show the

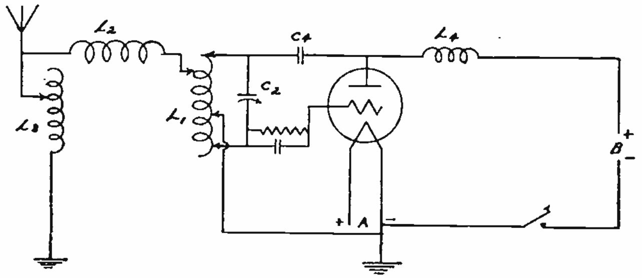


Fig. 124. Hartley Circuit with r. f. Line to Antenna.

Hartley circuit. The grid and plate turns are made variable so that adjustments can be made for correct grid excitation. The filament is connected at or near the middle of the inductance. If the number of turns from filament to grid is made greater than the number from filament to plate, a higher feed-back will result with a corresponding increase in plate ccurrent.

The portion of the coil between the filament clip and plate clip is referred to as the "plate coil." The part between the filament clip and grid clip is called the "grid coil." On making adjustments to this circuit if it is found that the plate current is higher than the normal rating the plate lead should be moved farther away from the filament.

The variable condenser C^1 in figure 125 permits precise control of the frequency. The relation of the grid tap to filament allows

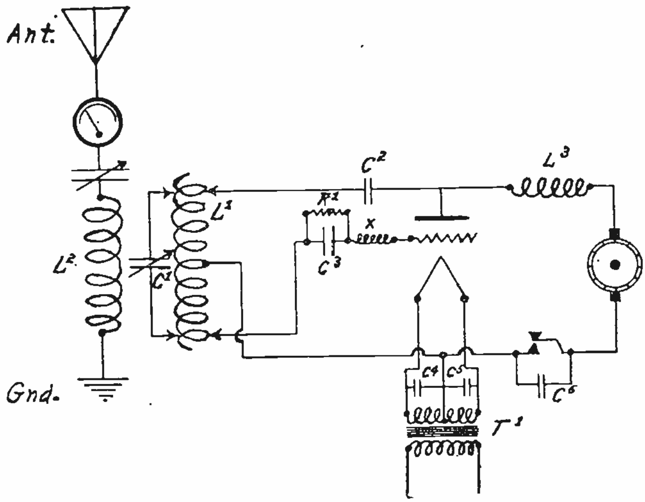


FIG. 125. Hartley Circuit Inductively Coupled to Antenna.

a rough variation in frequency. Moving the grid farther away from the filament decreases the frequency or vice versa.

The condenser C^2 prevents the high voltage generator from being short-circuited through the inductance L^1 but allows the radio frequency currents to pass from plate to inductance. The condenser C^8 prevents the high negative potential from the plate supply generator reaching the grid and also allows the radio frequency voltages to pass through. The function of the resistance R^1 is to place a negative bias of the correct potential on the grid of the tube thereby reducing the grid current and hence the power dissipated by the grid circuit. Condensers C^4 and C^5 by-pass the radio frequency currents across the secondary of the filament transformer T^1. Condenser C^6 prevents severe arcing which would otherwise occur when keying a 1000- to 2000-volt negative supply line. The radio frequency choke coil L^3 prevents the radio frequency currents reaching the armature of the high voltage generator. Should this occur it would result in a rupture to the insulation and consequent damage to the machine. The small radio frequency choke coil X in the grid circuit close to the grid of the tube prevents the generation of ultra high frequency or "parasitic" oscillations. By preventing the generation of these parasitic high frequencies (wavelengths in the vicinity of 20 to 60 meters) the plates of the tubes are made to operate much more coolly and the losses in the circuit are greatly reduced.

3. **Meissner Circuit**—Figure 126 shows a simplified arrangement of the 3 coil Meissner circuit. It has only one tuned cir-

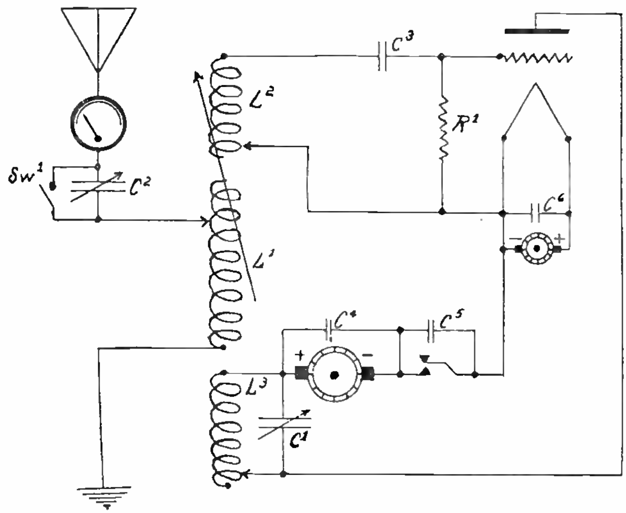


FIG. 126. Meissner Circuit with Series Plate Feed.

cuit, the antenna circuit. However, the circuit is not suited to wavelengths below 60 to 100 meters as the plate and grid circuits then fall into tune. Inasmuch as the antenna circuit controls the frequency of oscillation of this type of transmitter every precaution must be taken to support rigidly both antenna and counterpoise as well as all lead-in wires. This will prevent a shift of frequency which would occur at each change of capacity, such as produced by the swaying of the antenna in a wind.

Referring to the diagram it will be noted that the plate circuit is tuned by a variable condenser C^1. This condenser does not tune the circuit but merely acts as a control of the load taken by the tube depending upon the amount of capacity in use.

When the key is closed the place voltage is applied through the inductance L^3. Starting the plate current through L^3 induces an e.m.f. in L^1 which in turn induces an e.m.f. in grid coil L^2. The voltage acting on the grid produces a corresponding change in the plate current. The pulsating plate current flowing through L^3 induces an e.m.f. in the antenna inductance L^1 and radio frequency oscillations start, the frequency of oscillations being determined by the constants of the antenna circuit. A r.f. voltage is induced in the grid circuit which produces correspondingly larger variations of plate current and the action is repeated. Radio frequency currents are generated as long as the key is closed.

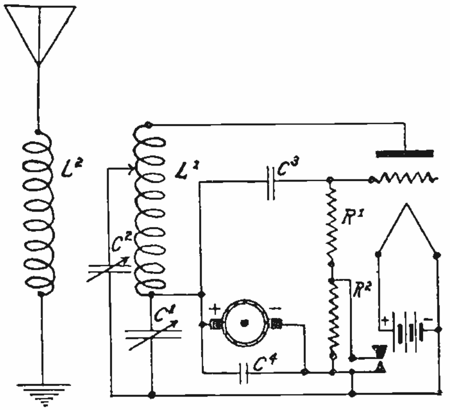


Fig. 127. Colpitts Circuit—Series Feed Tuned Primary.

The plate and grid currents are regulated by the number of turns employed in their respective coils. For this reason each coil is usually tapped so as to secure the maximum output with minimum plate and grid current. Variable condensers are sometimes employed to tune both plate and grid coils. Another arrangement employs four coils. The additional coil is placed in the antenna circuit. One is coupled closely to the plate coil, the other to the grid coil.

4. **Colpitts Circuit**—It was stated at the beginning of the chapter that Colpitts circuit depended upon capacitive excitation of the grid; figures 127 and 127*a* show such an arrangement.

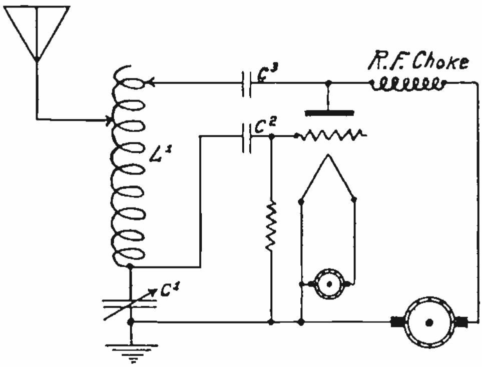


FIG. 127*a*. Colpitts Circuit Directly Coupled to Antenna and Using Parallel Plate Feed.

The voltage drop across the condenser C^1 provides the excitation or the capacity is changed to obtain the correct excitation. Condenser C^2 controls the frequency of oscillation. For changes of condenser C^2 it is necessary to readjust C^1 for best excitation. It should be noted that both of these condensers are in shunt to the high voltage supply and they should be designed to withstand this voltage. The grid leak resistance in a Colpitts circuit is always connected directly to the filament rather than across the grid condenser as is done frequently in other circuits. An examination of the circuit will show that this is necessary to provide a direct current path for proper grid bias. This would be prevented by condenser C^1 were the resistance shunted across condenser C^3.

5. Shunt and Series Feed—Two methods of supplying the voltage to the plates of the tubes have been shown. The shunt or parallel supply in the Hartley figure 125, and Colpitts figure 127*a*. The series feed is shown in the Meissner circuit, figure 126 and Colpitts, figure 127. In both shunt and series feed the radio frequency and direct current leave the plate together. In both the currents split apart before getting to the generator. In shunt feed the split is made at the *plate* side of the plate coil, in series feed it is made after the two have gone through the plate coil together. In any case both d.c. and r.f. rejoin again at the filament.

When shunt feed is employed it is necessary to include a radio frequency choke coil in series with the plate supply lead. Should the choke coil in this lead fail to function the radio frequency currents will be induced in the windings of the generator possibly rupturing the insulation and resulting in damage to the machine. As an added precaution to prevent this, r.f. chokes are sometimes placed in both negative and positive plate supply leads. The choke in the positive lead is always connected close to the plate binding post of the socket, at right angles to, and as far removed from the inductance as possible.

The r.f. currents of the plate circuit find an easy path to the inductance through the plate blocking condenser which also prevents the plate supply unit from being short circuited by this coil. Plate blocking condensers are designed to withstand several thousand volts more than are normally used. As an added precaution fuses are placed in the plate supply leads. Frequently an overload relay is provided in the positive lead which will trip and interrupt the circuit if the overload, or short circuit occurs.

6. Coupling the Energy to Antenna—There are three general methods by which the r.f. energy is coupled to the antenna to be radiated. They are:

1. Direct coupling,
2. Inductive coupling,
3. Capacity coupling.

Other methods of feeding the antenna are discussed in chapter XIV.

In a direct or conductively coupled circuit the antenna system is connected directly with the same inductance to which the plate, grid and filament are connected. Figure 128 shows such an arrangement. The capacity of the antenna system is connected directly across a portion of the tuning inductance and therefore is one of the frequency determining elements of the circuit. Any weather conditions effecting a change in the capacity of the antenna system will likewise cause a change in the radiated frequency.

If the antenna were to fall down or ground accidentally the tube would stop oscillating and draw a heavy overload. The same effect

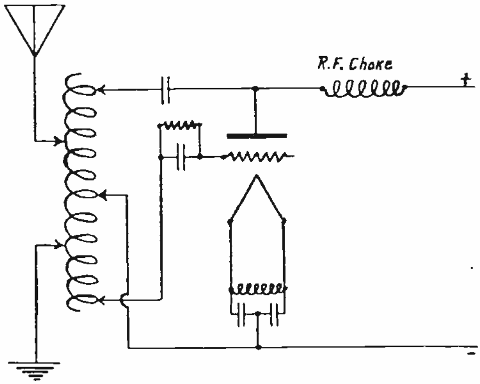


FIG. 128. Hartley Circuit Directly Coupled to Antenna.

takes place to some extent in a rain or snow storm or if the insulators become covered with ice.

A transmitter employing direct coupling would operate very inefficiently on shipboard especially during bad weather and heavy seas. Obviously such coupling is seldom employed in commercial transmitters.

7. **Inductive Coupling**—This method of coupling is accomplished by placing two coils in an inductive relation to each other. The transfer of energy is accomplished by an alternating electromagnetic flux or field surrounding the primary coil. The secondary or antenna coupling coil is placed near or inside of the primary so that part of the alternating flux surrounding the primary will flow through the secondary. The Colpitts circuit in figure 127, is inductively coupled to the antenna. The primary coil is sometimes called the tank circuit inductance. The secondary is called the antenna coupling inductance. Sometimes an antenna loading coil is necessary in order to tune the transmitter to long wavelengths. This coil is connected in series with the coupling coil and antenna.

Inductive and loose coupling should not be confused. The antenna may be capacitive coupled and still have a loose coupling depending upon the value of the coupling condenser.

8. Adjustment of the Inductively Coupled Circuit—The primary circuit is first tuned to the desired frequency. Before proceeding with this adjustment the secondary should be loosely coupled to the primary. The antenna and ground connections should then be disconnected. It is best to start with low power. Referring to figure 124, the condenser C^1 is varied until the primary circuit is oscillating at the desired frequency. The filament clip F is usually connected near or at the center of the inductance and the plate clip P and grid clip G varied until the correct feed-back is secured to start oscillations. More turns are usually included from F to P than from F to G. If the grid is too close to the filament the tube will not oscillate well; if it is too far away F the tube efficiency will be bad. Usually 2 or 3 plate turns are used for each grid turn. The variable condenser C^1 should always be connected inside of the plate and grid clips. The fewer the turns included between the condenser clip increases the amount of condenser capacity required (Hartley circuit). This will tend to steady the output of the tube.

If the clips are improperly adjusted excessive plate current will be indicated by the plate milliammeter. If no milliammeter is connected in the plate circuit the color of the tube plate is the best indication of correct plate current. Excessive plate current causes heating of the plate to a light red or white heat. When operating normally the plate will show just a cherry or dull red.

A wavemeter coupled loosely to the primary inductance will indicate the wavelength at which the primary circuit is oscillating.

If the capacity of the condenser C^1 is reduced to zero and the wavelength as measured is too high the number of turns shunting C^1 should be decreased. If on the other hand with the condenser set at its maximum capacity the wavelength is too low more turns should be included in shunt to C^1. In making these adjustments it might be noticed that for a certain setting of C^1 the tube stops oscillating or draws a heavy overload. This is indicated by a sudden rise of plate current or excessive heating of the plate. The capacity of C^1 should be varied at once until the tube starts oscillating normally as indicated by a sharp drop in the plate current or the change of color of the plate from light red to dull or cherry red.

The Hartley circuit oscillates easily and no difficulty should be encountered in making adjustments to the desired frequency and keeping the plate current within its normal operating value.

With the primary circuit oscillating at the desired frequency the power may be increased to normal value.

The antenna and ground can now be connected to inductance L^2. Upon starting to resonate the two currents the inductance L^2 should be coupled fairly closely to L^1. The turns on L^2 are varied until the antenna radio frequency ammeter indicates maximum current. Resonating the two currents should be accomplished with the key closed. A test should now be made by transmitting dots and dashes in the usual way. It may be noticed that the radio frequency ammeter in the antenna circuit does not follow the key or tends to lag behind the same. A measure of the radiated frequency may show that it is a few meters off from that to which the primary circuit was tuned. This is caused by too close coupling.

When the circuits are too closely coupled the circuit has two frequencies at which it is capable of oscillating. The transmitter may therefore, oscillate at one frequency for some time and suddenly when keying start to oscillate at another frequency.

As the coupling is loosened by increasing the distance between the primary and antenna inductance the two frequencies at which the transmitter may oscillate approach each other and at a given value of coupling these two frequencies coincide.

The value of coupling at which this occurs is called "Critical Coupling." When this value is attained the transmitter oscillates at only one frequency.

As the coupling is further loosened the current in the antenna circuit is decreased resulting in lowered efficiency. It is therefore necessary to operate the transmitter or at immediately below the value of critical coupling in order to secure maximum power in the antenna with good frequency stability.

In some commercial transmitters where several different frequencies are employed in transmission a small coupling coil of few turns is used as L^2 and external loading coils are used to tune the antenna circuit to the desired frequencies. A loose coupling may be employed in this way by keeping the position of the primary and coupling coils fixed and employing only enough turns in the coupling coil to obtain maximum transfer of energy. The loading coils are the tuning inductances.

The shifting from one frequency to another is accomplished by one operation from the front of the control panel. During this operation the antenna is connected to the correct position on the loading coils and at the same time the condenser C^1 engages the current number of turns in shunt to it for that particular frequency.

9. One-Wire Feed Lines—It is frequently convenient to place the antenna at some distance from the transmitter and to connect them by a radio frequency feed line. It is convenient here to

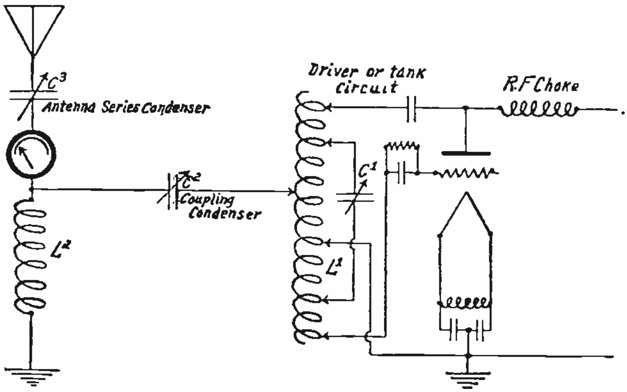


FIG. 129. Hartley Circuit with r. f. Line to Antenna. (Capacitive Coupling Control.)

show how a one-wire feed line may be used with a normal Hartley circuit. In figures 124 and 129 such connections are shown and the coupling between the primary and the antenna is in each case provided by a sort of link circuit which can be traced as follows. From the ground through the antenna inductance (L^3 in figure 124 and L^2 in figure 129) through the line with its series reactance (L^2 in figure 124 and C^2 in figure 129), thence through L^1 to filament and back to ground. The line is usually not resonant; hence the series reactance (L^2 of figure 124 or C^2 of figure 129) device is not exactly a tuning unit but rather a coupling *control.* It is definitely not a "coupling coil" or "coupling condenser" nor is it proper to call such systems "impedance coupled" or "capacity coupled."

10a. Adjustment of One-Wire Feed Systems—Disconnect the feed line and tune the primary circuit as previously described. Now connect the feed line with all of L^2 (figure 124) or very little of C^2 (figure 129) in circuit. Watching the antenna ammeter, resonate the antenna by adjustment of the antenna inductance and condenser. A milliammeter in the plate supply lead of the tube will assist considerably. Now increase the setting of series condenser C^2 (figure 129) or decrease the inductance of L^2 (figure

124). Slight readjustment of primary or antenna tuning may be necessary to maintain the correct frequency. As the series reactance in the line is decreased a point is reached at which the tube ceases oscillating. Less than this amount of coupling must be used by either increasing the series reactance or moving the feeder tap toward the filament on L^1. Resonance between the primary and antenna circuits is indicated in the usual way.

While the use of a condenser as in figure 129 is more convenient it has been found that harmonic frequencies are radiated freely and to suppress them the circuit of 124 is recommended.

It is possible to operate an antenna at its fundamental by eliminating all condensers and inductances from the circuit and supplying it through a one-wire feed line tapped on at a point removed from the ground connection by about 28 per cent of the antenna length. For a straight ungrounded antenna the feed point should be 13.9 per cent of the antenna length from the center. The figures are due to Byrne, Windom, and Everitt of Ohio University.

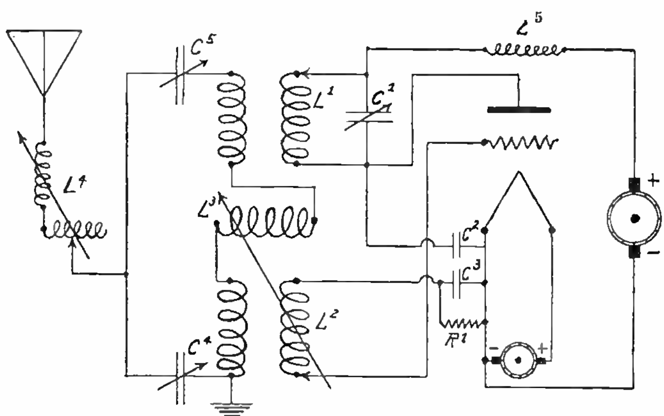


FIG. 130. Modification of Meissner Circuit with Capacitive Coupling of Antenna.

10b. Capacity Coupling—Because one-wire feed systems are often mistakenly called "capacity coupled" when working as in figure 129 it is thought advisable to show a *true* capacity coupled system in figure 130. The coupling is due to condenser C^4 which is *common to the antenna circuit and the primary tuned circuit.* As its capacity is made smaller the voltage across it rises and therefore the coupling increases. This adjustment simultaneously tunes both primary and antenna circuits which must be corrected by C^5 and L^4. With due regard to the avoidance of short-circuits any type of oscillator may be capacity coupled to any antenna since it is almost always possible to add a series condenser common to both circuits.

11. **Transmitters with r.f. Amplification**—It is desirable in some transmitters to use the main vacuum tubes as r.f. amplifiers supplied by a small oscillator. This is usually done for one of two causes, (a) to permit the use of a special oscillator circuit which it is not practical to apply to the large tubes or (b) to permit modulation at a low power level so one does not need to amplify the speech or music up to the level of the final set output. Device (b) is obviously saving of power while device (a) permits the use of crystal control (page 185), stiff oscillator circuits not practical for large powers (see pages 539–542) or battery-driven oscillators (see Burgess Battery Co. engineering circulars).

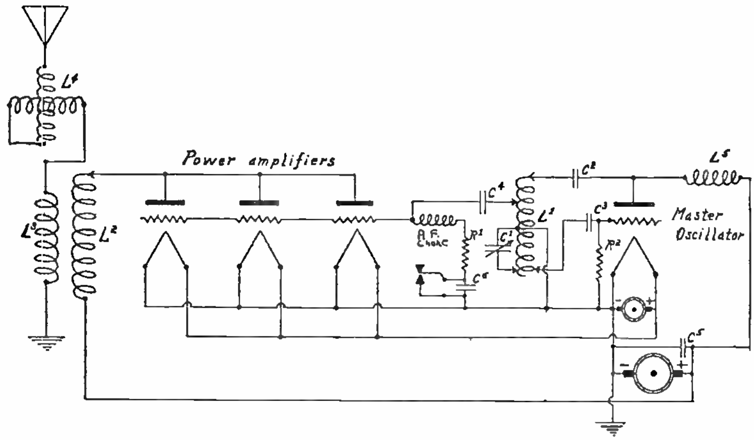


FIG. 131. Oscillator Driving Three Amplifier Tubes.

A study of the diagram will show that the master oscillator (exciter) tube is connected in a Hartley shunt feed circuit. The condenser C^1 is used to tune the circuit to the frequency desired. Condenser C^4 is the coupling condenser and is connected to the inductance L^1 and to the grids of the power amplifier tubes. By providing a variable connection from C^4 to L^1 permits the grids of the amplifiers to be properly excited.

The amplified radio frequency currents in the plate circuits of the power amplifier tubes flow through the inductance L^2 which is in inductive relation to the antenna coupling coil L^3.

By the use of the variometer L^4 the antenna circuit is tuned to resonance with the power amplifier frequency until maximum antenna current is obtained. Changes in the values of L^2 and L^3 have no effect upon the frequency of the waves radiated by the antenna but only of the amount of power transferred between the two circuits.

As the turns in the primary inductance L^2 are decreased, the step-up ratio of the transformer is increased and therefore the load is increased. In any tube circuit if the load resistance is too great the plate current will be high without any attendant increase in antenna current. To determine the best adjustment it is advisable always to start with a minimum number of turns in antenna inductance L^3 and gradually increase the number until the proper loading is obtained but never to the point where an increase of plate current does not increase the antenna current.

It is possible to use a much larger value of coupling than if the tubes were self excited, therefore, a greater transfer of energy to antenna circuit results.

However, the advantages of the master oscillator-power amplifier circuit fail to appear if the power amplifier grid puts more than 20 percent load on the master oscillator. Two identical tubes may be used to advantage.

A variation of this arrangement consists of a master oscillator which supplies grid excitation to one or more intermediate amplifiers through a condenser as C^4. The plate circuits of the intermediate amplifiers are in turn coupled to the grids of the main amplifiers through a similar condenser. The antenna circuit is coupled to the main amplifiers as shown in the drawing.

A neutralizing condenser is frequently employed to prevent reaction of the amplifier on the master oscillator through the internal capacity of the amplifier tubes. The principle involved is like that employed in the Hazletine neutrodyne receiver as described in the previous chapter. By connecting a small variable condenser from a point of correct potential on L^1 to the plates of the amplifier tubes a voltage is fed back opposite in phase to that existing across the internal capacity of the tubes effectively neutralizing the tendency to oscillate. This permits the amplifier tubes to be fully excited without danger of generating self oscillations.

12. Master Oscillators with Piezo-Electric Crystal Control of Frequency—The quartz crystal which has attracted considerable interest of late as a frequency standard depends for its action on what is known as the piezo-electric effect.

If a section of a quartz crystal is placed between two electrodes having a difference in potential the crystal becomes shortened or lengthened.

The piezo-electric phenomena are reversible, that is to say that as an electric field alters the size of the crystal so can alteration in size of the crystal produce an electric field in the crystal.

A quartz crystal prepared as a radio frequency oscillator may be round or rectangular in shape. Rectangular crystals have the advantage of being cheaper to make and will control a greater radio frequency output without cracking or chipping.

There are three frequencies at which a quartz crystal is capable of oscillating. One frequency corresponds to what is known as the X dimension, one to the Y dimension and the other to a frequency which is between the X and Y frequency and is termed the coupling frequency.[1]

The frequency of vibration of a quartz crystal is very constant. When connected in a circuit with a small vacuum tube it acts as an oscillator, the frequency of which depends wholly upon the mechanical vibrations of the piece of crystal. A frequency thus produced is accompanied by numerous harmonics. These harmonics are produced in a plate circuit of the tube and not in the crystal. By making the inductance large in comparison with the capacity the harmonic frequencies will be increased considerably both in magnitude and number. The wave form of the fundamental frequency in the vacuum tube is not sinusoidal, but distorted, thus indicating the presence of harmonics. By employing a large inductance in the plate or phase adjusting circuit a means is provided for matching impedance at harmonic frequencies with that of the plate filament circuit of the vacuum tube due to the fact that such a coil system responds to a wide band of frequencies. This matching of impedance provides a maximum generation of power at the harmonic frequencies. The fundamental frequency and harmonics can then be used for frequency standards for cali-

[1] For further information relative to dimensions and fundamental frequencies of quartz crystal oscillators see proceedings of The Institute of Radio Engineers, January, 1927, article by A. Crossley entitled "Piezo-Electric Crystal Controlled Transmitters."

bration purposes. The application of the piezo-electric crystal as a frequency standard is discussed in chapter VII.

It has been found that the frequency of any crystal is subject to change with temperature and for absolute constancy of frequency it is necessary that some method be employed to control the temperature either directly or indirectly to the crystal. One method is to place the crystal in a hermetically sealed container and by use of a thermostat and heating unit in this container maintain the crystal at a pre-determined temperature.

The quartz crystal oscillator may be employed to check the frequency of a radio transmitter. The crystal can be ground to the desired size whereby one of its natural frequencies of vibration corresponds to the assigned frequency of the station. The emitted wave of the transmitter can be then adjusted to "zero beat" with the natural period of the crystal. If desired the crystal can be cut so that its fundamental frequency differs by 500 or more cycles from the assigned frequency of the station and thus the operator can by listening in, compare the beat frequency from time to time during operation and determine if the transmitter has shifted from its correct frequency.

When the crystal is employed by this method such a station is said to be "crystal checked" rather than crystal controlled.

However, the method is subject to an error and for this reason it is desirable to first adjust or check the transmitter with a reliable wavemeter. Assume that the assigned frequency of the station is 640 kilocycles and that the crystal is ground to produce a 500-cycle beat frequency (640.5 kilocycles).

It is therefore apparent that if the transmitter was oscillating at 641 kilocycles there would still be produced a 500-cycle beat note with a 640.5 kilocycle crystal. Obviously the transmitter frequency would be one kilocycle higher than that at which it was desired to transmit.

To use the crystal as a means of frequency control of a transmitter it is necessary for the crystal to be cut so that its natural frequency or one of its harmonics corresponds exactly to the frequency it is desired to transmit.

The amount of power that a crystal can directly control is limited and for this reason it is necessary to start the crystal oscillating by placing it in the grid circuit of a vacuum tube of small power. The frequency thus generated by the crystal can be amplified by exciting the grids of tubes of higher power and the amplified energy fed to the antenna.

Atmospheric conditions may change the capacity of the antenna system but the transmitted frequency remains constant as controlled by the crystal.

Figure 132 shows the general arrangement of a crystal controlled power amplifier circuit. A transmitting tube of small power

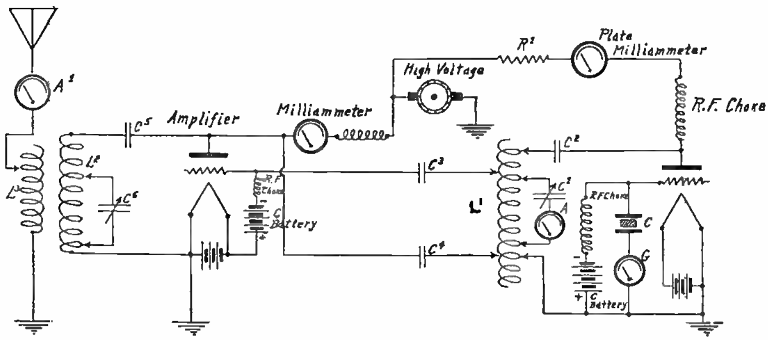


FIG. 132. Crystal-Controlled Oscillator Driving an Amplifier.

is used to start the crystal oscillating. If excessive plate voltage is used on the oscillator tube the crystal will develop heat and possibly explode.

Referring again to figure 132 the crystal *C* is placed between two electrodes which are connected to the filament and grid of the tube respectively. A thermo-galvanometer is also sometimes connected in series with the crystal to assist in adjustment. The battery *C* provides the proper negative bias on the grid of the tube. A radio frequency choke in series with the "C" battery and grid prevents radio frequency currents from flowing through the "C" battery and aids in starting oscillations. By correct adjustments of inductance L^1 and condenser C^1 the necessary feed-back is secured to start the crystal oscillating. The grid of the power amplifier is excited by the voltage drop across condenser C^3 which is connected near the plate tap on inductance L^1. The condenser C^6 and inductance L^2 permit the amplifier circuit to be tuned to resonance with the crystal frequency. Negative bias to the amplifier grid is provided by a "C" battery. A radio frequency choke coil prevents r.f. currents from flowing through the battery.

The neutralizing condenser C^4 prevents reaction of the amplifier on the crystal. It is advantageous to isolate each circuit by shielding which permits complete neutralization.

The inductance L^3 permits the antenna circuit to be adjusted for maximum output.

13. Frequency Doubling Power Amplifier—To employ the quartz crystal as a means of frequency control of a transmitter designed to operate on the high frequencies in the neighborhood of 6000 kilocycles would necessitate grinding the crystal until it was extremely small and thin. Such a crystal would be difficult to handle. Figure 133 shows an arrangement whereby this difficulty is overcome. A large crystal is used as a fundamental oscillator. The frequency thus generated excites the grid of the second tube, the plate circuit of this tube is tuned to twice the fundamental frequency of the crystal oscillator.

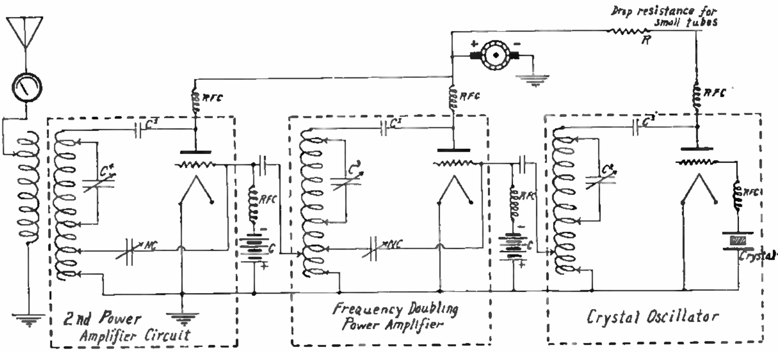


FIG. 133. Crystal Control with Frequency Doubling Amplifier.

This new frequency, which is the second harmonic of the crystal oscillator, is amplified and the amplified energy is then transferred to the antenna circuit to be radiated.

This method is employed considerably by amateurs in their transmitters operating on high frequencies.

14. Filament Supply—The drawings of the different circuits show that the filaments of transmitting tubes may be heated from either alternating or direct current.

Transmitters designed for telegraphy alone usually employ alternating current whereas radio telephone transmitters employ direct current.

Alternating current is preferable as the life of the filament is prolonged. It is rarely used on radiophone transmitters due to the objectional a.c. hum accompanying the modulation. When a.c. is used it is generally derived from a small step down transformer provided with a mid-tap. Across each half of the output windings a condenser is employed to by-pass the radio frequency currents thus preventing them from puncturing the insulation of the windings.

When the filament supply is provided by a generator or storage batteries a polarity reversing switch is sometimes installed. This permits the plate current to be returned through one side of the filament for half the period of operation. Where no switch is provided it is best to connect the negative of the plate supply to the positive side of the filament.

If the negative side of the plate supply is connected to one side of the filament at all times an inequality in filament current results due to the plate current flowing through one side of the filament. This causes one side of the filament to operate at a higher temperature than the opposite side and results in the filament burning out at the point of excess current while the remainder of the filament is only partially used. By the use of the polarity switch mentioned in the previous paragraph the wear on the filament can be divided thus prolonging the life of the tube.

A filament voltmeter is provided on all commercial transmitters. The voltage at which the filaments should be operated is sometimes indicated by a red mark or arrow on the scale of the instrument.

Usually there is provided with each transmitter an instruction book wherein the operator may learn the normal operating voltage for the tubes in that particular set. At no time should the filament voltage exceed that in the electrical data accompanying the tube.

Operating the filament at an increased voltage of 5 percent will reduce the life of the tube by half, whereas, if operated at the same percentage below normal the life of the filament will be doubled. However, if the filament is operated too far below normal the tube will heat excessively and the efficiency of the transmitter will be reduced.

Source of Plate Supply.

15. **Storage Batteries** are used to supply the high plate potential for tubes employed in radio telephone transmitters. Such an installation usually consists of many " B " batteries of 45 volts each, connected in series to secure the voltage desired, a series parallel connection being used for charging.

16. **Motor Generator**—The most practical method for production of high plate voltage up to and including 2400 volts is

from a direct current generator driven by either an a.c. or d.c. motor. Such generators are so designed that the output voltage is constant on load.

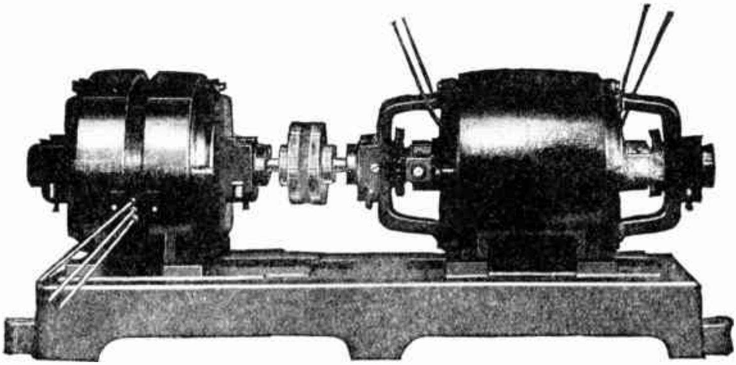


FIG. 134. Esco Motor Generator Supplying Plate and Filament Power for a Vacuum Tube Transmitter.

Direct current generators of this type when operating under normal conditions have three sources of disturbance, which if not eliminated greatly impair the quality of voice and musical transmissions. These disturbances are called the commutator ripple, slot ripple and the noise of moving contact.

The Commutator Ripple is explained as follows: Armature windings consist of a series of coils wound around the armature, forming one large coil with taps brought to commutator segments. During rotation the brushes make contact with one segment and then the next in line. As the brush leaves one segment and passes to the next the voltage changes slightly. The resultant fluctuation in voltage is known as the commutator ripple or whirl.

Slot Ripple—The space between each coil of the armature is called a slot. As each slot passes a field pole there is a slight interruption of the field at this point. Each surge in the field slightly changes the value of the voltage induced in the coils. The resultant disturbance is known as slot ripple.

The **Noise of Moving Contact** is due to the infinitesimal sparking caused by microscopic unevenness in the surfaces of the commutator and the brushes.

To eliminate these disturbances filter circuits consisting of capacity or inductance or combinations of both are inserted in the supply line.[2]

[2] The Electric Specialty Co., 201 South Street, Stamford, Conn., manufacturers of high grade motor generators, dynamotors and rotary con-

For voltages exceeding 1000 there are usually provided two armatures winding connected in series. A filament current generator is sometimes provided and is coupled to same shaft. The filament current also provides a means of exciting the fields of the high voltage generator. A field rheostat is usually provided to permit adjustment of plate voltage.

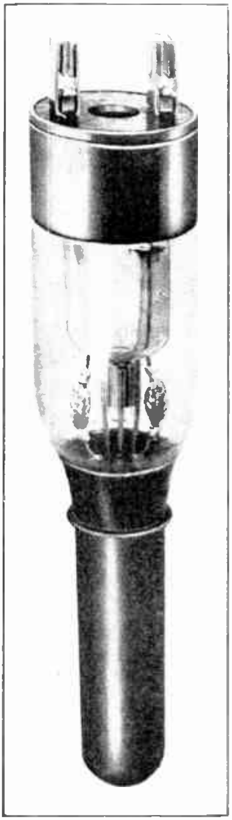


FIG. 135. A Western Electric High Voltage Half-Wave Rectifying Tube.

The motor driving these units is either a d.c. or a.c. machine, depending upon the local supply line. If no d.c. is available a separate exciting generator is also coupled to the motor.

Dynamotors—On low power sets such as on a yacht or small pleasure craft a small dynamotor may be employed.

This consists of a self-contained motor generator unit, the primary of which uses direct current at voltage from 6 to 110 volts. The secondary voltage varies 350 to 1000 volts d.c.

17. Vacuum Tube Rectifiers—Vacuum tubes employed for rectification of alternating current have two elements, namely, the filament and plate. Some such tubes have two plates. Those having one plate are called half wave rectifiers and those having two plates, full wave rectifiers. The half wave rectifiers are employed for high voltages such as used in transmission. They are employed to rectify the alternating current voltages ranging from 110 volts to 24,000 volts. One is usually employed on each side of the cycle, thus permitting full wave rectification.

Where a single phase a.c. supply is used it requires an elaborate filter circuit to completely eliminate the a.c. hum in order that such a system may be used successfully for radio telephone transmission. For continuous wave transmission alone the filter re-

verters for radio transmission, publish a small pamphlet entitled, "Esco Filter Facts" which they will mail to anyone making application for the same. The student who is interested further in the study of filters for generators should secure this pamphlet.

quirements are not so elaborate. Vacuum tube rectifiers of a.c. are employed in practically all radio telephone transmitters of 5 K.W. and upward in power.

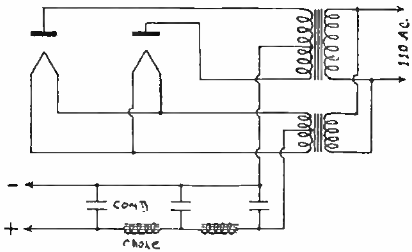


FIG. 136. Arrangement for Full Wave Rectification of A.C. with Two Half Wave-Rectifier Tubes.

The general arrangement of filter circuit as employed with a two-tube full wave rectifying system is shown in figure 136.

18. Chemical and Mercury Arc Rectifiers—Rectifiers of this type are employed considerably by amateurs but are seldom encountered in commercial radio transmission.[3]

19. Continuous Wave Transmission—The oscillations generated by a vacuum tube having a direct current plate supply such as from a d.c. generator, rectified and filtered a.c. or a high voltage battery, are of a sustained nature or constant amplitude. When these oscillations are heterodyned at the receiver by an oscillatory detector tube or separate oscillator, they produce a pure liquid note in the telephones. The emission from such a transmitter is called a continuous wave. Figure 137 shows the characteristic of a continuous wave. It should be noted that it is a continuous oscillation of a constant amplitude.

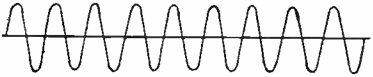


FIG. 137. A Continuous Wave Train.

It is sometimes noted that signals are heard from a nearby C.W. station on a non-oscillating vacuum tube or a crystal detector. This is usually caused by disturbances of the plate generator modulating the oscillations at an audio frequency, usually the result of a poor

[3] For further information on these types of rectifiers see "The Radio Amateur's Handbook," published by the American Radio Relay League, Hartford, Conn.

filter, or poorly designed machine. A dirty or uneven commutator surface will aggravate this condition.

Where the plate supply is rectified a.c. it may be caused by the a.c. component passing through the filter and thus modulating the output at a frequency dependent upon the frequency of the supply mains.

If the plate supply is secured from batteries no signals will be heard by a non-oscillating detector when continuous waves are being transmitted with the exception perhaps of the key clicks. It may be possible too, that the signals may be heterodyned by an unknown source such as from another receiver in the immediate vicinity or possibly a tube oscillating feebly in the operator's receiver.

20. Interrupted Continuous Waves—It is sometimes desirable to transmit waves from a continuous wave transmitter so that they will be audible at the receiving end on a non-oscillating vacuum tube of crystal detector. This may be accomplished in one way by the use of the chopper which breaks the continuous waves up into audio frequency groups. The chopper consists of a wheel of metal construction with insulating studs set in its face. Wiping contacts or brushes are provided to make contact with the metallic segments in the wheel. When it is desired to transmit C.W. signals the chopper brushes are short circuited. The wheel is fastened securely to the shaft of a motor. The speed at which the motor turns and the number of segments in the wheel determine the frequency at which the continuous waves are broken

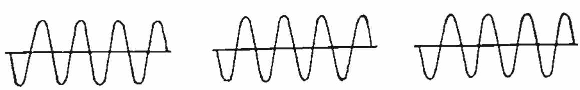


FIG. 138. Interrupted Continuous Waves (ICW).

up into audio frequency groups. Figure 138 illustrates the character of interrupted continuous waves (I.C.W.).

Figure 139 illustrates one method of connecting a chopper to a transmitting circuit so as to produce interrupted continuous waves. It will be noted that the antenna inductance has several of its turns shorted by the chopper during a revolution of the wheel. This causes the wavelength to be altered a few meters several times each revolution resulting in a continuous musical note being produced in the receiver, without the aid of locally generated oscillations.

The chopper is also connected in series with the grid of the oscillator tube, thus permitting the undamped waves to be broken up into audio frequency groups.

21. Half Wave Self Rectifying Transmission—Figure 140 shows a method of employing ½ cycle of alternating current as the plate supply of a vacuum tube transmitter. A study of figure 140 will show that from a 500 cycle supply the plate will be positive 500 times per second. Thus the tube oscillates 500 times per second corresponding to the positive alternations. During the negative alternations the tube is idle. An antenna connected to such an oscillating system would radiate energy the wave form of which is of varying amplitude and in groups of 500 per second. As these groups are within the audio range of the human ear and headphones the dots and dashes made would be audible on a receiver fitted with a non-oscillating vacuum tube or crystal detector.

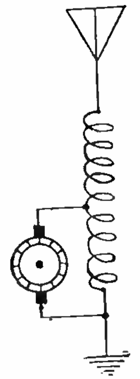


FIG. 139. Arrangement of Chopper for Producing Interrupted Continuous Waves.

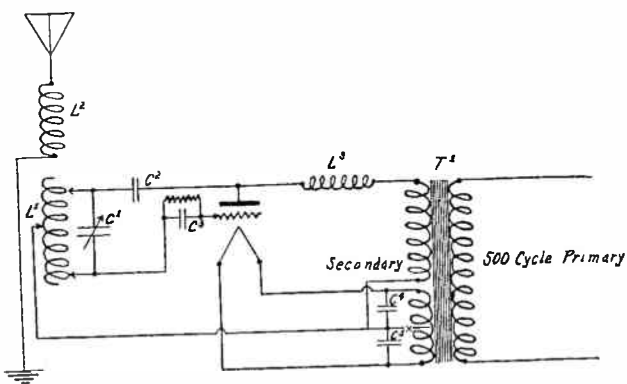


FIG. 140. Half Wave Self-Rectifying Transmitter Circuit.

22. Full Wave Self Rectifying Transmission—By the employment of two tubes connected to the secondary of a plate transformer it is possible to utilize both sides of the alternating current cycle. In this arrangement it is necessary that the plate transformer have a mid-tap. The schematic arrangement is shown in figure 141. One tube oscillates during the first half of the cycle and the other tube on the second half of the cycle.

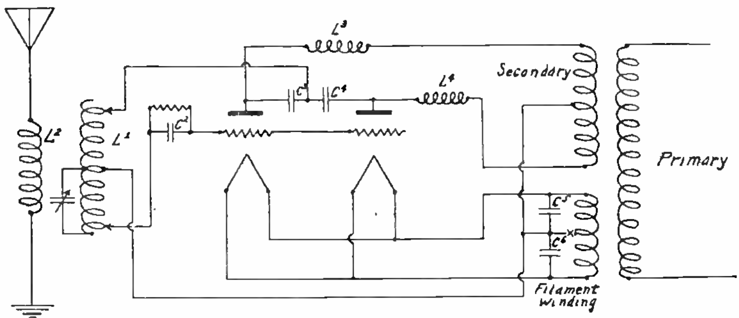


FIG. 141. Full Wave Self-Rectifying Transmitter Circuit.

In the case of the tube on one side of the cycle it is noted that a group of oscillations occur every 1/500 of a second. With a tube on each side of the cycle a group of oscillations occur every 1/1000 of a second. The radio frequency oscillations are periodically reduced to zero or in other words the oscillations radiated by the antenna system are completely modulated by the frequency of the a.c. supply.

The heterodyned signals from such a transmitter is very pleasing to the ear if the frequency of modulation happens to be in the neighborhood of 500 cycles.

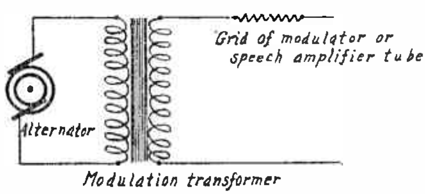


FIG. 142. Tone Modulation from an Alternator.

23. Tone Modulation—It is possible to periodically modulate the generated radio frequency currents by impressing upon them a tone within the audible range. Figure 142 shows an arrangement whereby an alternator is used to modulate the radio frequency oscillations generated by a vacuum tube. By the use of a one-stage audio frequency amplifying circuit the modulated plate current is amplified considerably before acting upon the radio frequency oscillations.

The schematic diagram of figure 143 shows the schematic diagram whereby a vacuum tube is made to oscillate an audio

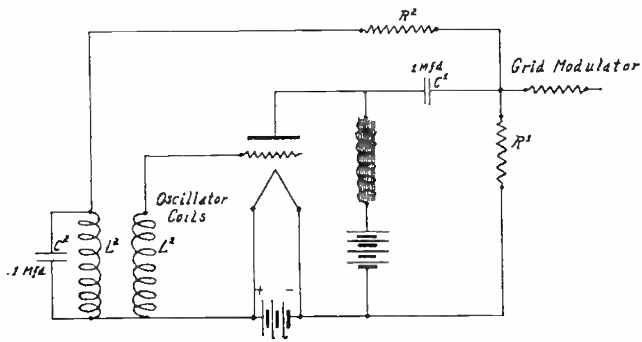


FIG. 143. Vacuum Tube Audio Frequency Oscillator.

frequency, the same being used to modulate the radio frequency output of an oscillator. The constants of the audio frequency oscillating circuit are of such values that a 500 to 900 frequency is produced.

Circuits have been devised whereby it is possible to generate simultaneously both audio and radio frequency oscillations from the same tube. Such an arrangement being quite critical in adjustment it is seldom used in commercial transmitters.

24. Methods of Keying—In commercial practice the most common methods of keying are:-

1. Breaking the negative high voltage lead either directly by hand key or by a relay fitted with extra heavy contacts and connected to an auxiliary key.

2. A system is shown in figure 144. If the key is open the plate current is forced to pass through resistance R^1. It should be noted that the tapped point of this resistor is grounded and not the negative side of the 1000 volt plate supply. Since the grid return is connected to the tapped point on resistance R^1 any cur-

rent flowing in R^1 causes a bias to be placed on the grid. Therefore, when the key is opened a large bias stops oscillation due to the total plate current flowing and subsequently a holding bias exists due to the smaller current maintained through resistance R^1 by the generator.

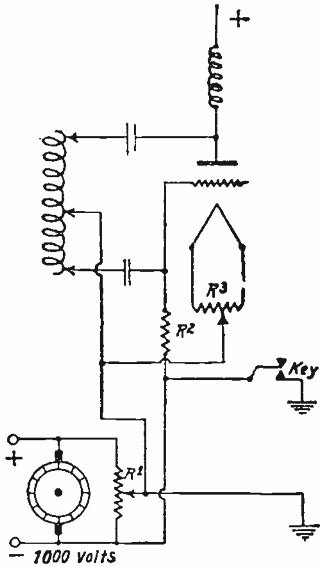


FIG. 144. A Method of Keying by Supplying and Removing a High Negative Bias to the Grid of a Vacuum Tube R.F. Amplifier.

3. When the plate supply is secured from an alternating current transformer as in self-rectifying circuit the key is usually placed in the low voltage primary circuit. It should be understood that a separate filament transformer or other means of heating the filaments must be provided in order to do this.

25. Antenna Resistance Measurements—If the antenna resistance is known it is helpful in determining the efficiency of the transmitter. Antenna resistance comprises three distinct resistances which are measured in ohms. They are radiation, ohmic and dielectric absorption.

Radiation resistance is the most useful. Energy lost by this resistance is instrumental in producing the signal at a distant station. Therefore, it is this quantity multiplied by the square of the antenna current that determines the power of the radiated waves.

The power delivered to an antenna is equal to the square of the antenna current multiplied by the effective resistance. The resistance must be measured at the same part of the antenna as the current. Thus it can be seen that by comparisons of the power delivered to an antenna to the power that is actively radiated it is possible to determine the efficiency of the radiating system. Also it will show at what wavelength it is best to operate on.

Radiation resistance of an antenna depends upon its effective height, shape and the wavelength at which it operates. It is at a maximum at the fundamental and decreases rapidly as the antenna is loaded.

Ohmic resistance is not useful. It is due to heat losses by the current flowing in the antenna wires, ground wires, and condensers comprising the open circuit. The value of this resistance remains practically constant over the whole wavelength range.

Dielectric absorption also represents another power loss. It is due to imperfect dielectrics within the field of the antenna such as masts, guys, trees and if on shipboard the smoke stack of the vessel. The value of this resistance increases in proportion as the antenna is loaded.

For the practical purpose of securing the power input to the antenna the three resistances are combined and called the total antenna resistance.

Figure 145 shows how the different resistances are distributed for an antenna having a fundamental wavelength of 300 meters. The following numbers correspond to:

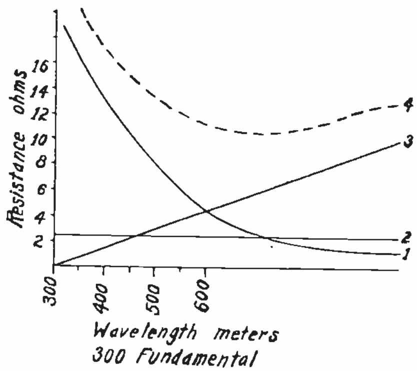


FIG. 145. Antenna Resistance Curves.

(1) Radiation resistance, (2) ohmic resistance, (3) dielectric absorption, (4) total or effective resistance.

There are two methods by which the antenna resistance may be measured. They are known as the resistance variation and resistance substitution methods.

The variation method consists of inserting a known resistance in series with the antenna and noting the values of the antenna current at different wavelengths and plotting these values as a curve. The arrangement apparatus is shown in figure 146.

The driver circuit must be coupled very loosely to the antenna circuit. A switch is provided for shorting out the known resistance. All the apparatus that is included in the open circuit should remain in the circuit in order to measure the resistance under actual working conditions.

In order to measure the resistance at the fundamental wavelength of the antenna the natural period of the antenna system must be found. This is done by connecting the antenna directly

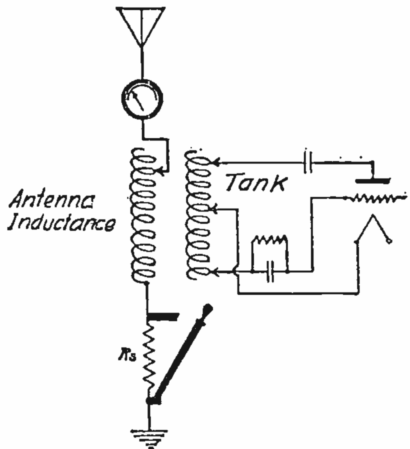


FIG. 146. Arrangement for Measuring Antenna Resistance by the Variation Method.

to the ground or counterpoise. If a grid current milliammeter is included in the driver circuit a pronounced dip of the needle will be indicated when the driver is in resonance with the natural frequency of the antenna system. If an antenna milliammeter is included in the antenna circuit it should indicate its maximum deflection when the grid meter makes its lowest dip. The deflection of the grid meter should be gradual as resonance is approached on either side. A very sharp dip of the needle with a sudden turn to its normal position indicates too close coupling between driver and antenna circuit. The coupling should be still further loosened until there is absolutely no reaction between the two circuits. A powerful driver separated by several feet from the antenna is necessary if accuracy is desired.

After determining the fundamental wave length of the antenna its resistance at this frequency can be measured.

The antenna current at resonance is noted and then the known resistance is put in series with the circuit and the antenna current read again. The driver adjustment should not be disturbed when the resistance is inserted in the circuit. The resistance of the antenna circuit is then coupled by substituting:

$$R_a = \frac{R_1}{\frac{I}{I_2} - 1}$$

R_a = Antenna resistance
R_1 = Value of known resistance
I = Antenna current before resistance was inserted
I_2 = Antenna current after inserting known resistance in circuit.

Readings can then be taken at 5 and 10 meters apart from below the fundamental (by inserting series condenser) to two or three times this wave. A curve can then be plotted as previously shown.

Humps in the curve indicate resonance circuits within the field of the antenna at the wavelength at which the hump occurs.

If the bend in the curve is exceptionally high it probably indicates a high resistance ground. If the curve at the right of the bend goes up very steep, it indicates excessive dielectric absorption probably due to the proximity of trees and houses.

Measurement of an antenna resistance by *substitution method* consists of coupling the driver circuit to a dummy or artificial antenna circuit comprising inductance, capacity and a calibrated variable resistance. The circuit of such measurements is shown in figure 147.

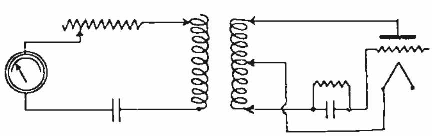


FIG. 147. Arrangement for Measuring Antenna Resistance by the Substitution Method (Artificial or Dummy Antenna).

To measure the resistance of the antenna at a given wavelength the process is as follows:

Adjust transmitter to power desired and resonate antenna circuit. Measure wavelength to see if it is correct. Record antenna current as R_a. Couple artificial circuit loosely to tank circuit and with no change in power adjust artificial circuit to same wavelength as driver. The antenna inductance can be used in the dummy in place of a separate coil this permitting a more accurate computation of total antenna resistance. The antenna and ground leads should be disconnected. When dummy circuit is tuned to same wavelength as tank circuit the variable resistance in dummy circuit should be varied until the radio frequency current is the same as R_a. The value of resistance in use when the same value of current is noted is approximately that of the antenna circuit. The resistance of the dummy circuit can be recorded as R_d substituting in the formula the antenna resistance:

$$R_a = \frac{I_d^2 \times R_d}{I_a^2},$$

R_a = Resistance of antenna,
I_d^2 = Current in dummy,
R_d = Resistance in dummy,
I_d = Current in antenna.

The artificial antenna circuit is also useful for testing purposes without the necessity of radiating a strong wave. Supposing it was desired to find out what antenna current to expect when 500 watts of power was delivered to an antenna having a resistance of 10 ohms. Substituting in the formula

$$I^a = \sqrt{\frac{P}{R_a}},$$

or

$$I^a = \sqrt{\frac{500}{10}} \quad \text{or} \quad I^a = 7.07 \text{ amperes},$$

P = Desired antenna power,
R_a = Antenna resistance,
I^a = Antenna current.

Another example of the use of these values is as follows: Suppose it was desired to adjust the same transmitter to 750 watts output at the same wavelength. The transmitter should be adjusted until the antenna current was

$$I^a = \sqrt{\frac{P}{R_a}} \quad \text{or} \quad \sqrt{\frac{750}{10}} \quad \text{or} \quad I^a = 8.66 \text{ amperes}.$$

Proof: Watts in antenna = $I^2 \times R$,
Watts in antenna = $8.66^2 \times 10$,
Watts in antenna = 749.9.

If 750 watts were put into the antenna and 450 watts were shown as energy lost by radiation the remaining 300 watts would be lost in heating the wires, ground connection, dielectric absorption surrounding the wires and by eddy currents induced in nearby wires and metal masts.

26. General—When starting up a tube transmitter for the first time, the operator should first light the filament at a voltage below normal, gradually building it up by decreasing either the resistance of the filament rheostat or by increasing the resistance of the filament generator field.

The tubes should be allowed to warm up 20 to 30 seconds before applying the plate voltage. If means are provided, start operations with about half of the normal plate voltage and gradually build it up to normal operating value. Should any trouble occur such as condensers flashing over, excessive and rapid heating of the plate, or potential breakdown to any other parts of the circuit the power should be instantly cut off and all parts of the apparatus gone over.

If a defective coil or condenser is found it should be replaced by a new one and operation of the transmitter renewed exercising the same precautions previously outlined.

If all the meters read normally and antenna current is indicated the power may be increased to the maximum rating of the tubes.

Where several tubes are operated in parallel it is best to start with one tube first. After oscillations are established the other tubes may successfully be added to the circuit. Readjustment of power, both filament and plate, will be necessary with the increased load.

Due to the added capacity of the other tubes it may require a slight adjustment of the primary condenser or a movement of the plate or grid clips a fraction of a turn to establish oscillations. The wavelength should be checked when normal operation is attained.

If several tubes are operated in parallel, difficulty may be encountered through failure of the tubes to divide the load or failure to develop normal output.

To remedy the first difficulty individual grid leaks and condensers should be tried. If possible the grid leak resistances should be adjusted in steps. Then, if one tube tends to take more than its share of the load, the grid leak resistance of that tube must be increased.

If normal output is not obtained, then probably the tubes are generating ultra-high frequency oscillations. This may be overcome by making all grid and plate leads of the same length. In addition to this a small radio frequency choke coil should be inserted in each grid lead as near to the grid terminal of the socket as possible. The choke may be made up by winding in a single layer from 15 to 20 turns of number 24 or 26 D.S.C. wire on a form one inch in diameter. Each choke should have the same number of turns. An inductive resistance of approximately 15 ohms may be used in place of the choke coil to suppress generation of these parasitic oscillations.

The operator is cautioned not to expect double or triple the antenna current for each tube added. With normal plate voltage the antenna *power* will be increased in proportion to the number of tubes providing the efficiency remains the same. The antenna *current* is increased in proportion to the square root of the number of tubes. Therefore the antenna current to be expected is equal to the original antenna current times the square root of the new number of tubes, divided by the square root of the original number of tubes or:

$$I_n = \frac{I \times \sqrt{\text{new number of tubes}}}{\sqrt{\text{old number of tubes}}}.$$

If one tube is in use and another is added it will be found that the antenna current is approximately 1.4 times that shown for one tube.

In circuits employing full wave self rectification those tubes acting on one side of the cycle only are computed as the power rating of the transmitter. Assume one 250-watt tube on each side of the cycle of a transmitter. The power output is computed as one tube alone. It will probably be somewhat higher than the normal rating of the tube.

27. General Suggestions for Locating and Correcting Trouble in a Tube Transmitter—If the tube fails to oscillate it is usually indicated by:

(*a*) High or no plate current.

(*b*) Excessive and rapid heating of the plate.

(*c*) Grid leak remains cool.

(*d*) Failure of the current indicating device on a wavemeter to register when placed in an inductive relation to primary circuit and varied within a band of frequencies at which the primary circuit is supposed to be oscillating.

(*e*) Antenna radio frequencies ammeter fails to indicate current providing the circuits have been previously resonated.

Failure to oscillate may be due to:—

1. No voltage reaching the plate usually indicated by no reading of plate current milliammeter or by the failure of the plate to heat as the key is closed.

An opening in the plate milliammeter will prevent the high voltage from reaching the plate.

All choke coils from the source of plate supplies should be tested for open circuits or grounds.

Condensers should be tested for short circuits or potential breakdowns of the dielectric. A potential breakdown may not be visible from the outside, but the operator, may by attentive listening, hear a steady or interrupted sparking or arcing when the plate voltage is applied. If a plate milliameter is provided it will jump suddenly each time a breakdown flashover occurs.

2. **Open Grid Circuit**—Usually indicated by reduced or no plate current. Grid leak fails to warm up as plate voltage is steadily applied. Test each tube in grid circuit separately such as grid leak, ultra high frequency, choke coil.

3. **Lack of Sufficient Feed-Back to Grid**—This is corrected by moving plate and grid clips, trying them on different turns always including more turns from filament to plate than from filament to grid. Vary capacity of tuning condenser through full value of minimum to maximum capacity for each new adjustment of the clips.

High Resistance Contact of Clips on to Inductance—Clean clips and inductance with fine sand paper or emery cloth. Make sure all clips are making positive contact to correct turn of inductance. Make sure that clips are correctly placed so as to make contact only on one turn and not short-circuit those on either side.

4. **Radio Frequency Choke Coil Lacks Sufficient Turns** (Parallel Feed)—The natural period of an untuned r.f. choke coil should be greater than the longest wavelength at which the transmitter is expected to operate. If choke coil heats excessively it is an indication that it is wound with wire of too small a size or possibly the transmitter is oscillating at the fundamental or a harmonic frequency of the choke coil. A larger size choke coil should be tried.

A test can be made as follows to determine if the choke coil is preventing the radio frequency currents from feeding back into the plate supply current.

With a screw driver having a well insulated handle, touch the terminal of the coil nearest the plate with the metal end of the screw driver. This will cause sparks to fly as an indication of the radio frequency energy providing the tube is oscillating. Tap the opposite terminal of the choke leading to the high voltage supply. If the choke is functioning correctly no snappy sparks will be observed. If sparks are observed it is best to remove the choke and replace with another having a larger inductance.

To make this test the operator must take every precaution to insulate himself from the ground and to be sure that the object with which he makes the test is insulated from his hand. It is not advisable to make this test with a transmitter employing voltages in excess of 1000 volts.

5. **Defective Tube**—If the tube shows a yellowish, white smoke in the interior when the filament is heated it is an indication that air has leaked into it thus destroying its vacuum.

Possibly an overload has liberated a large amount of gas from the metal plate. Usually indicated by a purple glow in the interior near the plate when the high voltage is applied.

If the tube has been subjected to an overload for a long period of time the filament may have lost its normal emission. This is generally indicated by a reduced reading of the plate milliammeter. Where several tubes are operated in parallel it will be necessary to test one at a time for oscillation. Failure to show normal plate current or to oscillate is a good indicator that the tube needs reactivation.

6. **Grounds**—It sometimes happens that ground or potential breakdown will not occur until the plate voltage has built up to half or full voltage. This is usually indicated by successive blowing of fuses or tripping of the circuit breakers in the plate supply leads before the voltage reaches a maximum value. The defective wire should be located and the ground cleared or the wire replaced by a new one.

This may often be found in lead-covered wire caused by the lead sheathing breaking and cutting through the insulation to the conductor inside, thus grounding the circuits. Any circuits run with this kind of wire and not at ground potential should be tested out with battery and phones or voltmeter to ascertain if this has occurred.

It sometimes happens that in soldering copper lugs to the conductor within a lead-covered wire that insufficient sheathing is removed and as a result the shoulder of the lug makes contact to the lead covering resulting in a short circuit or ground. This trouble is rather difficult to locate as it is the usual practice to tape up the shoulder of the lug to the lead covering after completion of the soldering.

Only by testing one circuit at a time can the defective wire be)cated. It may be necessary to sustitute one or two new leads efore the trouble is finally eliminated.

Substitution for Defective Parts.

28. **Condensers**—Where a condenser is blown and no spare ; available it is sometimes possible to remove one from some ther part of the circuit where it is not so essential and try it in lace of the defective one.

Coils—Defective coils can usually be removed or the deective portion shorted out. If the insulating material on which ıe coil is wound has become charred due to arcing over or burnıg, cut away insulation if possible, or cut winding and remove ufficient turns to clear the defective part of coil support.

Grid Leak Resistance—Most any type of non-inductive reistance from 4,000 to 10,000 ohms will do in an emergency ·roviding it has sufficient current carrying capacity. A grid ɜak can be constructed from a piece of rubber hose 12 inches)ng, filled with water and plugged at each end. Wire electrodes an be inserted through the plugs making contact with the water t each end. If the resistance is too high add a little salt or washıg soda. A glass jar similar to a fruit preserving jar can be .sed in lieu of the rubber hose. One electrode can be stationary nd the other variable so that adjustments to the correct value can ·e made.

Burned Out Filament Transformer or Generator—Connect nough storage batteries in series to give the desired voltage at ʋhich the tubes operate. If the filament transformer is burned ut it will be necessary to disconnect all wires running to the midap and connect them to the positive side of the filament battery. f the filament d.c. generator is defective disconnect the leads from he output terminals of the machine and connect the battery.

In searching for trouble it should be done systematically. It ; generally possible to immediately isolate the trouble, that is, to)cate it in some unit of the equipment such as the motor genrator, filament transformer, fuse blocks, radio transmitter.

Frequently it is possible to still further isolate the trouble, as or example in the radio transmitter, it is possible to determine ʋhether it is a defective tube, open grid circuit or a potential ıreak-down, of condenser.

By keeping in mind the function of each part of the transmitter he trouble can soon be located and a remedy applied.

CHAPTER 6

MODULATING SYSTEMS EMPLOYED IN RADIO BROADCASTING

The purpose of a radio telephone transmitter is to radiate waves which conform to the frequency and amplitude variations of speech and music produced in the studio of the station.

The process of superimposing these audio frequency currents upon the radio frequency energy is called modulation. To understand what modulation is and how it may be accomplished will be explained by following the voice or music from the studio to the antenna.

1. The Microphone—A typical microphone as employed in the ordinary house telephone is shown in figure 148. The front

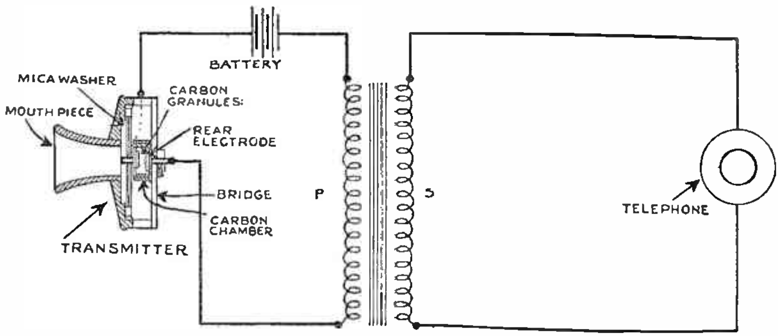


Fig. 148. Details of Telephone Transmitter Circuit.

and rear electrodes, the granular carbon and mica washer which is associated with the front electrode are all mounted in a cup, the mica washer being clamped in position and fastened rigidly to the front electrode leaving this electrode free to vibrate. The rear electrode is fastened rigidly to the bridge. The granular carbon is placed between the front and rear electrode so as to be in contact with both. The carbon chamber is never completely filled. The diaphragm is fastened directly to the stud of the front electrode, and is held in position by two damping springs. These springs

Fig. 148*a*. Studio of Broadcasting Station WBAL at Baltimore, Md.

are also to prevent the diaphragm from vibrating at its natural period, instead of at the periodicity of the sound-waves striking it.

Operation of Microphone—The operation of the microphone is as follows: Normally the current flows from battery to the front electrode through the granular carbon to the real electrode, and back to the other side of the battery. (See figure 148.) This circuit has a certain resistance. When the microphone is spoken into or sound waves otherwise created, the diaphragm will vibrate, the pressure on the carbon granules will change and the resistance of the microphone will vary thereby causing a current to flow in the local transmitter circuit.

2. Double Button Microphone—The carbon type of transmitter employed in radio broadcasting studios differs somewhat

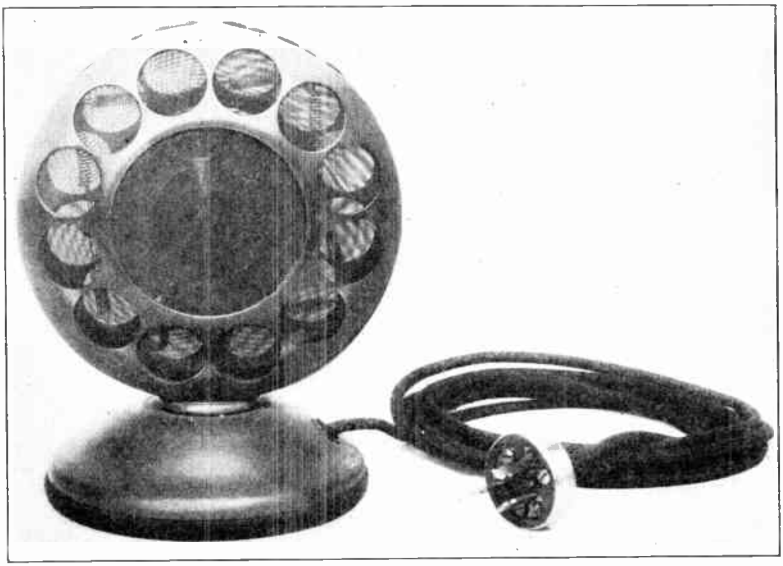


FIG. 149. Western Electric No. 373-W Transmitter (Double-Button).

in construction from that described, but the principle of operation is the same. In ordinary conversation it is only necessary for the telephone microphone to convert from sound vibrations into electrical impulses with frequencies ranging from 200 to 2,000 cycles per second, whereas the studio microphone must convert all the voice and musical frequencies ranging from 16 to 7,000 cycles per second. Such a microphone is shown in figure 149.

This type of microphone is employed with all Western Electric Broadcasting equipment and is known by its trade name as "Western Electric No. 373 W. Transmitter." It is of the double button carbon type, the diaphragm of which is of duraluminum .002 of an inch thick and is so stretched and dampened that its frequency response curve is flat from about 1,000 to 6,000 cycles. On each side of the diaphragm is a gold plated area against which the carbon rests. The carbon is held in place by means of a felt ring separated .003 of an inch from the diaphragm and as the smallest carbon granules are about .005 of an inch in diameter they stay in place. As the sound waves strike the diaphragm they compress the carbon in one button and loosen it in the other, thereby changing its resistance. By the arrangement of the push-pull action, distortion is minimized and the output increased.

The microphone circuit is shown in figure 150. The current through each button is regulated by the potentiometer in shunt to the 12-volt battery. It is essential that the resistance of each button is balanced, otherwise the output will be distorted.

One disadvantage of the carbon microphone is the hiss produced by the carbon itself when current is flowing through it.

3. Condenser Type of Microphone—The condenser type of microphone makes use of the principle of a variable capacity actuated by sound waves. It consists of two plates having an air dielectric. One plate of the condenser is usually a steel plug while the other plate, which is the diaphragm, is made of duraluminum of approximately .0018 of an inch thick. The diaphragm is stretched nearly to its elastic limit in order to make its resonant frequency above audibility. The plug and diaphragm are separated about .0015 of an inch.

Usually a change of approximately 200 volts is maintained on the condenser by means of a battery. When the sound waves strike the diaphragm and cause it to vibrate the electrical capacity of the condenser is varied which in turn changes the voltage applied to the grid of the amplifying tube.

Speech Amplifier—The feeble currents produced in the microphone circuit are not sufficiently powerful to modulate the radio frequency energy generated by the radio transmitter, therefore, a speech input amplifier must be interposed between the microphone and transmitter. This amplifier takes power in the form of direct current from batteries and converts it into alternating currents of speech and musical frequencies which produce the form of the microphone currents exactly, but which are sufficiently increased in amplitude to be of service in controlling the radio transmitter. The schematic of such an amplifying arrangement is shown in figure 150.

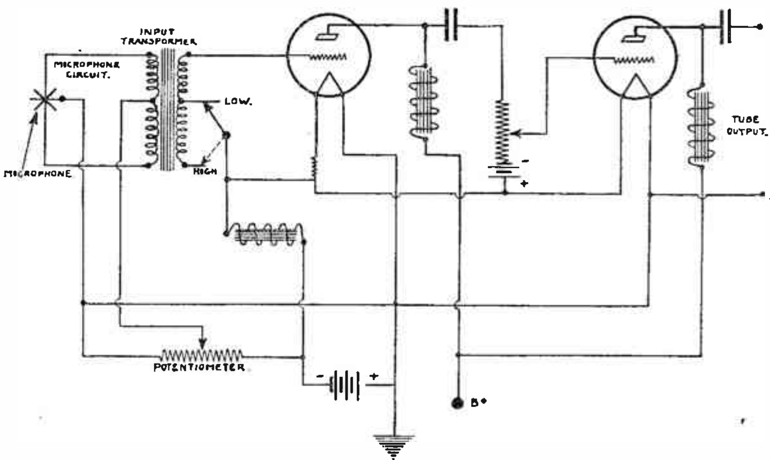


FIG. 150. Schematic Microphone and Speech Amplifier Circuit.

4. **Radio Telephone Wave Forms**—In figure 152 the carrier wave of a radio telephone transmitter is shown. It consists of a single frequency of constant amplitude indicated as the "non-signalling amplitude." When the microphone is spoken into, the modulation of the current causes the amplitude of the carrier frequency to rise and fall as indicated by the "signal amplitude." If the apparatus is incorrectly adjusted it is possible to vary the amplitude in one direction only. Figure 153 shows the carrier wave of a transmitter varied downward only. Imperfect reproduction at the receiver will result, caused by the failure of the system to allow the amplitude of the current to rise.

Side Band Frequencies—A radio frequency carrier wave of 500,000 cycles (600 meters) may be modulated by frequencies such as 100, 200, 500, and 5,000 cycles. There will be radiated by the antenna the carrier frequency F, and the side frequencies, $F + 100$; $F - 100$; $F + 200$; $F - 200$; $F + 500$; $F - 500$; and $F + 5{,}000$; $F - 5{,}000$ cycles.

The $F+$ indicates the upper side frequencies and $F-$ the lower side frequencies. The modulation of the radio wave thus

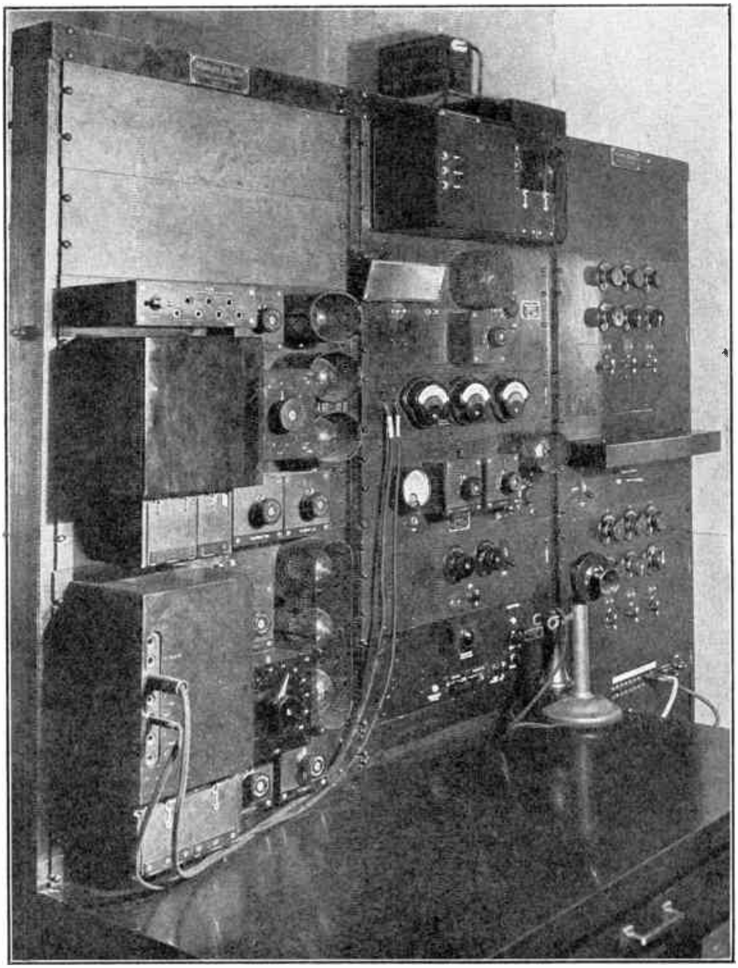


FIG. 151. Western Electric Speech Amplifiers and Monitoring Apparatus.

takes the form of the production of side frequencies. The carrier frequency remains unchanged. At the receiving station, the beats between the carrier frequency and the side frequencies when rectified produce the frequencies picked up by the microphone.

Thus with a carrier of 500,000 cycles there will occur in the antenna the frequencies:

The carrier 500,000 cycles.

Upper side frequencies between 500,100 and 505,000 cycles.

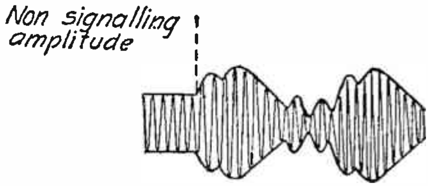


FIG. 152. Radio Frequency Carrier Wave Modulated by Speech Signal.

Lower side frequencies between 495,000 and 499,900 cyles, giving a band of 10,000 cycles wide necessary for the accurate transmission of speech and music. Converted into wavelengths at this frequency the transmission would occupy a wavelength band from 593.7 meters (505,000 cycles) to 605 meters (495,000 cycles) or

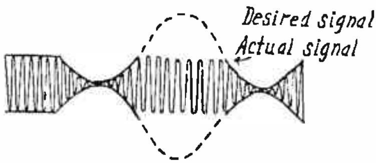


FIG. 153. An Improperly Modulated Wave.

11.3 meters wide. With a higher carrier frequency the width of the frequency band must necessarily be required but the wavelength band will be reduced.

Radio broadcasting stations in the United States and Canada are assigned frequencies between 550,000 and 1,500,000 cycles. Each station is assigned a frequency channel designated in even numbers of kilocycles. There are 10 kilocycles separation between each assignment. Several stations are assigned the same frequency and operate with a division of time or having sufficient geographical separation and difference in time so as not to interfere with each other.

However, should the station be operating off its assigned frequency it will cause interference with the station occupying the channel towards which the carrier frequency has drifted. This causes distortion in the receiver of the listener and results in the transmission of each station being impaired. A steady whistle, similar to that of a peanut roaster, is audible during the transmission caused by the carrier waves of each station heterodyning each other and producing a beat frequency.

5. **Grid Modulation**—One of the simplest methods of modulating the radio frequency current generated by a vacuum tube is

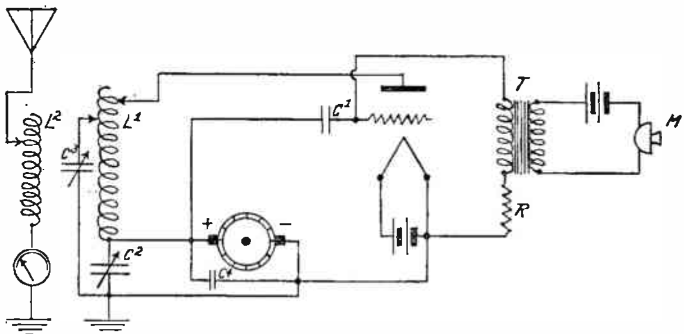


FIG. 154. Logwood's Grid Modulating Circuit.

the Logwood system. Referring to figure 154, the secondary of the modulation transformer is in series with the grid leak resistance of the oscillator. The speech signal is impressed upon the grid which controls the amplitude of the oscillations. However, as the grid is also used for controlling the current through the tube while oscillating it is compelled to perform two different functions simultaneously and unless the circuit is very carefully adjusted it fails in one or the other. Usually the transmitter is adjusted to secure maximum antenna current and the signal is impressed upon the grid expecting perfect operation. This, however, is not what results. Better modulation will be obtained if the tube is operated at reduced output. In either case it is almost impossible to secure over 20 per cent modulation. If the grid voltage is sufficiently reduced, the tube may suddenly stop oscillating and the antenna will drop to zero resulting in distortion of speech.

6. **Absorption Method of Modulation**—A system often employed by amateurs to modulate the transmitter at speech frequencies is shown in figure 155. Coupled to the antenna inductance is a few turns of wire in series with which is connected the microphone. As the microphone is spoken into the resistance of the loop circuit is varied and energy is extracted from the an-

tenna at speech frequencies. This system is fairly efficient but limited to a transmitter of low power.

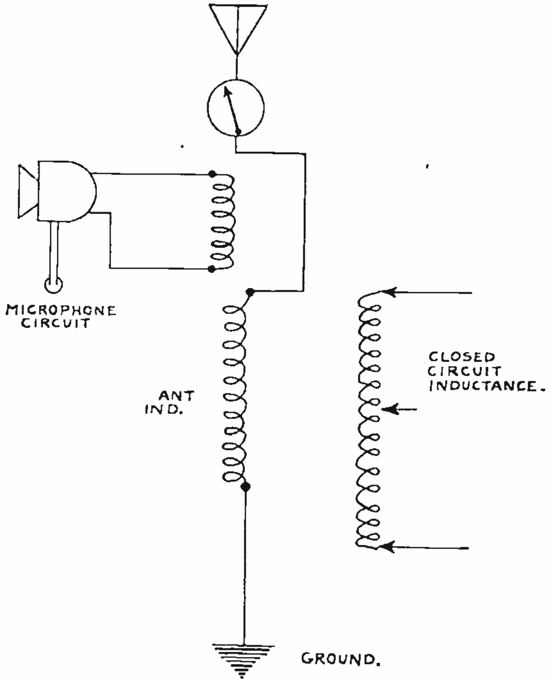


FIG. 155. Absorption Modulation.

Modulation can also be obtained by connecting the microphone directly in the ground lead of the transmitter. In this way the resistance of the antenna is varied at an audio rate causing a corresponding variation of the radio frequency output.

7. **Heising Constant Current Modulation**—The system of modulation employed by the Western Electric in their radio broadcasting equipment is known as the Heising or "constant current" modulation.

Figure 156 shows a simplified diagram of a radio telephone transmitter employing one tube as a generator of radio frequency oscillation, another tube as a modulator, and still another as a speech amplifier.

The inductances *LFC* are of such values as to choke out radio frequency variations of the plate current in the circuits of which they are located. The plates of all tubes receive their voltage from the high voltage generator through these chokes.

The speech amplifier tube is of smaller power than that of the oscillator and modulator tubes; therefore, a resistance DR_1 is em-

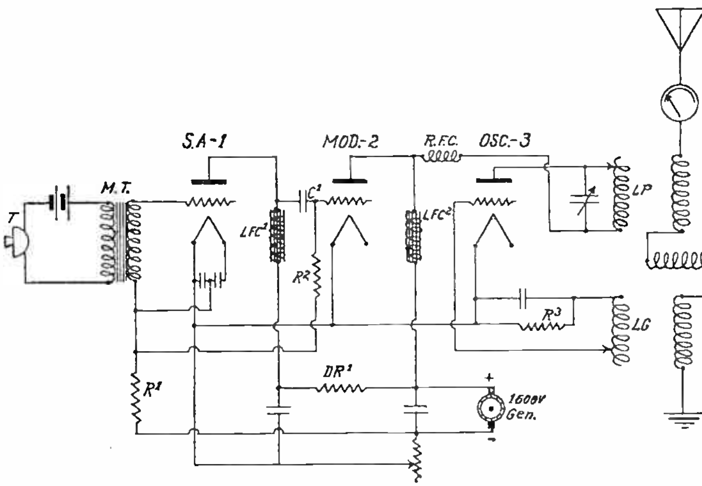


FIG. 156. Heising's Constant Current Modulating Circuit.

ployed to reduce the voltage to the correct value for this tube. The inductance RFC is a radio frequency choke coil and prevents passage of the radio frequency currents into modulator and power supply circuits. The grids of the speech amplifier and modulator tubes are connected to the negative high potential through the resistances R_1 and R_2 giving them the correct negative potential for efficient operation. The grid of the oscillator tube acquires its correct negative potential by the voltage drop through resistance R_3 connected to the negative side of the filament supply.

The operation is as follows: Speech into the microphone varies the current in its circuit. This varying current passing through the primary of the transformer induces a varying current potential in the secondary. This potential is impressed upon the grid of the speech amplifier tube. The plate current in this tube is therefore an amplifier reproduction of the microphone current. These audio frequency currents charge the condenser C_1. They cannot take any other path as the impedance of choke coil LFC_1 rejects them. The condenser C_1 prevents the positive potential of the plate sup-

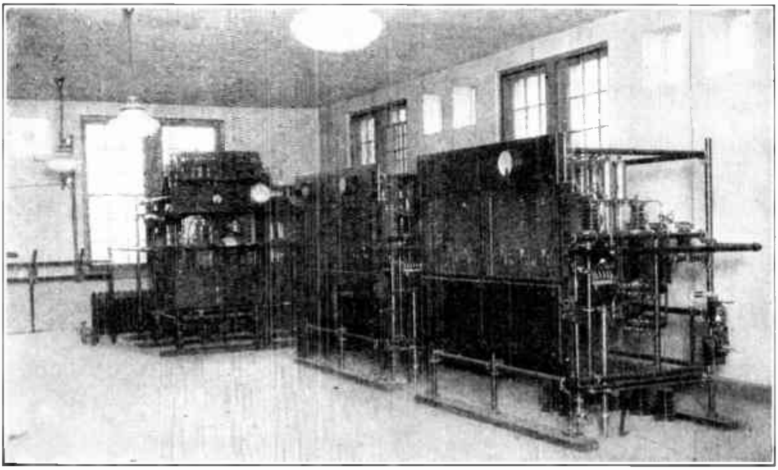


FIG. 156*a*. 50-KW. Oscillators and Constant Current Modulators (WJZ).

ply from reaching the grid of the modulator tube (MOD_2), at the same time the alternating low frequency currents successfully pass through.

The radio frequency oscillations are generated by the oscillator tube OSC_3. This tube receives its plate potential from the plate generator through the iron core choke coil LFC_2 and the radio frequency choke coil RFC. Constant current is supplied to both modulator and oscillator tubes by action of the iron core choke LFC_2 which prevents any variation in current that takes place in either of its branch currents from affecting the supply from the generator. The audio frequency variation in the potential grid of the modulator tubes produces an audio frequency variation of current in the plate circuit. This variation of current cannot come directly from the generator, as the constant current choke coil LFC_2 prevents, it must come from the oscillator tube. When the current in the modulator tube plate current is increased that of the oscillator is decreased likewise, then the modulator plate current is decreased and that of the oscillator is increased. Thus, the amplitude of oscillations is modulated by this increase and decrease of current. It is the output of the oscillator tube which is radiated by the antenna.

Figure 157 illustrates the transfer of energy between the modulator and oscillator tube. The battery *B* furnishes a constant cur-

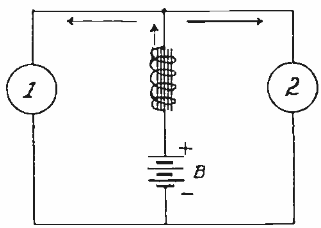


FIG. 157. Illustration of Transfer of Energy between Modulator and Oscillator Tubes in a Constant Current System of Modulation.

rent passing through the iron core inductance. This current divides, half of it going through tube 1 and half of it through tube 2 when both have the same resistance. If the resistance of tube 2 is decreased, more current will flow through it, but the choke coil does not allow any variation of current, therefore, the extra current passing through tube 2 must come from the circuit in which tube 1 is located. In other words the current passing through *L* does not split 50–50, but say, 80–20, the larger part going through tube 2 circuit. When the resistance of 2 is increased the reverse of this takes place, the larger potential on the grid of the modulator tube has the effect of changing the resistance of that tube. Modulator tubes are usually operated with sufficient negative bias to prevent the grids from swinging positive by action of the signal voltage. When two or more tubes are operated in parallel care must be exercised to make sure they are of equal values of impedance, otherwise, one tube will take all the load.

8. Instability of Carrier Frequency—A transmitter employing self-excited tubes which are acted upon directly by the modulator tubes as previously described is subject to the production of amplitude distortion. This is manifest by a wobbling or rapid shifting back and forth in frequency of the amplitude modulated carrier. In other words, the carrier and side bands without change in their relative frequencies, are subjected to frequency modulation.

It is quite unlike the slow wandering of frequency which for instance, produces beat notes between carriers of different stations, to drift gradually in pitch. It is governed by the cyclic variations of the modulations. This form of distortion in transmission of the carrier frequency has been termed "dynamic instability."

The instability of carrier frequency in most cases can be identified by the broad interfering wave emitted by a transmitter when modulated by a transmitter by a jazz orchestra. It is a common fault of the majority of composite broadcasting transmitters in use at the present time.

In order to overcome this effect on the instability of carrier frequency it has led to a more general use of the master oscillator power amplifier system, in which the audio frequencies are impressed directly on the amplifier radio frequency currents and not on the oscillator. Such a system is now employed by the Western Electric Company in the type of transmitting apparatus sold by them for broadcasting purposes. The arrangement is known as a master oscillator frequency stabilizer circuit. It is described in detail in the last ten pages of chapter nine.

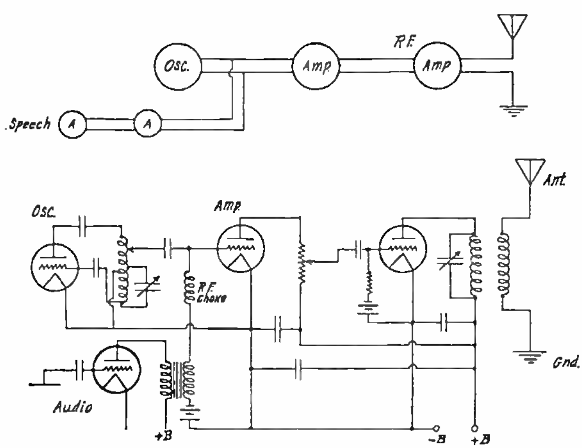


Fig. 158. Grid Modulation of Power Amplifier Circuit.

In figure 158 there is shown the schematic circuit of a system which is being used increasingly and has definite advantages over the Heising system. Whereas the Heising system depends on a straight line plate characteristic of the oscillator the system now spoken of depends on a curved characteristic of grid voltage against output. The advantages of this system over the Heising system are:

1. Speech need not be amplified since it is put into the grid instead of the plate.
2. Less power is consumed because the modulator waste is less.
3. While not getting as high a possible output from the oscillator tubes as the Heising system, it gets from them much more than the other system (absorption, grid leak, etc.), and it does it without ever exceeding normal plate voltage as in the Heising system.
4. Since the oscillator is not operated on the frequency steadiness is better.

9. **Frequency Modulation**—The Heising system of modulation is based on amplitude variation. In the constant current circuits this amplitude variation of the carrier is accomplished by changing the plate potential of the radio frequency amplifier or oscillator at audio frequency. Since the output of such a converter varies with the plate potential the amplitude of the carrier will vary with the vibrations of the microphone diaphragm, these of course being first greatly magnified.

However, these audio oscillations might just as well be used to vary the frequency of the carrier within a certain band. A scheme such as that shown in figure 159 can be used. Here the microphone is shown as a small audio frequency alternator. The output of this machine amplified, is impressed across the variable condenser C, varying its capacity in accordance with the sound vibrations. The capacity of this condenser then varies according to the sound pressure. If now C, is part of a radio frequency circuit C_1, C_2L

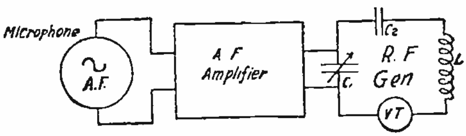


FIG. 159. Schematic of Frequency Modulation.

the frequency of the carrier generated by the tube VT will vary according to the sound pressure, a loud sound producing a greater deviation in frequency than a faint sound.

The signal might be demodulated by means of a receiver with a very sharp resonance characteristic, the peak being set at the unmodulated carrier frequency. As the carrier varied from this value the rectified current would drop off conceivably with respect to the original sound pressures. With such a radio broadcasting system all the modulation would be confined to approximately a 500 cycle band thus allowing more stations to be crowded in owing to the narrowness of their transmitting band.

10. Definition of Transmission Unit—In the transmission of electrical energy which is eventually converted into sound, it becomes necessary to have a measuring unit which bears a relation to the sensitivity of the human ear. Telephone engineers have worked out such a unit known as the transmission unit (T.U.).[1] It is possible for the ear to just distinguish the difference between two powers that differ in intensity by one T.U. The transmission unit is defined as ten times the common logarithm of the base ten of the ratio between any two powers, or twenty times the logarithm of the ratios of the two voltages or currents into equal impedances. It is expressed mathematically as follows:

$$T.U. = 10 \log_{10} \frac{P1}{P2},$$

$$T.U. = 20 \log_{10} \frac{E1}{E2},$$

$$T.U. = 20 \log_{10} \frac{I1}{I2}.$$

Consider two audio frequency amplifiers whose power output is 800 and 1,000 milliwatts, respectively. It would appear from these figures that the amplifier of 1,000 milliwatts would give a considerable increase in volume over that of the 800 milliwatts amplifier. However, this would not be so as the difference between the two amplifiers could hardly be detected by the ear. Referring to the formula of T.U. the ratio of the two powers is:

$$\frac{1000 \text{ Milliwatts}}{800} \text{ or } 1.25 \text{ to } 1.$$

Consulting a table of logarithms to base 10 it will be found that the common logarithm is 0.097. Substituting in the formula for T.U.

$$T.U. = 10 \times .097,$$
$$T.U. = .97.$$

[1] The new name for the Transmission Unit is to be known as the Deci-Bel, abbreviated "DB." The prefix Deci signifies tenth. The new name honors Alexander Graham Bell. It was adopted at the assembly of International Advisory Committee of long distance telephone engineers at Como, Italy.

Therefore, the difference being less than on T.U. no perceptible difference will be detected in the two amplifiers.

11. **Volume Indicator**—The volume indicator is employed as a part of the control apparatus of Western Electric broadcasting equipment to indicate the volume level of the program at the output of the speech amplifying apparatus which feeds the modulator tubes. Indication is given by a sensitive galvanometer in the plate circuit of a vacuum tube. The grid of the tube is energized by the output of the speech amplifier. A potentiometer is employed to permit adjustment of the negative grid bias. A level measuring key for large steps and a level measuring switch for small steps connected in the grid circuit are calibrated directly in transmission

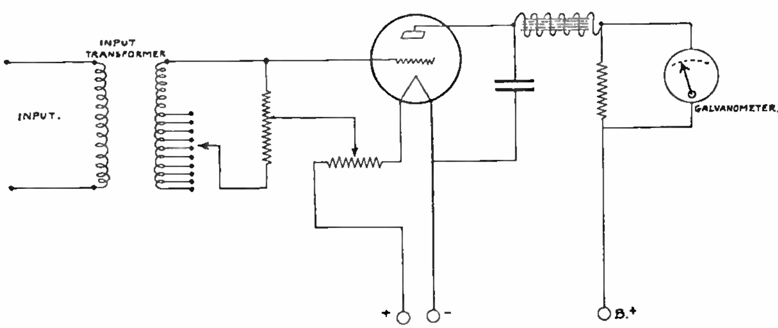


Fig. 160. Schematic of Volume Indicator.

units from zero level of volume. By adjustment of these keys the volume level at the input can be determined as indicated by a certain deflection of the galvanometer in the plate circuit of the tube. If the volume level is too high as indicated by the T.U. readings the correct adjustment can be made at the speech amplifier until the level is at the value desired.

Other methods of measuring the volume level make use of an a.c. voltmeter transformer coupled to the modulator tubes or a radio frequency pick up of the output which is rectified and coupled to a meter the scale of which is calibrated directly in transmission units.

Equalization of Telephone Lines—When it is desired to pick up a program from a point remote from the radio transmitter certain additional apparatus is necessary such as vacuum tube line amplifiers distributed at certain points in the line connecting the pick up apparatus and radio transmitter.

In transmitting a program over telephone wires the amplitude of the alternating current comprising the voice and musical frequencies is damped out with increasing distances. This effect is known as "ATTENUATION." Attenuation increases with increasing frequency. When it is considered that the frequencies encountered in musical programs range from 16 to 15,000 cycles per second, it is quite apparent that when the high frequencies are attenuated more than those of the low, the latter will then predominate. The program broadcasted by such a transmitter will be distorted as many of the higher frequencies will be missing.

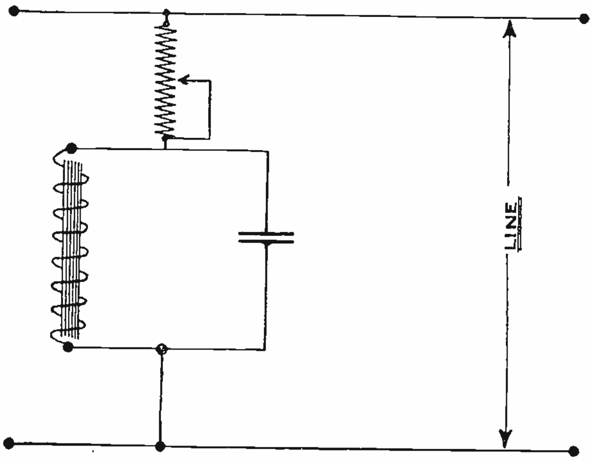


FIG. 161. Schematic of Equalizer.

Attenuation is compensated for by the use of line equalizers. The equalizer is employed to correct the frequency characteristic of the telephone line by forming a shunt which affords a variable impedance for different frequencies. This apparatus is composed of a variable resistance connected in series with a parallel circuit of inductance and capacity. The inductance forms a low impedance for the low frequencies so that the shunt is practically equal to the fixed resistance for low frequencies. As the frequency goes up the shunt goes up in impedance, due to the increased inductive reactance until the inductance and capacity resonate when the shunt impedance is at maximum.

Prior to transmitting a program the lines are equalized by sending out a signal of definite frequency and known strength. The

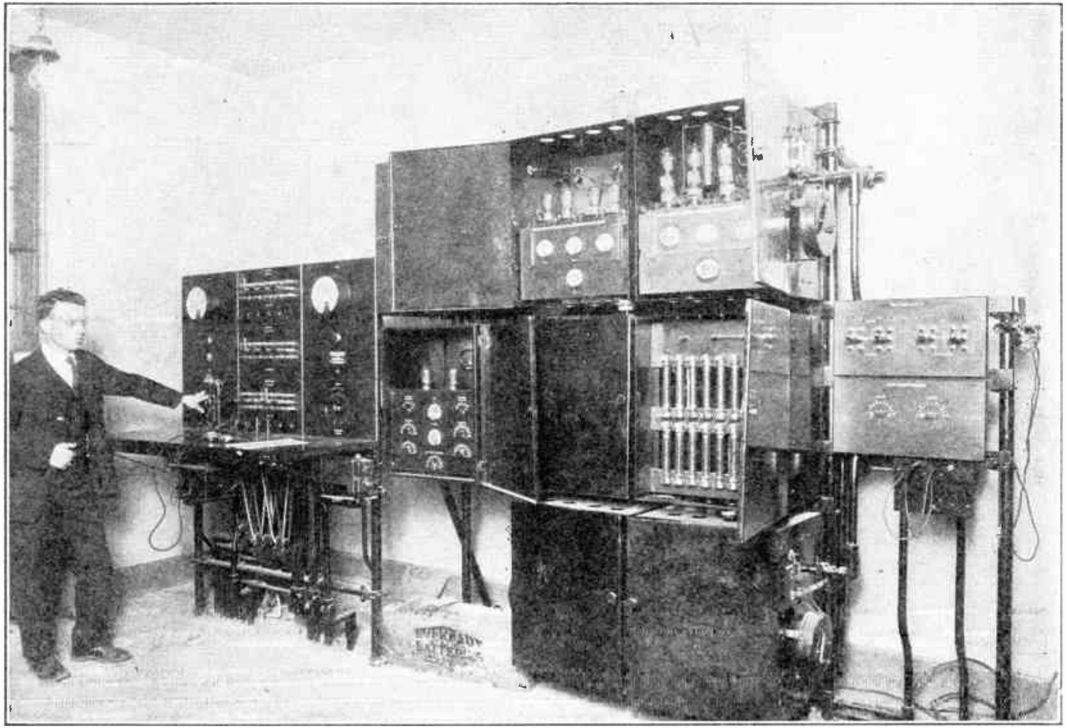


FIG. 162. Line Amplifiers and Equalizers Employed at WJZ, Bound Brook, N. J., to Amplify Program Received by Wire from Studio in New York City.

level is measured at the receiving end by means of the volume indicator. The process is usually started by transmitting a 100-cycle note and increasing the frequency of the note at intervals of 100 cycles until 5,000 cycles are reached. These signals must be received at a predetermined level and all frequencies should be received with almost equal strength. If any undue loss or gain is experienced at any particular frequency or band of frequencies the same can be corrected by the equalizer. Adjustments are made until a flat characteristic curve is obtained thus ensuring equal transmission of all frequencies throughout the musical range.

Audio frequency amplifier or repeaters are placed at certain

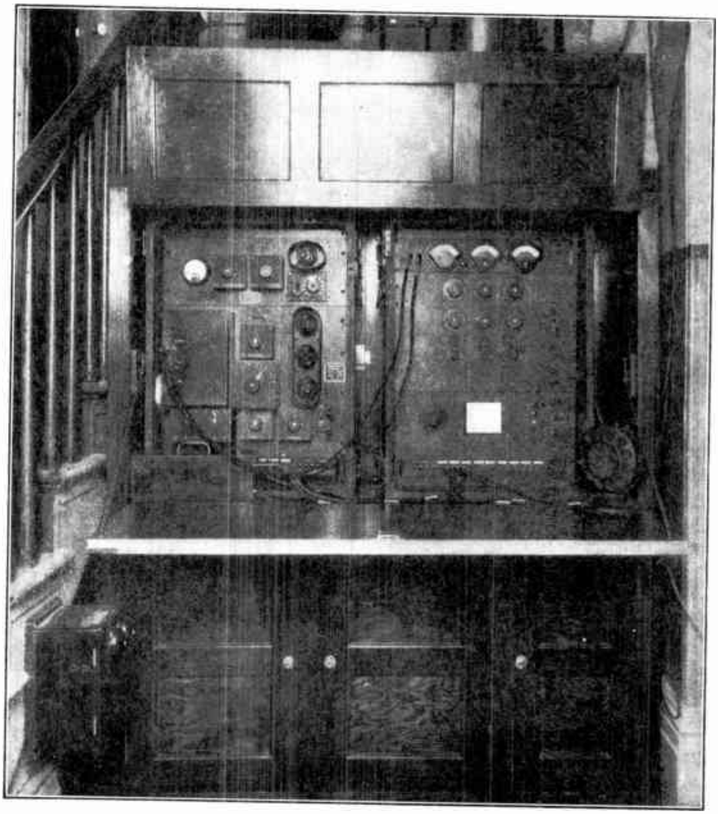


FIG. 162a. Portable Pick-Up Apparatus Employed in Broadcasting.

places along the circuit in order to boost the signals due to the loss encountered by the d.c. resistance of the line. These amplifiers amplify all frequencies to an equal degree. The amplification or gain of such amplifiers is adjustable and is carefully measured and regulated.

12. **Line Pad**—When broadcasting from a remote point it may be desirable to have the volume level equal to that when using the studio microphone. The transmitter and amplifiers used at the remote point may boost the level far above that of the studio level in order to have signal above the noise level. It then becomes necessary to insert an artificial line in the circuit having all the characteristic of an actual operating line, thus reducing the level to the value desired. (See figure 163.)

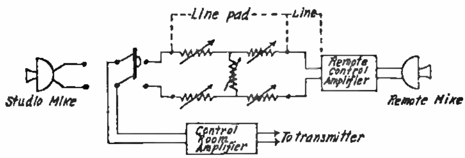


FIG. 163. Schematic Arrangement of Line Pad.

13. **Duties of a Broadcast Control Operator**—The duties of a control operator are best described by Carl Dreher, Staff Engineer of the National Broadcasting Company in an article entitled "Broadcast Control Operation" appearing in the Proceedings of "The Institute of Radio Engineers," Volume 16, No. 4. The latter part of this article deals particularly with control operating and putting a program on the air and the following text is taken verbatim with due acknowledgment to the source.

"The function of the control operators, whether in the field or at the studio, is partly coördinative, as in connection with inter-studio contact and switching, and partly regulative, in that it is found necessary to compress the natural volume in variation of speech and music, which may be as high in some cases as 60 T.U., into a compass of about 40 T.U., if overloading is to be avoided on the one hand and noise interference on the other. The operator makes up this 20 T.U. difference, in extreme cases, by bringing up his gain control carefully on low passages. Some vocal artists who have adapted their renditions to the requirements of broadcast transmission take care of this themselves by avoiding extreme pianissimos or by swaying back and forth as they sing, approaching the microphone during pianissimo portions and withdrawing during fortissimos. The former procedure may also be followed by orchestras. The rule is for the operator to handle the gain control as little as possible, but to regulate it when necessary to avoid overloading or the loss of low passages. The volume indicator galvanometer should flicker slightly during the peaks of low passages and rise to the maximum of 30–40 scale divisions during the loudest intervals. Gain regulation must be confined to one place, which is logically at the point of control nearest the origin of the program. The field operator therefore assumes the function of changing the level when necessary, in the case of field program, the studio operator in the case of studio programs, and the transmitter operator only in the event of serious line irregularities or careless operation which may endanger the radiation of the program at his end.

With regard to the placing of performers in the studio for the best musical balance there is some difference of opinion as to the proper arrangements. In general the non-technical studio staff wishes to place the musicians conveniently (for them) and to move microphones freely. The engineers, on the contrary, prefer a fixed position for the microphones, necessitating the grouping of musicians to secure the best musical balance. On this basis the microphone position is fixed according to the acoustic characteristics of the room. In studios which have not been highly damped it is frequently found that standing waves set up at certain frequencies between reflecting surfaces manifest themselves in their various interferences as rattling sounds following an initial impulse. It is possible, by placing a small rug on the floor near a wall drape, to form a space relatively free from such acoustic disturbances, in which the microphone will pick up a program with greater freedom from disturbing transients and distortions in reproduction. This amounts to stating that optimum microphone placing is a function of the studio characteristics and should be left to the judgment of the electro-acoustic experts, not to that of musicians, who, as a class are lacking in scientific qualifications. Musical balance then becomes a problem in placing instruments with reference to the fixed microphones and standardizing on the best positions. This responsibility may devolve on a musician especially delegated to the task, or on the announcer if he has musical training, or on a committee of musicians and musically-experienced technical men capable of listening critically and objectively to loud speaker reproduction. It is often helpful to allow the conductor of an orchestra to listen, during rehearsals, to the monitoring reproduction, either while his men play without him or under the baton of an assistant. The questions of orchestral balance involve many factors of musical taste, imagination, individual auditory characteristics, and imponderables, which make agreement difficult at best. The problems involved are complex and their full discussion would require a separate paper on the acoustic and musical principles underlying them.

In a broadcast station all program matters are laid out beforehand and printed schedules detailing the artists, announcers and announcements, selections, timing, and studio arrangements are distributed to all personnel concerned. The chances of a slip-up are further reduced by the fact that all program "features" are carefully rehearsed and timed beforehand. While this system does not contribute to spontaneity it has been found the only means of running off a complicated program with dispatch and reliability, especially in chain broadcasting. The function of the operating personnel, under such arrangements, is reduced, save in emergencies, to following routine previously established.

Communication between studios is maintained by means of telephone systems. The operator in the control room associated with each studio, and seated within sight through a double-glass window, is in touch with the other studio by means of a breast transmitter and single head-band receiver. He is thus in a position to converse with the other operator while continuing to monitor the program going out through his own studio. It is his duty to keep the other operator informed of the progress of the program and to warn him some minutes before a change from one studio to the other is due. Generally head-receiver facilities for listening to the program in another studio are also provided for the announcers, and in the more intricate set-ups of chain broadcasting it is necessary to devise complicated systems of mechanical switching whereby the announcer picks up his station on visual signal from the control room, by pressing buttons which actuate telephone relays and make the necessary circuit changes, which are, however, supervised by the operators, who sit before similar control boxes and are in a position to correct switching errors made by the announcers.

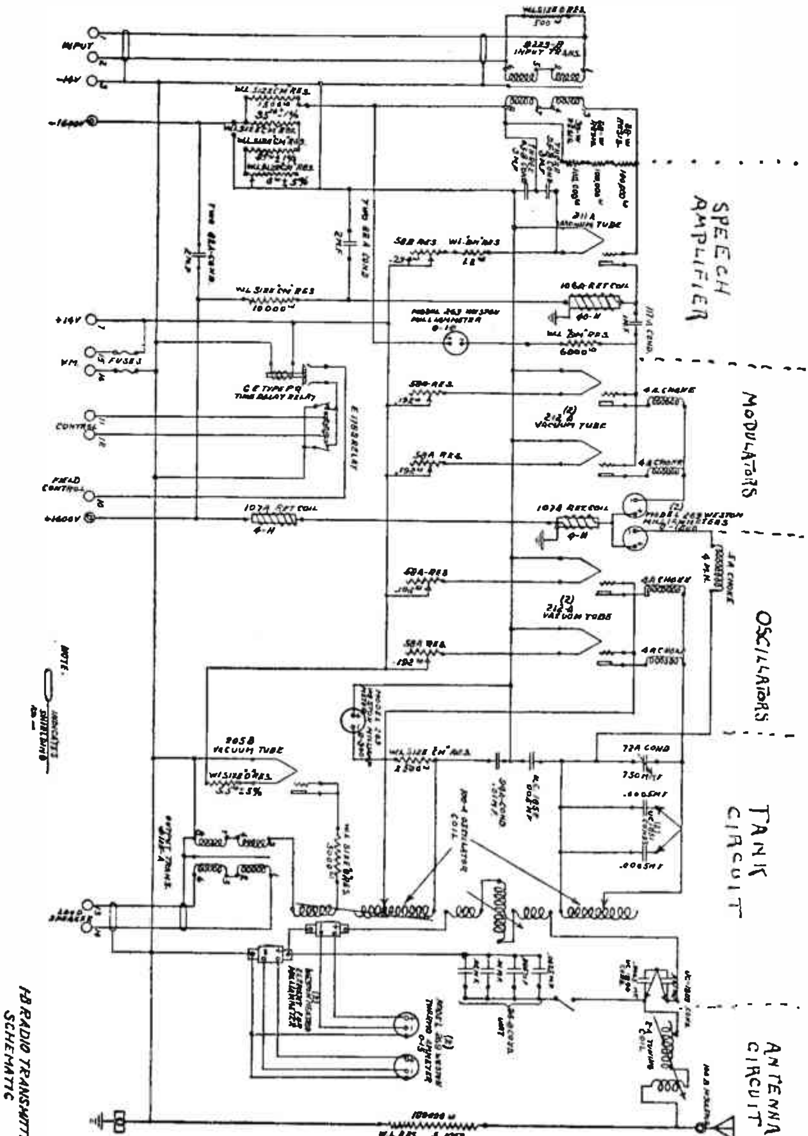


FIG. 164. Diagram of Western Electric 500-Watt 1-B Radio Telephone Transmitter with 50-Watt Speech Amplifier.

The preliminary procedure of field broadcasting gives a good idea of the precautions taken to prevent breaks in program continuity. Generally two broadcast pairs are provided, in addition to an order pair for speech communication only. The routine is as follows:

1. The field operator, having set up his microphones and amplifier, calls in on the order pair one hour before program time and talks to the control operator at the station.

2. The field operator tests all microphones by talking into them with the central operator listening.

3. The field operator sends test talk or preliminary program material over both regular and emergency broadcast circuits.

4. The station operator raises the gain of his amplifier 20 T.U. and listens closely for cross-talk from the order wire in his monitoring speaker, if this is available, while the field operator talks on the order wire, the input to the field amplifier having been cut off.

5. The field operator synchronizes his watch with the station operator, who takes time from a master clock system.

6. Ten minutes before program time the field operator sends room noise or preliminary program to the station for check of continuity of the broadcast circuit. This is kept on to within two minutes of program time.

7. At program time the field operator is told over the order wire, "Take it away" ["It" referring to the program] immediately after the broadcast trunk has been connected to the station amplifier input. He gives the signal to his announcer, who is generally within reach of a hand signal, and the remote program starts. Communication is then maintained throughout the program by the two operators for the purpose of criticism of quality and the affecting of any necessary changes.

All such circuits have been previously equalized (as previously described) by means of an audio oscillator sending out tones at a known frequency and level, with an amplifier and volume indicator showing the levels received at the station end.

In chain broadcasting similar procedures are followed, the principal difference being that contact between the originating station and the chain is maintained by telegraph. The originating station controls procedure entirely, since obviously with a multiplicity of stations receiving a program unity can be secured only by such a system. The method of making local announcements has been described previously. The fifteen-second intervals in the program left for the announcements are indicated to the chain stations by telegraph a sufficient time before each pre-arranged gap. The individual stations then cut the line input to their amplifiers and turn over to their local microphones, scurrying back to the chain before the fifteen seconds are up. Test tones are sent out by the head station to the network and the volume indicator readings at the points of reception telegraphed back to the key station, give a necessary check on wire conditions, possible need of re-routing circuits, etc. All the problems of high-quality telephony, as well as specialized broadcasting procedures, are involved. After each program the syndicate stations wire in reports as to technical quality, entertainment value, and the like.

CHAPTER 7

WAVEMETERS, PIEZO-ELECTRIC OSCILLATORS, WAVETRAPS AND FIELD STRENGTH MEASURING APPARATUS

1. **Wavemeters**—The wavemeter or frequency meter is a device employed to measure the length or frequency of radio waves either at their source or at a receiving station remote from the transmitter. It is sometimes constructed so as to be used as a transmitter of feeble intensity emitting electro-magnetic waves of a known length or frequency. In this way it can be used to calibrate a radio receiver. Other uses of a wavemeter are to measure the inductance of a coil, the capacity of a condenser, the fundamental wavelength of an antenna, or the decrement of waves radiated by an antenna.

Construction—A wavemeter is a calibrated closed oscillatory circuit, having inductance and capacity, either or both of which are variable. The general circuit diagram of a wavemeter is shown in figure 165, which consists of a fixed inductance *L*, and a variable condenser *C*. Usually there are several inductance coils which may be substituted for one another, thus giving the meter a large wavelength range. A resonance indicating device is usually included with the other elements of the circuit.

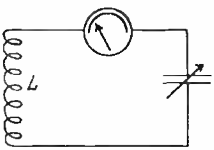


FIG. 165. General Wavemeter Circuit.

Requirements—The fundamental requirements of such a meter are that it is capable of maintaining its calibration over a considerable period of time. This requires a minimum of variation in the inductance of the coils and in the capacity of the condenser for any particular setting. The general construction must be such that the parts and wiring will not become displaced. It must have low resistance in order to obtain rapidly changing deflections of the resonance indicating device with small changes of condenser adjustment. The resistance is kept low by employing a variable condenser of good design and using inductance coils with sufficiently large wire properly spaced.

Variable Condenser—In order that the capacity of the variable condenser remain constant for any particular dial setting special attention must be given to its construction. The plates should be of sufficiently heavy material so that they will not become bent, and they must be rigidly supported. A condenser giving close spacing between the fixed and moving plates is undesirable because a slight shifting in the position of the rotating shaft will produce an appreciable change in capacity. The bearings must have large wearing surface so designed that there is no end play in the shaft. The dial must be secured to the shaft in such a manner that there is no possibility of loosening. A pigtail connection to the rotary plates is essential preferably with insulated flexible wire. If bare wire is use the calibration is liable to error caused by the turns of the pigtail touching each other as the rotary plates are turned. The condenser should have unimpeded rotation through 360 degrees as the use of stops is likely to shift the position of the rotary plates.

The dial of the wavemeter condenser is usually of metal having engraved over one-half of its circumference evenly spaced divisions which divide the dial into 100 equal parts or into 180 degrees. In order to secure precision the dial readings are arranged so that a reading to one-tenth of a division of the dial is possible. This is accomplished by a vernier scale.

Theory—It has already been explained that when oscillations are set up in a circuit and if another oscillatory circuit is placed so that they have mutual induction the first circuit will transfer energy to the second. If the frequency of oscillation of the latter circuit is the same as that of the first or driving circuit considerable transfer of energy will take place and if a current indicating device is included in the second circuit it will show a maximum deflection. As the frequency of the second circuit is decreased above or below the frequency of the driving circuit the deflection of the current indicating device will fall off.

If the second oscillatory circuit containing the current indicating device is provided with a graduated scale as previously described the wavelength or frequency of oscillations may be read directly from the scale or by consulting a calibration curve, the reading being taken at exact resonance. When such a device is calibrated in wavelengths it is called a wavemeter and when calibrated in frequency a frequency meter.

Expressing the capacity of the wavemeter condenser at resonance in microfarads and the inductance of microhenries, as is commonly convenient, the funamental wavemeter equation giving the wavelength in meters is:

$$\lambda = 1884\sqrt{LC}.$$

2. Measuring the Wavelength of a Transmitting Set—For the purpose of measuring the wavelength of a transmitting set, the wavemeter is usually fitted with a current indicating device such as a hot-wire ammeter, thermo-couple galvanometer or wattmeter, d.c. milliammeter and crystal rectifier, neon tube, flashlight bulb or with crystal rectifier and telephone receiver.

The various circuits are shown in figure 166. In operation the wavemeter is coupled loosely to the transmitting set and the capacity of the wavemeter condenser rotated until resonance is indicated by maximum indication of the current indicating device, that is, maximum deflection of hot-wire ammeter or galvanometer or milliammeter, maximum brightness of neon tube or flashlight bulb or maximum sound in the telephone receiver. The latter method is called measurement by means of maximum audibility. It will be noted that the crystal detector in this method is connected unilaterally. Sufficient energy is supplied to actuate the telephone receiver and the method has the advantage that the decrement of the wavemeter circuit is kept low, permitting sharp tuning and permits accurate calibration as the crystal detector and phone are not in the oscillatory circuit.

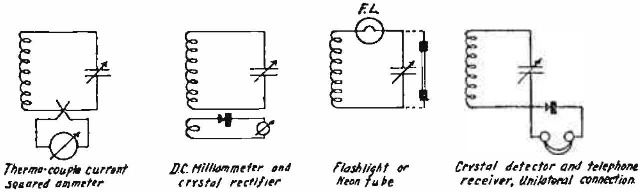


FIG. 166. Methods of Connecting Resonance Indicating Devices in Wavemeters.

2. The Wavemeter as a Small Transmitter—The wavemeter when employed as a transmitting set may be used to calibrate another resonant circuit such as a receiver. It may be made to oscillate at any desired frequency within its range by choosing the correct inductance and proper setting of the condenser. The circuit is shown in figure 167. When the battery circuit is closed some energy flows through the inductance L and when the circuit is interrupted at the buzzer, this energy oscillates in the LC circuit of the wavemeter at a frequency depending upon the setting of the wavemeter condenser. If the wavemeter is coupled to a receiver and the latter tuned to the frequency of the oscillations a signal will be heard.

3. Measurement of Fundamental Wavelength of Antenna—The anntenna may be excited by a vacuum tube oscillator as in figure 168. The oscillator circuit is tuned to resonance as indicated by a dip in the grid milliammeter of the oscillator or by maximum current in the antenna ammeter. The wavemeter can then be coupled to either the antenna or driver circuit and the wavelength measured. If more than one turn of inductance is used in the antenna circuit the wavelength reading will show the loaded fundamental which of course is higher than the natural period of the antenna without added inductance.

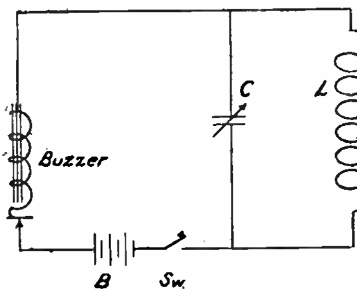


FIG. 167. Wavemeter as a Small Transmitter.

The fundamental can also be measured by exciting the antenna with a spark coil in which the spark gap is connected directly in series with the antenna. The wavemeter can then be coupled to the ground lead of the antenna circuit and a reading made by means of maximum audibility. Care should be taken to distinguish between currents induced in the wavemeter by induction and those set up by oscillations in the antenna circuit. The latter is clearly defined and will quickly disappear with a change of the wavemeter condenser.

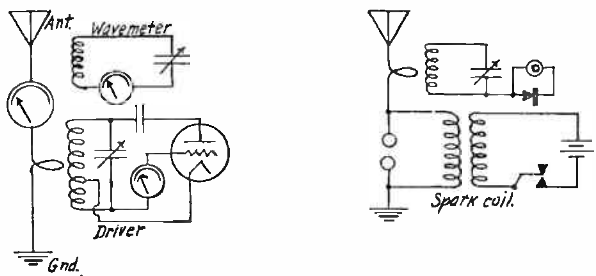


FIG. 168. Measurement of Fundamental Wavelength of Antenna System.

4. Tuning the Transmitting Set—This procedure has been taken up in detail in the discussion of various types of transmitting sets shown elsewhere.

5. Measurement of Decrement of a Radiated Wave—A definition of damping and logarithmic decrement will be found in the discussion of spark transmitters. Measurements of decrement can be made with a wavemeter fitted with a galvanometer or a hot-wire wattmeter. However, such measurements necessitate the use of much formula and will not be shown in this text.

6. Decremeter—A decremeter is a wavemeter conveniently arranged for measurements of resistance or decrement. Ways have been devised for manipulating the instrument in such a way that the decrement may be read directly from a scale. The Kolster decremeter is such an instrument and is employed by radio inspectors of the Radio Division, Department of Commerce, in their inspection of radio transmitting equipment on ships and land stations.

The operation for measuring the logarithmic decrement is as follows: The rotary condenser is first set at the position of complete resonance as indicated by the maximum deflection of the sensitive hot-wire instrument, the scale readings of which are proportional to the current squared. This maximum deflection is now reduced to one-half its value by decreasing or increasing the capacity of the rotary condenser. The decrement scale, which may be rotated independently, is now set at zero, then clamped so that when the condenser is again varied it will rotate with it.

Starting at the zero setting with the hot-wire instrument reading one-half the maximum deflection, the condenser is varied continuously in one direction until the needle of the hot-wire instrument makes a complete excursion from one-half deflection to maximum deflection, and back again to one-half deflection. The scale reading now opposite the index mark *O* is the value of $\delta_1 + \delta_2$, δ_1 being the decrement of the circuit under test and δ_2 the known decrement of the instrument. Subtracting the known decrement of the instrument from the observed decrement gives the true decrement of the circuit under test.

In measuring the decrement of a transmitting set care should be taken to couple the decremeter to the antenna circuit in such a way that no energy will be picked up from the primary or exciting circuit.

If the decrement observed is too great the coupling between the two circuits should be loosened and another measurement made; first making sure the circuits are in resonance after the change in coupling is made.

7. Measurement of Condenser Capacity at Radio Frequencies—The capacity of a condenser may be determined by substituting it in a circuit in place of a condenser whose value of capacity is known. Referring to figure 169, the circuit containing the unknown capacity is inductively coupled to the wavemeter which is excited by the buzzer *B*. A crystal detector uni-laterally connected is in series with the telephone receiver *P*. A double-pole, double-throw switch permits either condenser to be connected into the circuit.

With the buzzer circuit energized the capacity of the known condenser is varied until resonance is obtained as indicated by maximum audibility. The capacity of the condenser at resonance is observed. The switch is then thrown so as to connect the condenser of unknown capacity in the circuit. If the unknown condenser has a fixed value it will be necessary to vary the inductance of the wavemeter until resonance is obtained. The capacity of condenser *Cx* is then of the same value as *Ck* the known capacity. If *Cx* is a variable condenser its maximum and minimum values of capacity can be also determined by this substitution method; first by trying it at one setting and then at the other according to the procedure outlined above.

8. Calibration of a Radio Receiver—For this purpose it is necessary to plot a curve showing the relation between tuner setting and wavelength or frequency or to mark the wavelength or frequency corresponding to different settings directly on the tuner dials. In a two-circuit set, only the secondary circuit need be calibrated. Care should be taken to note the settings of the dials of the coupling controls and regeneration control when the calibration is made, and these same settings should be used when any reference is made to this calibration because a change in either coupling or regeneration may cause a change in frequency. Changing the detector tube will also affect the frequency calibration. In calibrating a single-circuit receiving set it must be remembered that a change of antenna or any change in the antenna constants after the set has been calibrated will destroy the accuracy of the calibration. The calibration of most receiving sets should be considered as only approximate since the calibration is changed by various adjustments and other factors in the use of the set.

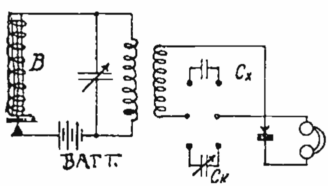


FIG. 169. Arrangement for Measurement of the Capacity of a Condenser.

9. "Resonance Click" Method—A method known as the "resonance click" method can be employed to calibrate a receiver of the regenerative type. Starting with zero capacity of the secondary tuning condenser and with the detector tube oscillating the wavemeter is coupled to the secondary inductance and the condenser of the wavemeter varied until a click is heard in the telephone receivers of the receiving set. This click is caused by the sudden absorption of power from the receiving set circuit by the wavemeter. If the coupling of the wavemeter is too close, the click will probably be heard with different readings of the condenser wavemeter, depending upon whether the capacity of the wavemeter circuit is being increased or decreased. These clicks will approach each other as the coupling is loosened until sufficiently loose coupling, giving only one click, is found. This coupling should be used for the measurements. The secondary tuning dial should then be turned 10 degrees and another measurement made and recorded. This process should be repeated until readings are secured from minimum to maximum capacity of the secondary condenser. The results can then be recorded on cross-section paper and a curve drawn connecting all the points. It may be possible to record the results directly on the dial of the receiver.

In order to calibrate a receiver of the tuned radio frequency type the wavemeter should be used as a transmitter employing the buzzer as the source of energy. Sufficiently loose coupling should be used until a well-defined sharp note is heard at only one point on the dials. The same procedure should be followed as above, i.e., the calibration completed from minimum to maximum capacity, of all the tuning condensers.

A receiver may be calibrated from signals of a standard frequency such as are transmitted by the Bureau of Standards or from a standard frequency transmitting station as listed in the Radio Service Bulletin each month.

Short wave receivers and wavemeters can be calibrated from the transmissions of experimental station 9XL of the Washburn Crosby Company, located at Anoka, Minnesota, acting as a standard frequency station of the experimenters' section of the American Radio Relay League, on all amateur bands. They transmit on waves where calibrations are not so generally available. The accuracy of the frequency of transmissions being 1/10 of 1 percent. Standard frequency signals are also transmitted by 1XM. (See QST for schedules.)

10. **Wavemeter Calibration**—Such signals may also be used to calibrate or check the calibration of a wavemeter. The zero beat method is the only one that is considered sufficiently accurate for this purpose. This method consists of tuning a small electron-

tube oscillator (generator) to the same frequency as the incoming wave from the transmitting station, by means of beats in a radio receiving set between the output of the oscillator and the incoming wave. When the frequency of the beat note is zero, the frequency of the oscillator is then exactly the same as that of the incoming standard wave. The frequency meter is then tuned to resonance with the generator. The frequency meter setting then corresponds exactly to the frequency of the distant transmitting station. Several different frequency measurements can thus be made yielding sufficient points to draw a curve for the wavemeter. The readings may be recorded directly on the dials of the receiver for future reference.

11. **Measurement Procedure**—If an unmodulated frequency is being received it will be most convenient to first adjust the receiving set to the point of self-generation. (Detector tube oscillating.) If a non-generating receiving set is used it is necessary to tune it approximately to the transmitting station and then adjust the generation until an audible beat note is produced in the phones of the receiving set. Returning the receiving set slightly will produce a beat note of maximum intensity. If a broadcasting station is being received, the set is tuned to maximum signal, but is not adjusted to a generating condition. The generator is then tuned until it produces an audible beat note with the incoming carrier frequency.

When the desired transmitting station has been tuned in on the receiving set, the local generator must be adjusted to a condition of zero beat while the receiving set is in a non-generating condition. This adjustment transfers the frequency of the distant station to the local generator. It must be made with great care so that the error in setting will be small. The observer should place himself in such a position that the body capacity will not effect the adjustments of the frequency meter and generator. An extremely precise adjustment of the generator may be obtained by tapping a pointer attached to the knob of the condenser. The frequency meter is now carefully tuned until the resonance indicator shows a maximum deflection. As it is tuned near the point of resonance, the reactive effect may cause a slight variation in the frequency of the generator, with the result that the beat note will again be heard. This change may be measurable on the frequency meter and therefore adjustments should be made to again attain the condition of zero beat. This may require decreased coupling between the frequency meter and the generator in addition to a slight readjustment of the generator. The coupling should at all times be kept as loose as possible consistent with obtaining precise adjustments of the frequency meter. To reduce the errors in observation as much as possible a number of successive readings of the frequency meter should be taken, the generator being of course always kept at the adjustment corresponding to zero beat. In general, the mean value of these readings will be most reliable. In case one of these readings shows a comparatively great deviation from the mean value, all the readings are doubtful and should be discarded.

Of equal importance to obtaining accurate frequency points is the plotting of these points on cross-section paper so that a smooth curve may be drawn between them permitting the accurate determination of frequencies corresponding to any setting of the frequency meter dial.

Assuming that the observations are accurate, the more points obtained for the plotting of curves, the better. If in attempting to draw a smooth curve through the points, some of them appear to be to one side, then these points usually indicate observational errors, and it is best to repeat the observations. However, it sometimes happens that in drawing a curve only a few of the points will be slightly outside of its path. In this case a "mean" curve should be drawn, that is, a smooth curve so located that these points will be equally on each side.

12. Calibration from Piezo Oscillator—The quartz crystal oscillator when used in conjunction with an auxiliary generator gives a method of calibrating a wavemeter. The quartz crystal oscillator due to its piezo electric effect will produce any one of three frequencies, fixed by the dimensions of the quartz plate in use. The piezo electric effect has been described in a previous chapter. Besides the fundamental frequency there are numerous harmonics produced by the non-linear output of the vacuum tube used in conjunction with the quartz plate. The auxiliary generator which should be variable in frequency can be adjusted to any frequency and will likewise give a series of harmonics for each fundamental frequency to which it is adjusted.

The interaction of a frequency from the piezo oscillator with a corresponding frequency produced by the auxiliary generator gives a beat note which may be heard in a pair of head phones in either circuit. The auxiliary generator may then be adjusted to zero beat, i.e., to the exact frequency of the piezo oscillator. This frequency can then be transferred to the frequency meter. The harmonics present in the piezo oscillator circuit and auxiliary generator make it possible to obtain a large number of points. Any frequency present in the piezo oscillator can beat with a corresponding frequency present in the generator and so give a frequency point which is directly related to one of the fundamental frequencies of the piezo oscillator.

The circuit connections of piezo oscillator, auxiliary generator and wavemeter are shown in figure 170. The coils employed with the auxiliary generation should have approximate calibration curves indicating the frequency range.

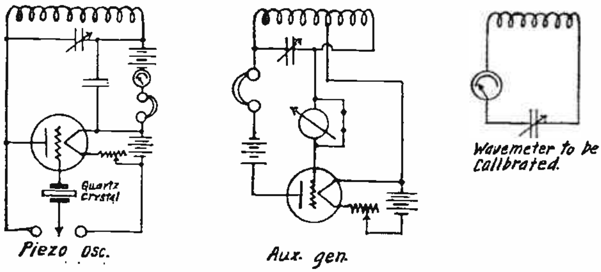


FIG. 170. Arrangement of Apparatus for Calibrating a Wavemeter from a Piezo-Electric Standard and Auxiliary Generator.

The milliammeter in the grid circuit of the auxiliary generator indicates the current flowing in the grid circuit of the electron tube and shows whether or not the filament is lighted.

13. Operation.—To transfer a frequency from the auxiliary generator to the frequency meter (wavemeter) the coils of the two circuits should be coupled rather closely. The frequency meter condenser should then be varied slowly while watching the grid current milliammeter on the auxiliary generator panel. When the frequency meter is adjusted near resonance to the generator the reading of the grid current milliammeter will start to decrease, reaching a minimum deflection at exact resonance. The coupling between the frequency meter and auxiliary generator should then be reduced so that the decrease of the grid current is only a few divisions. The setting of the frequency meter condenser for the exact point of minimum deflection now corresponds to the fundamental frequency produced by the auxiliary generator. If the auxiliary generator is adjusted to zero beat with the piezo oscillator or other source of radio frequency, the beat note should be observed during the adjustment of the frequency meter and the coupling kept loose enough not to change the beat note during the adjustment.

Assume the quartz crystal has the fundamental frequencies of 75,105 and 450 kilocycles. The piezo oscillator (quartz crystal) should be adjusted to give its low fundamental frequency (75 kc.) The coil employed with the auxiliary generator which includes 75 kc. should be plugged into the auxiliary generator and the condenser set to give approximately 75 kc. The piezo oscillator and auxiliary generator coils are placed so that the coils are a few inches apart. While listening with the head phones connected in the piezo oscillator circuit the condenser of the auxiliary generator is varied slowly back and forth until a beat note is heard. Beat notes may be heard at several settings of the auxiliary generator condenser, but no difficulty will be found in determining the setting for the frequency of 75 kilocycles when the approximate calibration of the auxiliary generator is used. The beat note produced by this frequency of the auxiliary generator will be much louder than the beat note produced by any other frequency. The generator condenser is now adjusted to the point of zero beat. As this condenser is turned continuously the pitch decreases, disappears and reappears again as an increasing pitch. The point at which the pitch disappears is the region of zero beat. The auxiliary generator is then producing exactly the same frequency as the piezo oscillator. The method of transferring this frequency to the frequency meter is described in the paragraph entitled "Operation" and gives the first point in the calibration.

14. **Use of Harmonics**—Having transferred the fundamental frequency of piezo oscillator to the frequency meter, the next point is to obtain the second harmonic (150 kc.). The piezo oscillator is left adjusted as before and the coil including 150 kc. plugged into the auxiliary generator. The condenser is set to a frequency corresponding to 150 kc. and as before, adjusted to zero beat. This frequency which is two times the exact frequency of the low fundametnal frequency of the piezo quartz plate is transferred to the frequency meter as before. The third, fourth, etc., harmonics of the piezo oscillator are similarly selected. The piezo oscillator is then adjusted to its medium fundamental frequency (105 kc.) and the procedure repeated. It is again repeated with the high fundamental frequency. To obtain points on the frequency meter of a lower frequency than the fundamentals of the piezo oscillator the phones are transferred to the auxiliary generator circuit and the piezo oscillator adjusted to give its higher fundamental frequency (450 kc.).

The auxiliary generator is then set approximately to one-half the frequency (225 kc.) and adjusted to zero beat. The frequency of the auxiliary generator which is now exactly one-half the high fundamental frequency of the piezo oscillator is transferred to the frequency meter. This is repeated for 1/3, 1/4, 1/5, etc. The process is then repeated for the other two fundamental frequencies of the piezo oscillator.

15. "Fractional" Harmonics—From the points already obtained it should be possible to draw calibration curves for the frequency meter. It may be found, however, that there are several regions of uncertainty, i.e., where calibration points are widely separated. The use of the so-called "fractional" harmonics will give points in any region of the curves. This consists of using the beats between harmonics of the piezo oscillator and harmonics of the auxiliary generator. If f is the fundamental frequency of the piezo oscillator which is being used and F the fundamental frequency of the auxiliary generator which gives zero beat, then

$$af = bF$$

where a and b are integers (1, 2, 3, 4, etc.).

For example, to obtain one of these points, adjust the piezo oscillator to give the low fundamental frequency, 75 kc. Set the auxiliary generator to give 50 kc. and adjust to zero beat. The second harmonic of the low fundamental of the piezo oscillator ($2 \times 75 = 150$) is beating with the third harmonic of the fundamental of the auxiliary generator ($3 \times 50 = 150$). Then

$$2f = 3F$$

$$F = \frac{2}{3} f$$

The fundamental frequency of the auxiliary generator is transferred to the frequency meter and is exactly 2/3 the low fundamental frequency of the piezo oscillator. This can be repeated for any combination of harmonics using any one of the three fundamentals of the piezo oscillator. The phones should be in the circuit which is producing the higher harmonic. In some cases there may be some uncertainty what harmonics are producing the beat note. However, with the approximate calibration of the auxiliary generator available it will be usually possible to identify them. In case an error is made it will be obvious when the point is plotted with the others on cross section paper. It will probably only be necessary to use fractional harmonics for the lower frequency range of the frequency meter. Such values as 3/4 f, 2/5 f, 5/4 f, 4/3 f, 3/2 f, 5/3 f, 7/4 f, etc., may be useful.

In practice these fractional harmonics [1] may be identified as follows: Using a quartz plate with a fundamental frequency of 90 kilocycles, the 6th and 7th harmonics which are easily located will be 540 and 630 kilocycles, respectively, between which there will be noted when rotating the condenser of the auxiliary generator several other beat notes which are somewhat weaker than the 6th and 7th harmonics. Approximately midway between the 6th and 7th harmonics a fairly strong beat note will be noted, this is the result of the second harmonic of the auxiliary generator beating with the thirteenth harmonic of the crystal which is 1170 kilocycles. Since the second harmonic of the auxiliary generator is beating with the thirteenth harmonic of the crystal, the frequency of the auxiliary generator will be one-half of this harmonic and may be expressed as follows:

$$\frac{13}{2} = \frac{1170}{2} = 585 \text{ kilocycles,}$$

at which setting at calibration point for the frequency curve of the wave may be obtained after the auxiliary generator is adjusted to zero beat.

It will also be noted that between this point and the point where the sixth harmonic is found another but still weaker beat note may be heard, this will be the result of the third harmonic of the auxiliary generator beating with the nineteenth harmonic of the crystal. In other words, the fundamental of the generator will equal one-third of the nineteenth harmonic of the crystal expressed as follows·

$$\frac{19}{3} = \frac{1710}{3} = 570 \text{ kilocycles.}$$

A point for the calibration curve at this frequency may be made as usual.

Another beat note may be heard at a point between the last setting of the auxiliary generator and the point where the sixth harmonic is found, this will be due to the fourth harmonic of the auxiliary generator beating with the twenty-fifth harmonic of the crystal and may be expressed as follows:

$$\frac{25}{4} = \frac{2250}{4} = 562.5 \text{ kilocycles.}$$

[1] "A Method of Using Fractional Harmonics," by John Barron, Jr.. Radio Inspector, Radio Division, Dept. of Commerce, published in Radio Service Bulletin, No. 129.

As this beat note is very weak, it may be more easily determined by the use of the two-step audio-frequency amplifier connected to the auxiliary generator.

Points may be also obtained at the twentieth harmonic of the crystal with the third harmonic of the generator as

$$\frac{20}{3} = \frac{1800}{3} = 600 \text{ kilocycles,}$$

and the twenty-seventh harmonic of the crystal is the fourth harmonic of the generator as

$$\frac{27}{4} = \frac{2430}{4} = 607.5 \text{ kilocycles.}$$

Points between other fundamental frequencies may likewise be determined. However, as the frequency is increased, the higher harmonics become weaker and it is ordinarily not possible to readily make use of higher than approximately the twenty-fifth harmonic unless audio-frequency amplification is used. For instance between the seventh and eighth harmonics may be found the

$$\frac{15}{2}, \quad \frac{22}{3}, \quad \frac{23}{3} \text{ harmonics}$$

Should there be any question as to which harmonic is being heterodyned, it may be identified by reference to the curve plotted between known harmonics. The calibration curve should be plotted using a hard pencil on a large sheet of cross-section paper, allowing 10 kilocycles to the inch for the abscissa and 10 degrees on the small vernier dial of the wave meter to equal 1 inch for the ordinate.

It is essential that wavemeters be checked against the crystal frequently in order that errors due to temperature changes, etc., may be corrected. The correction for temperature changes affecting a quartz crystal may be computed as follows:

$K \times F \times (T_1 - T_2)$ = kilocycles correction to the fundamental frequency.

F = calibrated fundamental frequency

T_1 = temperature at which crystal was calibrated.

T_2 = temperature of crystal at time of use.

K = frequency change in cycles for each degree change in temperature per Cent.

The result will be obtained with a plus or minus sign, which of course must be added or subtracted from the calibrated fundamental frequency as required. An increase in temperature will lower the fundamental frequency which of course requires that the correction be added to the calibrated frequency. This requires that all the harmonics be recomputed.

16. **Use of Piezo Oscillator to Check Frequency of Transmitter**—The use of the piezo oscillator is very useful and satisfactory to check the frequency of a transmitter, especially that of a broadcasting station, where the penalty for deviation from the assigned frequency by more than 500 cycles is sufficient to warrant cancellation of the station license.

When properly designed such a device delivers a particularly constant frequency and is unaffected by fluctuations in the station's power or degree of modulation.

17. **Location**—A convenient location is chosen for the oscillator in the operating room whereby frequency adjustments can be made to the transmitter while listening in with headphones. If the piezo oscillator is too close to the source of power, its operation may be unsteady as evidenced by fluctuations of the needle of the milliammeter. If too far away, a beat note of satisfactory intensity will not be obtained.

18. **Operation**—When first placing the piezo oscillator in operation it is well to adjust the transmitter to the approximate assigned frequency with a wavemeter. This will ensure that the beat note obtained is that of the fundamental frequency and not by fractional harmonics.

After making the approximate adjustment of the transmitter with the wavemeter the rheostat of the piezo oscillator should be turned on. If the quartz crystal starts oscillating a beat frequency may be noticed caused by the interaction of the two frequencies. The frequency of the transmitter is then varied until a zero beat is produced; that is, the condition where the beat is no longer audible in the headphones of the piezo oscillator but reappears when the frequency of the transmitter is increased or decreased slightly. Zero beat is an indication that the transmitter is oscillating exactly at the same frequency as the piezo oscillator. The operator should listen in at intervals to ascertain that the condition of zero beat is being maintained and also see that the piezo oscillator is generating. Otherwise, it may appear that a zero beat adjustment is being maintained when actually the frequency of the transmitter has shifted.

19. Failure of Piezo Oscillator to Generate—

1. Defective or discharged batteries.
2. Reversed polarity of batteries.
3. Defective tube.
4. Quartz plate sticking in holder. Overcome by shaking or tapping holder slightly.

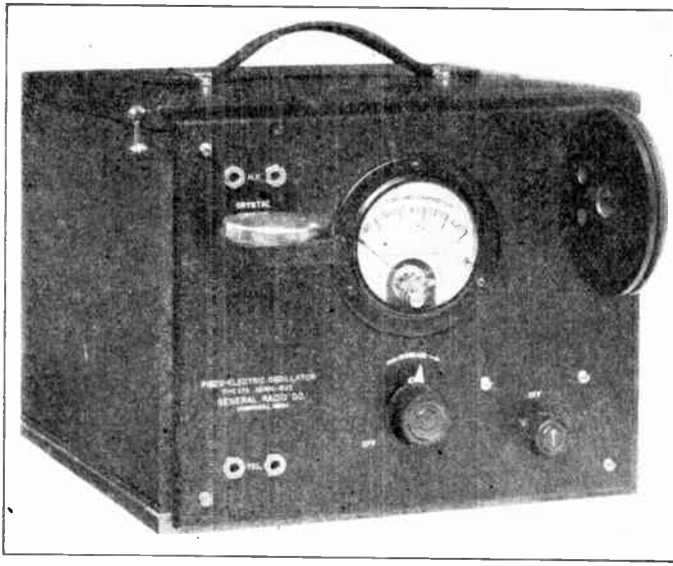


FIG. 171. General Radio Piezo-Electric Oscillator.

20. Care—The quartz plate and holder should not be opened. The plate and holder should be used in the same position in which they were when the device was calibrated. Reversing the position may cause a slight change in frequency.

21. Wave Traps—Wave traps may be employed in conjunction with a radio receiver in order to eliminate an undesirable signal. When used with receivers at the transmitting plant of broadcasting stations they are tuned to offer a high impedance to the transmitter frequency and a low impedance to the frequency it is desired to receive, such as 500 kilocycles, the frequency employed in marine channels on which signals of distress are transmitted. Radio fans who experience interference from a local broadcasting station may employ one to advantage in order to eliminate the interfering signal.

Wave trap circuits may be divided into three classes, namely, rejector, acceptor and by-pass filter circuits.

The rejector circuit opposes the interfering signal, the acceptor circuit extracts energy from the interfering signal and prevents it getting to the receiver while the by-pass circuit offers it a path of low impedance to earth.

22. The Rejector Circuit—The rejector circuit takes two forms known as the shunt rejector and the series rejector. The most powerful of all wave traps is the shunt rejector as shown in figure 172. The shunt rejector prevents signals both above and below the wavelength to which it is tuned from being received. It is properly constructed with a large capacity and low loss inductance of few turns, the value of capacity predominating in the tuned circuit. The series rejector is shown in figure 173, and rejects the signals to which it is tuned from being received. The series rejector circuit is employed to advantage to eliminate signals from a local broadcasting station which might otherwise pre-

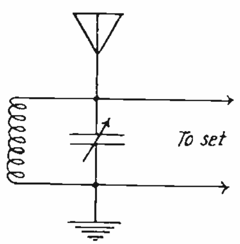


FIG. 172. Shunt Rejector Circuit—Rejects All but One Station.

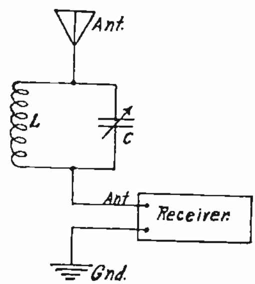


FIG. 173. Series Rejector Circuit — Rejects One Station Only.

vent reception of other signals. A series rejector wave trap may be constructed by winding approximately 40 to 50 turns of No. 22 S.C.C. wire on a 3-inch form and tuning the same with a .0005 mfd. condenser.

When first placing this wave trap in operation the tuning condenser should be set at zero capacity or short-circuited. The receiver should then be tuned until the signal from the station it is desired to eliminate is at a *maximum*. The tuning condenser of the wave trap should then be varied and as the wave trap circuit approaches the frequency of the received signal it will gradually disappear and at exact resonance will be entirely eliminated or weakened so as to cause no interference. The wave trap condenser should be left in this position and the receiver then tuned until other desirable stations are heard. If the so-called " single circuit " receiver is used the tuning on the dials will be somewhat upset, i.e., the station will not come in on the same dial setting as before.

Theoretically the rejector circuit has an infinite impedance at its tuned wave when the resistance of the circuit is zero. Therefore, a good grade of condenser and wire no smaller than that stated should be used so as to keep the resistance as low as possible.

23. **The Acceptor Circuit**—The acceptor or absorbing circuit is shown in figure 174. In this arrangement a tuned circuit is coupled to the antenna by a few turns of a coil connected in series with the antenna. The tuned or absorbing circuit is tuned to the wavelength of the interfering station. The energy from the interfering wave is thus extracted and builds up in the tuned circuit an e.m.f. which opposes that due to the interfering signal and prevents the same from reaching the receiver.

The antenna coil should have no more than 10 turns tapped and wound directly over the tuned circuit inductance which have ap-

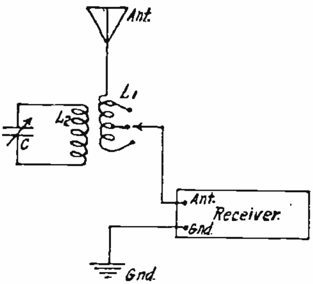


FIG. 174. Acceptor Circuit—Absorbs Energy from Interfering Frequency.

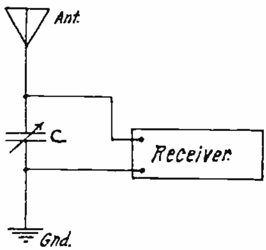


FIG. 175. By-Pass Filter.

proximately 35 turns of number 24 S.C.C. wire on a 3-inch form. The variable condenser should have a capacity at maximum of .0005 mfd.

The condenser of the absorbing circuit is tuned until the interfering signal is eliminated, at the same time trying different values of *LI* until the best filtering action is obtained.

24. **The By-Pass Circuit**—Referring to figure 175, the con- .enser *C* is so arranged as to offer a low reactance to all radio fre- uency currents and they are consequently by-passed to earth with he exception of the frequency to which the receiver is tuned. 'he reactance of the tuned receiver to the desired signal is much ɔwer than that of the by-pass condenser; hence it receives a ignal rather than the by-pass condenser.

The interfering signal which is different in wavelength is ffered a greater impedance by the tuned receiver than the by-pass ffers and consequently it is largely shunted to earth and causes no ıterference. The value of this condenser for ordinary broadcast- ıg wavelengths can best be determined by trial, using a variable ɔ05 mfd. condenser. Some of the incoming desired signal will be y-passed to earth resulting in a diminution in the intensity of this ignal, however, the reduction in interference warrants this. A oil of 10 turns of No. 20 S.C.C. wire may be substituted in place f the condenser and will likewise produce excellent results. It perates essentially on the same principle, i.e., the difference in npedance which it offers to the two incoming signals.

FIELD STRENGTH MEASUREMENTS.

25. **Purpose**—The measurement of radio field intensity en- bles one to determine the distribution of the field in various direc- ions from the antenna system of a given transmitting station. In he case of a broadcasting station it shows the service area of roadcasting stations. It also shows the effects produced by ɔcating stations in cities on or near large steel structures and he effects produced by locating stations in the open country away rom steel structures or electrical networks. From the results f such measurements one may choose a desirable location for a ransmitter in order to serve a certain area. This can be done ı conjunction with a portable transmitter and field strength meas- .ring apparatus.

26. **Unit of Measurement**—There are several different nethods and types of apparatus employed in field strength meas- .rements. The universally adopted unit of measurement is "volt ɩer meter." The unit volt per meter is a large one, and for ordi- .ary purposes it is more convenient to use "millivolts per meter" r "microvolts per meter."

Meter-amperes—The regulations of the International Radio- elegraph Convention require that the normal radiated power of a ransmitter be expressed in meter-amperes; or lacking this, the height of the antenna and intensity of the current at the base of the antenna.

The expression meter-ampere is the unit of antenna current moment and is found by multiplying the antenna current by the effective height of the antenna in meters. The effective height is generally about 60 per cent of the mean height of the flat top above ground.

27. **Derivation of "Millivolt Per Meter"**—When oscillations are set up in an antenna there is created an electro-magnetic field surrounding the antenna. This field consists of two distinct parts: First, there is the field of electro-magnetic induction which rapidly dies out and usually cannot be detected at more than a distance of one wavelength or so from the transmitter; second, there is the field due to radiation which represents the energy of wave propagation.

As has been described in the previous chapter, this electro-magnetic field travels with the speed of light. The value of the field strength at a distance from the transmitter is given by the formula:

$$E = \frac{188\, hI}{\lambda r} \text{ millivolts per meter,}$$

where h = effective height of antenna in meters.
I = current in antenna in amperes.
λ = wavelength in meters.
r = distance in kilometers.

The effective height is defined as the height of a vertical single wire having the same amount of current throughout its whole length, and giving the same field strengths at given distances. In the case of a transmitting antenna with one end grounded the current is unevenly distributed being at a maximum at the base and decreasing with height and reaching a minimum at the extremity. By keeping the effective height as high as possible a more even distribution of current is obtained and results in a maximum of radiation and therefore more millivolts per meter at a given distance. From the above the actual field strength from a transmitter at any given distance can be computed, provided there is no absorption of energy nor interference by waves bent back to earth from an ionized layer.

Actually there is absorption of the ground wave and a factor must be introduced depending on the wavelength, and on the nature of the ground and what is on it over which the wave travels. In the case of absorption the radiated energy is conducted to ground and therefore lost as far as being of any practical use is concerned.

A field strength of 1 millivolt per meter means that the potential difference due to the field between two points a meter apart on the same line of electric force is 1 millivolt. Consequently if a 1-kilowatt transmitter has a field strength of 20 millivolts per meter at a distance of five miles and a broadcast receiving antenna is erected having an effective height of 5 meters, there will be 100 millivolts of energy available for the receiver. The more sensitive the receiver, the greater will be the volume delivered by the loud speaker for a given signal strength.

28. **Apparatus and Methods of Measurement**—As previously mentioned, there are several different methods of measuring the strength of radio signals. Usually, the actual voltage across a given antenna is measured by the substitution method, which consists of substituting for the received signal a known locally-generated signal identical in frequency to the signal and of such magnitude as to produce the same receiver output as that resulting from the received signal. Under these simulated conditions, the known locally-generated e.m.f. is equal to the voltage induced in the antenna by the signal. Usually, a loop antenna is employed with a superheterodyne receiver. The field strength is obtained by dividing the induced voltage by the effective height of the loop. (The effective height of a loop is defined as the height of an equivalent vertical wire having the same induced voltage.)

The magnitude of the locally-generated e.m.f is usually obtained by passing a known current through a known impedance inserted at the loop center. The known impedance must be non-inductive so as to be independent of frequency and its value kept as small as possible. The minute known currents are obtained by attenuating measurable currents by known amounts through the use of suitable circuits. This system requires separate and thorough shielding between the local oscillator and the attenuating circuit in order to eliminate "pick-up" comparable in signal strength to the small induced voltage.

As shown by Friis and Bruce, in their paper entitled "A radio field-strength measuring system for frequencies up to forty megacycles," Proceedings of Institute of Radio Engineers, Volume 14, August, 1926, considerable advantage is obtained if a voltage of sufficient magnitude measureable by means of a tube voltmeter, is induced into the loop from the local oscillator. In conjunction with this, a voltage attenuator could be located elsewhere in the receiver proper. This would eliminate the undesirable "pick-up" from the local oscillator by the attenuator circuit and minimize the necessity of elaborate shielding of the oscillator.

This paper says, " furthermore, the search for an appropriate location for the voltage attenuator, beyond the loop, revealed the desirability of placing it on the output of the intermediate-frequency detector of a double-detection (super-heterodyne) scheme, with due regard for the limits of overloading of this tube. The importance of this arrangement should be emphasized. It means that the attenuator need operate at only the fixed intermediate frequency. Since this frequency has been selected as 300 kilocycles, great accuracy is possible without elaborate attentuator design, regardless of the signal frequency."

The intermediate frequency detector also serves a tube voltmeter actuating the d.c. plate circuit meter. The gain control or voltage attentuator is calibrated directly in voltage ratios; thus, a reading of 10,000 indicates that the input voltage to the attenuator is 10,000 times larger than the output voltage.

The procedure of operation of the apparatus shown in figure 175-*a* is as follows:

TABLE OF PROCEDURE

	Attenuation Ratio of Attenuator
I. The receiving set is tuned to the incoming signal. The attenuator is adjusted until a convenient output deflection is obtained. This deflection is noted.	a_1
II. (1) The local comparison oscillator is started and tuned to resonance with the receiving set.	
(2) The attenuator is adjusted to make the ouptut the same as in *I*.	a_2
(3) The input *V* to the grid of the intermediate frequency detector is determined (beating oscillator is off during this measurement).	
III. (1) The grid of the intermediate frequency detector is connected through L_B to the local oscillator input as shown in figure above.	
(2) The attenuator is readjusted to make output the same as in case I.	a_3

From this table we have

Voltage across half of the loop due to incoming signal $= \dfrac{V}{\frac{a_2}{a_1}}$ volts.

Loop voltage step-up (the ratio of half of the loop terminal voltage to the induced voltage) $= B^* = \dfrac{a_2}{a_3}$

Voltage induced in loop by comparison oscillator $= E = \dfrac{V}{B}$ volts.

Voltage induced in loop by incoming signal $= \dfrac{V}{\frac{a_2}{a_1} B}$ volts.

*B = magnetic flux density.

It should be noted here that it is entirely unnecessary for the transmitter of the incoming signal to stop while measurements are being made.

As the paper progresses the authors discuss some refinements in the accurate measurement of the voltage set-up B of the loop.

29. Report of Field Strength Measurements Made by the Radio Division, Department of Commerce—In November, 1925, the first radio test car operated by the Department of Commerce was fitted with portable radio field intensity measuring ap-

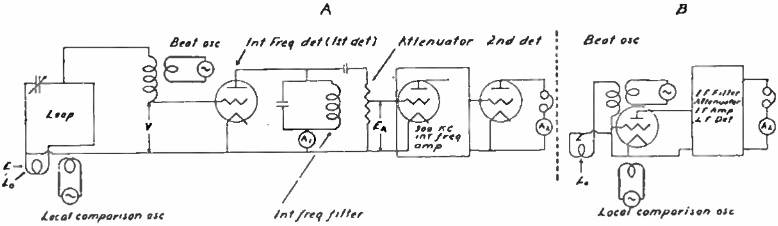


FIG. 175a. Diagram of Field Strength Measuring Apparatus.

paratus. As described by Supervisor of Radio, S. W. Edwards of the 8th Radio District in Department of Commerce, Radio Service Bulletin No. 120, March 31, 1927: "The set permanently installed aboard the car is capable of making measurements on frequencies between 1,500 kilocycle-seconds and 500 kilocycle-seconds and is calibrated for field intensities ranging from slightly below 5 millivolts per meter to 50 millivolts per meter.

"The measurement of the field strength of a radio station must be made in a definite orderly fashion and in accordance with a predetermined method in order that the conclusions drawn may be based on actual measure values rather than on estimates. All the surveys made thus far have been made using the same method and as a result all of them are comparable and of the same accuracy. When it is decided to determine the field distribution of a radio station, a map of the area surrounding the station is obtained showing in detail all the roads and streets in the area under consideration. Directions are then selected which lead radially from one station in all directions, and roads corresponding to these directions are chosen on which actual measurements are to be made. These roads should not be too widely separated from each other. Measurements are then made on the chosen routes at intervals of approximately three-tenths of a mile, and measurements are continued until the readings indicate that the limit of the reliable service area has been reached. By making the individual measurements frequently, so that there are relatively short distances between, it is possible to accurately determine the values of signal intensity for the entire distance over which the measurements are made. From the data obtained the various levels are noted on curves which have the field strengths as ordinates and the distance as abscissae, which shows the falling off of field strength with increasing distance. The curve will also show any effects produced on the strength of the signal by steel buildings or electrical networks. One of the curves is obtained for each direction in which measurements were made. These curves furnish data for those employed in making typographical survey maps. Usually it is desired to transfer to a contour map. The contour maps are made using methods similar to show the location of certain contour lines, such as the 50, 40, 30, 20, 10, and 5 millivolt per meter lines. The data for these contours is obtained from the curves. It is very necessary that the data obtained be represented in graphic form in order that the general distribution of energy after it leaves the antenna, as well as the various strengths of field at various points may be seen at a glance. Each of the six field strength surveys conducted by this office was made using the procedure described above.

"**Accomplishments**—When a radio broadcast station is placed in operation, its first purpose is presumably to serve a certain area with reliable signals. In general, this means, at the present development of the art, that it is desired to propagate signals of equal intensity in all directions. It is desired to achieve as far as possible the perfect field which is a circle, the transmitter being its center. How far actual installations in operation in the broadcast spectrum to-day deviate from this condition can be seen by reference to the illustrations accompanying this article. The results obtained in the several surveys which this office has made show that a realization of the ideal field or anything approaching it is an exception. That this condition should prevail is largely a result of the locations in which broadcast stations have been placed. The majority of broadcast stations to-day are located on buildings in cities of varying sizes and within their metropolitan limits. Further, most of them are located on buildings which contain steel frameworks and are generally near electrical networks. That these conditions in the majority of cases produce undesirable effects on radio transmission has been fairly well demonstrated in the measurements made by this office and discussed in this paper. These surveys were made on stations in widely separated parts of the United States east of the Mississippi River on wavelengths from 270 meters (1,110 kilocycle-seconds) to 469 meters (640 kilocycle-seconds). These stations were some of the best in this area. Some of these stations were located on buildings of steel construction and others were located in the country and they used power from 750 watts to 3,500 watts. One station was surveyed twice in order to ascertain whether or not a radical change in antenna system changed the distribution of the field where absorptive conditions were known to exist.

"Anybody capable of conducting electricity has a natural period of oscillation. Therefore, if a radio station be located in a large city there cannot help but be certain conditions which develop due to the location of the station with regard to conductive bodies. Two of the most serious factors occurring are absorption and shadowing. In the case of absorption the radiated energy is conducted to ground and therefore lost as far as being of any practical use is concerned, and in the case of a shadowing a reduction of good service area in the departure from a perfect radio field will be realized. This condition of shadowing in a radio field is analogous to shadowing as found when an opaque object is held near a source of light. Of the two, the phenomenon of absorption has been found to be more common and is clearly seen by refer-

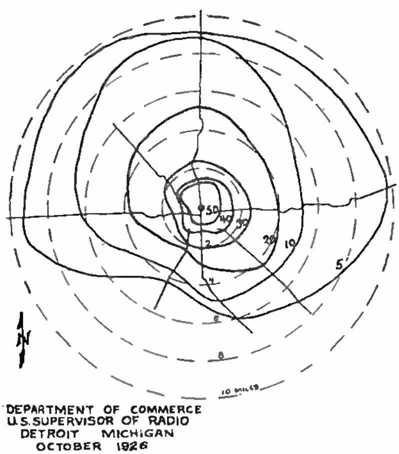


FIG. 175-1. Radio Field of a Transmitting Station Subject to Absorption Showing Unequal Distribution of Energy.

Figures 175-1 to 175-7 obtained from Radio Service Bulletin, publication of the Department of Commerce, used by permission.

ence to figures 175-1, 175-2, 175-4 and 175-5. Shadowing may not necessarily result in a loss of energy but absorption does, and usually in such a fashion as to be extremely detrimental. How serious this condition may be can best be appreciated when it is stated that signals from a transmitter whose radio field is shown in figure 175-1 are rarely heard 75 miles away in the direction in which absorption takes place, while in other directions this range is very much increased, and signals are consistently received. It is quite evident that the location of a radio station in a metropolitan district desiring to serve a large maximum propagation of signal energy in all directions is concerned. These conditions may not only be due to steel structures in the city surrounding the station but may be caused by absorption in the building on which the station itself is located. Figure 175-2 shows the field of a

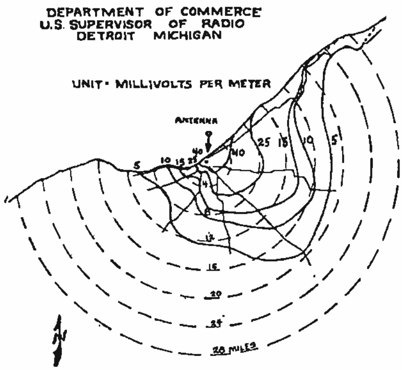


FIG. 175-2. Pattern of Field Due to Absorption from a Steel Building Near Antenna.

broadcast station located on a large steel building. This building has the ability to absorb energy from the transmitter on its normal wavelength and to radiate very strongly on another and higher wavelength to a degree that it was audible more than 75 miles away. This double emission has been corrected.

"The conditions outlined above, as determined by actual measurements, represent an average situation in radio broadcasting at the present time and have two effects: One of them is the low efficiency realized by the stations in its transmission and the other is the somewhat inferior service given to the listeners whom the station is intended to serve.

"Some typical examples pertaining to the two conditions described above will be given. In the first place, there are to-day certain cities in which there are located two or more stations using the same power and the same wavelength, both located in the metropolitan area, and sometimes both stations use the same type of apparatus. In certain directions one of these stations gives much better signal strength than the other. In some cases the signals from one station are much stronger than they are from the other. Assuming that both transmitters are operated efficiently, any radical difference in results obtained is probably due largely to the location—whether on or near large metallic bodies. Almost universally if one of the stations is in the country it is far superior in the public service it renders than that given by the station located in the city. These two exemplar stations may desire to serve the same area, and, if such is the case, it is readily seen that in order to produce the same signal voltage over the service area desired the station in the city must of necessity use a higher power input than the one in the country. Quite obviously, then, the rating of the power input to the transmitting apparatus is unfair to the listening public, since similar powers will not produce similar results. This condition may be observed by reference to figure 175-3. The measurement of a station's transmission in micro-volts

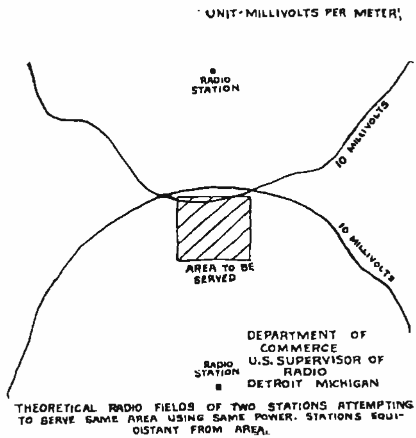


FIG. 175-3. Typical Radio Fields of Two Stations Attempting to Serve Same Area Using Same Power. Stations Equi-Distant from Area.

or similar units per meter is the only basis on which the transmission can be so regulated that both the broadcast listener and the competing stations can receive fair and equitable results from their respective investments. At the same time these field intensity measurements will show whether or not the broadcasting station is using too much or too little power to serve the area desired.

"Our observations would seem to indicate that in cases where transmission is difficult from a station located on a steel building conditions of transmission from that station may be greatly improved by a proper selection of frequency so as to avoid the resonant effects of the building.

"Measurements made by this office and by others indicate that at the present time signal strengths on the order of 10,000 or more microvolts per meter furnish excellent radio reception. Values of radio intensities below this figure may give excellent reception under some conditions. Where reproduction of clarity on the order of that secured from a musical instrument is desired, the signal must be of such a level that ordinary noises encountered in reception will be overridden. These noises are power leaks, turning on of switches in the electrical circuits, and tube and set noises, as well as those caused by the making and breaking of electrical circuits. A signal of 10,000 microvolts per meter is generally sufficient to override most of these interference conditions except in very severe cases. With lower values of signal energy, less satisfactory reception will occur; therefore, a station must not be located at too great a distance from the area which it should serve or it will not secure the desired results. Signals above 10,000 microvolts per meter intensity bring into existence the question of interference with other stations due to the spreading of energy over too broad a band of frequencies on the average radio receiver. The question, therefore, becomes a matter of balance between furnishing ample signal to the listener, too great a signal or a signal not strong enough. A determination of this balance is practical only through the measurement of signal intensity and it is by this means alone that the ideal relation between broadcaster and broadcast listener can be secured.

"Having considered the peculiarities of radio transmission and the requirements of good service to the broadcast audiences, a few samples of actual conditions will be cited. The remarks are based on observations on a number of broadcast stations. The contour maps of field distribution of these stations are shown in figures 175-1, 175-2, 175-4, 175-5 and 175-6, respectively.

"The transmitter whose field is represented in figure 175-4 is a 1-kilowatt transmitter of modern design located approximately one-quarter mile west of the business district of a large city. This business district consists of many steel structures, some of which are 30 to 40 stories in height. The effect of the business district

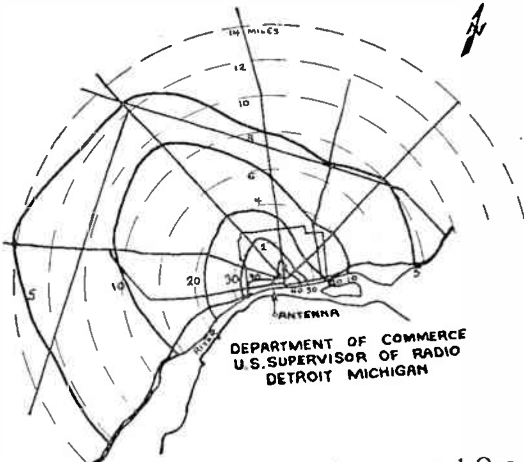


FIG. 175-4. Field of a 1-Kilowatt Transmitter Located One-Quarter Mile from a Steel Building Area.

on the field of the station will be plainly seen by reference to the contour map. There is a decided falling off of signal strength to the east of transmitter. At the time these measurements were made the antenna used by this station was supported on one end by a steel building and on the other by a steel mast. Subsequently, the antenna system was radically changed. Steel towers were erected on the building in which the transmitter is located and a higher antenna erected. A counterpoise system was also installed. Field strength measurements on this station after the change of antenna system was made indicated that the general shape of the field of the station remained unchanged, which would indicate that the field distortion was entirely due to the near-by steel buildings. However, by a happy circumstance this broadcast station serves very well the area in which the station is located and the city limits are fairly well within the 10-millivolt contour line. It may be remarked that at the time these measurements were made, reception 150 miles east or northeast of the station was difficult, while reception 150 miles south, southwest, or west was consistent.

"Another example of the effects of business districts on broadcast stations is shown by the contour map in figure 175-1. This transmitter whose field is here represented is located 1 mile northeast of the steel building area. The station itself is located on a 10-story steel building, and in addition to the detrimental effects on the station's transmission caused by the steel area of the city in

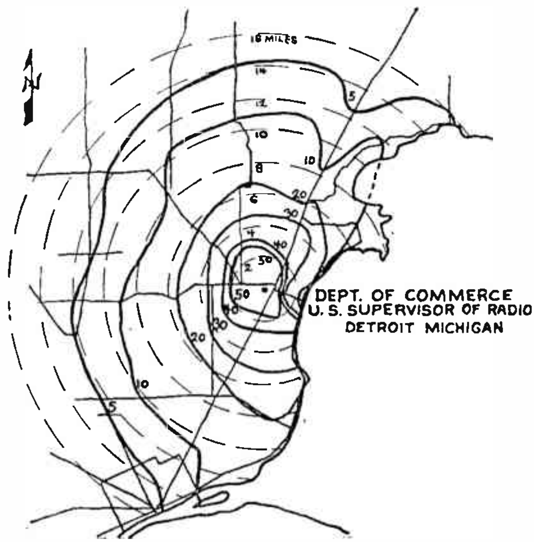


Fig. 175-5. Field of a 1500-Watt Transmitter Located in the Open Country. Some Absorption Due to Telephone and Power Wires in Field of Antenna.

which the transmitter is located the building itself materially decreases the output of the transmitter. While this station is frequently heard north or northwest of the transmitter, it is seldom heard in a southerly or southwest direction.

"Figure 175-6 shows the field of a 750-watt transmitter located at a considerable distance from any steel buildings of appreciable size. The field of this station very nearly approaches the shape of a circle and may be considered very good. The field has a tendency to be slightly stronger in three directions which lie over three river beds showing the apparent tendency to good transmission over water in this locality.

"The field depicted in figure 175-2 represents that set up by a station located on a 20-story building on the easterly fringe of a tall steel building area. The pronounced attenuation in a westerly direction is at once apparent, and it appears that transmission is exceptionally good along the lake shore, in an easterly direction from the transmitter. This condition is a good example of what

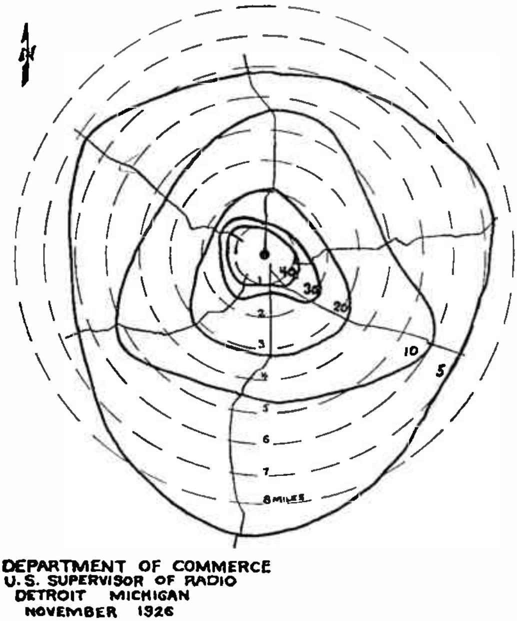


Fig. 175-6. Field of a 750-Watt Transmitter Located at a Considerable Distance from a Steel Building Area.

a radio station in a business district of a large city is liable to encounter.

"The field shown in figure 175-5 is that of a 1,500-watt transmitter located in the open country approximately 15 miles from large steel buildings and quite well removed from populous areas. Due to the location of the station it would be expected that the field intensities would be reasonably uniform, and this expectation is realized to a certain extent. The coverage obtained here considering the power used is greater than other stations measured. The noticeable indentations on the curves in a north by east direction from the transmitter are due to absorption by a number of power telephone and telegraph lines closely grouped.

"Figure 175-7 represents two signal strength curves. Curve

No. 1 is an actual curve drawn from measurements made on the station. No. 2 indicates a curve whose values are computed from one good value on signal curve No. 1. No. 1 shows the actual variation of signal voltage while No. 2 shows what would be the ideal signal curve.

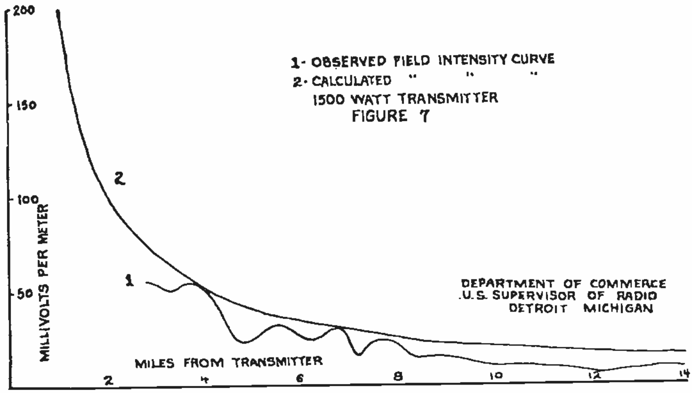


FIG. 175-7. Signal Strength Curves.

"As a result of the surveys which this office has conducted there are evidently two conditions which a radio broadcast station must meet before it can operate with a maximum efficiency and serve the greatest possible area and number of listeners with a given power input to the antenna. The first of these conditions is the design of the transmitting apparatus and its associated antenna to radiate properly. The conditions that must here be met are that maximum effective antenna height with a maximum antenna current be secured. The second condition is the proper location of the transmitter. For equally effective service in all directions the station must be located a reasonable distance away from all electrical networks and from any steel buildings of any great size. Unless these two conditions are met the field obtained will probably not be uniform.

"There are a number of possibilities that the use of field strength measurements in connection with radio transmission create. A leading possibility is that of rating stations in terms of microvolts per meter at a specified distance rather than in watts input to antenna. In itself the term 'microvolts per meter' indicates the service which a radio transmitter is giving in actual reception, whereas the power input to antenna indicates in no manner what the strength of the received signals is or will be and therefore what its usefulness may be. Where we have two transmitters both trying to serve the same area and one of which is hampered by absorptive conditions, the only fair method of power rating is that of field strength at a certain distance.

"It has long been known that certain broadcast stations radiated well in one direction and very poorly in another. Whether this was a consistent condition or not was never determined until field-strength measurements had been made. In the case where such a condition may be found to exist there does not seem to be any sound reason why another station cannot be operated on the same frequency at a considerable distance away in the direction of poorest radiation without causing interference. This duplication would, no doubt, prove very helpful in the allocation of frequencies to broadcast stations."

DESCRIPTION OF RADIO TEST CARS OPERATED BY U. S. DEPARTMENT OF COMMERCE, RADIO DIVISION.*

Upon the enactment in 1910 by the United States of radio laws and regulations it became necessary to organize a radio inspection service for the enforcement of this and subsequent radio legislation. These laws required the licensing of radio stations on ship and shore, the examination and licensing of applicants for radio operator licenses of all grades and the inspection of radio transmitting stations.

At the time of the passage of the Radio Act of 1910, the art was in such a state that practically no apparaus other than wavemeters were necessary for the enforcement of its provisions. Very shortly it became necessary to adopt the automatic Continental Morse Code transmitter known as the omnigraph in the examination of applicants for all grades of radio operator licenses. Further development required the use of such instruments as accurate meters capable of reading antenna currents, decremeters, wavemeters, hydrometers and other measuring instruments. The rapid strides made in the advancement of radio communication so multiplied the duties of the radio inspection service that the use of this apparatus became constantly necessary.

With the coming of radio broadcasting, the functions of the radio service were still further increased and the situation de-

* By courtesy of W. D. Terrell, Chief, Radio Division, Department of Commerce.

veloped became greatly aggravated. In brief, a radio inspector when traveling away from his home office could not possibly transport all of the necessary apparatus for the proper performance of his duties. The difficulties of transportation were greatly increased by virtue of the extreme delicateness of the instruments used. At the same time an examination of the future of radio communication seemed to indicate that with the passage of time more and increasingly delicate apparatus would be required as more complete use was made of the radio spectrum. To solve this problem, attention was turned to an automobile upon which could be mounted a special body capable of housing all of the apparatus needed to perform any of the duties prescribed by law in the enforcement of radio legislation.

The problem became still further complicated in that the apparatus is in the main carefully calibrated and of a very delicate nature. Further, unless the means of transportation compared favorably with that obtainable by rail, it was of no great value. To this end an automobile was selected which was capable of traveling long distances at high speed with reasonable economy. Means were provided so that rough roads could be traversed without injury to the apparatus carried.

A car designed to fit these requirements was placed into service in October of 1925. It was equipped with all necessary instruments for the proper performance of the Radio Division's work in the field. The apparatus consisted of wavemeters, omnigraphs and numerous other instruments. On board the car were permanently mounted a complete radio direction finder and sensitive radio receivers. Provision was made for the carrying of a complete 50-watt transmitter for emergency communication work in the areas where all line services were out of commission. Such equipment as a typewriter was carried making the car in reality a traveling office in which it became possible to do any of the things which could be done at the district headquarters. In November, 1925, a radio field intensity measuring system was placed aboard the car. Such a piece of apparatus had become almost as important as frequency measuring apparatus for by means of it the possibility of regulating and determining the external effect produced by a radio transmitter came into being. Equipped in this manner, the first radio test car operated by the Department of Commerce went into commission in a form which has been found so thoroughly practical, that the changes made in the cars now in use and those proposed to be placed in service are purely in the nature of refinements and not of radical diversions from the original experimental model. As a matter of fact, the experimental model is at the present time in continuous use, it having been built in such a manner as to be adaptable to improvements as they came along.

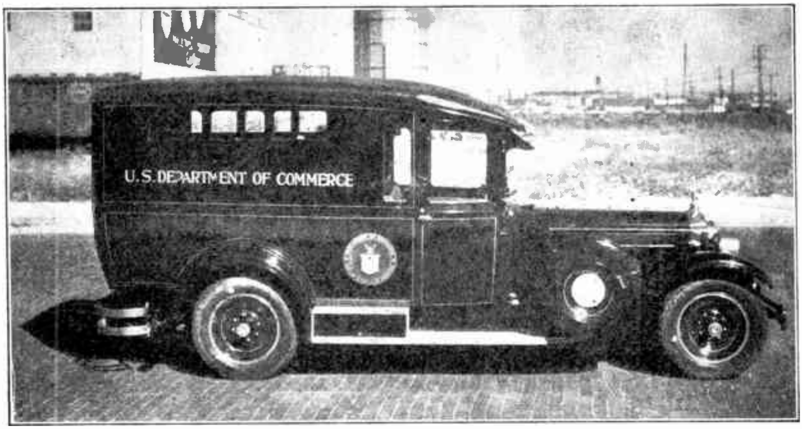


FIG. 175-8. Test Car Used in the Field by Radio Division, U. S. Department of Commerce.

Picture by permission of W. D. Terrell, Chief Radio Division, U. S. Department of Commerce.

In a very short time after the institution of the first radio test car, it became clearly apparent that this method of fulfilling the duties determined by law for the radio inspection service was of invaluable assistance making possible the accomplishment of work never before possible and of great importance. Briefly, this consisted of making inspections of radio apparatus on ships in remote ports, examination of applicants for radio operator licenses at points far removed from the ordinary places of examination and finally the making of radio field strength surveys about radio transmitters. The making of these surveys would be extremely difficult and very expensive if a hired vehicle were to be used to transport the equipment.

Economically the type of radio test car as used by the Radio Division of the Department of Commerce shows a great saving over previous costs of doing as much of the same work as possible using other means of transportation. In the two years in which the original test car has been used, sufficient savings in transportation and subsistence have been effected to show that within a comparatively short time the car will have paid for itself. The results obtained are considered very favorable both economically and from the point of the vastly increased service which the Radio Division is now able to give the public.

The record attained by the original car proved to be of such merit that the scheme of traveling by automobile for the regulation of the radio law could safely and to great advantage be taken from the experimental state and reduced to a practical form wherein a number of cars equipped exactly alike in each case would be supplied to the various radio districts of the United States. As a preliminary step in the ultimate motorization of the radio inspection force, three more cars were built.

These cars have bodies constructed entirely of a composite nonmetallic compound and have metal in them only at places where its effect on the apparatus used in the car is of no importance. Special effort is made to insure good riding qualities together with a high factor of safety. To this end all of the heavy objects are located as near the chassis of the car as possible. The storage batteries furnishing power for the apparatus used are set below the car floor level. Further, the internal arrangement of the car is such that the operator in the radio compartment finds everything he will require in a location easily accessible to him. The front end of the body or driving compartment of the car is carefully arranged to give a maximum of comfort to those riding in it. All known accessories which are of assistance in driving long distances with safety under varying conditions are supplied. This includes high power, light equipment for night travel of which a great deal is done. Compartments are provided in which may be kept the necessary record books, road maps and other articles.

While the front end of the new model radio test cars shows considerable refinement over what is found in the first car, it is perhaps the radio compartment in which the more extensive innovations have taken place. These have been caused both by the experience gained in two years of operation of the original car and by the changes in radio equipment carried. All of the apparatus constantly used is mounted on the car desk running the length of each side across the front of the car. Under the desk across the front of the car are located the storage batteries. These are placed in a shielded compartment access to which is gained by removal of the front seat cushions. Under the desks on each side of the car are located compartments and drawers in which various pieces of apparatus, tools, spare parts, etc., are carried. The apparatus includes wavemeters for all frequencies, an omnigraph, a portable superheterodyne receiver, hydrometers, flashlights, and component parts for the apparatus mounted on the desks. A portable typewriter, forms of various kinds, record sheets and stationery are also carried in individual housings conveniently located. All of these things in addition to being accessible to the operator inside the car are also accessible from the rear door in the car making it unnecessary to step into the car to obtain anything which might be used outside of it.

In arranging the location of the apparatus to be used on the desks, it was necessary to keep in mind the several functions which the car and its apparatus had to fill. These are the measurements of field intensities, the monitoring of transmissions from radio stations, checking of station frequencies by the local oscillator zero beat method, the calibration of wavemeters and the examination of applicants for radio operator licenses.

Located on the desk across the extreme front end of the radio compartment is the combined monitoring and field strength measuring apparatus. When used as a receiver, transmission from 50 meters to 1,200 meters can be monitored by means of an interchangeable system of coils and loops. Used as a receiver, this apparatus works into a high power, high quality audio frequency amplifier whose output passes to the loudspeaker. It will be noted that the receiver as well as its filament and plate batteries are very carefully shielded. When used as a field intensity measuring set, signals on the order of 10 microvolts to 2 volts per meter over range of 50 meters to 600 meters can be accurately measured. The apparatus being of the self-calibrating type in its important aspects is capable of producing similar and comparable results giving values which are of practical use. From measurements made by this apparatus, it is possible to accurately determine and represent graphically the service field of a radio transmitter. It is possible to determine the relative efficiency of the station and the direction of best propagation from it. Finally and perhaps most important, the apparatus furnishes a means by which it is possible to rate a radio station on the basis of its signal strength at various distances from its antenna. By this means, the output ratings of any number of radio stations are placed on the same standard comparable basis.

On the right desk is located a radio frequency oscillator covering a range of 10 meters to 20,000 meters. This oscillator serves the dual purpose of being used for frequency meter calibrations and the measurement of the frequency of radio stations. In measuring the frequency of a distant transmitting station, the station is tuned in on the receiver and the oscillator is tuned to produce zero beat with the incoming signal. The frequency of the oscillator is then measured with a frequency meter. Both audible and visual resonance indication methods are used resulting in great accuracy. By the use of this apparatus it became possible to meas-

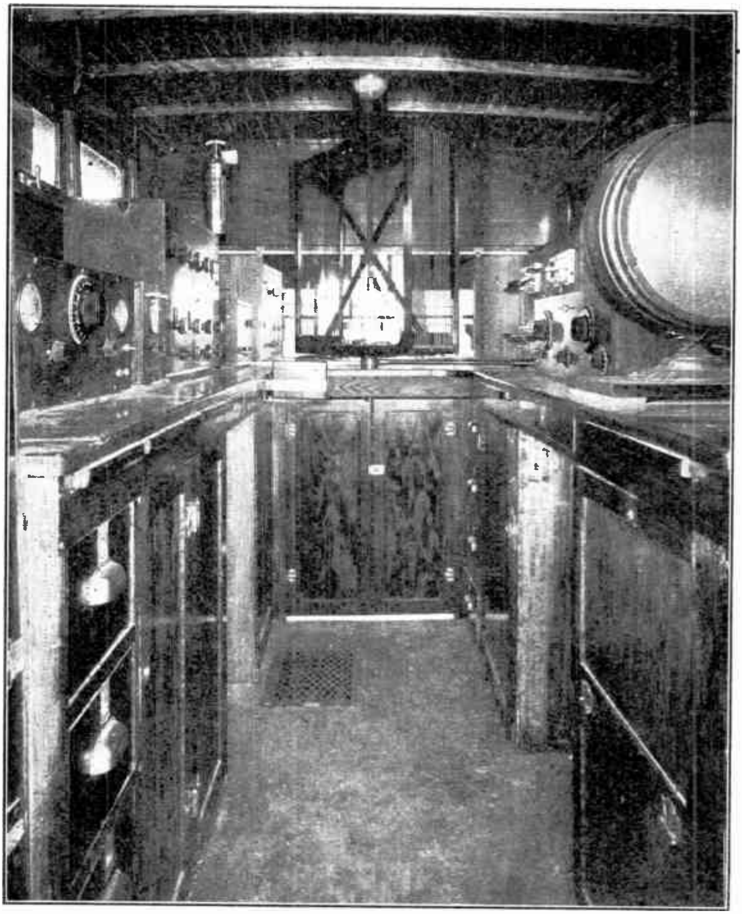


FIG. 175-9. Interior View of Test Car Showing Field Strength Measuring Apparatus and Other Instruments.

Picture by permission of W. D. Terrell, Chief Radio Division, U. S. Department of Commerce.

ure the frequencies of stations at points away from the radio district headquarters, thereby making possible the checking of stations which cannot be heard at the district headquarters' monitoring station.

On the left desk is located an oscillator whose frequency is controlled by a piezo electric crystal. Several crystals are used furnishing a great number of harmonics. It thus becomes possible by means of this oscillator together with the oscillator located on the right desk to conveniently and rapidly either calibrate a frequency meter or check an existing curve on the meter. Using these means, a high degree of accuracy is maintained at all times in the measurements. Frequency meter calibrations or checks are performed by the conventional method of heterodyning the fundamental of an oscillator with the fundamental or harmonics of a piezo electric crystal controlled oscillator. The frequency of the oscillator is then used as a point in the calibration of the frequency meter. During this operation visual and audible indications simultaneously obtained are used.

By the use of the field intensity measuring apparatus and the frequency checking system, it is possible to determine the two important factors in the regulation of radio transmission, these being the frequency and strength of the emitted wave.

There is a great number of applicants for radio operator license examination located at considerable distances from the cities in which such examinations are usually given. Whenever it is possible in these cases to examine such applicants, they are seated in the radio compartment and given the desired examination. It is possible to accommodate in this manner as many as three applicants at one time. In the event of a greater number of applicants, the apparatus is removed from the car and the examination is conducted in some convenient location.

Perhaps one of the greatest features of the radio test car is the speed at which the inspection of radio stations can be made. By using the car, the operator has with him at all times all of the apparatus necessary to make the inspection and has a rapid means of getting from one station to another. This feature is not only of importance for land station inspection work but also in ship inspection work where frequently ships are tied up at water-fronts many miles in length or at points considerably separated. The use of the radio test car makes possible the inspection of the radio equipment on ships at remote ports which formerly could not be visited owing to their inaccessibility. In this manner the car is of great importance to the protection of life and property at sea.

Three heavy duty storage batteries located under the field strength apparatus are used to furnish power to the filaments of the vacuum tubes in the apparatus used. These batteries are in a shielded compartment and have their outgoing leads carefully shielded. By means of a selecting system it is possible to use any desired battery on any piece of equipment in the car. The "B" batteries supplying plate potenial for the apparatus are located in individually shielded compartments located on the left side of the car adjacent to the field strength measuring apparatus. The use of extensive shielding has made possible operation of the apparatus without undesirable reactions taking place.

The interior of the compartment where all radio measurements are made and examinations are held is provided with two dome lights capable of adequately lighting the whole interior so that measurements may be made at night.

Many conveniences have been placed on the car both for the safety of its operation and for the assistance of the operators. The main feature of the entire automobile, inclusive of its radio equipment, has been the idea of providing a piece of equipment capable of furnishing the maximum of public service. With this object in view, every attempt has been made to produce a piece of equipment complete to the last detail in its ability to give the public the maximum benefit obtainable under existing radio laws.

CHAPTER 8

MARINE VACUUM TUBE TRANSMITTERS

1. Introduction—The radio service on vessels of the American Merchant Marine is carried on generally by radio service companies. These radio companies or corporations have contracts with the different steamship lines which are known as "Service" and "Rental" contracts. A service contract is entered into when the steamship company owns its own apparatus and desires that the radio service company maintain the apparatus, supply the radio operator and handle the abstracting of traffic on radiograms. Costs of major repairs and replacements are billed to the steamship company in addition to a fixed sum per month for the service as indicated above.

If the steamship company does not own any apparatus it may rent the same for so much per month by the means of a rental contract with the radio service company. The latter makes all repairs and replacements to apparatus as well as furnishing an operator, abstracting traffic and inspecting the apparatus on each arrival of the vessel at a large port.

In order to reduce interference to broadcast listeners and expedite traffic on marine radio channels these service companies have modified their apparatus used in mobile service by converting spark transmitters to vacuum tube operation. Meeting with much success from the start has led to the development of a transmitter employing the master oscillator power amplifier system for marine use. With such a transmitter, a steady pure continuous wave may be radiated and copied easily although the vessel may be rolling heavily due to high seas and strong gales.

This chapter deals entirely with such vacuum tube transmitters as manufactured by the General Electric and Westinghouse companies for the Radiomarine Corporation of America and sold or rented by them to different steamship companies.

It is the purpose of the following pages to give the student and operator a complete description of such transmitters as he might expect to find upon being assigned to a ship as radio operator. Several sets of nearly the same type are gone into in detail in order that the operator may use the same as a guide in maintaining the apparatus in good working order and at the same time to assist him in quickly locating trouble and applying a remedy while at sea.

2. Details of the Model ET-3628 ACW Tube Transmitter[1] —The model ET-3628 transmitter consists of a 2-KW, P-4 or P-8

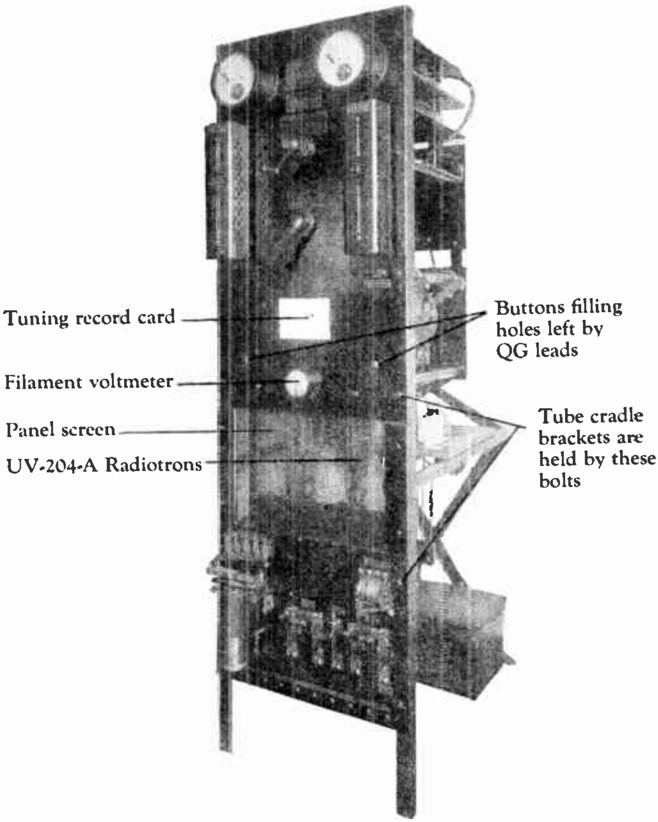


FIG. 176. Model ET-3628 A.C.W. Tube Transmitter.

spark transmitter which has been converted for tube operation. Two UV204-A Radiotrons are used in a self-rectifying " Split capacity " or Colpitt's circuit.

[1] Radiomarine Corporation of America mobile transmitters described in this chapter are ET-3626, ET-3627, ET-3628, ET-3629, ET-3630.

All connections to the motor generator and automatic starter are the same as for P-4 and P-8 spark sets. Keying is accomplished by breaking the primary circuit. Power regulation by means of a generator field and motor field rheostats is the same. A study of the diagram will show that the connections to the wattmeter and radiation ammeter remain unchanged.

The complete transmitter consists of the following apparatus:

1. The low frequency power apparatus and controls consist of motor and generator, field rheostats, 2 K.W. power transformers with mid-tapped secondary hand key, a.c. filament transformer and rheostat, wavelength changing switch, reactance regulator, the automatic starter and overload relay, rotary converter and filament transformer.

2. The meters on the panel, are radio frequency ammeter, wattmeter and a.c. filament voltmeter.

3. The motor generator is a 2-K.W. 500-cycle machine manufactured by either the Crocker-Wheeler or General Electric Co. A starting resistance and protective devices are provided. A small rotary converter is provided to supply a.c. current for filament heating.

4. The high frequency apparatus consists of the following: Two-plate radio frequency choke coils, two-plate blocking condensers, plate excitation condenser, grid excitation condenser, "tank" or primary inductance, coupling or secondary inductance, three fixed antenna loading inductances, variable antenna inductance, grid leak, grid leak ultra-r.f. choke coil, two-filament by-pass condensers and two UV-204-A Radiotrons.

5. Type I aerial change over switch. *Description of Apparatus* —*The motor* consists of a 4 H.P. 110-volt d.c. compound-wound motor directly connected to a 500-cycle a.c. generator. The motor is so constructed that it will operate on voltages varying from 95 to 115 volts with very little variation of speed. A field rheostat mounted on the panel regulates the speed of the motor within narrow limits.

The generator is of the rotating armature type and has a normal open circuit voltage of approximately 350 volts and a working or load voltage of 140 volts. This voltage can be varied by means of a rheostat which is mounted on the transmitting panel. This rheostat is in series with the generator field and permits varying the current throughout the field, which is excited from the direct current line.

An automatic starter permits the motor generator to be started and stopped from the operating table. A solenoid winding which can be connected directly across the direct curent line by pressing a starting button operates a plunger which moves in a vertical position, the acceleration being regulated by a piston drawn through a vacuum chamber. The speed at which the plunger moves may be varied by an adjustment screw attached to the base of the dash pot. The resistance coils in series with the motor armature are progressively cut out of the circuit. An extra contact is provided on the starter which closes the field of the generator after the motor has been brought up to field running position.

An overload relay is provided which opens the motor circuit when the current through the armature exceeds 35 amperes. Should the relay open the circuit the motor cannot be started until the start-stop switch is opened. It is then automatically closed so that the motor can be immediately started again when the start-stop switch is closed, unless there is a permanent short circuit on the line in which case the relay will open again.

The starter is fitted with an electrodynamic brake. When the plunger of the automatic starter opens, it automatically connects a resistance across the armature stopping the motor within ten seconds.

Two combined *protective devices and terminal blocks* are provided for the purpose of protecting the motor and generator windings from excessive potentials caused by induction from the radio frequency circuits. Each device consists of three mica condensers in one case. One terminal of each condenser is connected to the case, the other to a busbar or terminal bar on the cover. The device is screwed to the machine frame, which effectually grounds it. The terminal leads of the machine are brought out and conconnected to lugs on one end of the busbar. Leads to the panel are connected to lugs on the other end of the busbar.

The *transformer* is of the closed core type and is immersed in non-liquid oil. The primary is connected to the control panel by means of lead-covered wires which have their coverings grounded to the transformer case and to the panel frame. A mid-tap is provided on the secondary side which supplies high voltage of the correct polarity alternately to the two tubes. A safety gap is provided across the secondary terminals of the plate transformer which automatically prevents the use of excessive power.

The *plate blocking condensers* are of .001 microfarad capacity. They prevent the 500-cycle power from backing into the tank circuit; also furnish a low impedance path for the radio frequency currents in the plate circuit to the tank inductance. Safety gaps are provided on the plate blocking condensers.

The *plate excitation condenser* is of .02 microfarad capacity.

The *grid excitation condenser* is of .014 microfarad capacity.

The plate and grid condensers also comprise the tank capacity.

The *filament by-pass condensers* are each of 1 microfarad capacity.

The *choke coils* in the plate leads prevent radio frequency currents from entering the secondary of the transformer which would rupture the insulation causing the transformer to burn up.

The *choke coil* in the grid lead prevents the generation of ultra high frequency oscillations as explained in a previous chapter.

The *grid leak resistance* provides a path for the direct current from the grid which gives the proper negative bias.

The *primary inductance* is strip-copper wound edgewise in the from of a helix.

The *secondary inductance* consists of strip-copper wound edgewise in the form of a spiral.

The *coupling* is varied by means of changing the number of turns in the secondary inductance instead of by varying the distance between the primary and secondary coils. Usually not more than two or three turns are required on the secondary inductance for proper coupling. The same number of turns usually suffice for all wavelengths.

The *variable tuning inductance* in the antenna circuit is fitted with a sliding contact which can be revolved by a handle in the front of the panel, permitting the inductance to be increased or decreased until resonance is secured.

The *two fixed antenna loading coils* are connected in series with the variable coil and by the use of clips, on flexible leads the correct number of turns can be engaged in each coil for the wavelength desired. By connecting the correct number of turns in these two coils it is possible to make adjustments whereby resonance is secured on the variable coil within a turn or fraction of a turn for all wavelengths. Thus if the operator desires to shift from 600 to 706 meters it is only necessary to move the wavelength switch in the front of the panel and the correct number of fixed terms are engaged for that wavelength, the maximum radiation is secured with perhaps only a slight or no adjustment of the variable inductance. Five wavelength positions are provided.

The *Type I Aerial Change-over Switch* is fitted with the necessary contacts that when placed in the transmitting position performs the following operation:—

(*a*) Closes the field of the generator.

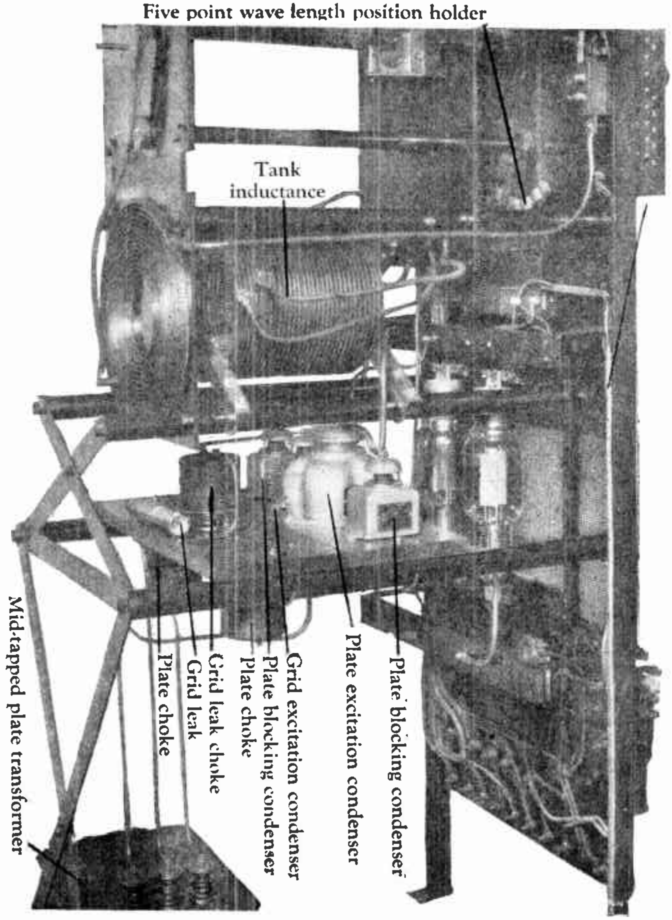


FIG. 177. Rear View of Model ET-3628 A.C.W. Tube Transmitter.

(*b*) Closes the primary of the plate transformer in series with the key.

(*c*) Starts the rotary converter that furnishes a.c. for lighting the filaments of the tubes.

(*d*) Starts and stops the motor generator in conjunction with the start-stop switch or allows motor to run while receiving.

(*e*) Opens the negative lead of the "B" battery circuit of the detector amplifier circuit thus preventing the radio frequency currents from burning out the audio frequency transformers.

(*f*) Connects the antenna to the variable loading coil of the transmitting secondary circuit.

When placed in the receiving position it:—

(*a*) Opens the field of the generator.

(*b*) Opens primary of plate transformer.

(*c*) Stops motor of rotary converter.

(*d*) Stops motor generator if desired.

(*e*) Closes negative lead of "B" battery circuit of receiver.

(*f*) Connects antenna directly to primary of receiver.

The numbered contacts stamped on the Type I switch usually connect to the following parts of the circuit:[2]

1. Terminal post 1 connects receiver to antenna.
2. Terminal posts 2 and 3 in series with negative "B" battery.
3. Terminal posts 4 and 5 spares.
4. Terminal posts 7 and 8 in series with the solenoid of automatic starter and also in series with start-stop switch if remote control is provided.
5. Terminal posts to 9 and 10 in series with the generator field. Also closes circuit starting filament rotary converter.
6. Terminal posts 11 and 12 in series with a.c. line to primary of transformer.
7. The base of the switch to ground by screw at the back.
8. Terminal post on top of the insulating tube marked "ANT. CKT" to the antenna lead.
9. Terminal post marked "OSC. CKT" to the antenna terminal of the transmitters.

The switch is in the sending position when the main switch blade is parallel to the base. In this position, it closes contacts 11 and 12 by short-circuiting the spring clips. The aerial is connected to the transmitter by the spring contacts on the "ANT. CKT" post making contact with the "OSC. CKT."

As the switch is thrown from the sending to the receiving posi-

[2] For converted tube transmitter only.

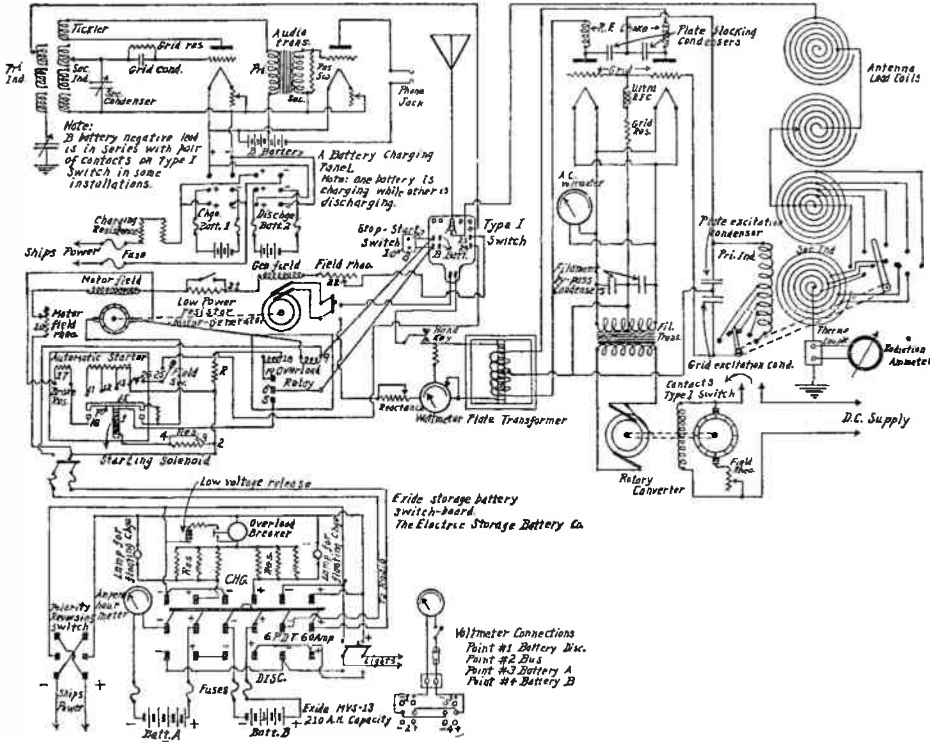


FIG. 178. Diagram of Model ET-3628 A.C.W. Tube Transmitter with Auxiliary Batteries Charging Panel and Type 106-D Regenerative Receiver and 1-Stage Amplifier. Note: This Complete Diagram as Shown Should be Drawn by Applicants Taking the Government Examination for Commercial First or Second Class Operator's License.

tion (main switch blade perpendicular with the base) the antenna is disconnected from the transmitter and connected to the receiver by the main switch blade opening the contacts at the top.

(*Caution.*) The contacts at the top consist of several fingers. They sometimes become bent in such a manner that to all appearances they seem to be disconnected from the copper tubing leading to the transmitting inductances when the switch is in the receiving position. A close inspection will disclose that one or more may still be making contact to the copper tubing. If this occurs the antenna is still grounded through the transmitting inductances. Signals may still be heard on the receiver but with considerable loss in audibility. It will also destroy the calibration of the primary receiver circuit.

The operator should also make sure that the fingers make good contact on to the copper tubing when the switch is placed in the transmitting position.

A study of drawing in figure 178 will show that the solenoid winding 1 of the automatic starter is connected to the positive pole of the d.c. line at point 2. The circuit continues through the resistance 3, by the switch 4, through the contacts 5 and 6 of the overload relay, through contacts 7 and 8 of the antenna switch, to a terminal of the winding 9, which is of negative polarity. Thus the solenoid winding *I* is connected in shunt to the d.c. line when either contacts 7 and 8 or the starting switch 10 is closed.

The switch 4 in shunt to the resistance 3 is automatically opened by the plunger *P* of the automatic starter when it is in full running position.

The resistance coils of the automatic starter, connected in with the d.c. line to the armature, are progressively cut out of the circuit at contacts 11, 12, 13 and 14 by the bar 15, when the circuit to the solenoid *I* is closed, the plunger *P* with the bar 15 moves in a vertical position, the acceleration being regulated by a piston drawn through a vacuum chamber when the contact is made between bar 15 and point 11, the circuit to the motor armature includes the entire set of resistance coils.

If upon starting the motor generator it may develop excessive speed which cannot be controlled by the motor field rheostat, it is apparent that the motor has no field. If allowed to run in this manner the overload relay should trip. In event it does not, the motor should be stopped at once to prevent injury to the armature.

The wires running to terminals 1 and 2 of the motor should be reversed and the machine started again. It will probably be found that the trouble has been eliminated and that the speed is normal and can be controlled by the motor field rheostat. If the same trouble appears the field rheostat and field coils should be tested for an open circuit.

The trouble just described usually appears at the time of installation of a new transmitter.

The plunger of the automatic starter should be adjusted to reach the full running position within 12 seconds. A small regulating screw *P* in figure 179 is placed just underneath and in the center of the dash pot. If the screw *P* is turned to the right the plunger will move up slowly and if to the left rapidly.

When the circuit to the winding *I* is interrupted, either at point 10 or at the aerial switch contacts 7 and 8, the plunger *P* drops downward and through the medium of contacts 15 and 16, the resistance coil 17 is connected in shunt with the motor armature. The motor armature thus temporarily becomes a generator and owing to the power expended in setting up a current through the brake resistance 17 a powerful braking action is set up against the armature, bringing it to a quick stop.

The shunt field winding of the motor is connected in shunt to the d.c. line through the field rheostat 20. As the resistance is increased at 20, the speed of the motor increases, and consequently, the frequency of the a.c. generator.

The generator field winding is connected in shunt to the d.c. line through the low power resistance 21 and the generator field rheostat 22. The field circuit continues to the contacts 23 and 24 of the Type I switch, through the generator field switch 25, and finally to contact 26 of the automatic starter. The generator field winding remains open until the bar 15 attached to the plunger *P* of the automatic starter has touched point 26, when the bar of the automatic starter makes contact with point 14, the d.c. armature is connected directly to the main d.c. line.

The voltage of the a.c. generator may be increased by reducing the resistance of the generator field rheostat 22. It may be reduced by increasing the resistance of the field rheostat. Low values of a.c. voltage may be secured at the terminals of the generator by opening the switch in shunt to the low power resistance 21.

The overload relay has the magnet winding 9, which may be called the tripping magnet, and the second magnet winding 18, the holding magnet. If more than a predetermined number of amperes, usually 35 for normal working, flow through the winding 9, the lever 6 is drawn up, breaking the circuit of the solenoid winding 1, through contacts 5 and 6. Immediately afterward the circuit through winding 18 and resistance is closed through contacts 6 and 19. This causes the lever 6 to be held in that position until either the main d.c. line switch or the starting switch 10 is opened.

When type *I* aerial switch is thrown to a transmitting position the motor generator is automatically started, provided the main d.c. line switch is closed. It will be brought to a quick stop when the antenna switch is placed in the receiving position, provided the starting switch 10 remains open. If the switch 10 is closed the motor generator can be kept in a continuous state of operation during the receiving period.

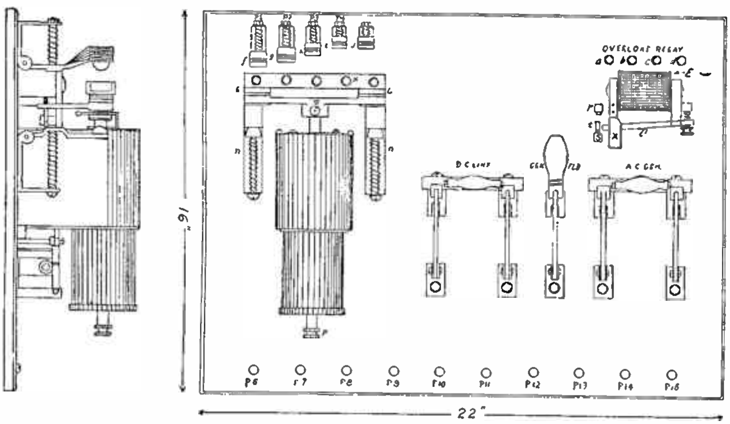


Fig. 179. Control Panel of 2-Kilowatt Automatic Starter.

The *overload relay* consist of an electro-magnet having an armature which has its distance from the poles of a magnet adjustable so that for each adjustment a certain strength of current is necessary to lift it. This armature operates a contact which, when in the down position, closes the circuit through a solenoid starter and when in the upper position, or after it has been lifted by the magnet, it engages the upper contact which closes a circuit through the holding winding, thus holding the lower contact open.

When the lower contact is opened, the circuit through the starter solenoid is opened, and this causes the plate *K* in figure 179 to drop and open the circuit through the motor armature. As soon as the control switch is opened the armature of the relay drops and closes the circuit through the starter solenoid, but as this circuit is still open at the control switch, it is necessary to close the control switch again to start the motor generator.

The coil *E* is composed of two windings. One is called a series coil and is in series with the motor armature so that all the motor current passes through it. When this current becomes excessive the armature *G* is raised and the contact between *T* and *S* is broken. This in turn opens the circuit between *K* and *F* of the starter.

When the armature is raised, a contact is made between *T* and *R* which closes the circuit through the shunt winding on the magnet which holds up the armature *G* until the control switch is opened.

A plate *X* has a scale indicating the point to which the armature must be set for different values of current. The screw *U* regulates this position. The normal working position of this relay is for 35 to 40 amperes. When a short circuit of overload occurs and this relay is opened, all that is necessary to re-start the machine is, to open and close the control switch unless there is a permanent short-circuit on the line, in which case the relay will again open the circuit. The short-circuit must be located and removed.

The shunt coil should be connected to *A* and *B* and the series coil to *C* and *D*. If the terminals of the shunt coil should become reversed for any reason, the relay will not work properly. This condition will be indicated by failure of the shunt coil to hold the armature up. When a short-circuit or overload occurs the armature will vibrate slowly. If this occurs, the terminals of the shunt coil should be reversed at *A* and *B*.

To remove the armature of the motor generator for repairs the following procedure should be followed:

1. Remove bearing bracket from the generator end by loosening bolts and removing same.

2. Lift brushes from commutator and collector rings.

3. Pull out armature and make repairs or insert spare.

3. **To Replace Armature**—

1. Hold up oil rings so as to permit shaft to pass through bearings.

2. Insert armature, taking care not to score commutator or collector rings.

3. Replace bearing bracket, and make sure armature rotates free by turning same over by hand.

4. Fit brushes to commutator and collector rings.

5. See that oil rings are working properly and that bearings are thoroughly oiled.

It should be noted that the mica of the commutator of this machine is undercut about 1/32 inch, and before it gets flush with the comutator bars, the mica should be cut out again. High mica will cause excessive sparking at commutator.

A small rotary converter and stepdown transformer supply alternating current for filament heating. The rotary converter operates directly from the 110-volt d.c. ship's power line and supplies about 70 volts, 60 cycles, a.c. to the primary of the filament transformer, which steps this voltage down to 11 volts for the tube filaments.

4. **Operation**—Cut in all filament rheostat and start filament rotary converter. See that filament voltmeter is indicating and that filaments of tubes are lighted. Set field rheostat controls with all resistance in and start the motor generator. Adjust filament voltage to 11 volts. Press key and adjust power to 500 watts as shown by wattmeter. Set wave change switch on wavelength desired and resonate open circuit by means of the variable inductance handle until maximum radiation is obtainable. The resonance point is sharp and the variable inductance must be adjusted slowly and carefully, otherwise, the resonance point may be passed over without noticing it. Increase power to amount necessary for efficient communication.

If the open and closed circuits are in resonance sparking across the safety gaps on either the secondary of the transformer or plate blocking condensers will occur when the power is increased to about 1,500 watts (1 1/2 K.W.). If the circuits are not in resonance sparking will take place even when low power is being used and no attempt should be made to increase the power until the two circuits are in resonance. With the average antenna, radiation of 10 to 12 amperes may be expected at about 1 1/2 K. W. No attempt should be made to use power in excess of 1 1/2 K.W. Make all adjustments for resonance on low power.

The filaments should be operated at not more than 11 volts and not less than 10 volts. If, on the other hand, the filament voltage is too low, the tube plates will overheat when the key is depressed even though normal power is being used. With transmitter in operation handling traffic and all adjustments properly made, the tube plates should not heat beyond a cherry red.

5. **Maintenance**—The filament rotary converter should be kept oiled and commutators clean. All parts of the transmitter must be protected from water and spray and kept clean and dry

at all times. The bakelite panel and rods and the treated maple boards used in the set should, in particular, be wiped off with a dry cloth every day. Should the transmitter accidentally get wet

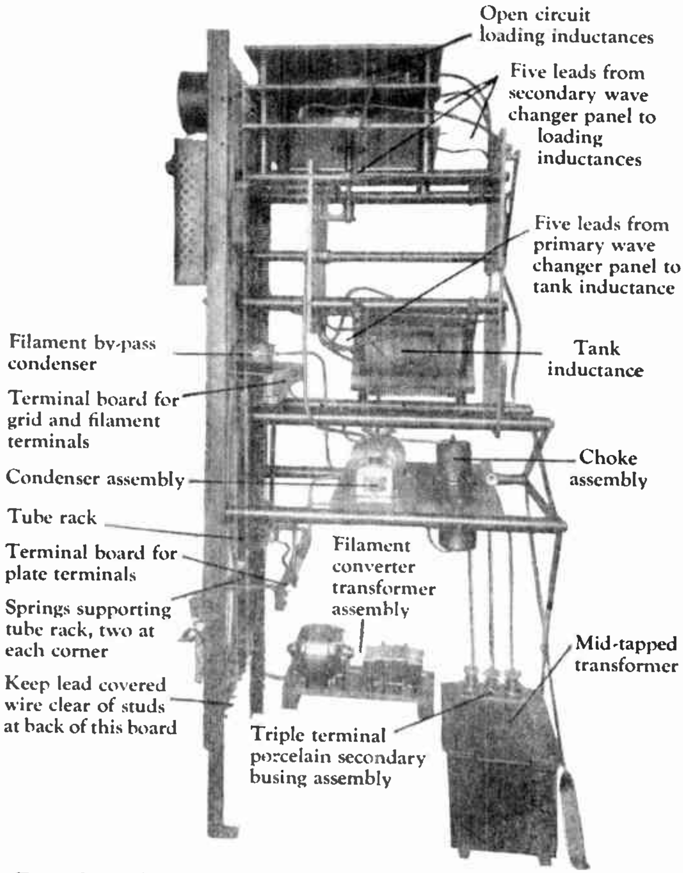


FIG. 180. Side View of Model ET-3628 A.C.W. Transmitter.

it should not be started until it has been wiped off and the insulation and choke coils have become thoroughly dry. The bearings of the 2-K.W. motor generator should be kept oiled and the commutators cleaned and free of sparking.

6. Troubles and Remedies—The circuit used is very stable and can be relied upon to operate satisfactorily under all conditions where the apparatus is not defective, except two conditions, as follows:

1. The oscillations will not start when the key is closed if there is a poor connection in the tank circuit or an intermittent breaking down of the tank circuit insulation either to ground or in the condensers.

2. When the antenna coupling is too high the maximum antenna current cannot be obtained as the tank circuit will shift frequently when approaching resonance of the antenna circuit.

When the antenna is small or the resistance very low, it will be found that the maximum output may not load the tubes to their full rating and, under these circumstances, no attempt should be made to increase the loading by overvoltage or change in circuits other than careful tuning and use of proper value of coupling.

7. **Swinging Signals**—Signals from these transmitters may swing slightly in rough weather due to the rolling of the ship, changing the antenna capacity. The antenna should be pulled taut to minimize this as much as possible. However, should excessive swinging be complained of, it will probably be because the secondary circuit is too closely coupled to the primary.

The coupling should be loosened by decreasing the number of turns used in the secondary of the oscillation transformer. Any change in the number of turns used in the secondary coil must be compensated for by a corresponding change in the aerial inductance to bring the set back into resonance.

8. **Burned Out Plate Choke Coil**—If no spare is available the grid leak choke coil, which is not essential to a satisfactory operation, may be removed from its place in the circuit and installed in place of the defective plate choke.

If this is done, the leads removed from the grid leak choke must be connected together to complete that circuit. The plate chokes and the grid leak chokes are exactly the same electrically and mechanically and are interchangeable. Another method of making temporary repairs is to use two 400-turn honeycomb coils connected in series, or an equivalent inductance, to replace a defective plate choke.

9. **Set Fails to Oscillate or Tubes Heat Badly**—Tighten all connections in tank and open circuits. See that wave change switch arms are making good contact. This is very important. See that sliding contact on antenna variable inductance is making good connections. Examine ground connections and see that they

are tight and clean. Check circuit with diagram to see that all connections are properly made. If trouble persists, change tubes.

10. **Burned Out Filament Voltmeter**—Reduce filament voltage until tube plates begin to overheat using normal power on the plate circuit. Then increase filament voltage slowly until tubes operate at normal temperature.

11. **Burned Out Wattmeter**—After circuits have been resonated increase power until satisfactory radiation is obtained or until sparking occurs at the safety gaps.

12. **Burned Out Radiation Ammeter**—Adjust aerial inductance in accordance with tuning record card and make final adjustment by watching wattmeter. Insert 40- or 50-watt light in aerial circuit. Operate at reduced power until circuits are in resonance as indicated by maximum glow of light. After securing resonance short out light and increase power.

13. **Burned Out Filament Converter, Filament Transformer or Filament Rheostat**—Disconnect all of these units and connect filament terminals directly to a five-cell lead-acid storage battery which will supply approximately the right filament voltage (10 volts). Leads formally connected to the mid-tap of the filament transformer should be connected to the negative side of the storage battery.

The regular filament rheostat cannot be used with a storage battery as it will not carry the heavy current flowing directly in the filament circuit. However, the voltage of a five-cell storage battery should be so close to normal that no regulation will be required.

14. **Burned Out Grid Leak**—The resistance of the grid leak used on this transmitter is 4,000 ohms. Should the grid leak become burned out with no spare available, a suitable resistance could be made up from material available on board ship by using a piece of rubber hose about a foot long, filled with salt water and plugged at both ends with wires extending through the plugs at both ends and making contact with the salt water in the hose. A little experimenting with the length of the hose to be used should result in obtaining the proper value of resistance for satisfactory operation. Any suitable resistance having a value between 2,000 and 10,000 ohms may be used.

15. **Filament Converter Fails to Start**—In some cases the filament converter may not start immediately when the circuit is closed if maximum resistance is cut in with the filament rheostat. In such cases the armature of the converter should be burned over immediately by hand.

16. **Trouble in One Side of Circuit Which Cannot be Repaired at Sea Due to Lack of Material**—Spare tubes, a spare plate choke, spare grid leak and spare transformer secondary sections should be aboard at all times. If necessary, this set may be operated at reduced power with only one good tube, one good plate choke, one good blocking condenser, or only one side of the secondary of the power transformer. Should there be available only one good tube, one good plate choke, one good plate blocking condenser, or only one-half of the secondary of the plate transformer, the defective part should be removed from the circuit and the lead to the plate transformer on that side disconnected.

The set may then be operated at reduced power on one tube, with about half the normal radiation. If only one tube is used care should be exercised to reduce the filament voltage to normal.

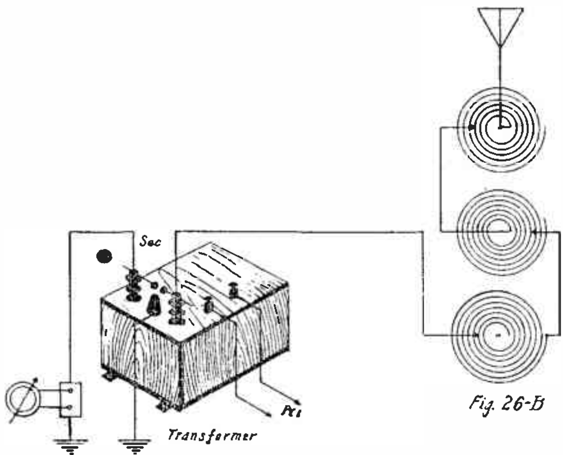
In the event of irreparable damage, making it impossible to use even one side of the circuit, a "plain aerial" spark transmitter for emergency use only may be made by removing all connections from the three secondary terminals of the plate transformer and connecting the antenna to one outside secondary terminal of this transformer and the ground to the other outside secondary terminal. The safety gaps on the secondary terminals will then serve as a spark gap; necessary changes may be quickly made by disconnecting the flexible lead from the secondary of the oscillation transformer, lengthening this lead as much as necessary and connecting it to one side of the power transformer. The other side of the power transformer should then be connected to the piece of copper tubing leading from the secondary of the oscillation transformer to the thermo unit of radiation ammeter. This will tune the circuit and permit of reading the radiation on the radiation ammeter. It is very improbable that it will even be necessary to resort to the use of the plain aerial circuit and such circuit should never be used unless the vessel is in distress and the transmitter damaged so that it cannot be made to function normally.

17. **Insulation**—Porcelain, micalex, or glass antenna insulators should be used throughout with this type of transmitter. If other forms of insulation are used there is likely to be an excessive drop in radiation during wet weather.

UV-204-A Radiotrons—The UV-204-A tubes used in this transmitter are provided with a XL or thoriated filament.

The UV-204-A tube has a normal power rating of 250 watts output. The current required for filament heating is 3.85 amperes. The filament voltage must never exceed 11 volts. The use of a low voltage will greatly increase the life of the tubes. Satisfactory operation should be possible at all times with the filament voltage adjusted to between 9 and 10 volts.

The terminals on the base of the transmitter are all numbered as well as the terminals on the motor-generator, starting resistances,



Note
Adjust gaps so that discharge takes place between safety gaps of transformer and not from safety gaps to point projecting upward from case of transformer

FIG. 181. Connections for Plain Aerial Circuit in Emergency.

and type I switch. Lead-covered wires leading from these terminals run to the following connections.

Terminal post *P*-6 on panel (two wires), one wire leading to *B*-1 of starting resistances, one wire leading to terminal 2 motor.[2]

[2] The fifth contact of automatic starter closes generator field.

Terminal post *P*-7 on panel to terminal post 1 of motor.

Terminal post *P*-8 on panel to terminal post 3 of motor.

Terminal post *P*-9 on panel to terminal post 8 of type I switch.

Terminal post *P*-10 on panel to terminal post 7 of type I switch.

Terminal post *P*-11 on panel to terminal post 5 of generator.

Terminal post *P*-12 on panel to terminal post 10 of type I switch.

Terminal post *P*-13 on panel to terminal post 9 of type I switch.

Terminal post *P*-14 on panel to terminal one side of key.

Terminal post *P*-15 on panel (two wires). One wire leading to terminal post 11 on type I switch. One wire leading to primary of transformer.

Terminal post *P*-16 blade of a.c. generator switch (two wires).

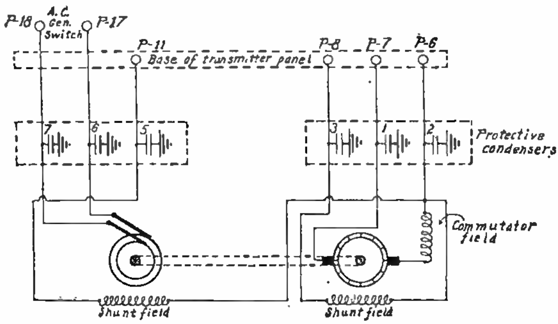


FIG. 182. Internal and External Connections of 2-Kilowatt Motor Generator.

One wire leading to other side or primary of transformer. One wire to wattmeter.

Terminal post *P*-17—Contact of a.c. generator switch to terminal post 6 of a.c. generator.

Terminal post *P*-18—Contact of a.c. generator switch to terminal post 7 of a.c. generator.

Terminal post *P*-19—Contact of d.c. switch to d.c. line.

Terminal post *P*-20—Contact of d.c. switch to d.c. line and one side of filament rotary converter.

B-2 of starting resistance to dynamic brake contact of automatic starter.

R-1 of starting resistance to first contact of automatic starter.

R-2 of starting resistance to second contact of automatic starter.

R-3 of starting resistance to third contact of automatic starter.

R-4 of starting resistance to fourth contact of automatic starter.

18. Model ET-3630 ACW. Tube Transmitter—This transmitter consists of a 1/2 KW. Type *P*-5 panel or 531 spark transmitter which has been converted for tube operation. The UV-211 Radiotrons are used in a self-rectifying Colpitt's circuit. All connections to the motor generator and automatic starter are the same as for the *P*-5 spark set. Keying is accomplished by breaking the primary circuit. One UV-211 Radiotron is used on each

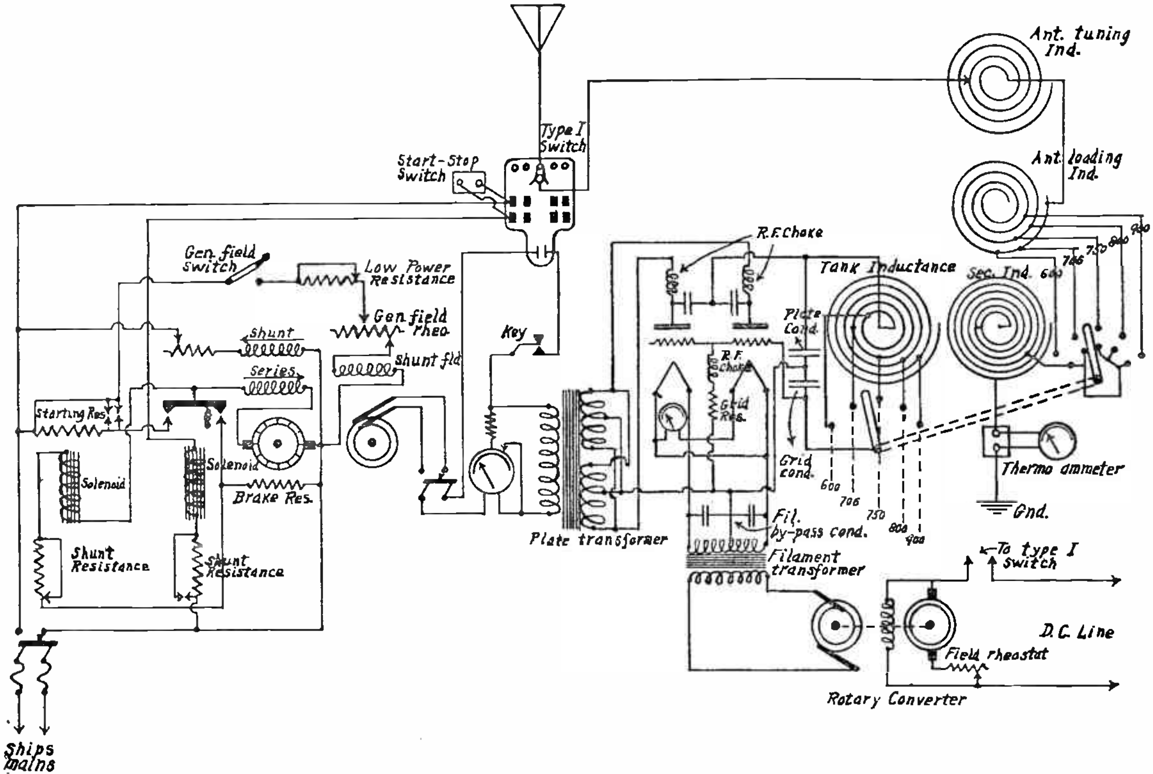


FIG. 183. Diagram of Connections of Model ET-3630 A.C.W. Tube Transmitter.

side of the cycle. The UV-211 Radiotron is rated as developing 50 watts output but may develop an average output of 100 watts if the rated plate dissipation is maintained. Two UV-203-A Radiotrons may be used if UV-211 tubes are not available.

19. **Description of Apparatus**—The motor generator comprises a 110-volt direct current motor directly connected to a 1/2 KW., 120-volt, 500-cycle generator.

The motor is designed to operate on voltages between 95 and 115 volts with little change of speed. A rheostat in the shunt field controls the speed of the machine.

The generator is of the inductor type having a stationary armature and field winding. The open circuit voltage of the generator is approximately 350 volts and the load voltage about 120 volts. The normal speed of the machine is 2500 R.P.M. The voltage at the armature terminals can be varied by the field rheostat mounted on the right hand side of the panel.

Protective devices are provided across the terminals of the motor generator. A closed core transformer with a mid-tap which has a series-parallel connection of the pies comprising the secondary is supplied, and is fitted with a safety gap.

Switches on the front of the panel are provided as follows: A single-pole double-throw high potential switch which either connects the aerial to the transmitter or connects it directly to ground for protection against lightning. A double-pole single-throw switch disconnects the motor from the d.c. supply mains. A single-pole switch permits the generator field to be opened. A double-pole single-pole throw switch opens the a.c. line from generator to the transformer. A single-pole switch to close low power resistance is in series with generator field.

The automatic starter consists of two magnets fitted with armatures, one of which connects the motor armature to the d.c. line through a single resistance coil and the other cuts out this resistance, thereby connecting the motor direct to the d.c. line. Appropriate resistance coils are connected in series with the solenoid windings automatically, when starter is in full running position.

This prevents the magnet windings overheating as the potential difference across the motor armature rises. A dynamic brake attached to the motor starter consists of a shunt armature resistance, which is connected across the terminals of the armature by a special set of contacts to the starter when the starting solenoid is opened.

The operation of the 1/2 KW. starter is as follows: The cutout switches of the automatic starter are energized by direct current from the d.c. line and operated by a distant control switch. When this switch is closed, the solenoid *A* in figure 184 is energized and moves the contact arm *C* radially in a vertical plane,

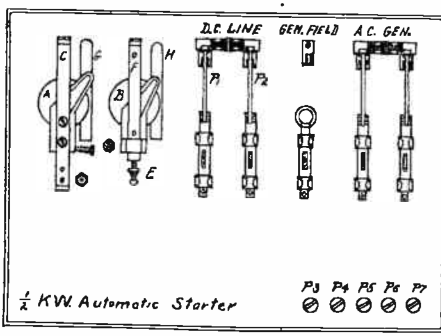


FIG. 184. Automatic Starter of ½-Kilowatt Model ET-3630 Transmitter.

perpendicular to the board, which cuts in the single resistance unit mounted in the resistance box behind the panel.

As the speed of the motor generator increases, the current falls off, and the potential difference across the armature rises. When it reaches normal value, the solenoid *B* is energized and draws the contact arm *F*, cutting out the resistance. This connects full line voltage across the motor.

The time of closing the contacts of the automatic starter is regulated by the set screw *E*, attached to the bottom of the starter arm *B*. Both solenoids should perform their functions within six seconds from the time the starting switch is closed. The motor starter is controlled by a special set of contacts mounted on the aerial change-over switch or the motor may be held in continuous state of operation by closing the flush switch mounted near to the antenna switch.

An extra set of contacts on the armature *F* closes the field of the generator when the motor is in full running position. A motor field rheostat on the panel controls the frequency. A generator field rheostat is provided to control the voltage at the terminals of the alternator.

A wave change switch on the front of the panel provides five operating wavelengths. There is also provided a direct reading wattmeter, range 0–750 watts, a radio frequency ammeter with thermo-coupling, range 0–10 amperes, and an a.c. filament voltmeter.

A small rotary converter and step-down transformer suppl; ılternating current for filament heating. The rotary converte: ›perates directly from the 110-volt d.c. mains and supplies abou ʼo volts, 60-cycle a.c. to the primary of the filament transformer vhich steps this voltage down to 10 volts for the the tube fila nents. A field rheostat is provided for close variation of voltage

Plate and grid condensers of the following capacities are pro 'ided: Two plate blocking condensers UC-1805 .001 mfd. each ›late excitation condenser UC-1822a .004 mfd.; grid excitatio: :ondenser UC-1821 .02 mfd. and two filament by-pass condenser: JC-2323 2 mfd. capacity each.

The grid and plate radio frequency chokes are identical as i: ?-8 model ET-3630 2 KW. ACW. transmitter. The grid leak i ›f 5,000 ohms resistance.

The tank and secondary inductances are strip-copper, spira vound edgewise on an insulating support. Connection are mad‹ o the inductances by flexible leads fitted with clips.

Two aerial tuning inductances are provided, one being a con inuously variable inductance having a sliding contact which ca: ›e revolved by a handle in the front of the panel, permitting th‹ nductance to be increased or decreased until resonance is secured

One fixed antenna loading coil is connected in series with th‹ ʼariable coil and by the use of clips on flexible leads the correc ıdjustments can be made whereby resonance can be secured on th‹ ʼariable coil at nearly the same position for all wavelengths.

The coupling is varied by means of changing the number of turn n the secondary inductance instead of by varying the distanc‹ ›etween primary and secondary. Four turns are usually employe‹ :or all wavelengths. A type I change-over switch is supplied an‹ ›erforms the same operations as in the description of the ET 3628.

20. Operation—Cut in all filament rheostat resistance an‹ ;tart filament rotary converter. See that filament voltmeter i ndicating and that filaments of tubes are lighted. Set field rheo ;tat controls at lowest points and start 1/2 KW. motor generato: Adjust filament voltage to 10 volts. Press key and adjust powe :o about 200 watts as shown by wattmeter. Adjust wave chang‹ ;witch for wavelength desired and resonate open circuit by mean ›f the variable aerial inductance handle until maximum radiatio: s obtained. The resonance point is sharp and the aerial induc :ance must be adjusted slowly and carefully; otherwise the reso ıance point may be passed over without noticing it. Increas ›ower to amount necessary for efficient communication, but no :xceeding 500 watts.

If excessive power is used or if the open and closed circuits are not in resonance, sparking will occur in the tube sockets. In such cases the aerial inductance should be adjusted for resonance and if sparking continues the power must be decreased. Make all adjustments for resonance on low power. With the average antenna radiation of about 5 amperes may be expected when using 500 watts input.

The UV-211 tubes used in this transmitter are provided with an X-L or thoriated filament. The current required for filament heating is 3.25 amperes per tube. The filament voltage must never exceed 10 volts. Satisfactory operation should be possible at all times with the filament adjusted to between 9 and 10 volts. If the filament voltage is too low, the tubes will overheat, when the key is depressed, even though normal power is being used. With

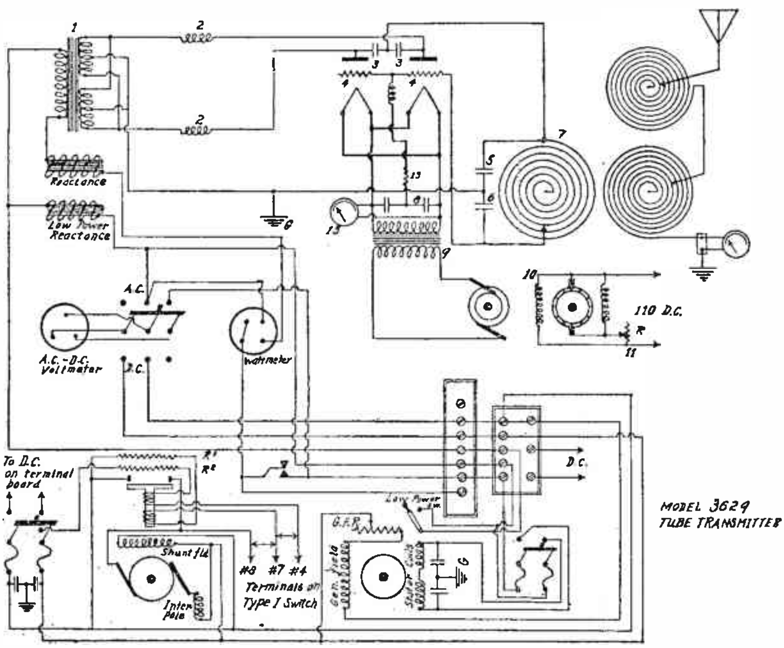


FIG. 185. Diagram of Connections of Model ET-3629 A.C.W. Transmitter.

transmitter in operation, handling the traffic and all adjustments properly made, the tube plates should not heat beyond a cherry red.

In case of severe overload resulting in overheating of the tube, the electron emission may decrease and oscillations may not start when key is closed. Unless the overload has liberated a large amount of gas, the activity of the filaments may be restored by operating at rated filament voltage for 10 minutes or longer with plate voltage off. See Chapter IV for reactivation of power tubes.

Maintenance, troubles and remedies as outlined in the description of the ET-3628 may be applied to the ET-3630. It should be noted that the ET-3628 uses UV-204-A tubes operating at a normal filament voltage of 11 volts, whereas the ET-3630 used UV-211 tubes operating at a normal filament voltage of 10 volts.

Model ET-3629 Transmitter—The model ET-3629 ACW. tube transmitter consists of a ½ KW. submarine type (C-296-B) spark transmitter which has been converted for tube operation.

All connections to the motor generator and automatic starter are the same as for the C-296 spark sets. The method of keying by breaking the primary circuit of the power transformer is exactly the same as used with the spark sets. Power regulation by means of generator and motor field rheostat are the same.

The changes which have been made in converting from spark to tube transmitters are principally in the closed or primary circuits, with some minor changes in the open circuit. Changes consist of the complete removal of the quenched gap, and some other units used with the spark set, in place of which new parts have been installed and connected as shown in figure 185. The figures shown on the diagram indicate the location in the circuit of the various units, which are as follows:

1. 1/2 KW. power transformer with mid-tapped secondary.
2. Plate choke coils.
3. Plate blocking condensers UC-1806—.002 mfd.
4. 2-UV-211 radiatrons.
5. Plate excitation condenser UC-1822-A or CD-158.
6. Grid excitation condenser UC-1821—.02 mfd.
7. Tank (primary) inductance.
8. Filament by-pass condenser UC-2323.
9. Filament transformer.
10. Filament converter.
11. Filament rheostat.
13. Grid leak 4,000 ohms resistance.
15. Filament voltmeter.

A small rotary converter and stepdown transformer have been added to supply alternating current for filament heating. The rotary converter operates directly from the 110-volt d.c. ship's power line and supplies about 70 volts a.c. to the primary of the filament transformer, which steps this voltage down to 10 volts for the tube filaments.

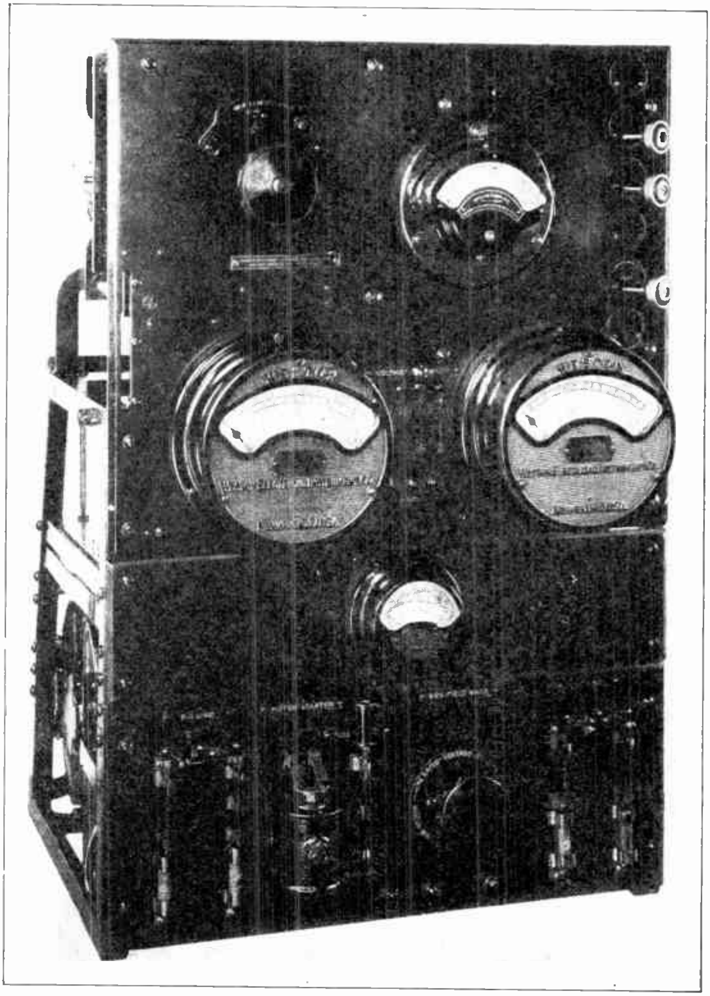


FIG. 186. Model ET-3629 A.C.W. Tube Transmitter.

Two UV-211 Radiotrons are used in a self-rectifying Colpitts circuit. Two UV-203-A Radiotrons may be used if UV-211 tubes are not available.

21. **Description of Apparatus**—The set is arranged so that it may be divided into two parts: One containing the motor generator and control panel, with switches, starter and rheostat, and the other containing the meters, oscillation transformer, loading coils, tube sockets, condensers and radio frequency choke coils.

The panel on the power unit mounts, reading from left to right, d.c. line switch, motor starter, low power switch, generator field rheostat and a.c. line switch. Just behind this panel is a strap iron frame which mounts the d.c. and a.c. protective condensers, and motor starter resistances.

Behind this frame is the motor generator. The power unit terminal block is mounted on the frame on the right hand side near the top, and has eight studs, two for the d.c. line connection, two for leads to the antenna switch to break the generator field circuit in the receiving position, and the balance for jumpers to the upper unit terminal block.

The *motor generator* consists of a shunt-wound direct current motor mounted on the same shaft and in the same frame with a single-phase, 500-cycle, inductor type alternator. It is a two-bearing machine and has two ball bearings. Since the alternator is of the inductor type, both the armature and field windings are stationary and there are no brushes except those on the motor end.

22. **Lubrication**—The ball bearings should be cleaned and refilled with a medium grade of grease about every six months depending upon amount of service motor generator is subject to.

23. **Cleanliness**—Great care should be taken to keep grease, gasoline, kerosene or oil from the electrical parts of the machine. It is an extremely important matter with ball bearings that all foreign material except the grease must be carefully excluded. This means that care must be taken to see that no dirt or grit of any kind is carried into the bearing with the new grease, or otherwise, when, for any reason, the bearing caps are removed.

Removing and Mounting the Bearings—The removing of ball bearings should be done as follows:

These instructions for removing a ball bearing may be applied to any type of motor generator employing such bearings.

Take off the outer bearing cap and after disconnecting any leads or brush rigging that may be attached to the shield, remove the shield, leaving the ball bearing on the rotor shaft.

Unscrew the clamp nut and then, using pressure on the inner end of the *inner race only,* force the ball bearing off the shaft, taking care that the pressure for pulling off the bearing is applied evenly around the inner end of the inner race.

When the bearing has been removed from the shaft it should be carefully wrapped up in clean paper to prevent any foreign substance from adhering to the grease and before it is put back on the shaft the old grease should be cleaned out by using gasoline or kerosene oil.

When replacing the bearing on the shaft, pressure should be applied at the outer end of the inner race only and *never* on the outer race, as otherwise the bearing might be damaged. This operation can best be done by using a short piece of pipe of the proper diameter. Such pipe should preferably be of brass, but could be of iron, if necessary. It is also possible to mount the bearing by light blows from a hammer applied through the medium of a brass rod at successive positions around the circumference of the inner race. If this latter method is used, care must be taken to prevent cocking the bearing on the shaft and damaging it on the shaft.

It is essential that the inner race be clamped securely against the shoulder on the shaft by the lock nut. Spare bearings, if any, must be kept wrapped in their original wrappings and package until needed. Before being placed on the shaft the bearing should be carefully examined to see that the outer race turns freely and that there are no evidences of foreign material in the bearing. If there is any such indication, the bearing should be thoroughly cleaned before being mounted on the shaft.

24. **To Replace a Rotating Element**—First remove the end shields and bearings as above. Place the bearings on the new shaft and then place the shaft in the frame of the machine. Then put on the end shield and replace the brushes and connections, taking care to get them the same as they were before taking the machine apart.

25. **To Replace a Generator Armature Coil**—First remove the rotating element as before. Disconnect and remove the defective coil and replace with a new coil and slot insulation. It will be observed that the inside of the coil tapers slightly and should be placed so that the big end of the coil is in the bottom of the slot. Connect the coil, taking care to make the connections the same as they were originally. Replace the slot key, solder the connections securely, insulate with two layers of one-fourth inch linen tape, paint with insulating varnish and assemble the machine as before.

26. To Remove a Generator Field Coil—It will be necessary to first remove the outer set of armature coils and core as a unit. This can be done by removing the bolts which hold it to the frame. All leads must be disconnected from the terminal blocks before this can be done. The field coil is ring-shaped and can be slid out easily.

27. To Replace a Motor Field Coil—Remove the rotating element as before. Remove the pole shoe by loosening its holding down screws. Disconnect the defective coil to replace with a new one, putting the long lead next to the frame. Replace the pole shoe, taking care to get it in the original position. Solder the connections to the coil and replace the rotating elements as above.

28. To Replace a Motor Armature Coil—This is a more difficult process; when this becomes necessary, the injured armature should be replaced by a spare and repaired later. After the injured armature coil is located, unsolder its leads from the commutator risers and also those of all the coils which have one of their sides in the slots included between the sides of the injured coil. Remove all the wedges from the slots in which the injured coil lies from those between, and lift out the coil-sides. This is necessary because the coils overlap all the way around the armature; when the coil is removed, put a new one in by the reverse process, taking care to get it in the proper relation to the others, without injuring the insulation of any of them; when soldering the leads to the commutator risers, be careful to make good tight joints, otherwise injurious sparking will result.

29. To Replace a Motor Brush—First remove the old one by disconnecting the pigtail and pulling back the pressure arm. Insert the new brush and turn same to fit the commutator by pulling a piece of No. 0 sand paper between the brush and commutator. Never use emery cloth or paper.

30. To Replace a Motor Brush Holder—Remove the old one by removing the nuts on the brush stud and the connections and unfasten the holder stud from the insulating bridge. In replacing the new holder, there should be a clearance of about 1/8 inch between the holder and the commutator. Before tightening nuts and making connections, be sure that the new holder inclines at the same angle as its neighbor.

31. To Replace a Brush Holderspring—Remove the holder and stud as above. The pin through the spring drum can be removed by using a small punch and hammer. After inserting a new spring and pin rivet the latter with the punch. Replace the parts as above.

32. **A Brush Holder Stud**—Can be replaced by an operation similar to the above.

The *transformer,* which is of the closed core, air-cooled type, is mounted in a case complete with the reactance necessary to give

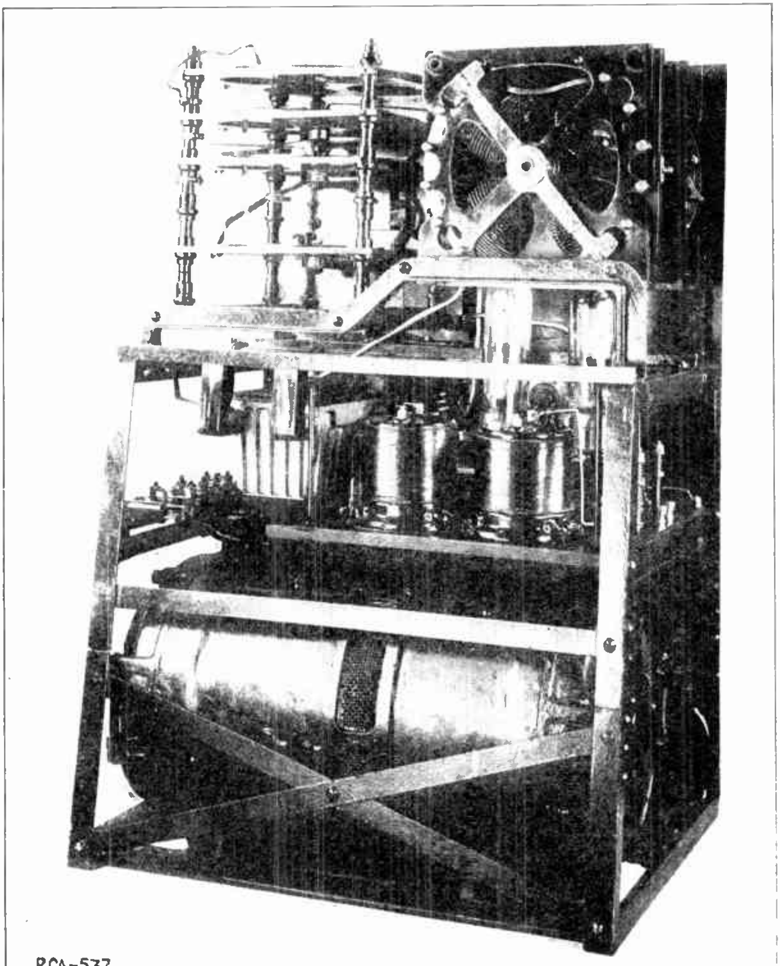


FIG. 187. Back View of Model ET-3629 Transmitter.

proper resonance conditions, and with an additional reactance for low power operation.

The *protective gap* is mounted, as usual, on the secondary insulators on the cover casting. There are three terminals on the primary, one connecting through the regular reactance to the primary, another connecting to the other end of the primary and to one side of the low power reactance. Leads from the latter two of these terminals go through the terminal blocks to the low power switch on the power unit, so that the additional reactance may be short-circuited by putting the switches in the *full power position.*

The coils of the inductive coupler and wavechanger are wound with 1/4 inch x 1/32 inch hard-drawn round-edge copper strip. Two of the coils are used as primary and secondary. Six of these spirals are used as loading coils. The secondary coil has only one variable tap, the same number of turns being used for all wavelengths.

Coupling is accomplished by the variable tap. The position of the coils remains fixed.

33. **Operation**—Cut in all filament rheostat resistance and start filament rotary converter. See that filament voltmeter is indicating and that filaments of tubes are lighted. Set field rheostat controls at lowest point and start 1/2-KW. motor generator. Adjust filament voltage to 10 volts. Press key and adjust power to about 200 watts as shown by wattmeter. Adjust wavechange switch for wavelength desired and resonate open circuit by means of aerial inductance knobs until maximum radiation is obtained. The resonance point is sharp and the aerial inductance must be adjusted slowly and carefully; otherwise the resonance point may be passed over without noticing it. Increase power to amount necessary for efficient communication; but not exceeding 500 watts.

If sparking occurs in tube sockets adjust aerial inductance for resonance and if sparking continues decrease power. With the average antenna, radiation of about 5 amperes may be expected when using 500 watts input.

The filaments should be operated at not more than 10 volts and not less than 9 volts. With transmitter in operation handling traffic and all adjustments properly made, the tube plates should not heat beyond a cherry red.

Maintenance, troubles and remedies as outlined in the description of the ET-3628 are applicable to the ET-3629 with the following exceptions:

1. The tubes used in the ET-3629 are rated at 50 watts with an operating filament potential of 10 volts.

2. To replace a burned-out plate choke coil when no grid choke of the same type is available, repairs may be made by using two 400-turn honeycomb coils connected in series, or any equivalent inductance, to replace a defective plate choke.

The characteristics and care of the UV-211 tubes used in this transmitter will be found in the description of the model ET-3630 ACW. tube transmitter.

34. **General ET-3628-29-30**—Signals from self-rectifying circuits such as the ET-3628, ET-3629 and ET-3630 may be received with a crystal or non-oscillating tube detector due to the modulation of the 500-cycle plate generator. A chopper is not required. Greater distances may be covered, however, if the receiving station uses an oscillating tube detector for beat reception. Signals from transmitters of this type should always be tuned in with the detector oscillating, which will mush up any interfering spark signals and permit reception of the C.W. beat note through heavy interference or static.

35. **Model ET-3627-A 200-Watt Transmitter**—The model ET-3627-A, 200-watt transmitter and associated equipment described in these instructions are designed primarily for shipboard installations or for other service where a compact radio telegraph transmitter is required. The equipment as normally supplied consists of the following component units:

1—200-watt transmitter, model ET-3627-A.

1—motor generator set rated: model 55-A-5, type M.C.C.; ball bearings. 2500 R.P.M. no load speed. Weight 390 lbs.

1—automatic starter CR-4012. 1½ H.P. 155 volts d.c.

1—Mesco No. 80 telegraph key.

36. **Installing**—The transmitter proper is designed for table mounting and has the following overall dimensions: Height, 40 inches; width, 21 inches; depth, 25 inches; net weight, 208 lbs.

The automatic starter is supplied for independent mounting and should be located as near the motor generator set as posible. This will result in short leads from line to the motor and will improve the overall regulation by reducing the voltage drop to a minimum.

Number 12 B. & S. lead-covered wire is recommended for leads running between the motor and automatic starter and number 14 B. & S. lead-covered wire may be used for the remaining external connections. The leads from the generator armature to transmitter should be insulated for 1,000 volts. The normal full-load current drawn from the line by the motor generator set when used with the ET-3627-A transmitter is approximately 11 to 12 amperes at 115 volts d.c. The load on the plate generator with this transmitter is approximately 550 watts. The generator is rated as 1.68 KW., amperes 1.4, volts full load 1,200 d.c.

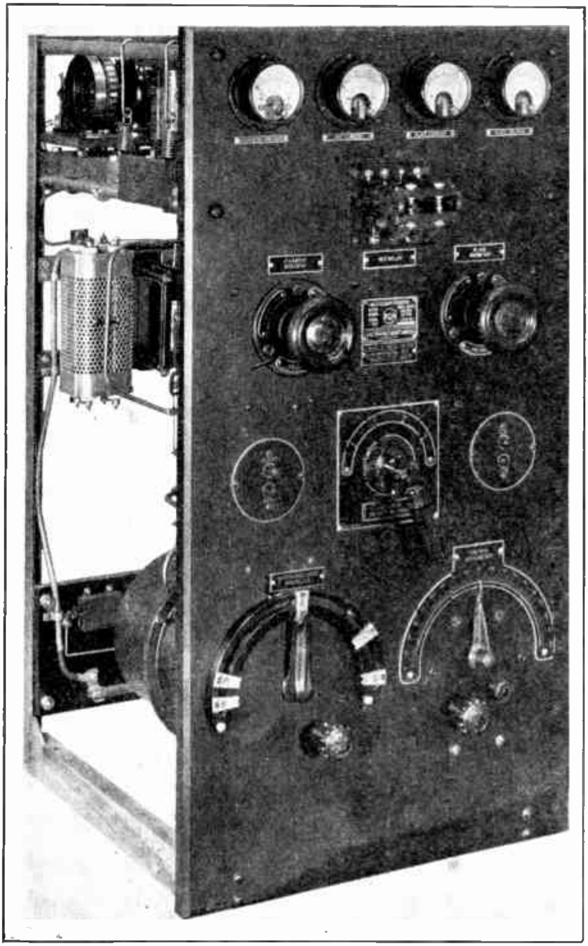


FIG. 188. Model ET-3627-A Tube Transmitter.

The automatic starter is designed with adjustments so that the motor generator may be brought up to speed in a short time without subjecting the line or motor to excessive current. It is provided with two magnetic contactors, one of which closes first and connects the motor to the line through a suitable resistor. When the machine reaches a certain speed, the counter e.m.f. of the motor closes the second magnetic contactor which short-circuits the resistor, bringing the machine up to full speed. The second, or accelerating contactor, is the one near the base of the starter and is provided with a spring adjustment which determines the time required for the contactor to close. If this spring is too loose, the starting resistance will be cut out of the circuit too soon, while if too tight, the accelerating contact may fail to close. A few trials will enable a correct adjustment to be obtained by observing the acceleration of the machine when the start button is depressed. Be sure to lock the adjustment screw with the lock-nut after the best adjustment has been determined. The line switch in the starting box should be fused with thirty ampere fuses.

The adjustments of the automatic starter should be made with the transmitting key open. The machine will then start with the filament load but without the plate load, as this is the normal operating condition.

37. **Antenna Characteristics**—The transmitter is designed to operate on an antenna whose characteristics fall within the following limits:

Effective capacitance .0004 to .001 mfd.

Effective resistance 2 to 10 ohms.

Fundamental wavelength 175 to 350 meters.

In general, an effort should be made to use an antenna whose capacitance is near the upper limit specified. On the higher capacitance antennas whose resistance is four ohms, 200 watts or more output may be obtained. On antennas of lower capacitance, and when the resistance is near the upper and lower limits specified, slightly less than 200 watts may be obtained.

38. **Wavelength**—A continuous wavelength range from 600 to 960 meters (500 to 312 KC.) is covered by the transmitter when used on the specified antennas.

39. **Rating**—The transmitter is rated on the normal output delivered to the antenna on CW. telegraph, namely, 200 watts.

40. **Methods of Signalling**—A push button switch mounted at the right side of the panel provides straight CW. and ICW. transmission. The latter is obtained by means of a motor-driven chopper.

41. **Vacuum Tubes**—Three model UV-211 vacuum tubes are used as follows:

1—UV-211 as master oscillator.

1—UV-211 as power amplifier.

42. Type of Circuit—The master oscillator, power amplifier type of circuit is used in the transmitter. A schematic diagram of the circuit is shown in figure 189. The tuning of this type of circuit consists fundamentally of setting the master oscillator at the desired wavelength and then resonating the antenna circuit for

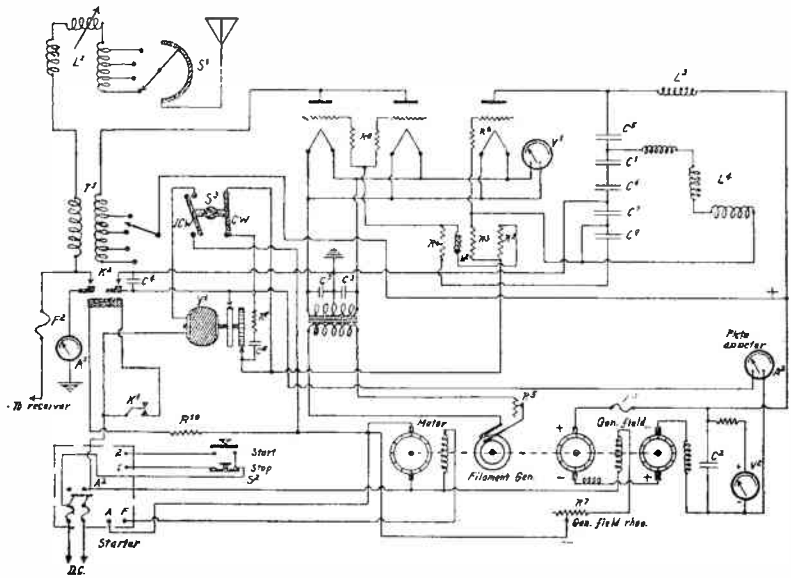


FIG. 189. Circuit of Model ET-3627 200-Watt C.W.-I.C.W. Transmitter.

maximum antenna current. The master oscillator variometer which is mounted in the lower left section of the panel is provided with a five-point positioning device, so that it may be calibrated for any five wavelengths within the band and the movable stops then locked at the correct places. At the same time, intermediate wavelengths from five normal ones may be obtained easily by setting the pointer at the proper position.

43. Adjusting the Transmitter—The antenna circuit is tuned by means of a four-point antenna inductance switch and the antenna variometer. The variometer is designed with sufficient range to overlap the taps on the coil so that continuous inductance range may be obtained.

The only adjustment to be made inside the transmitter is that on the antenna transformer plate winding. This winding has several taps brought out to the micalex terminal board and is used to permit adjustment for maximum efficiency on the particular antenna with which the transmitter is to be used.

The following procedure is recommended for adjusting the transmitter:

1. Turn both rheostat knobs to the extreme right.
2. Start motor generator set by depressing the start push button.
3. Adjust filament voltage to 10 volts.
4. Adjust plate voltage to 750 or 800 volts (for preliminary adjustment) by means of the plate rheostat.
5. Place signal switch on CW.
6. Close the key switch which will start the master oscillator and adjust the master oscillator for the desired wavelength. It is not necessary that antenna current be obtained for this adjustment and the wavemeter should be coupled to the leads which are brought out from the shielded master oscillator compartment.
7. Tune the antenna circuit by means of the antenna variometer until a maximum reading is obtained on the antenna ammeter. The correct position of the antenna inductance switch must be determined by trial for this adjustment and for each operating wavelength. On the average low resistance antenna, the antenna tuning is very sharp with the ET-3627-A transmitter, and it is necessary to rotate the antenna variometer carefully to secure maximum output.
8. Raise the plate voltage to 1,000 volts, which is the normal working voltage, and observe carefully if all the tubes are operating without excessive plate heat.

Facing the transmitter panel, the tube at the left is the master oscillator and will ordinarily run with the plate cold or at a very low temperature. The remaining two tubes to the right of the master oscillator are the power amplifiers, and when delivering output to the antenna, should not show more than a dull red heat after the key has been depressed several minutes.

The plate ammeter on the transmitter panel should be used to secure the proper adjustment of the tap on the transformer plate winding. This tap should be adjusted so that when maximum antenna current is obtained at 600 meters, the total plate current does not exceed .6 ampere. On a low resistance, low capacitance antenna most of the plate winding will be required, while on higher capacitance antennas, and those of higher resistance, less plate inductance is required. Once the proper tap has been selected to give efficient operation on 600 meters it will hold satisfactorily for the entire wavelength band.

The plate voltage should be removed from the transmitter by shutting down the motor generator set whenever adjustments are made inside the transmitter.

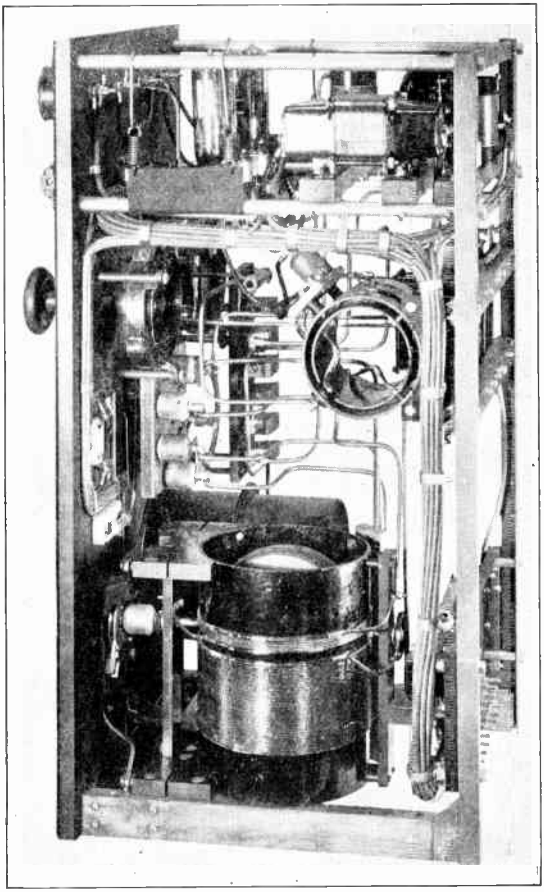


FIG. 189a. Side View of Assembly of Model ET-3627-A Transmitter.

The antenna transformer is designed to protect the tubes from overload during the tuning of adjustment, but for maximum tube life, it is recommended that the plate voltage be reduced to 700 or 800 volts when the transmitter is being calibrated. After the correct position of the master oscillator variometer has been determined and the positions recorded for the antenna inductance switch and the antenna variometer for the different operating wavelengths, changes from one wavelength to another can be made in a few seconds and the plate voltage can be maintained at its normal value of 1,000 volts. The filament voltage should be maintained at 10 volts at all times, higher or lower values being detrimental for long tube life.

A typical set of performance data obtained on a .0008 microfarad, four-ohm antenna with a natural period of 315 meters is tabulated below:

Wavelength	Plate Amps.	Ant. Amps.	Ant. Watts	Ant. Var.	Ant. Ind. Switch
CW 600	0.59	7.1	201	55 degrees	1
ICW 600	0.39	4.75	91	55 "	1
CW 800	0.6	7.1	201	41 "	2
ICW 800	0.39	4.6	85	41 "	2
CW 960	0.61	7.25	210	102 "	2
ICW 960	0.41	4.6	85	102 "	2

The second tap on the antenna transformer plate winding was used for the above readings.

The performance of the transmitter on a .0004 microfarad, four-ohm antenna is tabulated below:

Wavelength	Plate Amps.	Ant. Amps.	Ant. Watts	Ant. Var.	Ant. Ind Switch
CW 600	.05	6.1	150	45 degrees	2
ICW 600	0.33	4.0	64	45 "	2
CW 800	0.5	6.4	164	70 "	3
ICW 800	0.32	4.0	64	70 "	3
CW 960	0.55	6.25	156	79 "	4
ICW 960	0.32	3.5	49	79 "	4

The third antenna transformer tap was used for the above readings.

Occasionally an antenna will be encountered whose capacitance is about .0004 microfarad and whose resistance is from ten to fourteen ohms. Under these conditions, using the lowest plate tap on the antenna transformer, the tubes may not draw sufficient input and the plates will show but little heat. It is then permissible to increase the plate voltage to 1,200 volts, but no more, provided the plates of the tubes do not operate at more than a dull red heat, and provided the total plate current does not exceed .5 ampere. The full output of the transmitter will be obtained on high resistance antennas if the foregoing instructions are carefully observed.

44. Adjustment of Break-in Relay—A special break-in relay is mounted on the front panel. The relay is provided with two pairs of contacts, the pair on the left, when facing the panel, being connected in series with the low side of the antenna circuit, and the pair at the right being connected in the "key" circuit of the transmitter. The radio receiver is connected to the antenna through the transmitter inductance whenever the left pair of contacts are open; when these contacts close, they short-circuit the input to the receiver, thereby protecting it from transmitter voltages. Careful adjustments of the relay contacts must be made in order to secure the proper time required in operation so that the receiver input is short-circuited by the antenna contacts before the key contacts, or the pair at the right, close. This is best done by adjusting the antenna contacts, or the left pair, so that they are separated by not more than 1/32 of an inch. The "key" contacts should be separated by approximately 1/8 of an inch. Then, when the transmitting key is depressed, the antenna contacts close first, but since one of them is spring mounted, they stay closed while permitting the "key" contacts to make. When the proper adjustment has been secured, no sparking will take place on the antenna contacts, and but very slight sparking on the "key" contacts. Silver is used on the antenna contacts and tungsten on the "key" contacts, and both should be kept clean and the faces parallel in order to secure the most efficient operation.

Care must be exercised in running the lead from the receiver fuse, which is mounted at the rear of the panel, to the receiver. This lead must not coupled to the transmitter circuits, as otherwise voltages induced in it will affect the receiver even with proper operation of the break-in relay. A well-shielded receiver will provide the most satisfactory operation with the break-in system.

45. Care of Chopper—When the signal switch is placed in the ICW. position, one pair of contacts on the switch start the chopper motor and the other pair remove the short circuit maintained around the chopper during CW. transmission. The grid leak circuits of the master oscillator and the power amplifier tubes are broken by the chopper at the rate of approximately 1,000 times a second in order to produce ICW. telegraphy. The chopper wheel, therefore, breaks grid current and the brushes and the surface of the wheel should be maintained in good condition. The brush which bears on the chopper wheel proper is made of spring silver in order to secure good contact to the segments. It is held against the wheel by a small coiled spring. Only sufficient pressure should be exerted by the spring to make good contact as excessive pressure will cause premature wearing of the silver brush. The best criterion of a suitable adjustment is to listen to the ICW. note in the receiver, using only sufficient pressure to secure a clear note. The second chopper brush, which is made of copper braid and bears on the brass collector ring, needs but little attention. The chopper wheel should be smoothed off occasionally with very fine sand paper (not emery cloth), taking care not to grind down the insulation faster than the contact segments. The collector ring should also be kept bright and clean by means of fine sand paper.

46. **General Maintenance**—The transmitter should be maintained in good condition at all times in order to secure efficient performance. The various connections in all circuits, particularly radio frequency circuits, should be kept tight and clean. Dust should not be permitted to accumulate on the antenna inductance or other units which operate at high voltage.

The ratings of the various condensers, resistors, and so forth, are given in the following list:

A-1—Antenna ammeter 0–10 amperes, type DO-5.
A-2—Plate ammeter 0–2 amperes, type DO.
C-1—M.O. plate condenser UC-2226, .003 mfd.
C-2—Filter condenser, each UC-490, 1 mfd.
C-3—Filament by-pass condenser, each UC-487, .5 mfd.
C-4—Key condenser, UC-2214, .015 mfd.
C-5—M.O. plate blocking condenser, UC-2226, .003 mfd.
C-6—M.O. plate condenser, UC-2219, .002 mfd.
C-7—M.O. grid condenser, UC-2219, .002 mfd.
C-8—Chopper condenser, UC-2226, .003 mfd.
C-9—P.A. grid condenser, UC-1811, .0003 mfd.
F-1—Plate fuse Cat. No. 230075, 2 amperes.
F-2—Receiver antenna fuse, Cat. No. 219075, 1/2 ampere.
K-1—Hand key, mesco No. 80.
K-2—Break-in relay (key relay) T-2617362, G-1.
L-1—Antenna variometer T-2854634, G-1.
L-2—P.A. grid leak choke P-2805438, G-2.
L-3—M.O. plate choke P-2805438, G-2.
L-4—M.O. variometer T-2854618, G-1.
R-1—P.A. grid resistance, QCK-1924014, 500 ohms.
R-3—M.O. grid resistance QCK-1924014, 7500 ohms.
R-4—P.A. feed resistance QCK-1924014, 150 ohms.
R-5—Filament rheostat, Cat. No. 1916233, 20 ohms.

R-6—M.O. parasitic resistor, QLK-2155993, 15 ohms.
R-7—Plate field rheostat, Cat. No. 1916249, 250 ohms.
R-8—Power amplifier parasitic resistor, QLK-2155993, 15 ohms.
R-9—Chopper resistor, QCK-1924023, 50 ohms.
R-10—Key relay resistor, QCK-1924014, 400 ohms.
S-1—Antenna inductance switch, T-2686071, G-2.
S-2—Start-stop switch, P-2873639, G-1.
S-3—Signal switch, P-2873639, G-2.
T-1—Antenna transformer, P-2873650, C-1.
T-2—Filament transformer, Y-1054, .125 K.V.A.
V-1—Filament voltmeter, 0–15 volts a.c.; type AO.
V-2—Plate voltmeter, 0–1500 volts d.c.; type DO.
Y-1—Chopper motor, model 28354, 1/50 H.P.
Y-2—Motor generator set, model 55-A-5.
Y-3—Motor starter, DL-1772869, G-10.

47. **Operation and Care of High Voltage Generator. Operation**—Before starting the generator for the first time:

1. See that the voltage on the generator name plate corresponds with the line voltage.
2. Check all connections to the generator with the wiring diagrams furnished with generator.
3. Make sure that the drain plugs are tight and that the bearings are properly lubricated.
4. If possible, turn the armature by hand to see that it rotates freely.

Before putting generator in service it is desirable to operate without load long enough to determine that there is no unusual localized heating and in order to check voltage, polarity, etc.

48. **Care**—High voltage generators are provided with enclosing covers to prevent coming in contact with the commutator or brush rigging of the machine. These covers, therefore, must not be removed or left off while the machine is in operation.

To insure the best operation, make systematic inspection *at least once a week*. Give the following points special attention.

49. **Cleanliness**—Keep both the interior and exterior of the generator free from water, oil, or dirt. Wipe the exterior and clear the interior with dry compressed air or a small bellows.

50. **Oil Ring Bearings**—Prevent excessive heating and wear of all bearings by proper lubrication, belt tension, and alignment. When bearings are unduly worn replace them.

Fill the oil wells with a good quality of clean, light mineral oil to the top of the oil fillers. Fill the oil wells through the oil fillers. To avoid incorrect oil level, never fill the oil wells when the generator is running. After the generator has operated the first week, draw off the oil, pour fresh oil or kerosene through the bearings to wash out all sediment. Then refill. Before replacing the drainage plugs dip them in a mixture of red lead and shellac, then replace and tighten securely to prevent leakage. Refill the bearing at regular intervals, the frequency depending upon local conditions, such as cleanliness, severity or continuity of service.

51. **Ball Bearings**—A light grease or non-fluid oil should be used on motors for speeds up to and including 1800 R.P.M. For speeds above 1800 R.P.M. use a light mineral oil.

52. **Grease Lubrication**—The factory packs these bearings with grease which under ordinary operating conditions should suffice for about three months of continuous service. Unscrew the drain plug and make sure that this grease has not been removed. A short time after the motor has been put into operation it is good practice to remove the bottom drain plug to see if the grease has turned dark or fluid. If so, wash out the bearings with kerosene and pack with new grease. If the grease is put in under pressure, leave the bottom plug out and stop filling when grease starts to come out of the bottom plug hole. Inspect the bearings occasionally.

53. **Oil Lubrication**—Fill the oil wells through the oil fillers with a good grade of light mineral oil (not vegetable or animal oil) to the top of the oil fillers. To avoid incorrect oil level never oil the motor when running. A short time after the motor has been put into operation it is good practice to draw off the oil and pour fresh oil or kerosene through the bearings to wash out all sediment. Then refill. Before replacing the drain plugs dip them in a mixture of red lead and shellac, and then replace and tighten them securely to prevent leakage. Refill the oil wells at regular intervals, the frequency depending upon the local conditions, such as severity or continuity of service, cleanliness, etc.

54. **Waste Packed Bearings**—Pack waste from bottom of oil well to top of the lining, using a blunt stick in order not to cut yarn nor mar the lining and shaft.

Saturate waste with oil before packing.

Remove the drain plug after packing and pour a liberal quantity of oil over the waste and lining, allowing the excess to drain away thoroughly before assembling the drain plug.

Replace the drain plug, slushing it with a mixture of 50 percent red lead and 50 percent shellac, so that it cannot leak.

Pour into the top of the bearing a quantity of oil sufficient to fill it.

Be careful not to spill any oil on the outside of the bearing housing.

Reassemble the cover and thoroughly wipe the exterior of the bearing housing.

Use a good grade of machine oil.

Remove drain plug in refilling bearings, allowing old oil to drain off; pick up and repack waste to prevent its becoming matted and refill as above.

Refill the bearing at the end of the first month of operation under ordinary conditions of service and every three months thereafter, or as experience dictates. At long intervals, it may be necessary to remove the waste entirely and to clean the bearing thoroughly, inspecting it as to necessity for renewal and repack with clean waste. Use a good grade of wool yarn waste in these bearings.

55. **Brushes**—See that the brushes move freely in the holders and at the same time make firm even contact with commutator. The pressure should be between 1¾ and 2 pounds per square inch. Keep an extra set of brushes on hand. Fit new brushes carefully to the commutator. The position of the brush yoke should not be changed on commutating pole generator in order to improve commutation.

56. **Commutator**—Keep the commutator clean and maintain its polished surface. Ordinarily the commutator will require only occasional wiping with a piece of canvas or other non-linting substance.

57. **Heating**—Do not depend on the hand to determine the temperature of generators; use a thermometer. If there is any doubt about the safe operating temperature, take the temperature of the windings and confer with the nearest office of the company. Give full details.

58. **Installation**—When possible install the generator in a place that is clean, dry, well ventilated, and accessible for inspection and care.

Rigidly support and level the base of the motor generator set, wedging if necessary to secure true alignment of units. Undue vibration and unsuccessful operation may result, unless these instructions are followed.

The operating brush position is indicated by paint marks, one on the brush yoke and one on the bearing housing.

In installing high voltage generators, it is, of course, necessary that connections made to the generator be properly insulated, both from each other and from possible contact by the operator with line circuits. All wiring should be carefully installed in accordance with National Electric Code and any local requirements.

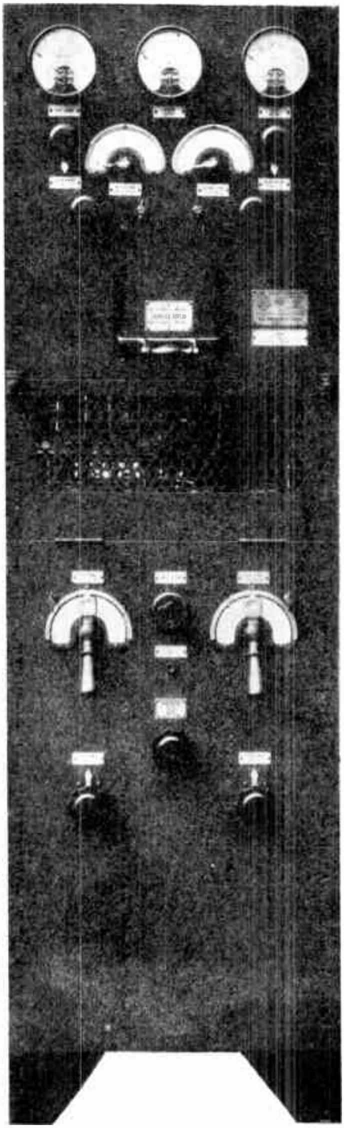


FIG. 190. Model ET-3626-A 500- to 750-Watt C.W.-I.C.W. Transmitter.

59. Model ET-3626-A 500- to 750-watt C.W., I.C.W. Transmitter—The complete equipment consists of three units:

(*A*) The radio panel.
(*B*) The motor generator set.
(*C*) The operator's control unit.

All units are ruggedly built to stand hard continuous service. Two wavelength ranges are provided, the lower one 600 to 1250 meters (500 to 240 KC.) where an output of 500 to 750 watts C.W. and I.C.W. is available; and the upper range of 1250 to 2500 meters (240 to 120 KC.) with an output of 500 watts C.W. I.C.W. operation is obtained by a motor-driven commutator which gives the transmission a characteristic 500-cycle tone. Telephoning may be obtained by addition of telephone attachment AT-829. The circuit is of the master oscillator-power amplifier type using two model UV-211 Radiotrons in parallel as master oscillators or exciters, and six model UV-211 Radiotrons as power amplifiers. Keying is uniwave and is effected through the keying relay which controls the grid circuit stopping the oscillation and applying 250 volts negative bias to both exciter and amplifier tubes insuring continued blocking while the keying is up. Additional contacts of the keying relay connect the antenna to the receiving set when the key is up, thus giving break-in operation.

Mistuning or detuning of the antenna does not harm or overload the vacuum tubes. The tuning operation is extremely simple. The set may be tuned to any wavelength within its range in 10 seconds and all adjustments locked in position. Harmonic radiation is negligible.

The front of the set is covered by brass panels finished black, upon which are mounted the following instruments and controls:

Antenna ammeter.
Plate ammeter.
Plate voltmeter.
Shortwave antenna variometer control with pointer scale and lock.
Shortwave antenna range switch.
Longwave antenna variometer control with pointer scale and lock.
Longwave antenna range switch.
Transfer switch handle, longwave-shortwave.
Shortwave exciter, wavelength control with pointer scale and lock.
Shortwave exciter range switch.
Longwave exciter, wavelength control with pointer scale and lock.
Longwave exciter range switch.
Signal switch, C.W.-I.C.W.
Generator field rheostat.
Test push button.

About midway of the panel, a hinged door covered with perforated metal allows access to the tubes for replacement and observation of the tubes during operation of the set. The lower half of the sides and back of the set are screened with perforated metal. A hinged door in the screen at the lower right hand side gives access to the terminal board, keying relay and motor starter.

Referring to the circuit diagram, it will be seen that all leads from the power supply mains, the motor generator set and operator's control panel and telegraph key are connected to the terminal board at the lower right hand side of the set. The positive 1000-volt lead from the generator connects to a 6-mfd. condenser and then through radio frequency choke coils to the exciter tube plates, and also through the long- or shortwave coupling transformer to the amplifier tube plates. The 77-volt, 60-cycle filament supply comes from slip rings on the motor of the MG set through fuses on the terminal board, and through a rheostat and a step-down transformer to the tube filaments. The keying break-in relay is operated by power from the 110-volt d.c. supply through a resistor and the operator's key.

The eight UV-211 vacuum tubes are placed in a spring-suspended socket assembly. Looking at the radio panel from the

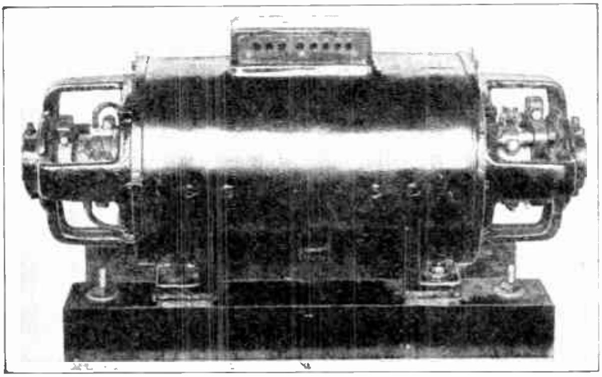


FIG. 191. Motor Generator for Plate Supply of 1000 Volts to Model ET-3626-A Transmitter.

front, and left hand tubes, front and rear, are used as the master oscillator, or exciter, and the remaining six tubes as power amplifiers operating in parallel.[3]

Two entirely separate exciter and antenna tuning circuits are provided, one for the 600–1250 meter range and the other for the 1250–2500 meter range. The transfer switch makes the proper connections between the tubes and the longwave circuits when thrown up and the shortwave circuits when thrown down. Both these ranges are divided into two parts, one from 600 to 900 meters and the other from 900 to 1250 meters for the shortwave, and 1250 to 1800 and 1800 to 2500 meters for the longwave. The range switches provide quick change from one to the other.

The shortwave exciter circuit consists of a variometer placed on the left side of the set just below the tubes with its handle on the front of the panel with appropriate wavelength scales and locking device. The usual oscillating circuit, plate and grid coupling condensers and grid leaks are provided. Four adjustable cams are

[3] In the first transmitter of this type known as model ET-3626 only one tube is used as a master oscillator and six as power amplifiers. One tube is used as a rectifier to provide a negative bias for the grids of the oscillator and power amplifiers. The grid and plate of the rectifier tube are connected together.

also provided on the variometer shaft and these may be set to hold the variometer at four different wavelength points. The variometer may, however, be locked at any wavelength within its range. The longwave exciter is of similar design, and is mounted on the right hand side of the set.

The amplifier tubes deliver their output to the antenna through coupling transformers, so designed that when the antenna circuit is not in tune with the exciter, the tubes are not overloaded, the plate current in fact being considerably less than when the antenna is in tune. These coupling transformers are located slightly above and behind the tubes, the longwave on the left side and the shortwave on the right side of the set. These are adjusted for best operation when the set is installed.

The antenna circuit is tuned by variometer, one for the shortwave range, near the top of the panel at the left, and another for the longwave range at the back of the frame on the right. These are controlled by large knobs, back geared five to one to the variometer shaft. Pointers and scales above the knobs show the position of the variometer rotors which may be clamped in any position. The antenna terminal is at the top of the set.

In case it is desired to transmit I.C.W. or modulated wave signals, a motor-driven commutator is provided which changes the tube grid bias at a 500-cycle rate and hence gives the set an output having a characteristic spark tone. This may be used on the shortwave range, and is brought into action by operating C.W.-I.C.W. switch on the front of the panel. The antenna meter will read somewhat less than when C.W. is used.

Keying is accomplished through the keying relay on the terminal board. This relay is provided with the necessary additional contacts to give break-in operation, connecting the receiving set to the antenna when the key is up and short-circuiting the receiver when the key is down. A separate receiving antenna may be used if desired.

The motor generator set (d.c. power supply) is a two-bearing unit 31⅛ inches by 10⅝ inches, weighing 550 pounds. The motor is a 3 H.P. four-pole, compound wound for 100 to 125 volts, and is provided with two slip rings from which 77-volt, 60-cycle, single-phase power is supplied to the radio set for filament heating. The generator is a two-pole shunt-wound machine giving a d.c. potential of 1000 volts. The speed of the machine is 1750 R.P.M.

The operator's control unit consists of a metal box 14½ inches high, 9 inches wide, 8 inches deep in which are mounted the filament rheostat, filament voltmeter, and the motor generator set start and stop push buttons. The motor generator set starter and control buttons are of the momentary contact type giving "No voltage" protection. Additional start and stop push buttons may be installed if desired. The control unit may be attached to the operator's desk on the bulkhead behind the desk.

60. Method of Installing—The radio panel should be securely fastened to the deck or floor through holes provided inside the angle iron legs. The operator's control unit should be fastened to the bulkhead or wall behind the operator's desk or in the desk within easy reach of the operator. The motor generator set should be securely fastened to the deck or floor in the radio room, or it may be placed in the engine room or other suitable location outside the radio room. The line of the shaft of the motor generator set should be fore and aft if possible rather than athwartship.

All wiring between units should be in conduit or lead-covered wire or cable.

The feed wires carrying the main d.c. supply should be No. 8 of larger. The motor armature leads marked *A*1 and *S*2 should also be No. 8 wire. All other external connections should be run with No. 12 wire. The leads carrying the plate supply from the high voltage generator should be insulated for 2500 volts.

When one antenna is used for both transmitting and receiving, the links on the terminal board of the transmitter should connect the post marked "GND 2" to "RG." When a separate receiving antenna is used, the links should connect "GND 1" to "GND 2" and "GND 2" to "RG." The separate receiving antenna should then be connected to post "A." In either case the antenna and ground posts on the receiver connect to the posts marked "RA" and "RG" respectively on the terminal board of the transmitter. The antenna and ground wires from the transmitter and receiver should be No. 14 rubber-covered and should be separated from one another several inches. The antenna wire to the receiver should also be kept away from all other wires at ground potential. When practicable this wire should be carried on porcelain cleats. When the break-in system is used with only one antenna, the post marked "GND 1" *must not be grounded* as to do so would short-circuit the leads to the receiver.

61. Explanation of Theory of Operation—In figure 192 are shown the schematic connections of the circuits involving the generating of oscillations, amplification and transfer to the antenna. The power, control, and protective circuits are omitted as they are not involved in the explanation. Since the circuits for the two wavelength bands are the same, figure 192 shows only one coil system.

The master oscillator, consisting of two tubes, uses the "split inductance" or "Hartley" method of feed-back to produce

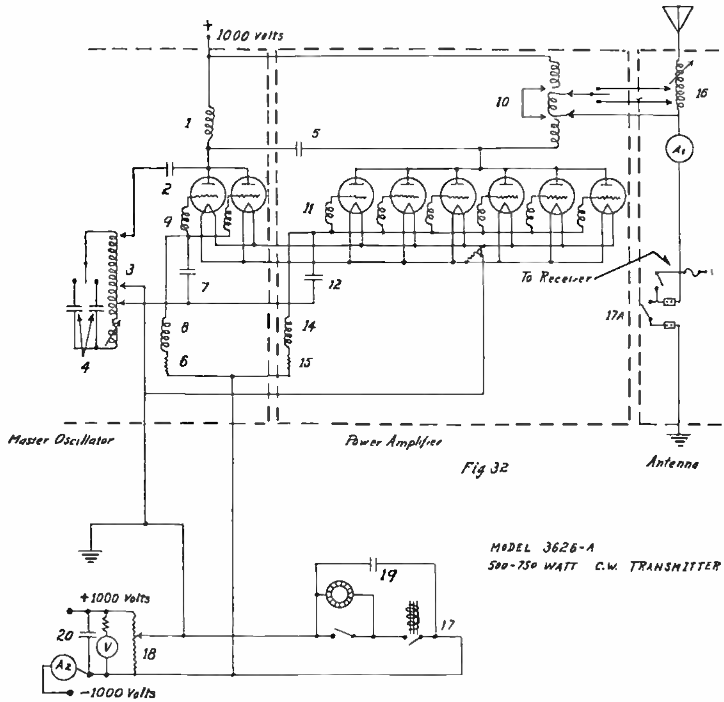


FIG. 192. Schematic Diagram of Model ET-3626-A Transmitter.

oscillations. The high voltage is fed to the plate through a choke coil (1) and the blocking condenser (2) separates the d.c. from the oscillating circuit. The oscillating circuit consists of the variable inductance (3) and the fixed condenser (4). The plate, grid, and filament taps have been set to give that ratio of plate to grid voltage which will give good efficiency and stable operation. It is not necessary to change these taps with change of wavelength since the inductance is varied by the revolving coil in such a manner as to maintain *the ratio* of plate to grid voltage constant. The neutralizing condenser (5) *prevents reaction* of the amplifier on the master oscillator due to the internal capacity of the amplifier tubes.

The correct grid bias voltage is maintained when oscillating by the resistor (6), the blocking condenser (7) separating the d.c. current of the grid from the oscillating circuit. The choke (8) separates the radio frequency of the grid from the keying circuit. The choke (9) is to prevent oscillations of very short wavelength from starting.

The power amplifier consisting of six tubes has the energy fed through the plate winding of the air core transformer (10) from the 1000-volt d.c. supply, thus eliminating the need for a plate choke and blocking condenser as was used for the master oscillator. The power amplifier grids have each a choke (11) which has the same function as (9) in the master oscillator grid circuit. The grids receive their excitation from an adjustable point on the inductance of the master oscillator. The condenser (12) blocks the d.c. bias voltage and the inductance (14) separates the radio frequency of the grid from the keying circuit. The correct grid bias voltage is maintained when oscillating by the resistor (15).

The antenna tuning is controlled by the variometer (16). The amount of power delivered to the antenna at a given plate voltage is varied by the ratio of turns in the transformer (10). Thus with a given setting or number of turns in the primary or plate coil the power is increased by increasing the secondary or antenna turns. Or if the antenna turns are not changed, the power can be increased by decreasing the number of primary turns.

The keying relay (17) is controlled by the hand key obtaining its current from the d.c. supply.

The keying relay has auxiliary contacts shown at (17A) which close preceding the closing of the grid circuit contacts and open after the opening of the grid circuit contacts, thus providing "break-in" operation. The opening of the keying contacts forces the plate current to pass through part of the resistor (18). It will be noted that the tapped point of this resistor is grounded and not the negative side of the 1000-volt plate supply. Since the grid return is connected to the 1000-volt and the filament and ground are connected to the tapped point on (18), any current flowing in (18) causes a bias in the grid. Therefore, when the key is opened a large negative bias stops oscillation due to the total plate current flowing and subsequently a holding bias exists due to the smaller current maintained through the resistance (18) by the generator.

62. Adjustments After Installing—Caution:—*The generator* *plate voltage is in the tube plates at all times when the motor generator set is running, even though the key is up. Do not change tubes or make adjustments with motor generator set running.*

Place two UV-211 tubes in the front and back left hand sockets. Turn filament and generator field rheostats to right to minimum voltage position. Start motor generator set and adjust filament voltage to 10 volts. The plate ammeter should read zero until the key is pressed when it should indicate roughly 1 ampere. The exciter should now be operating as indicated by a wavemeter brought near the proper exciter variometer. The transfer switch should be thrown up for the longwave range and down for the shortwave range.

The exciter coil taps are adjusted at the factory. A sample list of settings is given. This list applies to one particular set only, and is given merely to serve as the basis for further adjustment in case the leads have come off in transit.

Tap marked	Short wave coil Number turns	Long wave coil Number turns
Grid	27	51
Ground	21	34
Neut. condenser	18	27
W. L.	12	15
Plate (bottom turn)	0 (bottom turn)	0

(Turns counted from bottom of coil up)

Adjustment of Antenna Coupling Transformers—Shut down motor generator and place six UV-211 tubes in the six remaining sockets. Throw transfer switch to shortwave and adjust exciter variometer to approximately 600 meters. Start motor generator set and adjust filament to 10 volts and plate voltage to 800 volts. Press key. Plate ammeter should indicate less than 1 ampere. Holding down key or test button, adjust short wave antenna tuner until the antenna ammeter indicates a maximum current. Note tube plate temperature and if not over cherry red increase plate potential to 1000 volts. Plate meter should indicate 1.2 to 1.4 amperes. If plate current is low use less turns in primary of coupling transformer; if high, more turns. Maximum primary turns are obtained on the shortwave transformer by connecting jumper between binding posts or transformer marked 1 and 5. Minimum primary turns are obtained with jumper between posts 3 and 7 and an intermediate number of turns with jumper between 2 and 6. A fine adjustment between taps may be had by sliding the primary (outside) coils away from the antenna coil for less plate current or toward it for more plate current. The coils should be kept as close together as practicable however.

63. Adjustment of Longwave Coupling Transformer—The transformer for the longwave band is provided with taps on both primary and secondary windings. The same theory of operation applies here as for the shortwave band. It is desirable to keep the primary inductance as high as possible to protect the tubes when the antenna is detuned. Therefore, begin adjusting set with all the primary turns in circuit, and a minimum of the secondary. If the input and output is low, increase the number of turns in the secondary. If it is still low when all the secondary has been cut in, reduce the turns in the primary to the next tap, and adjust secondary turns as described above. Repeat this procedure until a satisfactory adjustment is obtained.

After obtaining a satisfactory adjustment of the coupling transformers of one particular wavelength in each band, check same by testing over the range.

Test chopper operation on shortwave range. Both the plate and antenna current will be somewhat lower than when straight C.W. is used.

With an antenna having a capacity of .001 mfd. and a resistance of 6 ohms the antenna current will be approximately 10 amperes for the shortwave range and 9 amperes for the longwave range C.W. with lower current for I.C.W.

64. Break-in Relay—A relay is provided to accomplish keying with " break-in " feature. The keying contacts open and close the grid circuit while the break-in contacts open and close the loop to the receiver. It is desired to have the break-in contacts close before the keying contacts close. It is also desired to have the break-in contacts open after the keying contacts open. The above operation is accomplished by the adjustments provided.

65. Wavelength Position Devices—Each exciter variometer is provided with four adjustable cams mounted on the variometer shafts immediately back of the front panel. These cams may be adjusted with a suitable socket wrench so that one of the rollers will fall into the slot in one of the cams at any four wavelength adjustments for which they may be set.

66. Operation—The operation of the model ET-3626-A transmitter is extremely simple. To time the set proceed as follows:

Turn generator field rheostat and filament rheostat to the right to their lowest voltage positions.

Close main line switch, if it has been opened, and press " start " button on operator's control unit. The motor generator should start and come up to speed immediately.

Adjust the filament voltage to 10 volts by means of the filament rheostat and voltmeter on the operator's control unit.

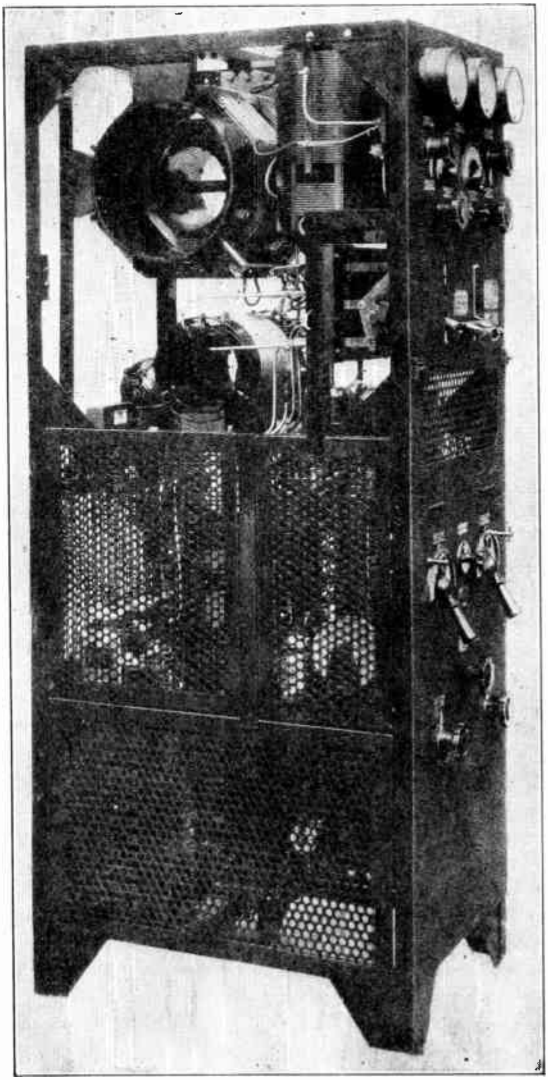


FIG. 193. Side View of Model ET-3626-A 500- to 750-Watt Transmitter.

Adjust the plate voltage to 1000 volts by means of the generator field rheostat and voltmeter on the radio panel.

Throw transfer switch up if it is desired to use wavelengths between 1250 and 2500 meters or down for wavelengths between 600 and 1250 meters. Set exciter tuning and range switch (left hand for shortwave range, right hand for longwave range) to the wavelength desired. See that the C.W.-I.C.W. switch is in the C.W. position and then adjust the antenna tuning (left hand for shortwave range, right hand for longwave range) for a maximum antenna current as indicated on the antenna ammeter, while pressing the "test" push button. The "test" push button is in shunt to the hand key terminals and provides a means of closing the relay circuit while making adjustments at the transmitter panel. Having tuned the set as above, the telegraph key may be operated for the transmission of messages.

Press "stop" button to shut down motor generator set when transmission is completed.

It will be seen that the shortwave and longwave exciters have two wavelength calibrations. Turn range switch to conform to calibration used.

A chopper is provided for I.C.W. transmission on the 600–1250 meter ranges. To employ I.C.W. transmission, simply throw C.W.-I.C.W. switch to the I.C.W. position after tuning, as in paragraph 62 or 63. The chopper should start immediately if the motor generator set is running, after which the telegraph key is operated in the usual manner. Always tune set with switch in C.W. position.

67. Maintenance—The *motor generator* set is a two-bearing unit using ball bearings. Ball bearing motors and generators are assembled and shipped with sufficient grease for a limited period of operation. The Texas Oil Company's grease, marfak No. 3, or equivalent, is recommended. The grease must be of such a consistency as not to flow out of housing in hot weather nor become hard in cold weather. Avoid too much grease. The housing *must not be more than 2/3 full.* Once a year the grease should be removed and new grease supplied.

Caution:—*Do not clean commutators with machine running, as high voltage end is dangerous.*

Before replacing screens, start the radio set and hold down the key to see that there is no injurious sparking on the commutators. The motor end should show no sparking but the high voltage commutator may spark slightly under the brushes. If brushes are worn short, replace them. Do not use emery cloth on commutators.

If necessary to smooth down commutators, use nothing but No oo sand paper. *The field circuit of the generator must be opene* before dressing the generator commutator. The brushes are se in the neutral position at the factory and the bracket to which the are attached is dowelled in position. This adjustment should no be altered as it is correct for either direction of rotation.

The *operator's control unit* requires no attention except an occasional drop of oil on the rheostat bearing and contacts.

The *motor starter* is of the automatic push button control type and is located in the lower right hand side of the radio panel Pressing the start button on the radio panel should close the firs contactor on the starter panel and the motor generator set shoul start immediately. From one to two seconds later the runnin contactor should close and the motor generator set come up to ful speed. In from one to two seconds, therefore, after the "start" button has been pressed, the machine should be up to speed. Th plate voltmeter on the radio panel should indicate 600 to 100 volts depending upon the position of the generator field rheosta and filament voltmeter on the operator's control unit should rea not over 10.5 volts. The running contactor may have to be adjusted occasionally so that it closes in the time given above. Th running contactor is nearest to the front panel of set, and th acceleration is controlled by the vertical setscrew directly underneath the magnet coil. Screwing this screw upward accelerate the starter, and downward vice versa. Be sure to tighten th setscrew locknut after making adjustments.

68. **Radio Panel**—Great care must be exercised by the operator in keeping the entire transmitter thoroughly free from moisture and salt spray. Go over all units daily, using a clean dry rag Especial attention should be paid to sockets, transfer switch an other points where moisture or dust is likely to collect. A grea many breakdowns are directly traceable to high voltage creepag along a dust or damp path culminating in the complete breakdow of the affected unit, a condition which can be avoided by prope care of the apparatus.

Oil all moving parts, the exciter variometer bearings and cams the antenna voltmeter shaft bearings and gears, and the choppe motor regularly. The chopper motor is wick oiled from greas cups. Do not oil the chopper commutator *nor the micarta bearings of the variometers.*

If set does not operate properly as shown by low antenna current or excess heating of the vacuum tubes, examine set carefull for loose or broken connections.

Examine relay, making sure that the contacts make and break properly. If contacts are badly pitted, press together against a very fine file to clean or replace with new contacts. See that grid leak resistors fit tightly in their clips.

Make sure that no vacuum tube acts in a suspicious manner, such as flashing blue, or changes its filament temperature when the key is pressed. If possible put in an entirely new set of tubes, placing the old tubes back in the set immediately if the new ones cause no improvement.

See that there is no sparking about the set when key is operated.

69. **Troubles and Causes**—*Pressing start button does not start motor generator set.* Open main switch on starter panel or defective main fuse. No line voltage or line voltage too low. Line voltage may be tested by operating telegraph key which will cause relay to work if line voltage is on. Burned out starting coil. If open push in with block of wood or tie in.

Start button causes start contactor to close, but motor generator set does not start. Burned out starting resistor on back of starting panel. Connection between starting panel and motor generator set open. Frozen bearing on motor generator set due to lack of oil.

Starter and generator satisfactory as indicated by plate voltage on radio panel but tube filaments do not light. Defective filament fuse on terminal board, probably caused by a tube having its filament short-circuited. Loose connection on filament transformer or terminal board. Defective brush on motor slip rings.

Plate and filament voltages and tubes O.K. and relays operate, but pressing key or test push button causes no antenna current while tubes do not heat beyond a very dull red when key is pressed. Antenna circuit out of tune. Adjust antenna variometer for maximum antenna current. If still no antenna current, shift transfer switch to other wavelength range. If this operates in the same manner, the trouble is probably in the antenna circuit outside the set or with the antenna ammeter. If antenna ammeter is burned out a 40-watt, 110-volt lamp may be connected in antenna lead to resonate set and should be shorted out when ready to transmit. If the other wavelength range works normally, the trouble is in the antenna variometer or coupling transformer of the wavelength range that doesn't operate. Examine them for open or loose connections.

Set operates normally when key is down but tubes heat badly when key is up. Tubes are not blocking properly, may be due to low bias voltage caused by defective resistor (18) in figure 192. May also be due to an amplifier tube that is soft and partially short-circuits bias voltage. This tube will probably flash blue and show a higher heat than the other tubes.

Tubes heat badly as soon as key is pressed. Exciter tubes defective or exciter circuit not oscillating. A wavemeter placed in an inductive relation to master oscillator variometer should show deflection on current indicating device of wavemeter when in resonance with M.O. circuit. Change the tubes and examine circuit for loose connections. Remove all but front and back left hand tubes from their sockets. Exciter tubes will still heat badly when key is pressed if tube or circuit is defective.

Amplifier tubes heat excessively when key is down and antenna circuit is in tune. Defective coupling transformer or insufficient number of plate turns in use.

Chopper motor does not start when switch is turned to I.C.W. position and motor generator is running. Examine connections to motor and motor brushes. See that motor turns freely by hand.

Insufficient tubes. The set may be operated with three or four amplifier tubes in place of six if the full number is not available. With a reduced number of amplifier tubes in use the plate voltage should be decreased to prevent overheating of the plates of the tubes. The two left hand tubes being the exciter, one must always be used.

70. Emergency Measures for Apparatus Failure—(*a*) *Insulation Break-down.* Charring of insulation resulting in continued arcing over and burning. Cut away insulation if possible, otherwise cut winding and remove sufficient turns to clear. Before cutting wire at each end of turns to be removed, make fast the ends of the winding remaining by cord. Put in temporary jumper to close circuit. If insulation is at terminal blocks in switches and arcover cannot be stopped by cutting away insulation, remove connections and complete circuit by temporary jumper.

(*b*) *Master Oscillator Plate Choke Burn-out.* If failure is inside so that turns cannot be removed, take out choke, and substitute the grid choke, having placed a jumper in place of removed grid chokes. The master oscillator will operate under these conditions with somewhat reduced efficiency.

(*c*) *Plate or Grid Blocking Condenser Shorting.* Remove the defective condenser and substitute the tank condenser which is in the other wavelength band. The connections may be lengthened to reach the substitute condenser as temporarily mounted.

(*d*) *Filament Voltmeter Inoperative.* Reduce filament voltage until tubes begin to heat or antenna current drops rapidly. Then increase filament voltage slowly until tubes operate at normal temperature and antenna current is not rising rapidly.

(*e*) *Plate Ammeter or Voltmeter Inoperative.* Maintain generator field rheostat in usual position and operate with tube temperature normal.

If plate ammeter is not functioning and other adjustments are to be made, insert a 150-watt lamp in place of ammeter and do not exceed full brilliancy.

(*f*) *Antenna Ammeter Inoperative.* Adjust in accordance with tuning record card and observe plate ammeter for final resonance. A 40- or 50-watt tungsten lamp may be substituted in place of antenna ammeter and set adjusted to resonance with reduced plate voltage. After adjustments light can be shorted out by placing jumper around same and power increased.

(*g*) *Filament Transformer or Filament Rheostat Burned Out.* Disconnect filament transformer and rheostat and connect five cells in series of lead-acid storage battery direct to filament busses with leads to carry 30 amperes. The voltage of the battery is practically correct for the tube filaments without rheostat control.

(*h*) *Grid Leak Open.* The grid leak of the power amplifier may be replaced by a 40-watt, 110-volt tungsten lamp or in the event this burns too brilliantly a 60-watt lamp may be used, but not larger.

The grid leak of the master oscillator may be replaced by a resistance of 4,000 to 10,000 ohms. A column of water, 12 inches long, in a rubber hose plugged at each end and having wire electrodes will be satisfactory. If the resistance seems to be too high add a little salt or washing soda.

(*i*) *Tank Condenser Shorted or Overheating.* Replace defective condenser by similar one taken from other tank circuit.

71. **Spare Parts**—There is supplied with each set the following parts:

(*a*) 4 UV-211 tubes,
(*b*) 1 Plate choke,
(*c*) 1 Exciter grid leak,
(*d*) 1 Amplifier grid leak,
(*e*) 1 Set MG brushes,
(*f*) 1 Set chopper and motor brushes.

72. **Rating of Units**—Item numbers refer to schematic diagram.

1, 8, 14—400 turns Dulateral coil.
2, 7, 12—Model UC 1842 Faradon Condenser, .004 mfd. 5000 V, plate and grid blocking.

4, 7, 12—Model UC 2398 Faradon Condenser, .002 mfd. 5000 V, shortwave exciter.
4, 7, 12—Model UC 1837 Faradon Condenser, .004 mfd. 5000 V, longwave exciter.
5, 7, 12—Model UC 2326 Faradon Condenser, .00014 mfd. 6000 V; neutralizing.
6 —Exciter grid leak, Ward Leonard, 6 inches, 5000 ohm vitrohm, Westinghouse S, No. 389102.
15 —Amplifier grid leak, Ward Leonard, 5 inches, 100 ohm vitrohm, Westinghouse S, No. 389171.
A1 —Antenna Ammeter, 0–15 amperes, Westinghouse Type DX S, No. 301822.
A2 —Plate Ammeter, 0–5 amperes, Westinghouse Type DX S, No. 301805.
V —Plate Voltmeter, 0–1500 volts; Westinghouse Type DX special filament voltmeter, 0–15 volts, Westinghouse Type DY S, No. 420498.
17 —Leach Break-in Relay, Model 18, Type S 3.
18 —Potentiometer, two 20,000 ohm resistors, STY No. 324410.
19 —Model UC-2210, Faradon Condenser, 1 mfd. 7502 Chopper Condenser.
20 —Condenser type LD 6 mfd.; 1700 volts.
—UV-211 Radiotron.

The UV-211 Radiotrons used in this transmitter are provided with an X-L or thoriated filament and the same care should be exercised in operating the same as described in the operation of the model ET-3630 transmitter.

Transmitting Tube Data

Manufacturer	Type Number	Signal Corps Number	Navy Number	Rating (Watts)	Safe Continuous Plate Dissipation (Watts)	Filament Volts	Filament Amperes	Type of Filament	Plate Volts	Plate Current (Milliamps.)
General Elec. Co. (RCA)	UV-202	—	—	5	12.5	7.5	2.35	Tungsten	350	50
	UV-203	—	—	50	100	10.0	6.5	Tungsten	1,000	150
	UV-203A	—	—	50	100	10.0	3.25	XL-Tungsten	1,000	140
	UV-204	VT-8	CG-1860	250	250	11.0	14.75	Tungsten	2,000	250
	UV-204A	VT-22	—	250	250	11.0	3.85	XL-Tungsten	2,000	250
	UV-205	VT-10	CG-916	250	250	20.0	3.85	XL-Tungsten	2,000	250
	UV-206	—	—	1,000	350	11.0	14.75	Tungsten	10,000	40
	UV-207	—	CG-1971	20,000	10,000	22.0	52.0	Tungsten	15,000	1.7 amp.
	UV-208	—	CG-1353	5,000	1,500	22.0	24.5	Tungsten	15,000	225
	UX-210	—	—	7.5	—	7.5	1.25	XL-Tungsten	350	50
	UV-211	—	—	50	100	10.0	3.25	XL-Tungsten	1,000	100
	UV-851	—	—	1,000	—	11.0	15.0	—	2,000	—
	UX-852	—	—	75	100	10.0	3.25	XL-Tungsten	2,000–3,000	75
Western Electric	220-B (water cooled)	—	—	10,000	10,000	22.0	42.0	—	10,000	650 to 1,500
	212-D	—	—	250	—	14.0	6.0	Oxide	1,500	175
	211-D	—	—	50	65	10.0	3.0	Oxide	750 to 1,000	65
	205-D	—	—	5	—	7.0	1.35	Oxide	350	40
	215-A (peanut)	—	—	—	—	1.25	—	Oxide	22½ det. 45 amp.	1 to 3
	222-A Rectifier	—	—	5,000 to 10,000	—	21.0	—	—	9,500 to 10,500	500 max.
DeForest	H	—	—	60 to 100	—	10.0	2.35	—	500 to 3,000	40–50

CHAPTER 9

RADIO BROADCASTING EQUIPMENT

1. **Introduction**—Radiophone stations differ in practically every way from those stations designed for radio telegraphy. Their equipment is different, and their operation is different. Instead of being concerned with the handling of messages through static and interference the radiophone station operator is usually engaged in the broadcasting of entertainment or educational material. The wires leading to his station are telephone wires, not telegraph, and at the other end there is a microphone and an amplifier instead of a key.

Since the whole thing is thus highly specialized it is not possible to describe all the possible makes and types of equipment—nor even the ways in which it may be used. It has therefore been thought wise to choose one example of the most generally used equipment (Western Electric) and to describe this type in such minute detail as to permit a good understanding of the station to be obtained. This description is taken almost without alteration from the maker's book of instruction. The type number of all apparatus and the peculiar language of the art have been left in the text so that one may have a better opportunity to read one's way into the current practice.

One must, however, not assume that this description represents the sum total of modern radiophone practice. There are additional types of Western Electric equipment; also there are other makes such as General Electric, Westinghouse (under their own name or that of the R.C.A.), Telefunken and others.

2. **The 104-A-5 KW. Western Electric Equipment**[1]—This equipment consists of a D-77964 Radio Transmitting Equipment, a 1-D Speech Input Equipment and a 6004-C Radio Receiving Outfit (described in Chapter 12). The entire equipment is arranged to operate from a primary power supply of three-phase, 220 volts, 60 cycles.

3. **Description of Transmitter and Function of Circuits**—The D-77964 Radio Transmitting Equipment consists essentially of a radio frequency oscillator, means for modulating this oscillator

[1] The converted transmitter with master oscillator and frequency stabilizer is taken up briefly in the concluding paragraphs of this chapter.

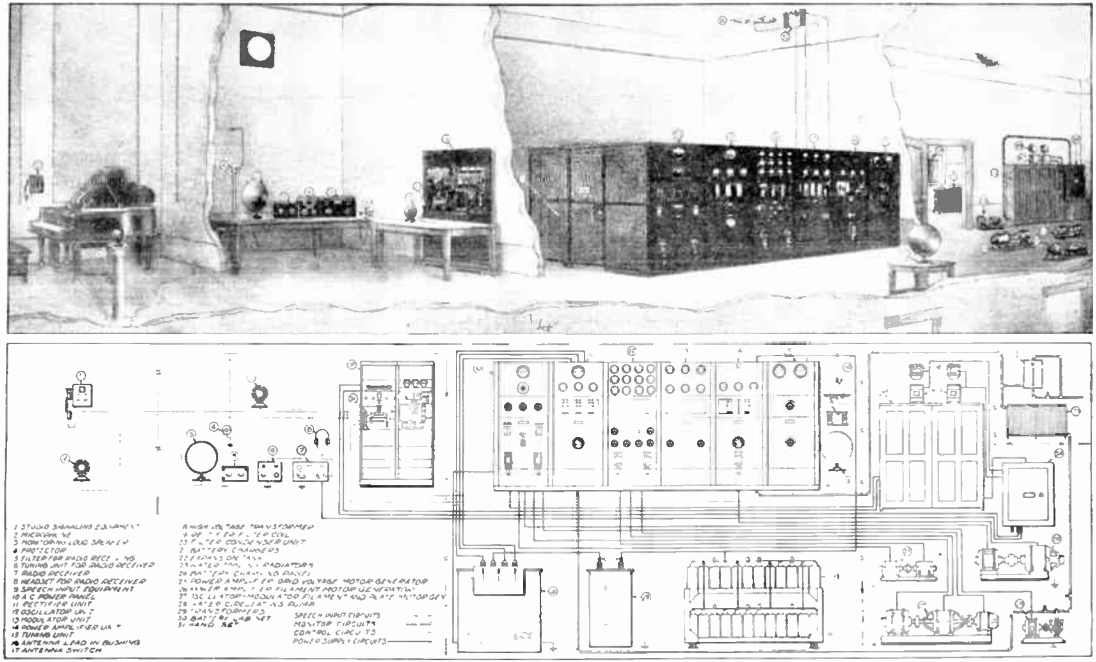


Fig. 194. Western Electric 104-B 5-KW. Radiotelephone Broadcasting Equipment.

with audio frequencies, a power amplifier for amplifying the modulated radio frequency, tuned circuits for transferring the output from the power amplifier to the antenna, and the necessary apparatus and circuits for power supply.

This equipment except for the larger pieces of apparatus, such as power transformers, filter equipment and rotating machinery, is mounted in several panel units according to its function. The panel units are lined up side by side to form the front of the assembly. The transformer and filter equipment is mounted on the floor behind the panel units and wire mesh fence with a gate which encloses the assembly. A water pump and radiators form a water system for cooling the larger power tubes. The pumps and three motor generators are installed in a separate room.

This radio transmitter operates entirely from three-phase 6c cycles 220-volt supply and requires approximately 25 KW. at a power factor of about 80 per cent. The supply is connected di- rectly to the main power switch on the a.c. power panel and fron there it is fused and distributed to the various circuits.

4. **Motor Circuits**—The four motors are started together b the operation of a motor magnetic switch. This switch operate automatically when the set is started as will be described later Motor supply fuses protect the branch circuit and motor protectio fuses protect the four motors separately. (See figure 195.)

5. **Transformer Primary Supply**—The transformers for sup plying plate and filament power to the rectifier unit are operate with primaries in parallel from the 220-volt three-phase suppl through the rectifier magnetic switch. This branch circuit is pro tected by rectifier power supply fuses and each transformer has it individual protection.

The high voltage transformer is mounted directly behind th a.c. power panel. Its primary is connected for three-phase delt operation with taps on one end of each coil for ± 5 percent lin voltage variations and taps on the other ends for secondary vol age control. The voltage variation taps are brought out to te minals on the back of the slate panel and should be connected a cording to the line voltage. Taps 2, 8 and 14 are used for a no mal voltage of 220 volts, taps 1, 7 and 13 are used for voltag 5 percent high and taps 3, 9 and 15 are used for voltage 5 perce low. Primary overload relay current transformers are connect in two of the primary supply leads and operate relays to prote the high voltage transformer from overloads. The high volta transformer disconnect switch is inserted in the primary supp to the transformer and is to be opened as a safety switch to insu keeping voltage off the transformer whenever the gate of the enclosure is open or whenever anyone is working inside the enclosure.

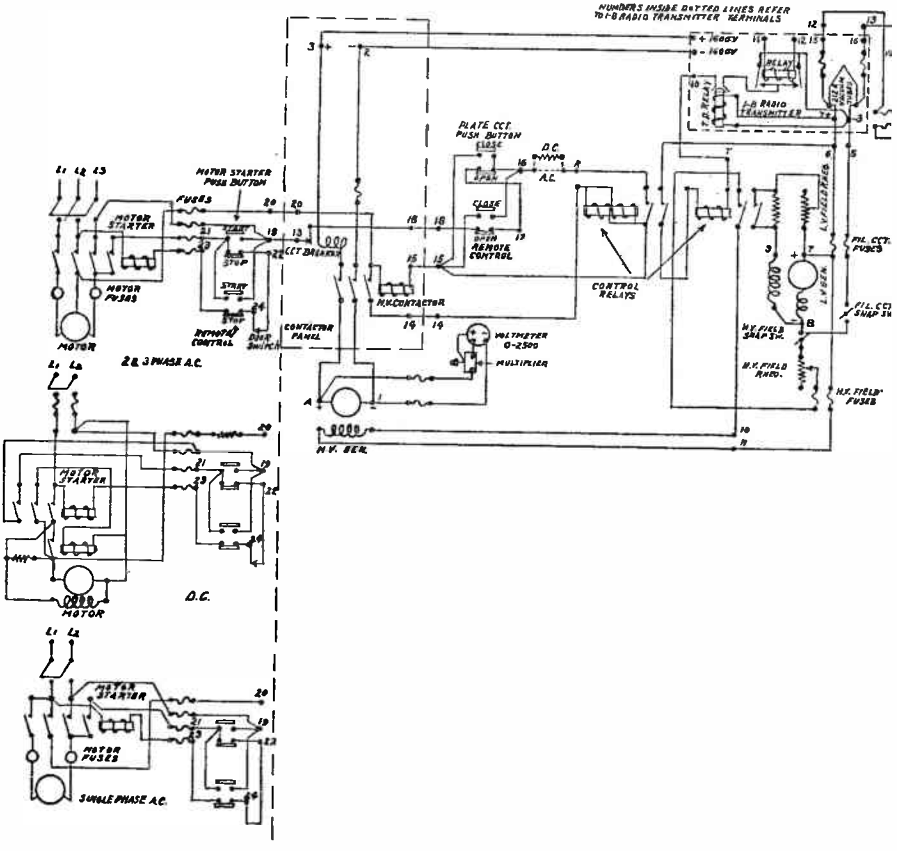


FIG. 195. Schematic of Radio Power Panel.

Three filament transformers $T1$, $T2$ and $T3$, shown in figure 196, are operated each from one phase of the three-phase supply. Taps are provided on these transformers for $\pm$ 5 percent voltage variation and brought out to a panel on the back of the rectifier unit. The connecting strap should be connected to the middle

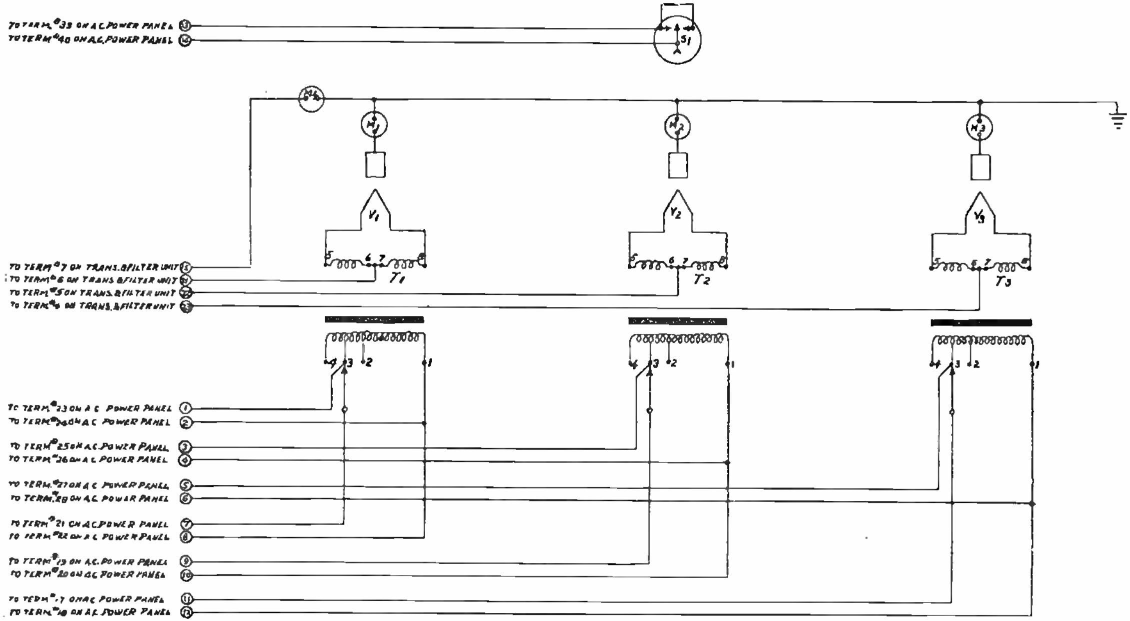


FIG. 196. Rectifier Schematic Diagram.

point marked "Normal Voltage" for a line voltage of 220, to the point marked " + 5 percent for a high voltage and to the point marked " — 5 percent for a low voltage. The three transformers get their primary supply through the rectifier filament transformer fuses on the a.c. power panel.

6. Starting Relay Circuits—The radio transmitter equipment is designed to be controlled remotely from the speech input equipment or locally from a push button on the a.c. power panel through a system of relays. The relays used to operate a.c. circuits are mounted on the a.c. power panel. Their circuits are shown in figure 197. The sequence of operation of starting is as follows:

The main power disconnect switch *D*4 must be closed for operation. The set is then started by pushing the top button of the master control push button switch *D*3. This closes the battery circuit from the speech input equipment through master control relay *S*5 operating that relay. Relay *S*5 locks itself up through one of its contacts and can only be released by pushing the lower button of *D*3 which opens the relay circuit. The second contact of *S*5 closes the circuit from the main control circuit fuse *F*12 to the bus feeding fuses, *F*1, *F*2, *F*3 and *F*4.

Fuses *F*4 supply power to operate the motor magnetic switch *S*8 which starts all of the motors together.

Fuses *F*3 supply power to operate the relays on the d.c. power panel controlling the d.c. power supply. These circuits will be taken up under d.c. supply circuits later.

Fuses *F*2 supply power to operate the rectifier magnetic switch *S*9 through a number of relay contacts which prevent *S*9 from operating to energize the 10,000-volt rectifier until the power amplifier circuits and water cooling system are in proper working condition. These protective relays are the grid voltage relay *S*3 on the d.c. power panel which is operated from the 250-volt grid voltage generator, the 10,000-volt time delay relay *S*5 on the d.c. power panel which operates in parallel with the 22-volt amplifier filaments and is adjusted for 15 seconds time delay to be sure the amplifier filaments are heated before the rectified 10,000 volts is on, and the rectifier control relay *S* on the a.c. power panel which cannot be operated unless the water pressure and temperature are normal.

Fuses *F*1 supply power to operate relays *S*1, *S*2, *S*3 and *S*4 on the a.c. power panel in the following manner: When the voltage is placed on *F*1 by the operation of relay *S*5 the water protection relay *S*3 operates immediately provided its winding is not shorted

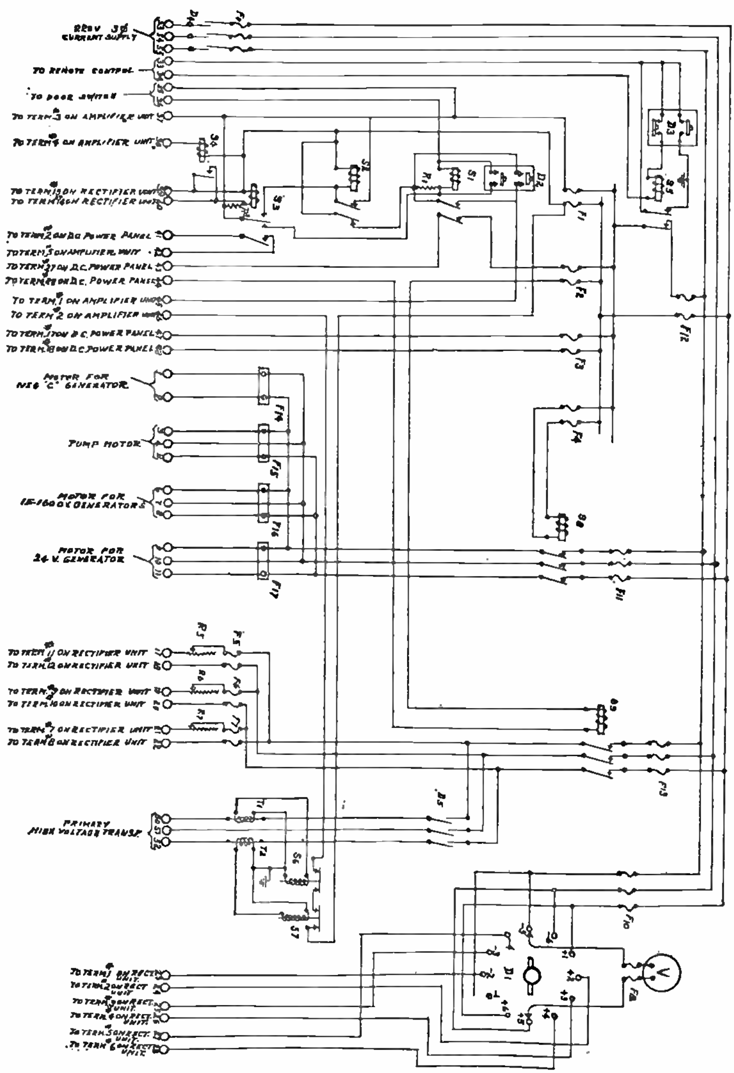


Fig. 197. Schematic of A.C. Power Panel.

by the contacts of the temperature protection relay *S4*, or the contacts of the contact making pressure indicator *S1* on the rectifier unit. This relay *S3* does three things: First, it opens a short circuit on the relay winding of *S1* second, it closes the field circuit of the 220-volt generator, and third, it closes a circuit to operate the slow acting relay *S2*. Relay *S2* which is made slow acting by means of the weight on its armature locks itself up by one of its contacts. It carries a back contact which remains in contact long enough after the relay is energized to allow the rectifier control relay *S1* to operate and lock itself up. Relay *S1* operates and locks itself up in series with a door switch, contacts of the primary overload relays *S6* and *S7*, on the a.c. power panel, and contacts on the plate overload relay *S1*, on the amplifier unit.

The second contact on relay *S1* closes the circuit to the rectifier magnetic switch *S9* provided the grid voltage relay *S3* and the 10,000-volt time delay relay *S5* on the d.c. power panel are operated. The operation of *S9* supplies filament and plate voltage to the rectifier.

Rectifier control push button *D2* is provided for starting and stopping the rectifier without stopping the rotating machinery. The rectifier is stopped by pushing the lower button of *D2*, thus short-circuiting relay *S*, causing it to fall back unlocking itself, and opening the circuit to *S9* which opens the power supply to the rectifier after the rectifier has been stopped by pushing the lower button or by one of the protective circuits described in the next paragraph. It can again be started after normal conditions are established in the protective circuits by pushing the upper button of switch *D2*. This closes the operating circuit for relay *S1*, and causes it to operate and lock itself up as well as to close the circuit to relay *S9* supplying power to the rectifier.

The relay circuits are arranged to shut off the rectifier in case the door of the enclosure is open or in case of an overload on the high voltage transformer or the amplifier plate or in case of failure of the water supply, negative grid voltage, or amplifier filament voltage. A door switch opens the winding of the rectifier control relay *S1*, when the door is open. An overload on the primary of the high voltage transformer operates primary overload relay *S6* or *S7* through primary overload current transformer *T1* or *T2* to open the holding circuit of relay *S*, causing *S1* to release and shut off the rectifier. An overload on the amplifier plate will operate plate overload relay *S1* on the amplifier unit which will open the holding circuit of the rectifier control relay with the same result. If the 250-volt generator does not build up or if its voltage fails, grid voltage relay *S*3 on the d.c. power panel will not pull up, thus leaving a break in the winding circuit of the rectifier magnetic switch *S*9 so that *S*9 remains open and the rectifier is off. A failure of the amplifier filament voltage will cause the 10,000-volt time delay relay *S*5 on the d.c. power panel to remain unoperated, thus allowing its contacts to remain open and the rectifier magnetic switch *S*9 to be open. This relay is timed to operate and close the circuit turning on the rectifier 15 seconds after the 22-volt filaments are lighted in order that the plate voltage will not be on the amplifier tubes until after the filaments are lighted. Relay series resistances *R*1 and *R*3 are connected in series with relays *S*1 and *S*3 so that the relays may be short-circuited without the flow of current becoming excessive.

7. **Voltmeter Circuits**—A.c. voltmeter *V*1 on the a.c. power panel (see figure 197) is provided with voltmeter switch *D*1 to measure the line voltage on each phase and to measure the voltage across fixed points on the rectifier filament lighting transformers *T*1, *T*2 and *T*3 of the rectifier unit. A.c. voltmeter fuses *F*8 are connected in the line between the voltmeter and the switch to protect the wiring. Voltmeter line fuses *F*10 protect the wiring from the voltmeter switch to the main supply leads where the line voltage is measured. The rectifier filament voltages are measured at fixed points on the rectifier filament transformers in the rectifier unit by means of separate lines from these points through the interconnecting cables to the voltmeter switch. The voltage between these fixed points should be 200 when the voltage across the rectifier tube filament is normal at 21.

8. **D.c. Power Supply Circuits**—The d.c. power supply circuits and apparatus are located as far as possible on the d.c. power panel. They control the filament, plate and grid supply for the oscillator modulator tubes and the power amplifier tubes.

9. **14-Volt Generator**—The 14-volt generator is used to light the filaments of the oscillator modulator tubes and the monitoring rectifier tube in the tuning unit. It is a shunt-wound generator controlled by rheostat *R*9 on the d.c. power panel. Figure 198 shows a simplified diagram of connections. The 14-volt field compensating resistor *R*1 is connected in series with the field resistor *R*9 and arranged to be short-circuited when relay *S*2 operates to close the field circuit of the 1500-volt generator. Short-circuiting *R*1 compensates for the extra load taken by the 1500-volt field. The armature is protected by fuses *F*5 on the d.c. power panel which fuses also protect the load of four 212-D tubes and one 211-D tube in the oscillator modulator unit. The circuit fused

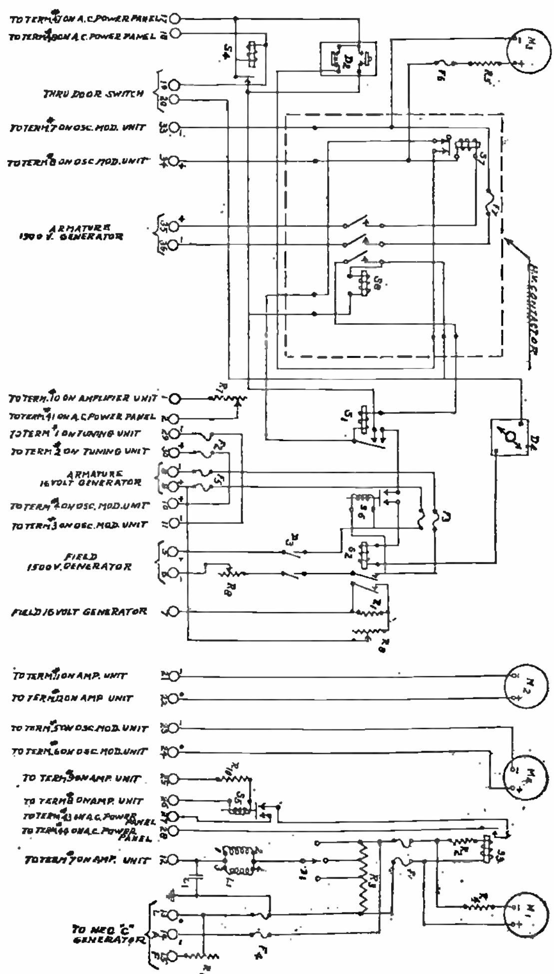


FIG. 198. Schematic of D.C. Power Panel.

by fuses $F2$ supplies filament current for the monitoring rectifier tube in the tuning unit. The other branch circuit protected by fuses $F3$ supplies the separately excited 1500-volt generator field through contacts of the 1500-volt generator field circuit relay $S2$, the field disconnect switch $D3$ and field rheostat $R8$. Relay $S6$ is connected directly across the 1500-volt generator field fuses $F3$ and operates to close the control circuit of the 1500-volt generator field circuit relay $S2$. It is adjusted to close the contacts 20 seconds after the voltage is on, thus requiring that the oscillator modulator tube filaments are lighted 20 seconds before the 1500-volt plate supply is applied.

10. 1500-Volt Generator—The 1500-volt generator is used for plate supply to the oscillator modulator tubes. It is separately excited from the 14-volt generator. Its field circuit was fully described as a branch of the armature circuit of the 14-volt generator. Its armature circuit is operated at 1500 volts with the negative lead grounded through one contact of the 1500-volt armature magnetic switch $S8$ and fuse $F7$. The positive lead goes

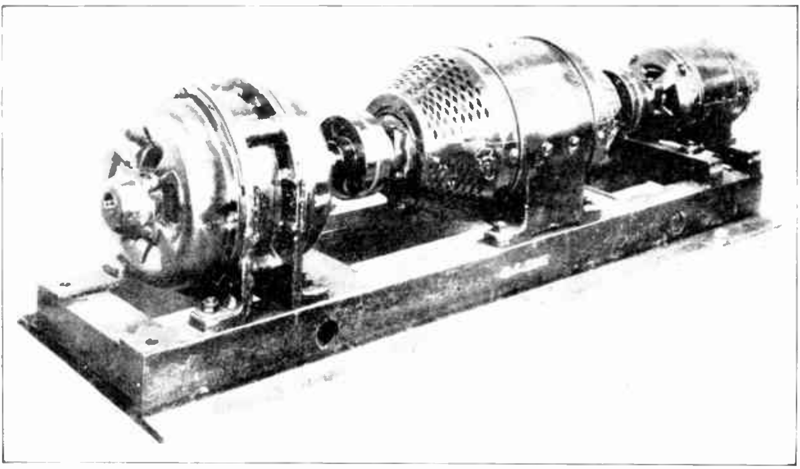


FIG. 198*a*. Motor Generator Set.

through another contact on $S8$ and through the winding of overload relay $S7$ to the plate supply circuit on the oscillator modulator unit. Voltmeter $M3$ is connected across the armature line as it leaves the d.c. power panel going to the oscillator modulator unit.

11. **22-Volt Generator**—The 22-volt generator is used for filament supply to the two 220-B power amplifier tubes in the amplifier unit. It is a compound-wound machine and is controlled by field rheostat *R7* on the d.c. power panel. Its field circuit is terminated with the armature circuit on the amplifier unit and from there it is run through a contact of the water protection relay *S3* on the a.c. power panel and back through the field rheostat on the d.c. power panel. Relay *S3* opens the field circuit if the water cooling system is not functioning normally. The armature circuit is protected on the amplifier unit by fuses *F2* which also protect the amplifier tube filaments. Reversing switch *D1* is connected between fuses *F2* and the amplifier tube filaments in parallel. Voltmeter *M2* on the d.c. power panel is connected through filament voltmeter fuses *F3* on the amplifier unit to read the amplifier filament voltage. Fuses *F1* protect a branch circuit from fuses *F2* to the 10,000-volt time delay relay *S5* on the d.c. power panel. Relay *S5* operates from the 22-volt filament circuit to close a control circuit on the a.c. power panel, allowing the rectifier control relay to operate. It is adjusted to operate 15 seconds after the 22-volt is on, allowing time for the amplifier filaments to heat up before the 10,000-volt plate supply is turned on. This circuit is grounded on the negative side through plate ammeter *M2* and plate overload relay *S1* on the amplifier unit. The amplifier plate current must return from the filaments to ground through this circuit. Condenser *C5* is provided to furnish a direct path to ground for radio frequency currents.

12. **250-Volt Generator**—The 250-volt generator is used to supply negative grid voltage for the power amplifier tubes. It is shunt excited and controlled by field rheostat *R6* on the d.c. power panel. Its armature is protected by fuses *F4*. Potentiometer *R3* is connected across these fuses with the positive side grounded and taps to points on the power amplifier grid voltage adjustment switch *D1* for 250 volts, 200 volts and 150 volts negative from ground. The flexible lead of *D1* is connected through a filter consisting of coil *L1* and condenser *C1* to the grid circuit of the amplifier unit. The 250-volt armature circuit is also connected through fuses *F1* to voltmeter *M1* and to relay *S3*. This relay must be operated before the rectifier magnetic switch *S9* on the a.c. power panel can operate to start the rectifier.

13. **10,000-Volt Supply**—The 10,000-volt plate supply for the power amplifier is obtained from a three-phase single-wave rectifier. This rectifier employs three water-cooled rectifier tubes

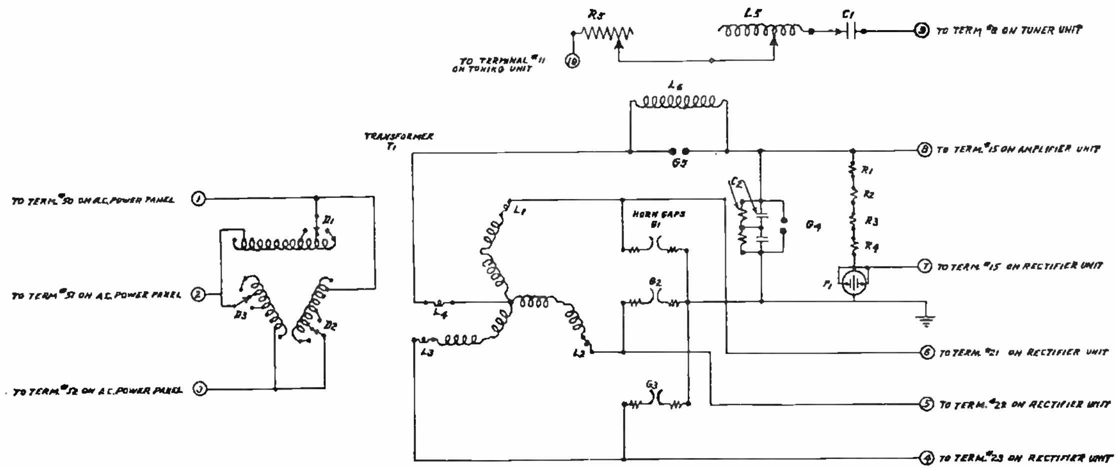


FIG. 199. Schematic of Transformer and Filter Circuit.

mounted in a unit as well as a high voltage transformer, a filter condenser and a filter coil.

The secondary of the high voltage transformer is distributed Y-connected with the neutral or center of the star connected to the filter coil. The rectifier tubes are operated with their plates

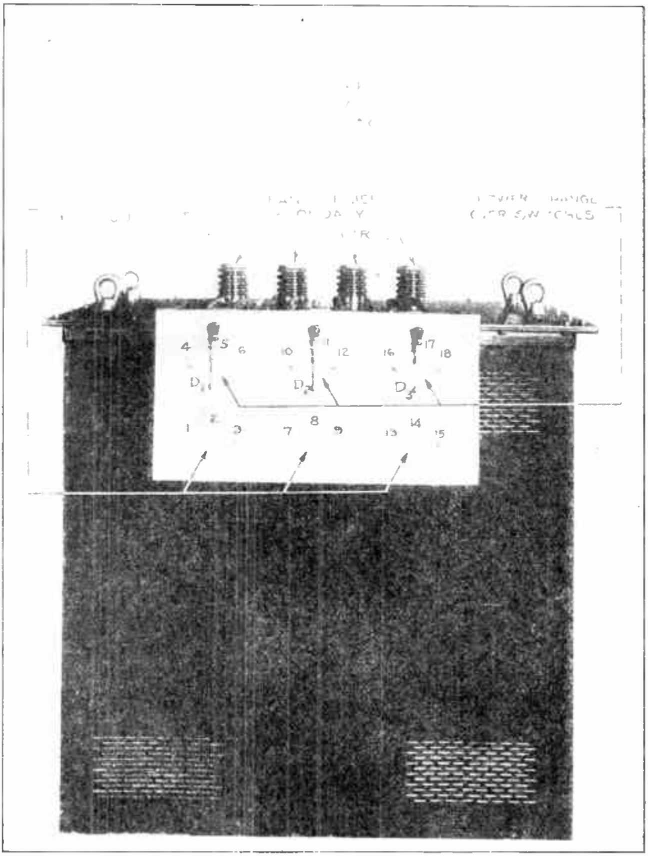


FIG. 200. High Voltage Transformer.

grounded and their filaments connected to the legs of the high voltage transformer at mid points on the secondary windings of the filament lighting transformers. Each secondary leg of the transformer is grounded by its associated rectifier tube during a

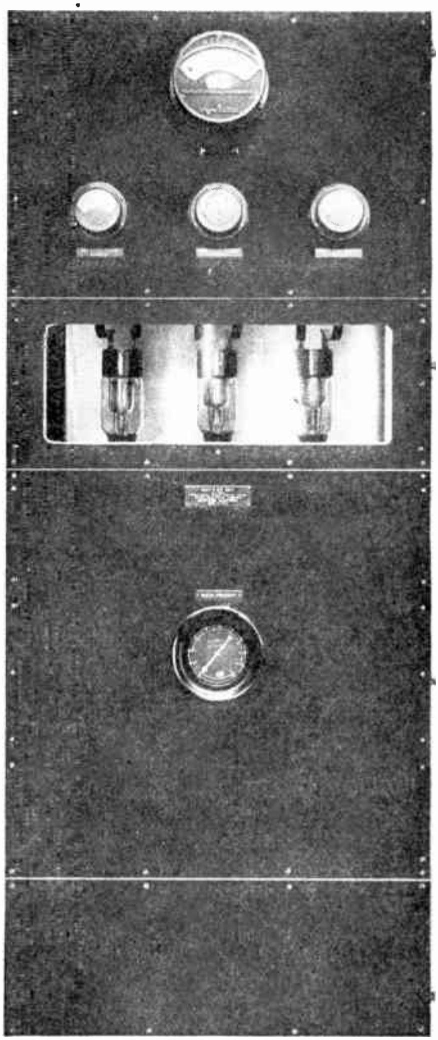


Fig. 201. Rectifier Unit.

fraction of each cycle in such a way as to cause the neutral point of the star to assume a direct current voltage. This voltage is applied to the amplifier tubes through a filter consisting of the filter coil and condensers mounted in the back of the enclosure. The rectified voltage applied to the amplifier tubes is measured by means of voltmeter *M*4 connected in series with a voltmeter multiplier mounted on the pipe rack at the back of the enclosure.

The rectifier tubes and filament transformers are protected against excessive voltages by means of horn gap protectors connected to ground from each leg of the Y-connected transformer; ball gap protection across the 10,000-volt condenser and the filter coil protect the filter units. The rectified current from each rectifier tube is measured by an ammeter connected between the rectifier plate and ground.

14. **Audio Frequency Circuits**—The " speech input " includes currents of frequencies throughout the entire audible range. It is necessary to greatly amplify these currents in order that they may be of sufficient magnitude to properly modulate the plate supply to the radio frequency oscillator. Thus amplification takes place in two stages by the speech amplifier and the modulator.

15. **Speech Amplifier**—The audio frequency input to the set is amplified by first one type 211-D tube. This tube is operated with approximately 1000 volts on its plate obtained from the 1500-volt supply through the resistor *R*9, figure 202. Condenser *C*9 together with this resistor forms a filter for the plate supply to this tube.

Grid battery *E* supplies a negative voltage for the grid of this tube which is applied through relay *S*1 when the filament is lighted. The speech input as it comes to the set goes through a 10-mile " Pad " and input transformer *T* to the grid of the tube. It is amplified in this tube and passed on to the modulator tubes by impedance coupling consisting of plate circuit choke *L*8 and condenser *C*8.

16. **Modulator**—The modulator consists of two 212-D tubes operated in multiple. 1500 volts are used for the plate supply of these tubes. Grid battery *E* supplies the same grid voltage to these tubes that it supplies to the speech amplifier tube. This battery is adjusted according to the plate impedance of the two modulator tubes which must be the same. The input to these tubes in parallel is obtained from the output of the speech amplifier tube through the modulator grid stopping condenser *C*8. The d.c. grid circuit of these tubes goes through modulator grid resistance *R*8 and modulator grid ammeter *M*6. A positive indica-

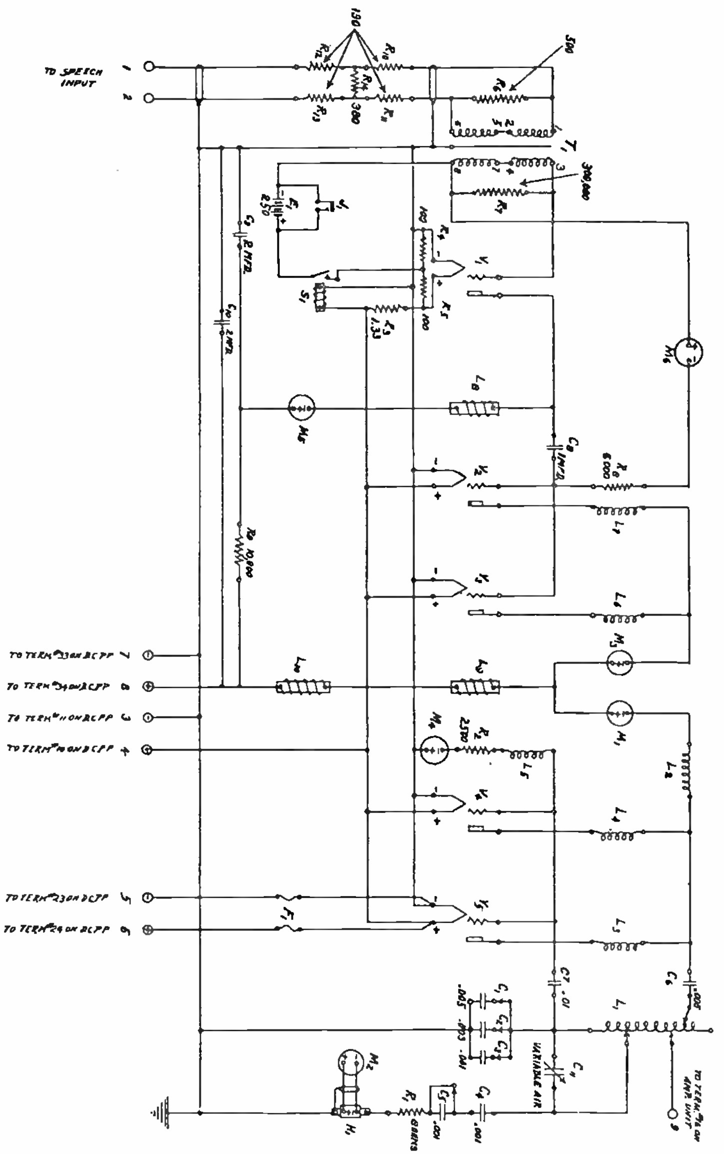


FIG. 202. Schematic of Oscillator-Modulator Circuit.

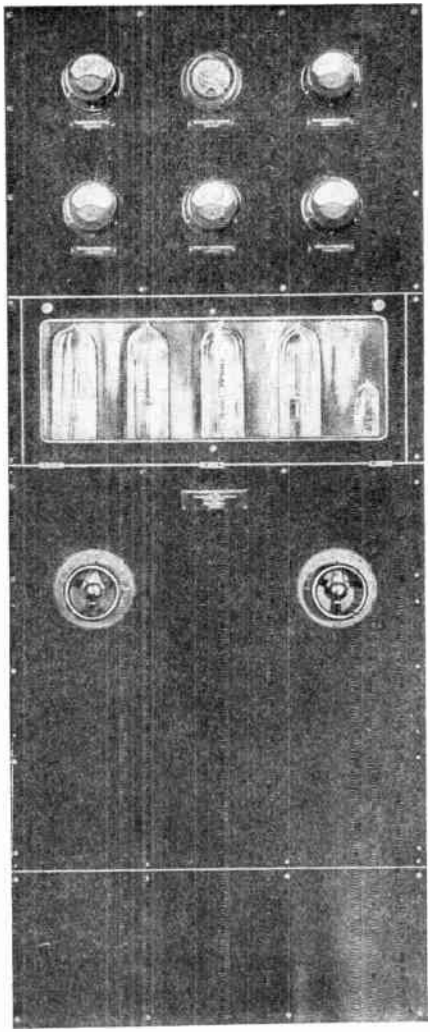


FIG. 203. Modulator Unit.

tion of current by this ammeter means that the negative grid voltage of the tube is being exceeded by the audio frequency input, and the modulator tubes are thereby overloaded. The output of the modulator tubes is applied to this oscillator plate circuit by means of modulator choke coils *L*9 and *L*10.

17. **Oscillator Circuits**—Two 212-D tubes are used in parallel as oscillators in a Colpitt's circuit. The oscillator circuit consists of the oscillator tuning inductance *L*1, the oscillator grid condensers *C*1, *C*2 and *C*3 and the oscillator plate condensers *C*4 and *C*5. Oscillator load resistance *R*1 is connected in series in the oscillator circuit as a permanent load on the oscillator. Oscillator variable condenser *C*11 is connected across the oscillator coil and furnishes a convenient means of making small adjustments of the generated frequency from the front of the panel. Oscillatory circuit ammeter *M*2 in connection with an external beating element *H* is used to measure the current in the oscillating circuit.

The oscillator grids in parallel get their radio frequency voltage through stopping condenser *C*7 from the voltage drop across condensers *C*1, *C*2, *C*3 and their d.c. voltage from the "*IR* drop" in resistor *R*2 connected from grid to ground through ammeter *M*4. The oscillator plates get their supply from the 1500-volt generator to which is added the audio frequency output of the modulator.

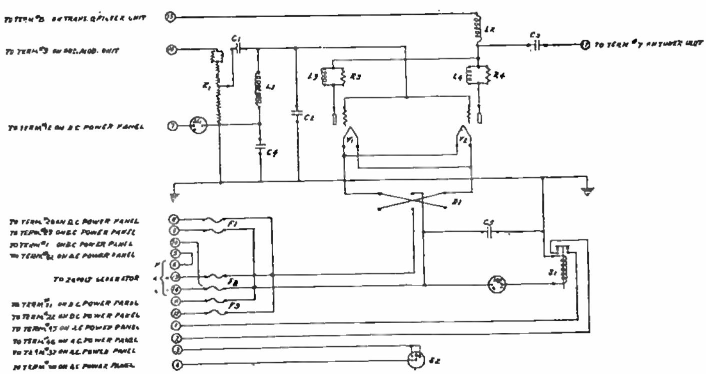


FIG. 204. Power Amplifier Schematic.

Taps are provided on the oscillator coil for adjustments of the frequency, plate coupling and output. The frequency tap is changed in conjunction with the fixed condensers *C*1, *C*2, *C*3, *C*4 and *C*5 to obtain the desired radio frequency. The plate coupling

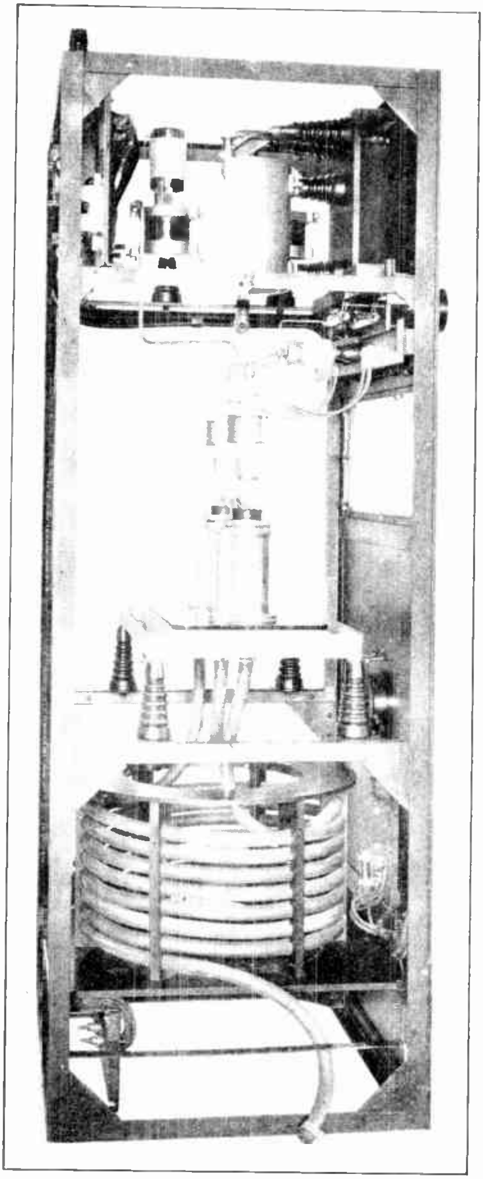


Fig. 205. Side View of Amplifier Unit.

tap adjusts the impedance of the oscillator plate circuit and thereby controls the plate current. The output tap provides means of controlling the radio frequency voltage delivered to the grids of the power amplifier.

18. Power Amplifier—The power amplifier consists of two 220-B tubes operated in parallel and its function is to amplify the modulated radio frequency produced in the oscillator-modulator unit. These tubes are operated in multiple with 10,000 volts on the plates and negative 250 volts on the grids. The radio frequency input voltage is the output obtained from the coupling tap on the oscillator coil through coupling resistance *R*1. (See fig. 204.) Resistance *R*1 and condenser *C*2 are shunted across the grids of the amplifier tubes and form a terminating impedance insuring stable operation of the amplifier and preventing singing. The negative 250-volt is fed into the two grids through choke coil *L*1 and grid ammeter *M*1 which indicates any d.c. grid current. The 10,000-volt plate supply is brought to the tube through radio frequency choke coil *L*2 and anti-sing circuits *L*3, *R*3 and *L*4, *R*4. The plate current returns to ground from the filament through plate ammeter *M*2 and plate overload relay *S*1 which indicates the current and protects the tubes from overload. Reversing switch *D*1 is placed in the filament circuit of these tubes so that the filament current of the tubes may be reversed periodically in order to prolong the life of the tubes.

19. Antenna Tuning and Coupling—Tuning and coupling circuits are provided in the tuning unit. These circuits filter the harmonics from the power amplifier output and provide means of transferring this filtered power to the antenna.

20. Closed Circuit—The amplifier output is coupled by a tap directly to a closed resonant circuit consisting of inductance coil *L*1, condenser *C*5 and coupling condensers *C*1, *C*2, *C*3 and *C*4. *L*1 and *C*5 are approximately tuned by taps to the frequency of the oscillator circuit. (See fig. 206.) The circuit is finally tuned from the front of the panel by means of a fine adjustment dial for the closed circuit inductance. This operates a sliding contact at the top of the coil. Resonance is indicated by the closed circuit ammeter which is connected to a thermal element *H*, connected in series in the tuned circuit.

21. Coupling Condenser—A coupling condenser consisting of *C*1, *C*2, *C*3 and *C*4 is connected in series in the primary closed circuit and also in series in the antenna circuit. In this way the voltage drop across this mutual capacity is applied to the antenna circuit. Choke coil *L*4 is connected directly across this condenser

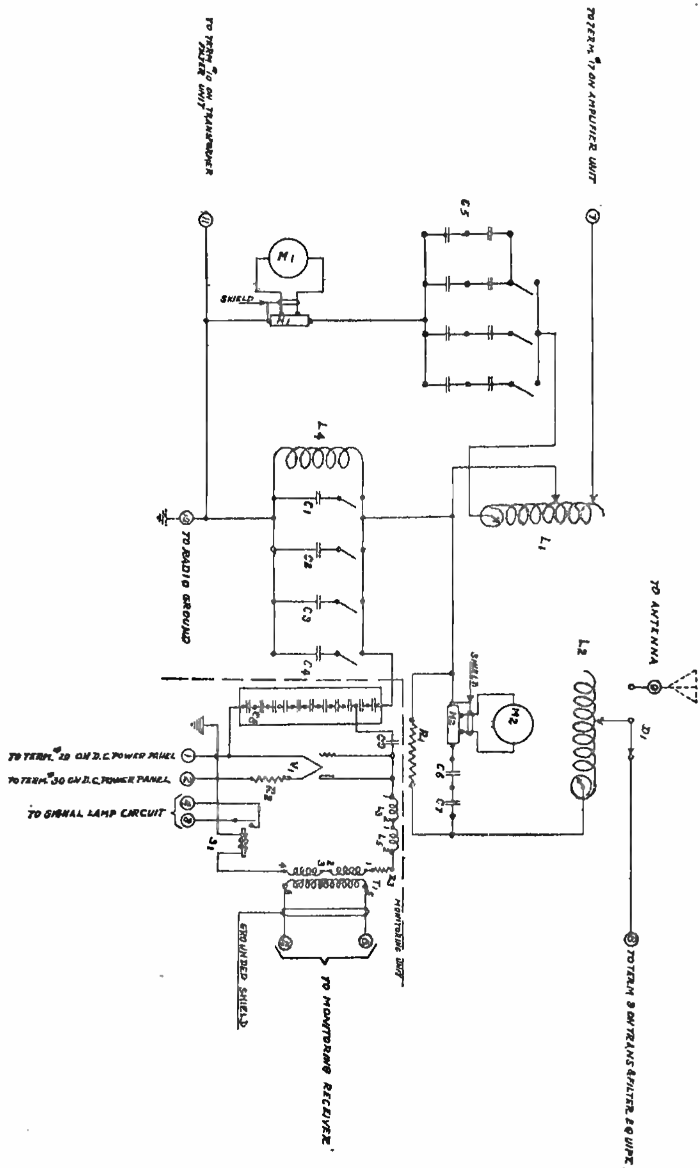


Fig. 206. Tuning Unit Schematic.

for the purpose of allowing any static charge from the antenna to flow off to ground and to avoid stresses from the d.c. plate voltage.

22. **Antenna Circuit**—Antenna loading coil *L2* and antenna series condensers *C6* and *C7* are connected in series between the high side of the coupling condensers and the antenna. These condensers and inductance are provided for tuning the antenna which should be operated approximately at its natural period. *C6* and *C7* both should be short-circuited when not required so as not to necessitate the use of a large portion of tuning *L2*. Resistor *R1* is connected across the series antenna condensers to allow any static charge from the antenna to leak off to ground. Antenna circuit ammeter *M2* in conjunction with thermal element *H2* indicates the antenna current. Final tuning of the antenna circuit is accomplished by means of the fine adjustment dial on the front of the panel which controls a sliding contact of the antenna loading coil *L2*. An artificial antenna is provided and mounted on the pipe rack at the rear of the panel unit for the purpose of testing the transmitter without radiation. It consists of a variable inductance, an adjustable condenser and a variable resistance which should be adjusted to the equivalent of the real antenna. It is then convenient to switch from the real antenna to artificial antenna by means of antenna switch *D1* for testing.

23. **Monitoring Rectifier**—A monitoring rectifier is provided in the tuning unit to rectify a portion of the antenna current for monitoring purposes. This rectifier consists of one 205-D tube, with plate and grid connections strapped together. The radio frequency voltage for the operation of this rectifier is obtained by capacity coupling with condenser *C8* connected across the coupling condensers of the antenna circuit. The variable tap on this condenser provides a convenient means for adjusting the input to the rectifier. The audio frequency component of the rectified output from the tube is fed through a transformer to the monitoring loud speaking telephone. The direct current component is fed through a signal lamp relay *S1* which relay may be used to operate a signal circuit in the control room to indicate when there is antenna current.

Operation and Maintenance.

24. **Cleaning**—For the best operation the radio transmitter must be kept free from dust and dirt. High pressure air is recommended for cleaning the apparatus inside the enclosure, but a soft clean cloth can be used with good results. Waste or oily

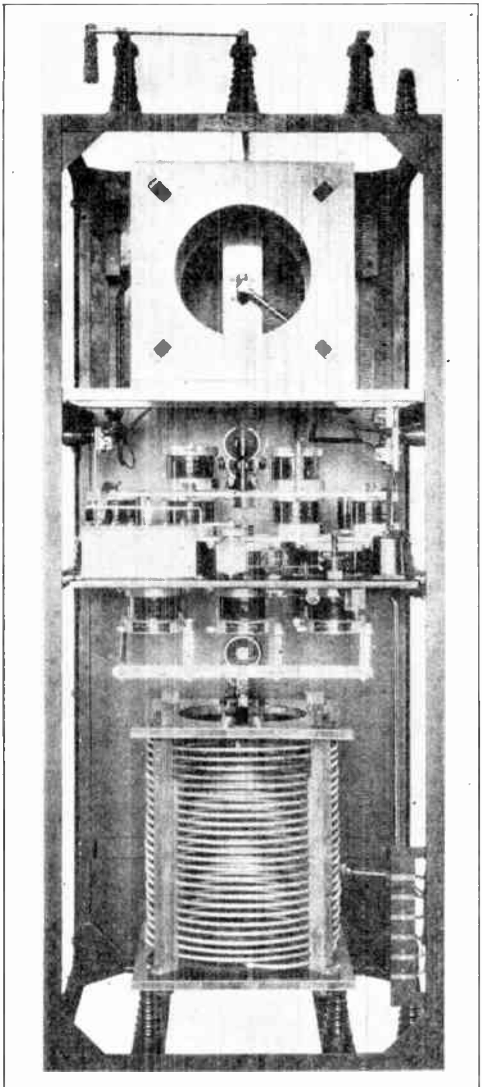


FIG. 207. Rear View of Tuning Unit.

cloth should never be used. Lemon oil is recommended as a polish for the front of the panel units. It should be used sparingly and wiped off with a soft cloth.

The meters on the front of the panel measure currents and voltages at various points in the circuits, and their readings should always fall within the following limits for proper operation at full power.

Permissible Meter Readings

Unit	Meter	Reading
AC Power Panel	Voltage Phase A	220 + or − 5%
AC Power Panel	Voltage Phase B	220 + or − 5%
AC Power Panel	Voltage Phase C	220 + or − 5%
AC Power Panel	Voltage Rectifier Filament	No. 1 200
AC Power Panel	Voltage Rectifier Filament	No. 2 200
AC Power Panel	Voltage Rectifier Filament	No. 3 200
DC Power Panel	14V Generator	14
DC Power Panel	1500V Generator	1,500
DC Power Panel	22V Generator	22
DC Power Panel	250V Generator	250
OSC. Mod. Unit	Mod. Plate Current	170–210
OSC. Mod. Unit	OSC. Circuit	3 Minimum [2]
OSC. Mod. Unit	OSC. Plate	600–700
OSC. Mod. Unit	Mod. Grid	0
OSC. Mod.	Sp. Amp. Plate	35–50
OSC. Mod.	OSC. Grid.	70–120
Amplifier Unit	Grid Current ( )	55 Max.
Amplifier Unit	Plate Current	1.3 Max.
Rectifier Unit	Rectified Voltage	9.5–10.5
	Rect. plate No. 1	.5 Max.
	Rect. plate No. 2	.5 Max.
	Rect. plate No. 3	.5 Max.
Tuning Unit	Closed Circuit Current	25 Max.
	Antenna Circuit Current	[3]

25. Adjustment of Relays, Protective Gaps, etc.—Protective apparatus requiring adjustment are listed below with a description of the proper adjustment.

(*A*) *Primary Overload Relays on the a.c. Power Panel.* These relays provide overload protection for the high voltage transformer through current transformers in the primary supply leads. They should be adjusted by means of the thumb screws at the bottom to the calibrated point marked 6. This corresponds to 60 amperes in the primary of the high voltage transformer. These relays are equipped with air bellows at the top for slow action. The air

[2] This current will vary greatly with frequency and should be larger for low frequencies.

[3] The antenna current will depend on the antenna resistance and will vary widely for different installations.

escapement value at the top of the bellows should be opened as far as possible so that this time delay will be short, as it is intended only to delay action long enough to prevent operation due to the starting transient.

(*B*) *1500-Volt Time Delay Relay on the d.c. Power Panel.* This relay operates on the control circuit of the 1500-volt generator field to keep the 14-volt filaments lighted. It should be adjusted by means of the adjusting screw at the bottom so that the armature will pull up when the 14-volt generator is operating at 14 volts. The air escapement at the top of the air bellows should be adjusted so that the contacts make 20 seconds after the relay armature is pulled up.

(*C*) *10,000-Volt Time Delay Relay on the d.c. Power Panel.* This relay operates on the control circuit of the primary power supply for the rectifier to keep that power off until 15 seconds after the amplifier filaments are lighted. The thumb screw adjustment at the bottom of the relay should be adjusted so that the armature pulls up as soon as 222 volts are applied to the amplifier filaments. The air escapement value at the top of the air bellows is adjusted to allow the contacts to make 15 seconds after the armature is pulled up.

(*D*) *Contact Making Pressure Indicator on the Rectifier Unit.* The water pressure from the pump is indicated on this gauge by a pointer which is arranged to make contact with adjustable contacts on either side. These contacts should be adjusted 10 pounds above and below the normal pressure which will vary with different installations but will usually be about 20 pounds. An abnormal water pressure causes a contact which operates on the relay circuit of the a.c. power panel to take all power off the water-cooled tubes.

(*E*) *Contact Making Thermometer on the Amplifier Unit.* The gauge indicates the water temperature as it comes from the amplifier unit. It is arranged with an adjustable contact which should be set so that the indicating arm makes contact with it when the temperature reaches 180 degrees F. This contact operates on the relay circuits of the a.c. power panel to shut off all power to the water-cooled tubes.

(*F*) *Plate Overload Relay on the Amplifier Unit.* This relay provides overload protection for the plate circuit of the power amplifier. Its winding is connected to carry the amplifier plate current on its return from the filament to ground. Its contacts operate on the relay circuits of the a.c. power panel to shut off the rectifier. It is instantaneous in action and should be adjusted to operate on 2.0 amperes by means of the thumb nut at the bottom of the relay.

(*G*) *1500-Volt Generator Overload Relay on the d.c. Power Panel.* This relay is in circuit with the plate supply to the oscillator modulator tubes to protect them from overloads. It operates on control relay circuits of the d.c. power panel to open the field and armature circuits of the 1500-volt generator when an overload occurs. It should be adjusted by the thumb screw controlling its armature to operate on 1.5 amperes.

(*H*) *Rectifier Protective Horn Gaps Mounted on Pipe Rack.* One of these gaps is connected from each corner of the high voltage transformer secondary winding to ground. They are adjusted to 7/8 inch between gap points to protect the recitfier tubes and transformer windings from high voltages. Each gap unit includes high resistances connected in series to limit the current drawn by the gap.

(*I*) *Filter Condenser Protective Ball Gap Mounted on Pipe Rack.* This ball gap is set accurately to .295 inch to protect the filter condenser from large transient voltages. The balls of this gap must be kept clean and should be repolished in case an arc crosses the gap.

(*J*) *Filter Coil Protective Ball Gap Mounted on Filter Coil.* This ball gap is adjusted to form 1/8 to 5/32 inch as a protection to the filter coil *L*4 from high voltages. It should be kept clean and well polished for proper protection.

(*K*) *Rectifier Voltmeter Protective Gap Mounted on Pipe Rack.* This protector is connected across the voltmeter on the rectifier unit and series to prevent high voltages from getting across this voltmeter. It consists of copper blocks separated with mica, leaving a very short air gap between the centers of the blocks. In case the voltmeter circuit from the voltmeter multipliers *R*1, *R*2, *R*3 and *R*4 of the transformer and filter equipment to the voltmeter on the rectifier unit becomes open a high voltage will occur across this gap, breaking it down. In this case it will be necessary to clean the copper surfaces and it may be necessary to replace the mica.

26. **Adjustment of Oscillator Modulator Unit**—The oscillator modulator circuit should first be adjusted without operating the rectifier or power amplifier unit.

(*A*) *Modulator and Speech Amplifier.* The modulator and speech amplifier circuits should be adjusted with the oscillator tubes out of the sockets. The modulator tubes should both bear the same impedance classification, and the negative grid battery *B* should be adjusted according to the classification as shown in the following table:

Modulator Tube Impedance Classification	Grid Battery Voltage
No. 1	67.5
No. 2	69.0
No. 3	70.5
No. 4	73.5

This voltage should be checked frequently with a voltmeter.

Meter readings of modulator and speech amplifier plate current should fall within the limits given in the table of permissible meter readings.

(*B*) *Oscillator.* The oscillator must be adjusted to the desired frequency by trial. It is affected by the amplifier and tuning units so that it is necessary to make final adjustments after the entire set is approximately tuned. The power amplifier grid tap on the oscillator coil should be open for the first approximations.

The following approximate apparatus settings are given as a help in making preliminary adjustments.

Oscillator Grid Condenser Adjustment (C1, C2, C3).

Osc. Grid Cond.	Freq. Min.	Freq. Max.
.003	1000 KC (300 M)	1070 KC (280.2 M)
.004	750 KC (400 M)	1000 KC (300 M)
.005	600 KC (500 M)	750 KC (400 M)
.006	500 KC (600 M)	600 KC (500 M)

Oscillator Plate Condenser Adjustment (C4, C5).

Osc. Plate Cond.	Freq. Min.	Freq. Max.
.0005	750 KC (400 M)	1070 KC (280.2 M)
.001	500 KC (600 M)	750 KC (400 M)

Oscillator Tap Adjustments Corresponding to .0005 Plate Condenser

Freq.	Tuning Turns	Plate Turns	Power Amp. Grid Turns
750 KC (400 M)	25	15	10 [4]
800 KC (375 M)	24	14	10 [4]
850 KC (353 M)	22	14	9 [4]
900 KC (333 M)	18	13	9 [4]
950 KC (316 M)	16	13	9 [4]
1000 KC (300 M)	15	12	8 [4]
1070 KC (280.2 M)	13	12	8 [4]

Oscillator Tap Adjustments Corresponding to .001 Plate Condense

Freq.	Tuning Turns	Plate Turns	Coupling Turns
500 KC (600 M)	33	21	14 [5]
550 KC (545 M)	28	20	13 [5]
600 KC (462 M)	24	19	13 [5]
650 KC (462 M)	21	18	12 [5]
700 KC (429 M)	18	16	11 [5]
750 KC (400 M)	16	15	10 [5]

The plate tap or lower tap of the coil is moved to the right to decrease the oscillator plate current. For best operation this current should be 650 milliamperes. The frequency adjustment condenser C_{11} is used for small adjustments of frequency from the

[4] These adjustments are approximately right for 5 KW. operation of the set. They will be lower for operation at reduced power.
[5] These adjustments are approximately right for 5 KW. operation of he set. They will be lower for operation at reduced power.

front of the panel. Final adjustments of the oscillator must be made after the amplifier output circuits are tuned.

27. **Adjustment of Tuning Unit**—Preliminary adjustment of the circuits of the tuning unit should be made with the amplifier working with minimum plate voltage by using the high volt-

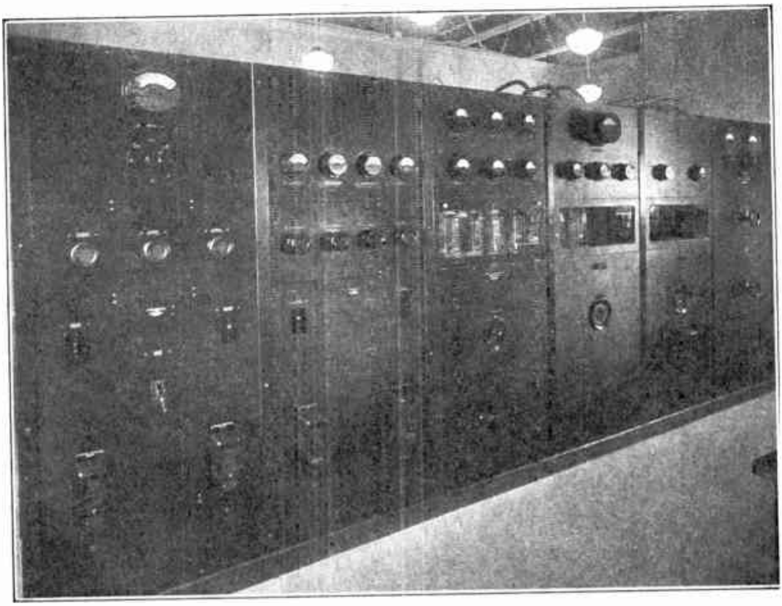


FIG. 208. Panel Assembly. Left to Right: A.C. Power—D.C. Power—Oscillator-Modulator Unit—Rectifier—Power Amplifier—Tuning Unit.

age transformer switches on minimum voltage setting. The plate voltage can then be raised to medium and full voltage, readjusting the set each time.

Caution—The plate voltage should not be raised until the antenna circuit is connected and tuned in order that the energy will be dissipated in the antenna and not cause a large circulating current in the closed circuit which may burn out the ammeter.

The adjustments of these circuits will depend largely on the carrier frequency and the effective resistance of the antenna at that frequency. The following tables are given as a guide to assist in the preliminary adjustments:

CLOSED CIRCUIT TUNING CAPACITY TO USE FOR DIFFERENT CARRIER FREQUENCIES.

Capacity	Frequency Min.	Frequency Max
.001 Mfd.	500 KC (600 M)	700 KC (429 M)
.00075 Mfd.	700 KC (429 M)	900 KC (333 M)
.00050 Mfd.	900 KC (333 M)	1070 KC (280.2 M)

ANTENNA CIRCUIT COUPLING CONDENSERS TO USE FOR DIFFERENT CARRIER FREQUENCIES ON AN ANTENNA HAVING 5-10-15-20 OR 25 OHMS EFFECTIVE RESISTANCE.

5 Ohm Antenna			10 Ohm Antenna			15 Ohm Antenna		
Coup. Cap.	Freq. Min.	Freq. Max.	Coup. Cap.	Freq. Min.	Freq. Max.	Coup. Cap.	Freq. Min.	Freq. Max.
.0375	500	525	.0375	—	—	.0375	—	—
.0350	525	575	.0350	—	—	.0350	—	—
.0325	575	625	.0325	—	—	.0325	—	—
.03	625	675	.03	—	—	.03	—	—
.0275	675	725	.0275	500	525	.0275	—	—
.0250	725	800	.0250	525	575	.0250	—	—
.0225	800	900	.0225	575	650	.0225	—	—
.02	900	1000	.02	650	750	.02	500	575
.0175	1000	1070	.0175	750	850	.0175	575	675
.0150	—	—	.0150	850	1070	.0150	675	800
.0125	—	—	.0125	—	—	.0125	800	975
.01	—	—	.01	—	—	.01	975	1070

20 Ohm Antenna			25 Ohm Antenna		
Coup. Cap.	Freq. Min.	Freq. Max.	Coup. Cap.	Freq. Min.	Freq. Max.
.0175	500	600	.0175	500	525
.0150	600	700	.0150	525	625
.0125	700	850	.0125	625	750
.01	850	1070	.01	750	1070

(*A*) *Closed Circuit.* The antenna circuit should be open while making preliminary adjustments of this circuit, which is tuned by the closed circuit tuning inductance and the closed circuit tuning condensers. The closed circuit tuning condensers should be set according to the above table for the frequency to be transmitted

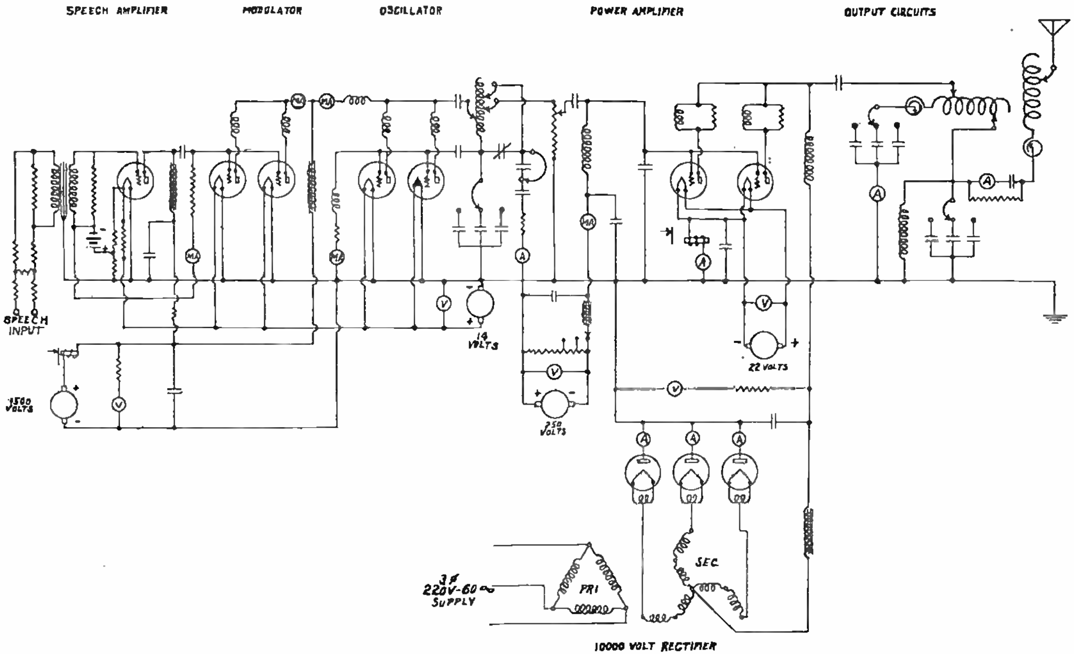


Fig. 209. Radio Broadcasting Transmitter Schematic.

The coupling condensers should be set according to the above tables if the resistance is known. If the resistance is not known, it is well to assume 15 ohms for preliminary adjustments. The tuning adjustment tap on the inductance must be tried in several places until the circuit can be tuned with the fine adjustment on the front of the set. Final tuning of this circuit must be accomplished after the antenna circuit is tuned.

(*B*) *Antenna Circuit*. The antenna is tuned by means of the antenna circuit tuning inductance which is connected in series with the antenna series condensers and the antenna coupling condensers. The coupling condensers are also in the closed circuit and furnish coupling by the voltage drop across them. Tuning is accomplished by trying the tap on the antenna tuning inductance at various places until resonance is obtained with the fine adjustment on the front of the panel. If several turns of this coil are found necessary, one or both of the antenna series condensers should be short-circuited and the used turns of the coil should be reduced accordingly.

Final tuning of the antenna, the closed circuit and the oscillator modulator unit are attained at the same time by readjusting first one and then another to obtain the following results:

1. The carrier frequency should be adjusted by the frequency dial on the oscillator modulator unit to that desired.

2. Both fine adjustment dials on the tuning unit should be adjusted to give a maximum antenna current. The closed circuit tuning adjustment may be moved off tune slightly to lower the amplifier plate current without greatly affecting the antenna current. This improves the efficiency of the amplifier by matching the impedance of the tubes.

3. All meter readings should be within the limits given under the table of permissible meter readings.

4. The closed circuit current in the tuning unit should be between 20 and 25 amperes when working 5 K.W. power output. This current is increased by increasing the antenna coupling condenser, thus decreasing the coupling between the closed circuit and the antenna.

5. With a sustained tone as "ah-h-h-h" spoken into the microphone and the 8-B speech input amplifier adjusted to give an indication of current on the modulator grid ammeter, the antenna current should show a decided increase.

Note: The adjustment of the microphone and 8-B amplifier will be taken up under the 1-D speech-input equipment.

(*C*) *Artificial Antenna*. The artificial antenna is intended to be used in place of the real antenna for testing purposes and to be most useful it must be adjusted to have the same reactance and resistance as the real antenna for the carrier frequency used. It is adjusted by trial, varying the resistance, inductance and capacity until the transmitter meter readings and wavemeter reading are exactly the same when the switch is in either position. For the first trial it is well to set the inductance and capacity the same as those in the closed circuit of the tuning unit. The resistance setting will be slightly below the effective resistance of the antenna on account of the effective resistance of the inductance and capacity in the artificial antenna. If the antenna resistance is not known a preliminary setting of 13.2 ohms will be satisfactory for first trial. The unit is ordinarily shipped for this resistance. The following table shows connections for a number of different values of resistance.

ARTIFICIAL ANTENNA RESISTANCE.

Resistance in Ohms.	Grids in Parallel for Each Group.	Groups Connected in Series.
4.9	9	1
5.5	8	1
5.9	15	2
6.3	14	2
6.8	13	2
7.3	12	2
8	11	2
8.8	10	2
9.7	9	2
13.2	10	3
14.7	9	3
16.5	8	3
18.9	7	3
22	6	3
25	7	4

Intermediate values of resistance may be had by adding or subtracting grids to one of the groups. In making these adjustments the smallest group should contain at least as many grids as the quotient of antenna current divided by 2.5 as 2.5 amperes is the maximum allowable current in any one grid.

(*D*) *Adjustment for Power in the Antenna.* The power output is adjusted by the power amplifier grid tap on the oscillator coil by the three switches on the high voltage transformer controlling the plate voltage of the power amplifier and by using one or two of the power amplifier tubes.

Both power amplifier tubes must be operated for outputs of from 2.5 to 5 kilowatts and may be used for less output power, but it is advisable from the standpoint of economy to use only one amplifier tube for lower powers by disconnecting the filament and grid terminals of one of the tubes. Care should be taken in doing this to be sure that all three terminals are disconnected and insulated.

The plate voltage of the power amplifier tubes can be adjusted to three values by means of switches on the high voltage transformer. These settings should correspond to settings of the power amplifier grid voltage adjustment switch *D*1 on the d.c. power panel as follows:

Plate Voltage.	Grid Voltage.
10,000	250
7,000	200
4,460	150

Reducing the plate voltage of the power amplifier reduces the power output to approximately one-half and one-fifth full power. These power steps are most useful in tuning when low power should be used for first approximate adjustments.

The final adjustment of power output should be made by means of the power amplifier grid tap on the oscillator coil. Approximate adjustments of this tap for full power are shown in the tables showing oscillator adjustment taps. An attempt to get more than 5 KW. of power output by increasing this tap will result in distortion of the transmitted signals and may seriously overload some of the power supply circuits and apparatus.

Any change of power will slightly change the adjustments as regards carrier frequency and tuning, necessitating retuning after each power change.

(*E*) *Example of a Power Adjustment.* The power delivered to the antenna is equal to the antenna current squared multiplied by the effective resistance of the antenna. (See Chapter V.)

If the effective resistance of the antenna is known the antenna current should be

$$I_A = \sqrt{\frac{P}{R_A}},$$

where P is the desired antenna power and R_A is the antenna resistance which is somewhat higher than the resistance of the artificial antenna resistor.

Suppose the antenna resistance is eight ohms and it is desired to adjust for 1500 watts output with a carrier frequency of 600 kilocycles. Using the formula

$$I_A = \sqrt{\frac{P}{R_A}},$$

the antenna current is

$$I_A = \sqrt{\frac{1500}{8}} = 13.7 \text{ amperes.}$$

First, adjust the transmitter for full power at 600 kilocycles.

Second, since the power is below 2.5 kilowatts, remove one of the amplifier tubes and retune the set.

Third, adjust the output as close as possible to 13.7 amperes by varying the amplifier grid tap on the oscillator, retuning the set after each change.

(*F*) *Monitoring Unit.* The monitoring unit output is adjusted by means of coupling condenser *C*8 which has 12 terminals. These terminals may be considered as being numbered according to the following sketch where zero terminal represents zero coupling to the monitoring rectifier and the coupling increases as the numbers increase.

11	8	7	4	3	0
10	9	6	5	2	1

The coupling tap should be set at a point which will give the desired signal strength from the output of the rectifier. This will vary whenever the antenna current changes due to a change in the transmitted power. The signal lamp relay *S*1 should be adjusted by the screws inside the cover so that it will operate when the transmitter is operating and the coupling to the monitoring rectifier is properly adjusted.

28. Care of Vacuum Tubes—(*A*) *Oscillator Modulator Tubes.* The vacuum tubes in this unit should be operated with 14 volts at filament terminals and 1500 volts for their plate supply. These voltages should be continually watched in order that the tube life may be prolonged. The plates of these tubes may be operated at a dull red color but should never be allowed to become bright red.

(*B*) *Rectifier Tubes.* The rectifier tubes are operated with a filament terminal voltage of 21 volts which is obtained when the rectifier filament voltage (primary) as read on the a.c. powe panel is 200 volts. This is lower than the normal voltage fo this tube, but it is sufficient to give filament emission required b this set and operating the tubes in this manner prolongs their life These tubes should be removed from their sockets and th anodes cleaned occasionally in order to prevent scale from ac cumulating on their copper anodes preventing proper cooling an possibly making their removal difficult.

(*C*) *Amplifier Tubes.* These tubes are operated with a fila ment voltage of 22 volts as indicated by the 22-volt generato voltmeter on the d.c. power panel. This voltage should not b allowed to vary appreciably in order to prolong the life of th tubes. A filament reversing switch is provided on the back o the amplifier unit for reversing the direction of the curren through the filament of the tube. This greatly prolongs the lif of the tube and should be done regularly. It is suggested tha this switch be used in one position for odd and the other positio for even days of the month.

(*D*) *Monitoring Rectifier Tube.* This tube receives its fila ment supply from the 14-volt generator and should operate satis factorily when the 14-volt generator is adjusted for the oscillato modulator tubes. Its plate and grid are connected together an receive their voltage from the monitoring unit coupling condenser For the protection of this tube the coupling tap of condenser *C*8 should never be connected to a higher terminal than necessary t deliver a reasonable volume of output to the monitoring lou speaker as an excessive voltage applied to the plate will result i the failure of the tube. This tube has sufficient capacity to oper ate two 540-A.W. receivers in parallel with good volume.

29. Care of Motor-Generator—(*A*) *KS-5213 Motor-Generator.* This motor-generator is used to supply filament and plate potential for the oscillator modulator tubes. The commutators o the 14 and 1500 volt generators should be kept polished and fre from sparking, and the bearings of the machine should be kep well supplied with a good grade of motor oil. The utmost car should be taken when cleaning the commutators of the 1500-vol generator to see that the field circuit is opened at switches *D*3 and *D*4 of the d.c. power panel.

(*B*) *KS-5046 Motor-Generator.* This motor-generator sup plies filament current at 22 volts to the amplifier filaments. I order to insure quiet transmission the commutator of the 22 vol generator should be given a great deal of attention. It shoul be cleaned and lightly lubricated about once every hour with a clean cloth and a mixture of kerosene and dynamo oil. The brush tension should be carefully adjusted so that the brushes make good contact but do not cut the commutator. Machine bearings should be kept full of a good motor oil.

(*C*) *Power Amplifier Grid Voltage Motor-Generator.* This motor-generator is used to supply negative grid voltage to the power amplifier tubes. Its commutator should be cleaned occasionally and the bearings should be kept full of good motor oil.

(*D*) *KS-2834 Water Pump.* The pump is used to circulate water through the jackets of the tubes in the rectifier and amplifier units and the associated cooling system. The fine mesh strainer at the input to the pump should be inspected and cleaned each day when the set is first installed and later it should be inspected as often as may seem necessary from the results of the first few days. The packing on both sides of the pump should be kept tight enough to prevent water leaks. A good grade of motor oil should be used for the motor bearings.

30. Location of Troubles—(*A*) *General.* Troubles in the radio transmitter should be located by studying the symptoms to determine first what part of the circuit could be responsible for the trouble. A number of typical troubles are discussed to illustrate this method of attack.

(*B*) *Failure of Antenna Current.* If current still flows in the closed circuit the failure may be due to an open, grounded or untuned antenna circuit or to a short-circuit of the antenna coupling condensers. Otherwise, some other symptoms should appear.

(*C*) *Failure of Amplifier Filaments to Light.* This is ordinarily an indication that the 22-volt generator field is open due to failure of water circulation or that the switch or fuse on the back of the amplifier panel is open.

(*D*) *Failure of Rectifier.* If the filaments light but no rectified voltage is produced, the disconnect switch on the back of the a.c. power panel or the switches on the high voltage transformer may be open. If two of the rectifier tubes light dimly, one of the rectifier power supply fuses *F*13 is open. If the rectifier filaments do not light, the trouble may be water failure, an overload on the amplifier plate or high voltage transformer, or the gate of the enclosure may be open. If none of these seem to be at fault, the rectifier should be started with the rectifier control push button. It may be that the sequence relay did not operate, or one of the high voltage transformer overload relays caused a shutdown.

(*E*) *Failure of Oscillator.* If the plate and filament voltages are all right and the oscillator plate current goes high with no grid current or a reverse grid current, one of the tubes may be bad. If this is not the trouble, it may be that the oscillating circuit is open, or the plate coupling tap on the oscillator coil may not include enough turns or the grid coupling condensers may be short-circuited.

(*F*) *Fuse Failures.* If a fuse blows, a thorough search should be made to find, if possible, the cause of the trouble before replacing the fuse. If nothing is found, replace the fuse and apply the voltage, being ready to disconnect the power and carefully watch the meters and apparatus that could be affected by this fuse. If nothing is seen and the fuse again blows the trouble should be found and rectified before the fuse is replaced again.

1-D Speech Input Equipment.

31. **General**—The 1-D speech input equipment involves the necessary apparatus for picking up the sound waves of music or speech, converting them into electrical currents and amplifying these currents to a sufficient volume to operate the radio transmitter. The operation of this apparatus will ordinarily require two attendants, one in the studio to care for the microphone and another in the control room to care for the amplifiers and to maintain the output volume at the proper level to operate the radio transmitter. A communication system of signals and telephone is provided between the studio and control rooms to facilitate the operation of the station. The greater part of this apparatus is mounted on a rack in the control room. The arrangement of this apparatus may be changed to meet the needs of the individual installation.

32. **Microphone (373-W Transmitter)**—The microphone is mounted in a housing and equipped with a cord and plug. On the microphone, a thin diaphragm stretched between two heavy metal rings vibrates with the sound waves in the studio. Attached to this diaphragm at its center are two carbon buttons, one mounted on each side. The two buttons are connected in series and to the primary of the input transformer of the 8-B amplifier. Their mid-point is grounded to the transmitter ring and to the main ground through a third lead from the microphone. Current is supplied to the microphone from the filament battery through a mid-point on the input transformer. The microphone is equipped with a cord and plug to facilitate rapid replacement or change of position where a number of receptacles are provided. The micro-

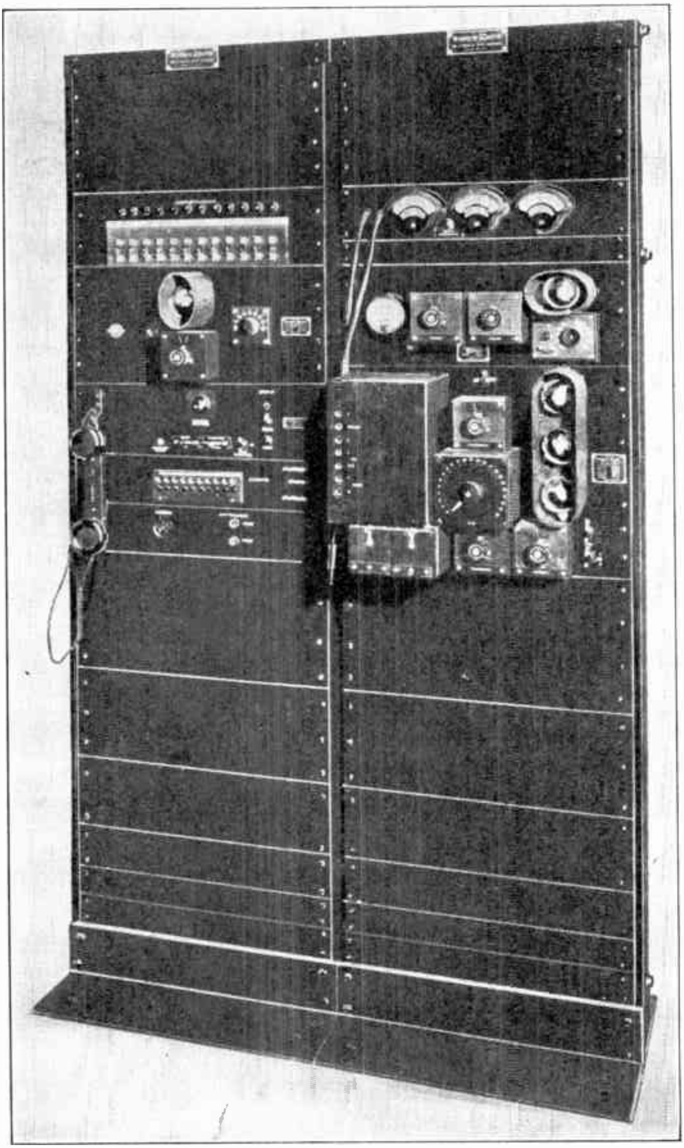


FIG. 210. 1-D Speech Input Equipment.

phone circuit runs in conduit from the amplifier and terminates in one or more outlet boxes located in the baseboard of the studio. This microphone is designed for high quality reproduction of all frequencies in the audible range. Its output volume is necessarily low and must be amplified many times before it is sufficient to operate the radio transmitter.

33. **8-B (Speech Input) Amplifier**—This amplifier is used to amplify the feeble currents from the microphone sufficiently to operate the radio transmitter. It is mounted on a rack in the control room. It has three stages of amplification. The first stage uses a 102-D tube and the second and third stages use 205-D tubes. A jack panel is provided on the amplifier for measuring the filament and plate currents of the tubes. Jacks are also provided for measuring the current supplied to the two carbon buttons of the microphone. They are connected in the leads from the input transformer which forms a part of this amplifier. Rheostats for controlling the filament current of the tubes and the microphone current are provided. A key for switching the microphone on and off is also provided. The gain of this amplifier is controlled by a 22-point potentiometer which operates on the first two stages to vary the gain gradually from minimum to maximum.

34. **518 (Volume Indicator) Panel**—This instrument indicates the volume level of the program (speech, music, etc.) at the output of the 8-B amplifier which modulates the radio transmitter. Indication is given by a sensitive galvanometer in the plate circuit of the 102-D vacuum tube. A rheostat and a key are provided to control the filament current and a potentiometer to adjust the negative grid bias of the tube. The grid is energized by the output of the 8-B amplifier. A level measuring key for large steps and a level measuring switch for small steps connected in the grid circuit are calibrated in transmission units from zero level of volume. The large steps are 0, 16 and 30 TU and the small ones are from — 10 TU to + 10 TU in steps of 2 TU. The algebraic sum of these settings is the volume level at the input of the unit required to cause the galvanometer needle to swing from 5 to 30 divisions about once in 10 seconds when transmitting speech. In other words, volume level may be measured by adjusting the key and switch until this deflection is obtained and taking the algebraic sum of the settings as the reading of volume level.

35. **18-B (Monitoring) Amplifier**—This amplifier is used for monitoring the speech input to the radio transmitter. It has one stage of amplification with a gain control and gets its input

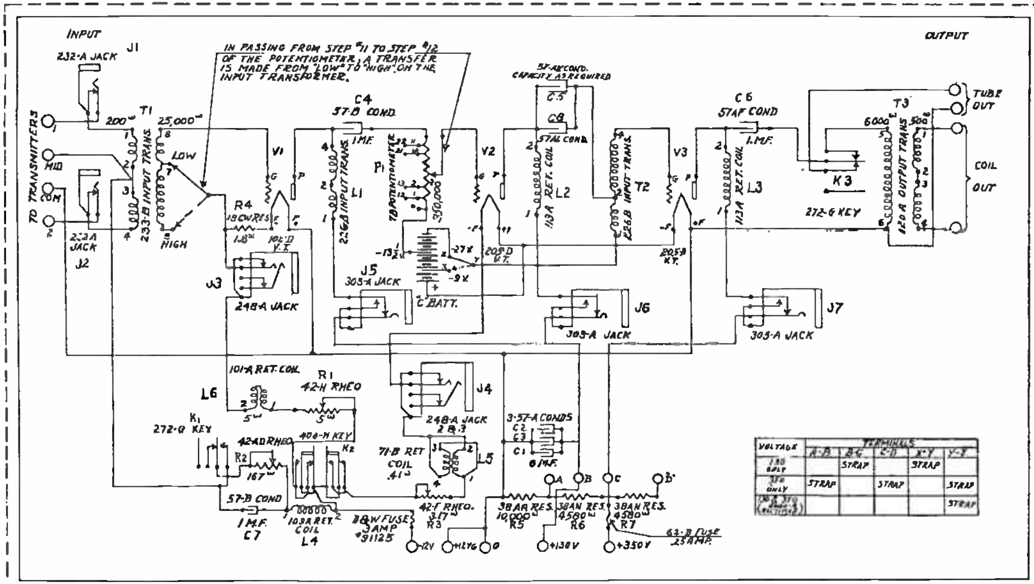


Fig. 211. Schematic of 8-B Amplifier, Public Address System.

from the output of the 8-B amplifier. A 205-D vacuum tube is used. It is designed to work into two 540-C.W. loud speaking telephones connected in parallel and delivers sufficient volume of

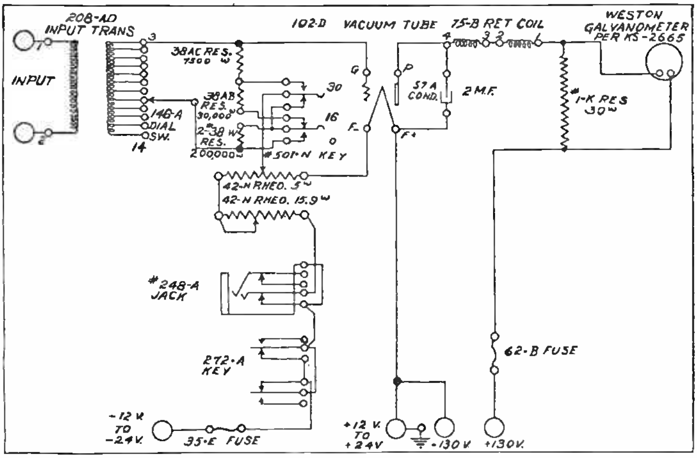


FIG. 212. Simplified Circuit of Land Speaking Public Address System. 518-B Panel.

sound for monitoring. It is provided with jacks for measuring filament and plate current and a switch for controlling the filament.

36. 514-A (Meter) Panel—The meter panel provides facilities for measuring filament, plate and microphone currents in the different circuits of the speech input equipment. Three meters are provided with two cords and a key. The 0–5 meter with a cord and small plug is used for filament currents in the different tube circuits. The other cord with the large plug is connected to the other two ammeters through the key which normally connects the 0–100 milliammeter and when pressed connects the 0–5 milliammeter. This plug fits the jacks in the plate circuits of the tube and microphone circuits while it will not enter the filament jacks. Plugging into a plate circuit jack gives a reading on the 0–100 milliammeter. If this reading is below 5 milliamperes it may be read more accurately by pressing the button and reading on the 0–5 milliammeter. This meter is provided for reading the plate current on the 102-D tube.

37. 534-A (Signal and Control) Panel—This is the control room terminal of the signal and control system between the control room and the studio.

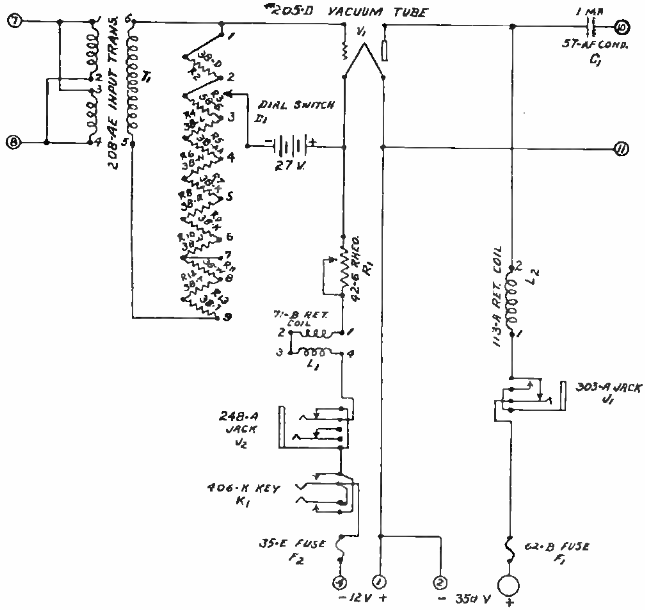


FIG. 213. 18-B Amplifier Circuit.

The amplifier input transfer key has three positions. One position is used to connect the 8-B amplifier input to the studio microphone; a second position to a microphone in the control room, and the middle position is used for connection to the extension panel and thence to a telephone line when it is desired to transmit a program from a distant point.

A monitoring key is provided for switching the monitoring 540-C.W. loud speaking telephone either to the monitoring rectifier in the radio transmitter or to the output of the 18-B amplifier. This provides a convenient means of comparing the quality of the radiated program with that of the input to the radio transmitter.

The ready signal key is provided to signal the studio when everything is in readiness for transmission. The radio room broadcast lamp will light when the ready signal key is turned on provided the amplifier input transfer key is thrown to the radio room position and the radio transmitter is operating. This red

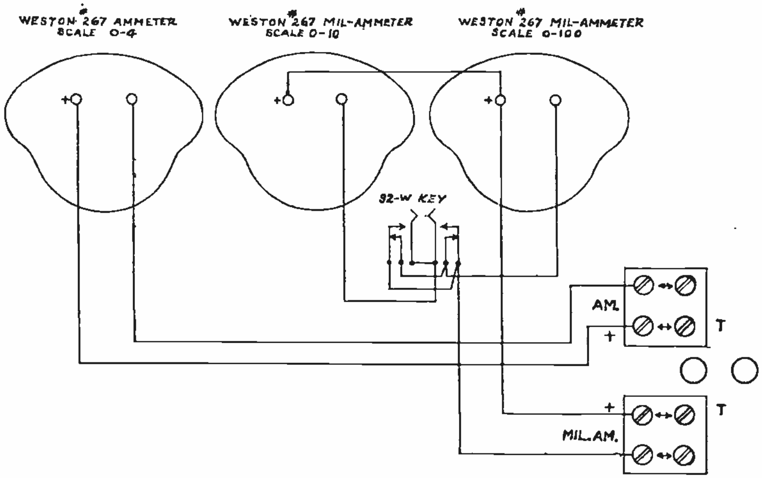


FIG. 214. Wiring Diagram of 514-A Meter Panel.

light means that all sounds in the control room are being broadcast. If the amplifier input transfer key is thrown to the studio position a light in the studio will burn showing that everything is in readiness for broadcasting. The studio operator then turns the microphone key "on" and the circuits are in readiness for broadcasting from the studio. Turning this key lights a red lamp in the studio and the studio broadcast lamp on the 534-A panel signaling both operators that the studio is broadcasting.

A hand telephone is provided for talking to the studio operator. A lamp signal and a buzzer are provided for telephone signaling and a switch is provided to turn the buzzer off when it is not wanted. A push button is used to signal to a similar set in the studio.

38. 6045-A Telephone Set—This telephone set is a signal and control unit for the studio. It has a ready signal lamp which lights when the control room operator has everything in readiness for broadcasting from the studio. The studio operator then turns the microphone key on, thereby connecting the output of the 8-B amplifier to the radio transmitter by the operation of the broadcast control relay on the 534-A panel, and the studio then is ready for broadcasting. The studio broadcast lamp lights as a warning that everything said in the studio is being broadcast. A hand telephone is provided for intercommunication between operators. This is equipped with a light and a buzzer signal and a push button for calling. A key is provided to open the buzzer circuit when it is not wanted. The buzzer is automatically disconnected by the microphone key whenever that key is turned on, thus making it impossible to buzz into the microphone.

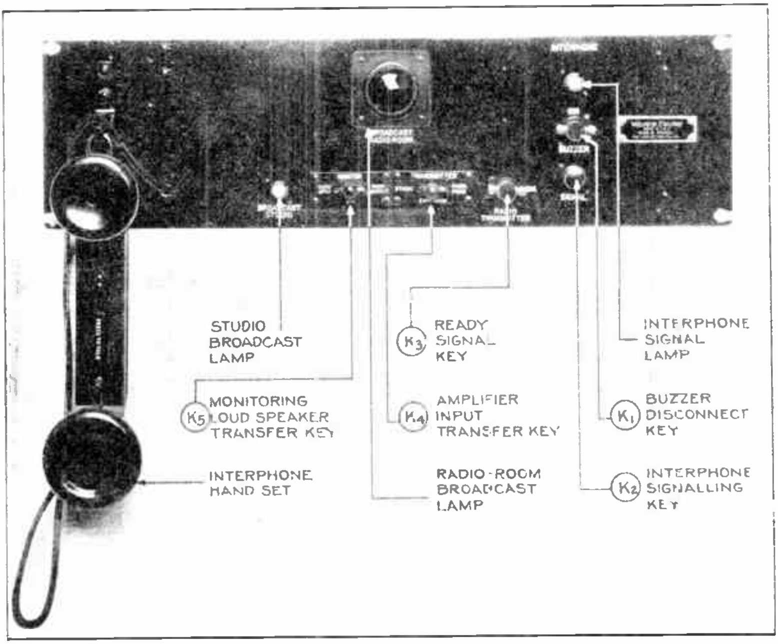


FIG. 215. 534-A Signal and Control Panel.

39. **D-76814 (Extension) Panel**—This panel is equipped with facilities for connecting the input of the 8-B amplifier to one of nine telephone lines by means of a patching cord. A key and 20-ohm resistance are connected from the 12-volt battery to terminal No. 12 on the 534-A panel for operating the broadcast control relay. A resistance network of about 20 TU equivalent with a key to short-circuit it is connected between terminals No.

25 and No. 26 on the 534-A panel and one of the jacks. The other wire jacks are for connection to nine telephone lines.

40. 547-A (Microphone) Panel—This panel carries a microphone receptacle and a remote control switch for starting and stopping the radio transmitter. The receptacle is connected to the radio room position on the 534-A panel. The start-stop switch is made up of two non-locking telephone push button keys. The start button makes a momentary contact for starting and the stop button momentarily opens a circuit for stopping the radio transmitting equipment.

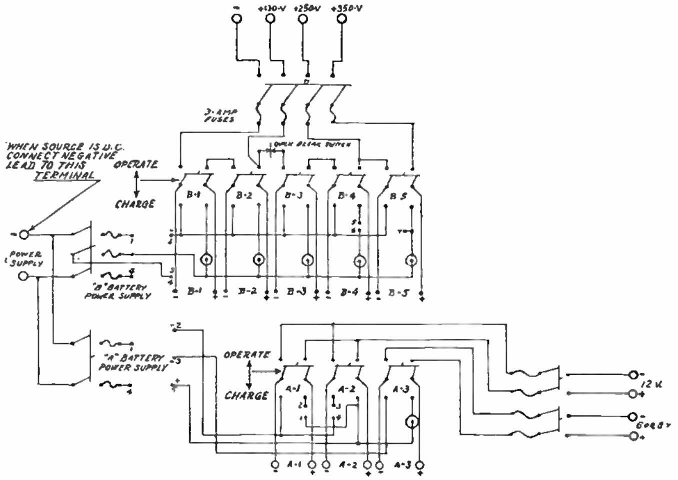


FIG. 216. Battery Charging and Switching Panel for Public Address System.

41. 536-A (Battery Supply) Panel—The battery supply panel mounts switches and fuse protection for battery circuits to each unit of the speech input equipment. A designation strip between fuses and switches indicates the circuit controlled by each switch and the fuse protecting that circuit.

42. KS-2805 (Battery Charging and Switching)—Panel—This panel is arranged with charging and operating positions for one set of 350-volt plate batteries in five sections, two sets of 12-volt batteries and one 8-volt battery. The five sections of plate battery of 70 volts each are charged in parallel with a lamp in series with each bank. A Tungar rectifier is used for this purpose and is controlled by switches and fuses on the panel. The second Tungar rectifier is used for charging the 8- and 12-volt batteries. Safety door switches are provided to sectionalize the 350-volt battery when the door of the panel is open.

Routine Maintenance and Operating Procedure.

43. **General**—The quality of program sent out by the station is largely dependent on the operation of the speech input equipment, and since there are many circuit controls to require careful adjustment, a well-ordered routine should be established for the care and adjustment of the apparatus.

44. **Storage Batteries**—The specific gravity of the batteries should be checked each day and distilled water should be added as often as necessary to keep the water level above the top of the battery plates. The batteries should be charged whenever the specific gravity indicates the need of a charge according to the instructions accompanying each battery. It is well to inspect the batteries just before closing the station at the end of the day or after shutting down for a long intermission in order that the batteries may be charged during the intermission.

45. **Studio Operation**—The studio manager is in direct charge of the program while it is being broadcast and he is in personal contact with the artist or speaker furnishing the programs. He is also in contact by telephone and signals with the control room operator and a certain routine should be established regarding his use of the signals and controls on the 6045-A telephone set mounted in the studio. The studio transmitter key on the 6045-A telephone set should normally remain on the "Off" position at all times, except when music or speech is being broadcast. The studio microphone should not be moved or jarred in any way while this key is on the "On" position. A program cannot be broadcast until the ready signal lamp marked "Radio" is lighted. This light means that the radio transmitter and other speech input circuits are in readiness to broadcast. Under this condition when the studio transmitter key is turned on the red lamp marked "Broadcast" will light, signifying that any sounds produced in the studio are being broadcast. The button marked "Signal" calls the control room operator to the interphone. The lamp marked "Interphone" is operated by the control room operator when he wishes to talk to the studio manager. The buzzer key when "On" connects a buzzer in the box in parallel with the interphone lamp when no program is being broadcast. The buzzer is automatically disconnected when the studio transmitter key is "On."

46. Control Room Operation—The control room operator is responsible for the operation of most of the speech input equipment. He must get all of his circuits in readiness before each program and continually watch the quality and volume of the input to the radio transmitter during the program. Before each program he should adjust the filament circuits of the amplifiers, adjust the current supply to the microphone and measure the plate current of each tube. The current in the various circuits should be within the limits given in the following table:

Unit	Circuit	Current
518-B	Filament	.95 Ampere
518-B [6]	Plate Circuit	5 Divisions
8-B	Plate Circuit No. 1	.0005–.001 Ampere
8-B	Plate Circuit No. 2	.005 –.008 Ampere
8-B	Plate Circuit No. 3	.015 –.028 Ampere
8-B	Filament No. 1	.95 Ampere
8-B	Filaments No. 2 and No. 3	1.6 Amperes
18-B	Filament	1.6 Amperes
18-B	Plate Circuit	.015 –.028 Ampere
8-B	Transmitter No. 1	15–25
8-B	Transmitter No. 2	15–25

The program will be obtained from one of three places, the station's studio, the control room, or an outside point. Each of these will require slightly different operation in the control room.

The apparatus is made ready for a program from the station's studio by making the following settings of switches a few minutes in advance of the program. The last operation should be to turn the key on the 534-A panel marked "Radio Transmitter" to the "On" position. This lights a signal lamp in the studio telling the studio manager that the circuits are ready.

Caution—Unbalanced currents in the two buttons of the microphone may be caused by opening the microphone circuit with any other switch than the microphone key on the 8-B amplifier. This key is shunted by a condenser for the purpose of protecting the microphone from an inductive kick due to opening the circuit. The microphone circuit should always be opened by this key before changing the amplifier input transfer key on the 534-A panel or before turning off the battery supply switch to the 8-B amplifier. As a further safeguard, the microphone current should be reduced by turning the controlling rheostat to a minimum position before opening the circuit. The microphone in use should

[6] An indication of this plate current is read on the meter mounted on the panel and is adjusted by the potentiometer marked "C Voltage."

never be disconnected by means of the base board plug until after the microphone key is turned off. (If a microphone becomes unbalanced it can usually be corrected by shaking it slightly with the current off.) Observing these cautions will greatly increase the life of the microphone.

Unit	Control	Setting
536-A Panel	Receiver Switch	Out
536-A Panel	8-B Amplifier Filament Switch	Out
536-A Panel	518-B Filament Switch	Out
536-A Panel	18-B Amplifier Filament Switch	Out
536-A Panel	534-A Panel Switch	Out
536-A Panel	547-A Panel Switch	Out
536-A Panel	518-B Panel 130V Switch	Out
536-A Panel	8-B Amplifier 130V Switch	Out
536-A Panel	8-B Amplifier 350V Switch	Out
536-A Panel	18-B Amplifier 350V Switch	Out
518-B Panel	Filament Key	On
518-B Panel	Level Measuring Key	Zero
518-B Panel	Level Measuring Switch	Operating Level
8-B Amplifier	Output Transfer Key	Coil Out
8-B Amplifier	Filament Key	On
8-B Amplifier	Microphone Key (Marked "Trans.")	On
8-B Amplifier	Amplification Control Switch	Determined by Experience
18-B Amplifier	Filament Switch	Out
18-B Amplifier	Amplification Control	Determined by Experience
534-A Panel	Monitor	Radio Output
534-A Panel	Amplifier Input Key (Marked "Transmitter")	Studio
534-A Panel	Buzzer Key	To Suit Opr.
534-A Panel	Radio Signal (Marked "Radio Trans.")	On (Last Key to Set)

The control room position for the microphone will ordinarily be used only for short announcements or testing. The apparatus is set as for the studio, except that the amplifier input transfer key on the 534-A panel is set to the position marked "Radio Room."

For broadcasting a program from some distant point the speech input must come in over a pair of telephone wires to the control room where it is again amplified before it goes to the radio transmitter. The control room apparatus will be set as for broadcasting from the studio except that the microphone key on the 8-B amplifier will be off, the amplifier input transfer key on the 534-A panel will be in the extension position, and the input key on the extension panel operates the broadcast control relay. The artificial line on the extension panel will ordinarily be in the circuit in order that the system will be operated with a sufficiently high volume level on the incoming telephone line to minimize the effect of noises picked up on the telephone line. The white light marked "Broadcast Studio" no longer indicates when broadcasting is in progress.

47. Monitoring—Two means of monitoring are provided to assist the operator in properly adjusting the speech input amplifier. They are the 540-C.W. loud-speaking telephone and the volume indicator panel.

The loud-speaking telephone is connected to either the output of the monitoring rectifier in the radio transmitter or the output of the 18-B amplifier by means of the monitoring loud-speaker transfer key on the 534-A panel. The output of the monitoring rectifier should be adjusted to a convenient level for monitoring and the output of the 18-B amplifier should be adjusted to the same level so that on switching the transfer key the sound should not be appreciably different. This method gives a comparison of the quality of the program at the input and output of the radio transmitter in addition to a means of judging the quality and volume of the radiated program. Monitoring should normally be done on the radio transmitter output.

The volume indicator is a more accurate means of adjusting the volume level of the input to the radio transmitter. As already recorded in the table of current readings on a previous page, the filament current should be adjusted to .95 ampere and the plate current reading on the galvanometer to 5 divisions by means of the grid voltage potentiometer while there is no input to the unit. The level measuring switch and key must be set according to a predetermined level at which the program is to be supplied to the radio transmitter. This level should be sufficiently low to insure good quality of transmission. Settings of — 6 to — 10 TU are usually found most satisfactory. Under no conditions should the modulator grid current meter on the oscillator modulator unit of the transmitter show a tendency to move while a program is being transmitted as this is a sure sign of overloading.

During the broadcasting of a program the volume indicator meter deflection should swing upward and for the louder tones should reach a deflection of 30 divisions but should rarely go over 30. These results will usually be obtained by an experienced operator with one adjustment of the amplification control of the 8-B amplifier for each number. It is ordinarily undesirable to change the amplification during a number as this impairs the expression of the artist; however, slight adjustments may be necessary during numbers in which unusually loud or faint passages are rendered.

Location of Troubles.

48. **General**—Troubles in this equipment will usually be found due to the improper operation of some of the switches, keys or adjustments and the first thing to do in all cases of trouble is to inspect carefully the adjustments of all the circuits. After this it is well to eliminate any units that are operating properly. Currents in the various circuits provided with jacks should be measured and should be within the limits as shown in the table of current values under the paragraph entitled "Control Room Operation."

49. **Amplifiers**—If an amplifier is in trouble and the filament and plate currents are correct, the trouble may be open connection in one of the circuits. If a usual inspection does not immediately locate the trouble it is well to check the circuit with a buzzer, using the schematic and wiring diagram to determine where each connection is made.

If the trouble is singing in one of the amplifiers it will usually be found due to a bad negative "C" battery. The plate current of the tubes will usually be high for this case of trouble.

50. **Power Supply Circuits**—Troubles with power supply circuits will usually be located very quickly with the aid of a d.c. voltmeter. The voltmeter supplied with the equipment is suitable for all circuits, except the 350-volt circuit, by using the proper voltmeter scale.

51. **Signal and Control Circuits**—Trouble in these circuits will be indicated by the failure of a lamp to light properly. This may be due to a burned-out filament if it does not light, or it may be a bad spring contact on one of the keys if it lights at the wrong time. By operating the keys and studying the circuit, the trouble can usually be located. If the trouble seems to be in one of the keys, it may be found by operating the key while watching the contacts. The trouble should be definitely located before any change is made as a changed connection is often very hard to find.

5-A Speech Input Equipment.

52. **General**—The 5-A speech input equipment involves the necessary apparatus to be used in connection with the 104-A radio telephone broadcasting equipment when the studio is located at a

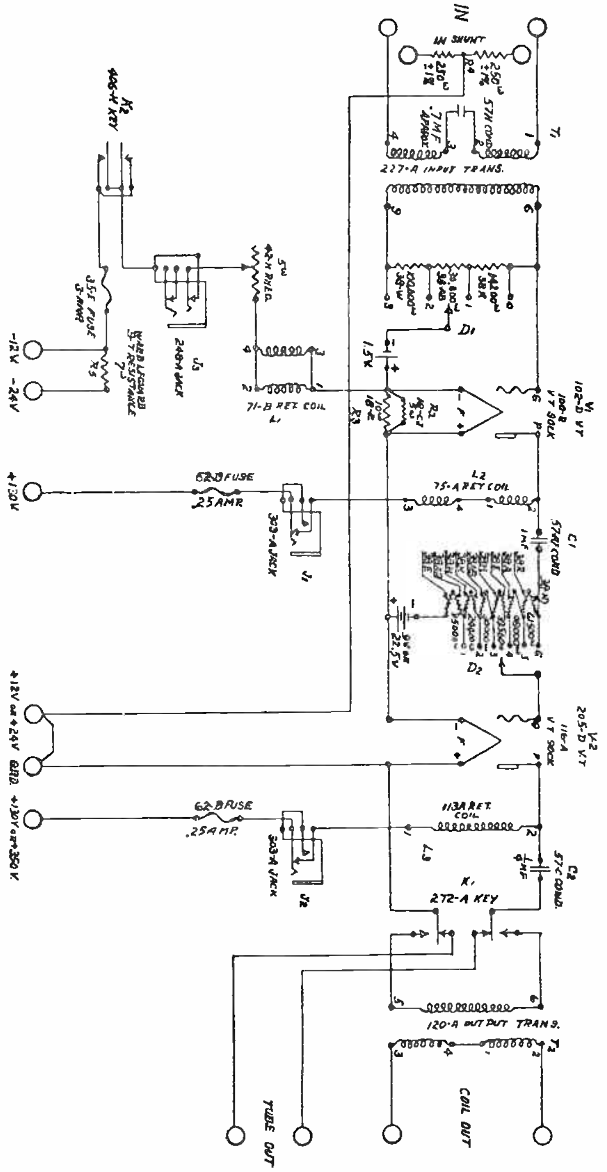


FIG. 217. Schematic and Circuit Label of 17-B Amplifier.

distance from the radio transmitter. For this condition, the 1-D speech input equipment is mounted in a control room near the studio and the 5-A speech input equipment is mounted in a room near the radio transmitter. These two equipments are connected by special telephone circuits and the radio transmitter and speech input apparatus are then operated much the same as for any other program received over telephone lines.

53. 17-B (Speech Input) **Amplifier**—The 17-B amplifier is used to amplify the speech input as it comes from the line before it goes to the radio transmitter. It is a two-stage amplifier using a 102-D tube in the first and a 205-D tube in the second stage. A shielded transformer must be used between this amplifier and the line because one side of the input circuit is grounded. A No. 77-A retard coil is preferred for this service but a No. 80-B or No. 75-A retard coil will do very well. A potentiometer is provided before each tube to control the gain of the amplifier. To prevent overloading of the 102-D tube, the left-hand gain control should be used on the lower steps while the right-hand gain control is used to make fine adjustments.

54. 518-B **(Volume Indicator) Panel**—The volume indicator panel is used here exactly as in the 1-D speech input equipment, to measure the speech frequencies input level to the radio transmitter, but in this case the amplification for different numbers of a program is controlled at the control room near the studio.

55. 18-B **Amplifier**—This amplifier is used the same as on the 1-D speech input equipment to monitor on the speech input to the radio transmitter.

56. 514-A **(Meter) Panel**—This panel is the same as that in the 1-D speech input equipment and is used to measure plate and filament currents.

57. D-72729 **(Microphone Control) Panel**—A microphone control panel is used in connection with a local microphone and the 17-B amplifier for broadcasting direct from the 5-A speech input equipment. The microphone plugged into the 547-A panel is connected to the input transformer on this panel. The key and microphone rheostat mounted on this panel are connected from the mid-point of the transformer to the battery and are used to control the microphone current. The secondary on the transformer is connected through an output potentiometer and an output key to the input of the 7-B amplifier. The output potentiometer is used in addition to the gain controls of the 17-B amplifier to regulate the volume level as measured by the volume indi-

cator. The output key is used to open the output circuit of the transformer when not broadcasting or when it is desired to change microphones without making a click in the output. The microphone key should never be operated unless the output key is turned off and should always be operated before opening the microphone circuit in any other place.

58. **D-79740 (Jack) Panel**—The jack panel is provided for connections to the incoming telephone lines by means of patching cords. The first upper and lower jacks at the left of the panel are multiplied and connected to the telephone set for order wire work. The second, third and fourth jacks at the left of the panel are used for three incoming lines, the upper and lower jacks being multiplied to provide one jack for the program connection and one jack for monitoring. The fifth vertical row of jacks and the lower jack of the sixth row provide three line jacks without parallel jacks for monitoring. The upper jack of the sixth row is connected to a 1-A equalizer and may be used with any line by means of a patching cord. The seventh row jacks are multiplied and the upper jack carries an extra contact to open a circuit when a jack is plugged in. The jacks are connected to the output of the microphone panel and the extra contact opens a circuit to the monitoring receiver when a plug is inserted in the upper jack. The eighth row jacks are multiplied and connected to the input of the 17-B amplifier. The ninth row jacks are multiplied and connected to the output of the 17-B amplifier. A connection is normally made through the back contacts of the upper jack on the tenth row. The tenth row jacks are multiplied and connected to the line which goes to the input terminals of the radio transmitter. The two-way key is provided for switching the monitoring receiver from the monitoring rectifier to the output of the amplifier.

59. **1-A Equalizer**—This equalizer is used to correct the frequency characteristic of one of the telephone lines by forming a shunt which affords a variable impedance for different frequencies. The shunt is composed of a variable resistance connected in series with a parallel circuit of inductance and capacity. The inductance forms a low impedance for the low frequencies so that the shunt is practically equal to the fixed resistance for low frequencies. As the frequency goes up, the shunt goes up in impedance, due to the increased inductive reactance, until the inductance and capacity resonate when the shunt impedance is a maximum. Two coils are provided with a key to connect either one or the other of them in the circuit. These circuits are good for equalizing fre-

quencies up to 3000 and 5000 cycles respectively and the key is marked for these frequencies. Equalizing frequencies up to 3000 cycles introduces a loss at 1000 cycles of about 6 TU and equalizing to 5000 cycles causes a loss of about 10 TU. The series resistance is adjusted by a key which throws 1000 ohms in and out and 3 dial rheostats controlling 1110 ohms in steps of 1 ohm. This gives a continuous range of 2110 ohms in steps of 1 ohm.

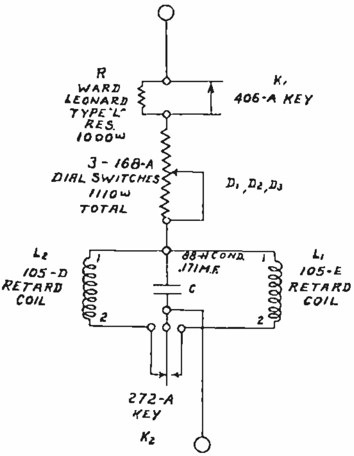


FIG. 218. Simplified Circuit of 1-A Equalizer.

Before connecting the equalizer to a line, the line should be tested to see that it is continuous and not shorted and that neither side is grounded. A 1-A equalizer is adjusted approximately by setting the resistance according to the attenuation of the line to be equalized as shown by the curve, figure 219. If the attenuation of the line is not known, or if this approximate adjustment is not satisfactory, it will be necessary to take gain-frequency characteristics of the line, using several values of equalizer resistance. As this operation requires the use of additional apparatus, it is suggested that the customer engage the service of the telephone company supplying the lines.

60. **Operation of 5-A and 1-D Speech Input Equipments Together.** **General**—The operating procedure of broadcasting with the studio at a remote point, using the 5-A and 1-D equipments, is very similar to broadcasting from a remote point when using the 1-D equipment at the radio transmitter. The connections of the 1-D equipment at the studio are slightly changed and the 5-A equipment is designed to better meet the needs of broadcasting remote programs.

61. **1-D Equipment**—The operation of the 1-D speech input equipment will be slightly different for this arrangement because another operation enters between this equipment and the radio transmitter. The transmitter is no longer started from the equipment, but the operator is provided with a direct telephone connection to the operator at the transmitter and he must learn, by

telephone, when the transmitter and the 5-A speech input circuits are in readiness for broadcasting.

62. 5-A Equipment—A routine procedure should be established for the operation of the 5-A equipments which will be similar to that for the 1-D equipment. Meter readings for this equipment should be within the following limits:

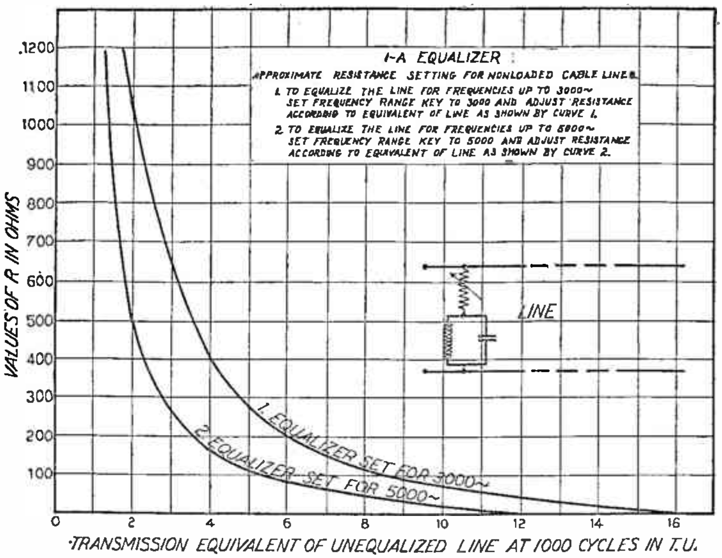


FIG. 219. Approximate Resistance Setting of 1-A Equalizer for Non-Loaded Cable Line.

Unit	Circuit	Current
518-B Panel	Filament	.95 Ampere
518-B Panel	Plate	5 Divisions
17-B Amplifier	Filament	1.6 Amperes
17-B Amplifier	Plate Circuit No. 1	.0005–.001 Ampere
17-B Amplifier	Plate Circuit No. 2	.020 –.035 Ampere
D-79739 Panel	Microphone No. 1	.015 –.025 Ampere
D-79739 Panel	Microphone No. 2	.015 –.025 Ampere
18-B Amplifier	Filament Current	1.6 Amperes
18-B Amplifier	Plate Current	.015 –.025 Ampere

The settings of the apparatus of the 5-A equipment for broadcasting from the studio or any of the lines terminated on the D-79740 panel are listed as follows:

Unit	Control	Setting
518-B Panel	Filament Switch	On
518-B Panel	Level Measuring Key	Zero
518-B Panel	Level Measuring Switch	Operating Level
17-B Amplifier	Output Transfer Key	Coil
17-B Amplifier	Input Potentiometer	Determined by Experience
D-79739 Panel	Output Key	Off
17-B Amplifier	Inter Pot.	Determined by Experience
D-79739 Panel	Microphone Key	Off
536-A Panel	Radio Receiver	Out
536-A Panel	Volume Indicator Fil.	Out
536-A Panel	17-B Amplifier Fil.	Out
536-A Panel	Microphone	Out
536-A Panel	547-A Panel	Out
536-A Panel	18-B Amplifier Fil.	Out
536-A Panel	Volume Indicator Plate 130V.	Out
536-A Panel	17-B Amplifier Plate 130V.	Out
536-A Panel	17-B Amplifier Plate 350V.	Out
536-A Panel	18-B Amplifier Plate 350V.	Out
D-79740 Panel	Monitoring Key	Output
D-79740 Panel	Patch Cord	Program Line Jack to Input of 17-B Amplifier
D-79740 Panel	Patch Cord	Lower Program Line Jack to 1-A Equalizer Jack if line is to be equalized
D-79740 Panel	Patch Cord	Telephone Set to order wire line
18-B Amplifier	Filament Switch	Out
18-B Amplifier	Gain Potentiometer	Determined by Experience
17-B Amplifier	Outer Pot.	Determined by Experience

Settings for the gain potentiometers of the 17-B amplifier may be obtained as follows: Set the level measuring key and switch of the 1-D speech input equipment volume indicator to + 2 TU (or the lightest level allowed by the telephone company) and the level measuring key and switch of the 5-A speech input equipment volume indicator to the predetermined value for modulating the radio transmitter. A test program should be transmitted from the studio while the operators of the 1-D and 5-A equipments compare volume indicator peak deflections over the order wire, the operator of the 5-A equipment adjusting the potentiometers of the 17-B amplifier until peak deflections of both volume indicators are equal.

During operation the volume indicator of the 5-A equipment serves as a check upon the operation of the 1-D equipment. Changes of the potentiometers of the 17-B amplifier should be unnecessary when the 1-D equipment is properly operated. The operator of the 5-A equipment should, however, constantly check both volume and quality, advising the 1-D operator when changes are desirable. In extreme cases it may be necessary to temporarily change the adjustment of the 17-B amplifier potentiometers until the 1-D operator is advised of and corrects the condition after which the adjustment should be returned to normal. For transmitting from the operating room one patching cord is needed from the D-79739 panel jack to the 17-B amplifier input jack, the microphone key on the D-79739 panel should be turned on and the output key of the same panel should be on for broadcasting and off at all other times. The other apparatus should be set as for broadcasting from a program line.

63. **Conversion of D-77964, 5 KW. Transmitter to D-81207 Radio Transmitter**—The conversion involves the installation of additional equipment and results in an improvement of the inherent stabilization of carrier frequency during modulation.

Practically all of the new equipment used in the conversion is mounted in the oscillator unit known as D-81206 which replaces the D-79008 d.c. power panel. The new oscillator unit contains the d.c. control equipment for the transmitter, a thoroughly shielded master oscillator and two stages of radio frequency amplification. The two 212-D tubes on the D-79180 panel which were formerly used as oscillators are caused to function as amplifiers, forming a third stage of amplification in which the process of modulation is affected. The power amplifier located on the D-79009 power amplifier unit forms the fourth and last stage. In the modified transmitter, therefore, the radio frequency circuits consist of a low power oscillator and four stages of amplification which progressively increase in power; the oscillator is rated at 50 watts and the last amplifier has an output of 5 kilowatts.

Minor changes are made in several of the other panels.

64. **Oscillator**—A 211-D tube (50-watt) in a series feed circuit of the Hartley type is used as the oscillator. The oscillator circuits are completely shielded within a copper box, access to which is obtained from the rear of the unit by loosening clamps on the hinged section. Referring to figure 220, the circuit consists of the tuning inductance L_1, auxiliary fixed tuning condensers C_1 and C_2 and variable tuning condenser C_3. C_4 is a stopping condenser keeping high plate potentials from the grid of the tube. C_5 is a radio frequency by-pass across the high plate supply.

The radio frequency output of the tube is delivered to the oscillatory circuit through the upper end of coil L_1 while the lower end of this coil furnishes the grid excitation for the tube. The "IR drop" across resistance R_6 which is connected from the lower end of the grid coil to the filament through the radio frequency choke L_2 and grid ammeter M_3 serves as the necessary negative bias for the grid. The oscillatory current is measured by means of a thermoammeter M_2 placed in series with the plate and grid coils on the low voltage side of the stopping condenser C_4. The re-

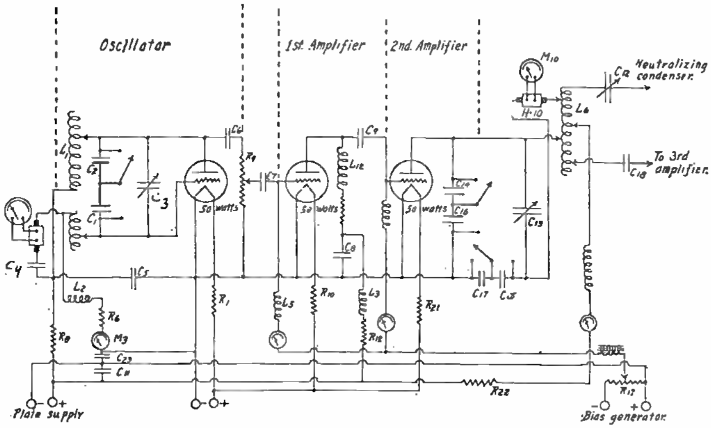


FIG. 220. Modified 5-KW. Transmitter with Master Oscillator, 1st and 2d Amplifier Circuits.

sistance R_9 connected in series with the plate stopping condenser C_6 imposes a constant load of suitable magnitude on the oscillator and also serves as a means of impressing a radio frequency voltage on the input circuit of the first amplifier. The oscillator plate is energized from the 1500-volt generator through series resistance R_8, plate current ammeter and the plate end of oscillator inductance L_1. Under normal operating conditions the potential on the plate should be approximately 750 volts. The oscillator tube together with the first and second amplifier tubes obtains filament power from the 24-volt generator through series resistances R_7, R_{10} and R_{21}. The by-pass condenser C_{23} is provided to furnish a short radio frequency path to ground from the filaments of the master oscillator and amplifier tubes within the unit. The filaments are grounded only through a relay and ammeter in the power amplifier unit.

65. First Amplifier—This stage is an untuned impedance coupled unit using a 211-D (50-watt) vacuum tube. Its radio frequency input is derived from the tap on resistance R_9 through stopping condenser C_7. A suitable negative bias is applied to the grid from the potentiometer resistance R_{17} through the grid meter and radio frequency choke L_5. The plate voltage is supplied through the series resistance R_{12}, plate current ammeter, radio frequency choke L_3, resistance R_{11} and coupling coil L_{12}. R_{11} is a non-inductive resistance which serves in connection with inductance L_{12} and condenser C_8 as the output circuit and the coupling element for the stage which follows.

66. Second Amplifier—The second amplifier is mounted in a copper box similar to and adjoining that of the oscillator. It consists of a 211-D (50-watt) vacuum tube working into a tuned circuit. The radio frequency output of the first amplifier is impressed on the grid of the second amplifier through stopping condenser C_9. The negative bias is supplied through radio frequency choke L_8 and grid meter from the same potentiometer tap as that used for the first amplifier. The plate supply voltage is obtained from the 1500-volt generator through series resistance R_{22}, plate current meter M_{11} and radio frequency choke L_7 to the center tap on inductance L_6 and through the plate tap on the coil to the

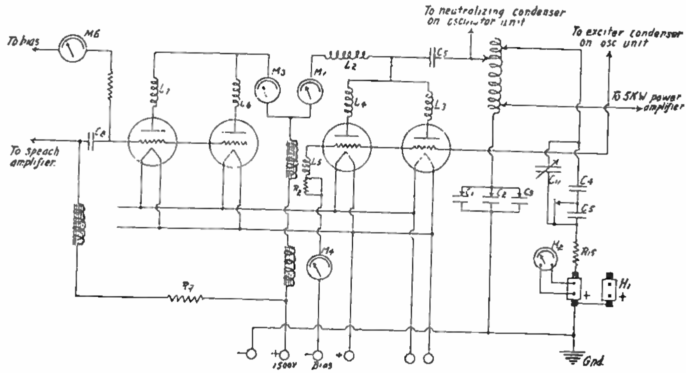


FIG. 221. Oscillator-Modulator Unit (3d Amplifier D-81207 Transmitter).

tube. The resonant circuit consisting of L_6 and tuning condensers C_{13}, C_{14}, C_{15}, C_{16} and C_{17} is tuned approximately by adjusting the taps on L_6 and short-circuiting links on the condensers C_{14}, C_{16} and C_{15}, C_{17}. The circuit is finally tuned from the front of the panel by means of variable condenser C_{13} which shunts the fixed condenser combination. Resonance is indicated by ammeter M_{10}, the thermoelement of which is connected in series with the tuned circuit at H_{10} (as a simultaneous indication, minimum plate current should be used). The output circuit is coupled to the third amplifier through condenser C_{18}.

67. **Third Amplifier. Oscillator-Modulator Unit**—In the modified oscillator-modulator unit the two (250 watts each) tubes formerly used as oscillators are employed as amplifiers in a balanced circuit shown in figure 221. The modifications are made by disconnecting the grids of the tubes from stopping condenser C_7 and connecting them to the output of the second amplifier through a switch. The grid resistance R_2 is short-circuited and the positive terminal of the grid meter M_4 connected to a tap on the grid biasing potentiometer through terminal No. 9. A connection is made from condenser C_{11} to condenser C_5 and resistance R_{15} replaces resistance R_1. An additional thermocouple H_1 is provided for use while neutralizing the circuit. The grid excitation is supplied by the second amplifier and the negative grid voltage is obtained through a potentiometer tap on R_{16} in the oscillator unit. The grid current is registered on grid meter M_4 which is in series with the radio frequency choke L_5. The plate supply is obtained from the 1500-volt generator to which is added the audio frequency output of the modulator tubes. L_1 now serves as a tuning inductance for the tuned plate circuit, the resonant frequency of which is determined by fixed condensers C_4 and C_5 and variable condenser C_{11}. The closed circuit current is registered as before on meter M_2. The third amplifier is neutralized by what is known as the Rice method in which a condenser is connected from the plates of the vacuum tubes back to a point on the input inductance which is at opposite potential from the grid. Condenser C_{12} in the oscillator unit is the neutralizing condenser.

68. **Adjustment of Transmitter**—The adjustment of the various circuits in the D-81207 radio transmitter consists of tuning the master oscillator to the desired carrier frequency and then resonating the amplifier circuits. Resonance is indicated in all circuits except the antenna circuit by an adjustment to minimum d.c. plate current of the tube whose plate circuit is being adjusted; in the antenna circuit resonance is indicated by an adjustment to maximum antenna current.

The coupling between the second and third amplifiers and between third amplifier and the power amplifier should be adjusted until the power desired is dissipated in the artificial antenna. (All adjustments are first made on artificial antenna.)

69. **Neutralizing Third Amplifier**—When all adjustments have been made and the desired power is being dissipated in the

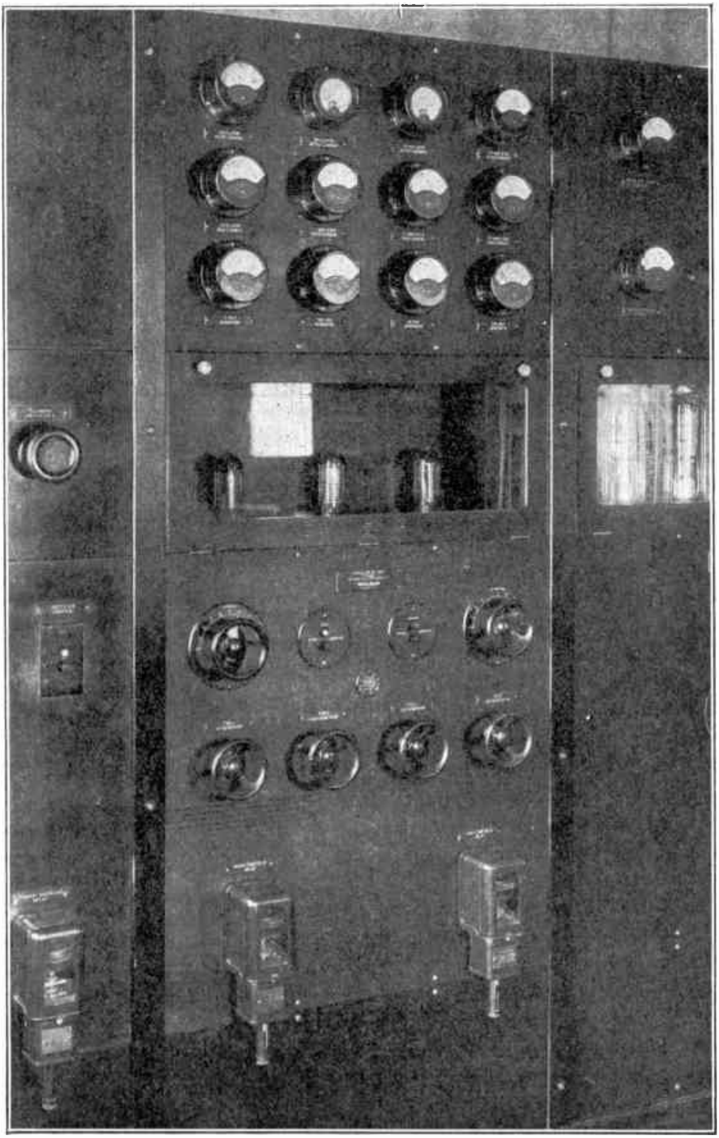


FIG. 222. Master Oscillator Frequency Stabilizer Panel.

antenna the third amplifier (in the oscillator-modulator unit) should be neutralized in the following manner: Disconnect the lead from the 1500-volt terminal No. 11 on the oscillator-modulator unit, connect in the 0.5 ampere thermocouple for meter M_2, open switch D_5 in the a.c. power panel, close the gate and energize the transmitter, having first adjusted the field rheostat of the 1500-volt generator to give minimum voltage. Increase the voltage of the 1500-volt generator gradually until a reading is obtained on M_2 (oscillatory circuit current) on the oscillator-modulator unit. Adjust the neutralizing condenser C_{12} in the oscillator unit until the reading of M_2 passes through a minimum.

70. Note—the neutralizing condenser adjustment C_{12} is located directly below the namplate and above the line of rheostat controls on the oscillator unit. It is adjusted by means of the spanner wrench furnished with the unit.

Readjust C_{12} to this minimum. Increase the voltage to 1500 volts and readjust C_{12} if necessary. Reconnect the high-current thermocouple for M_2 in the oscillator-modulator unit and replace the 1500-volt lead on terminal No. 11.

Close switch D_5 on the a.c. power panel and start the transmitter. Check oscillator frequency, tuned circuit adjustments and neutralizing adjustment. Take a set of all meter readings and be sure they fall within the specified limits.

With a sustained tone such as "Ah-h-h" spoken into the microphone and the 8-B speech input amplifier adjusted so that the modulator grid ammeter shows a slight current indication, the modulator plate current, third amplifier output current and antenna current should show an increase. In other words, the transmitter should "modulate up."

CHAPTER 10

THE ARC RADIO TRANSMITTER

1. **General Arc System**—A direct current arc transmitter is constituted of three essential parts, namely, the source of energy, the arc converter, and the oscillatory circuit.

2. **The Source of Power**—A direct current of a potential ranging from 200 to 1200 volts is required to furnish power for the operation of an arc transmitter, depending upon its size. Such current is usually supplied from a direct current generator driven by an electric motor or by an engine of some sort. Control of the power required from the energy source is secured through the utilization of an ordinary field rheostat for the generator mentioned. In some cases storage batteries have been utilized, but such instances have been very few and limited to small equipments.

3. **The Arc Converter**—Continuous undamped radio frequency oscillations are obtained in the arc transmitter by means of an arc converter, a device which changes direct current to a high frequency alternating current. The arc converter consists of a positive and a negative electrode enclosed within a chamber containing an atmosphere of hydrogen, or more commonly a hydro-carbon vapor such as alcohol vapor, the electrodes being so placed that the arc formed between them is acted upon by a powerful magnetic field.

4. **The Electrodes**—The electrodes in the modern type of arc converter are both made of copper and water cooled. In the past carbon and graphite have been used for the negative electrode with good results under rather limited conditions. It has been found, however, that the water cooled copper cathode gives much better operation over the wide range of conditions encountered on board ship.[1]

5. **The Arc Circuit**—A simplified circuit of an arc transmitter is shown in figure 223. It is seen that power for the arc is supplied by a d.c. generator. The positive terminal of this generator is connected through a combined choke and arc magnet

[1] The use of a copper cathode is a development of the Federal Telegraph Company.

winding to the positive electrode or anode. The windings set up the magnetic field required to act upon the arc and also serves as a choke coil to prevent radio frequency currents from getting back into the d.c. generator. The anode is connected through an antenna loading inductor to the antenna while the negative electrode or cathode is grounded.

The antenna is in effect a condenser in which the net work of antenna wires is one plate and the ground is the other plate. It forms in conjunction with the inductance of the antenna loading inductor an oscillatory circuit across the arc converter. The capacitance of the antenna together with the inductance of the antenna loading inductor determine the frequency of the oscillations in the antenna circuit.

6. Use of Hydrogen Gas—In maintaining oscillations in the antenna circuit it is necessary for the arc flame in the arc converter to be extinguished once every cycle and the magnetic field acting as a magnetic blow-out is employed to assist in accomplishing this result. Hydrogen being the lightest and having the

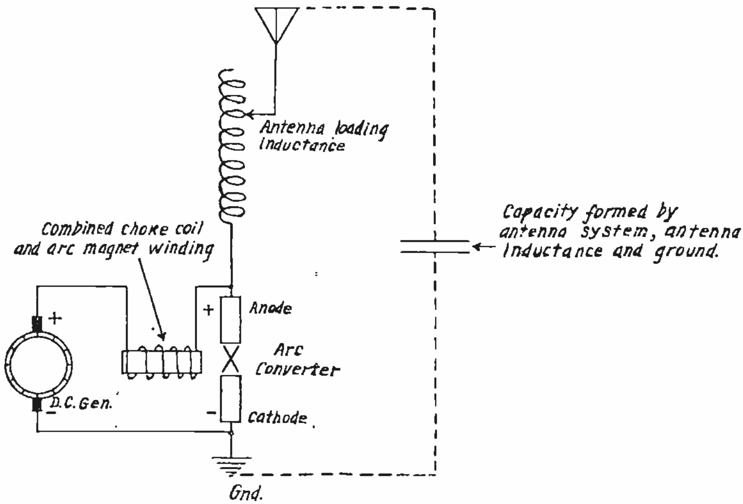


FIG. 223. Simple Arc Transmitter without Signalling System.

highest rate of diffusion of all known gases is used as the atmosphere in which the arc burns. This atmosphere is obtained by the use of some hydrocarbon such as alcohol, kerosene, or city gas. On board ship it is generally found that alcohol is the more satisfactory than kerosene on account of requiring less cleaning of the chamber. The cathode or negative electrode is rotated to insure uniform wear and maintain steady arc operation.

7. Theory of Operation—Referring to figure 223, the capacity formed by the antenna system and ground is in shunt to the arc. When the electrodes of the arc are first placed in contact and then given the correct separation considerable difference of potential exists across the terminals. Accordingly a part of the current flowing due to the difference of potential existing across the electrodes charges the condenser formed by the antenna system and ground. As the condenser is charged the arc is robbed of some of its current. The smaller arc current allows the voltage across the arc to rise. The increase in voltage causes more current to flow into the condenser until the potential across the arc no longer rises rapidly with decreased arc current. Thus there is no longer 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, decreasing its potential and that of the condenser. Immediately the condenser discharges across the arc and due to the inertia of the oscillation current the condenser is charged in the opposite direction. It immediately begins to discharge and this time opposes the arc current. The opposing currents neutralize each other causing the arc to be extinguished. It immediately is reformed, which is the beginning of another cycle. Direct current is constantly supplied to arc by the generator allowing the oscillation to be maintained at a constant amplitude, thus during the time the arc is in operation continuous waves are radiated by the antenna. As stated previously the frequency of oscillation is determined by the capacity of the antenna to ground as well as the inductance of the tuning inductance. As the capacity of the antenna to the ground is ordinarily fixed, the control of frequency is accomplished by adjustments to the antenna inductance.

With a given potential applied across the arc the resistance of the antenna circuit must not exceed a critical value or otherwise no oscillations will be produced. This is equivalent to saying that for any antenna there is a critical voltage below which the arc will not oscillate. This critical voltage may vary somewhat with arc conditions. In general for steady operation it is necessary to use a potential substantially above the critical value.

8. Signalling Systems—As previously stated, while the transmitter is in operation there will be a continuous flow of undamped current in the antenna circuit unless means are provided whereby it may be broken up into dots and dashes constituting the signals of the telegraphic code. There are four general methods of accomplishing signalling as follows:

1. "Back Shunt" method.
2. Ignition Key method.
3. Compensation method.
4. Chopper method.

9. **"Back Shunt" Method of Signalling**—The essential units constituting this method of signalling are:

1. The Back Shunt circuit.
2. The Back Shunt Relay Key.
3. The Morse Hand Key.

During operation the arc is switched from the antenna circuit to a local oscillatory circuit by means of a suitable double contact relay key. The circuit as used with sets equipped with the back shunt method of signalling is outlined in figure 224.

When the movable contact of the back shunt relay key presses against the stationary contact which is connected to the antenna loading inductor, the radio frequency current flows in the antenna circuit, when the movable contact presses against the other stationary contact, the radio frequency current flows in the back shunt circuit and there is no current in the antenna because it is disconnected from the arc. The relay key is adjusted so that its movable contact makes connection with one stationary contact before it breaks with the other. This permits the arc to remain in constant operation while the current is transferred from the antenna circuit to the back shunt circuit. The back shunt circuit consists of a resistor, inductor and condenser all connected in series. The resistance of the back shunt circuit is made variable so that the radio frequency current may remain at the same value whether the arc is operating on the antenna circuit or the back shunt circuit.

In practice the back shunt relay key is operated by an electro magnet, which is in turn controlled by a standard Morse hand key. When the hand key is depressed the electro magnet becomes energized and the movable contact of the relay key connects the arc with the antenna circuit. When the hand key is released, a spring causes the movable contact of the relay key to connect the arc with the back shunt circuit. Current therefore flows in the antenna circuit only when the hand key is depressed.

10. **Ignition Key Method of Signalling**—In the "ignition key" method the arc is extinguished during the periods between

the dots and dashes by shunting it with a resistance. Figure 225 shows a circuit employing the ignition method of signalling.

When the contacts of the ignition key are open, the arc oscillates upon the antenna circuit in the usual manner. When the

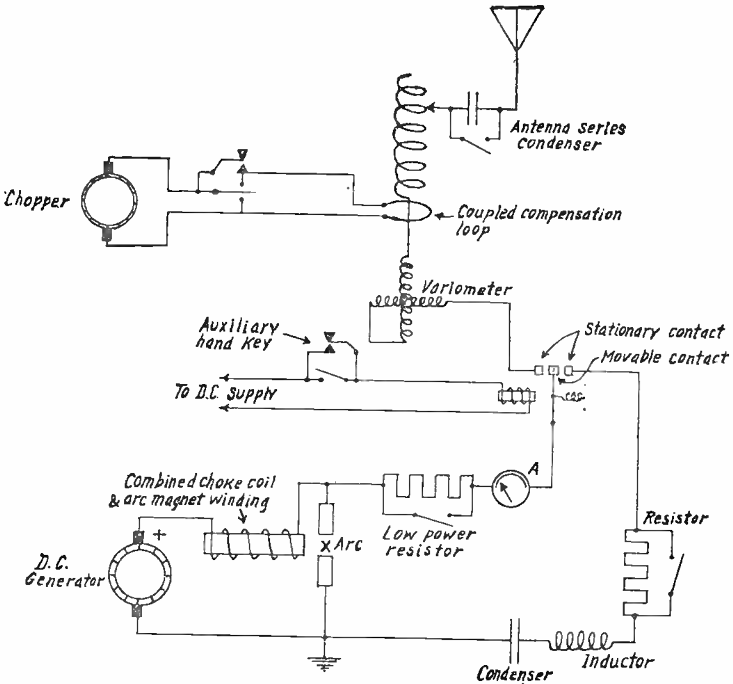


FIG. 224. Federal Arc Transmitter, Showing Circuits for Models "K" and "Q" 2-KW. "Back Shunt" Method of Signalling.

contacts of the ignition key are closed, the arc becomes shunted by the power absorbing resistor, which extinguishes it and stops all flow of radio frequency current in the antenna circuit. The ignition key contacts are located within the arc chamber in close proximity to the electrodes of the arc flame. When the ignition key contacts are opened, the flash which results is blown by the magnetic field into the gap between the electrodes and the arc flame becomes re-ignited. Current then flows in the antenna circuit. Signalling is therefore accomplished by alternately opening and closing the contacts of the ignition key and thereby alternately igniting and extingishing the arc flame. Energy is radiated by the antenna at but a single wavelength.

11. **Compensation Method of Signalling**—A "compensation method" of signalling is furnished with small sets for use in case trouble with the regular signalling system is encountered. In transmitting signals by the "compensation method" the length of the radiated wave from the transmitter is caused to vary.

There are two methods of varying the length of the outgoing wave which are in general use. Referring to figure 226, the con-

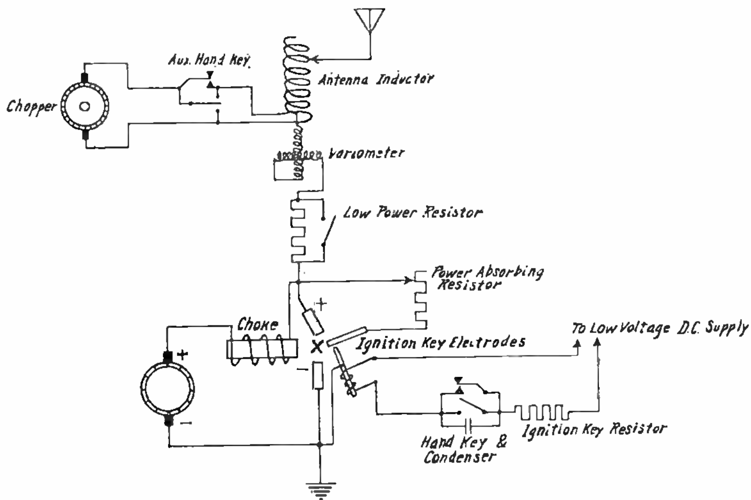


FIG. 225. Federal Arc Transmitter Showing Circuit of Model "X" 2-KW. Ignition Key Method of Signalling.

nection for signalling by the "straight compensation" method is shown in full lines in which the auxiliary hand key is connected around a portion of the antenna loading inductor. When the auxiliary hand key is depressed, the inductance of the antenna circuit becomes reduced and the length of the emitted therefore becomes shortened. Signalling is accomplished by operating the auxiliary hand key and thereby varying the wavelength. The receiving station must, of course, tune to receive on the shorter of these two outgoing waves.

The dotted lines in figure 226 show the "coupled compensation" method of signalling. In this, the auxiliary hand key is connected to a loop which is inductively coupled with the antenna loading inductor rather than being connected directly to it.

When the auxiliary hand key is closed, the loop becomes closed, thereby making a short-circuited turn around the lower part of the antenna loading inductor. This action decreases the inductance of the antenna circuit and shortens the length of the emitted wave. This is accomplished by introducing mutual inductance between the short-circuited loop and the antenna loading inductor, giving

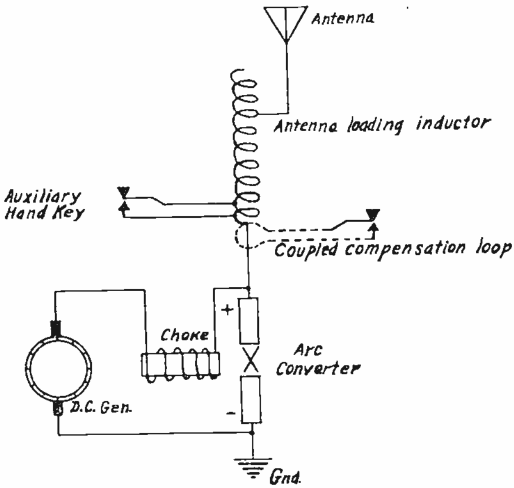


FIG. 226. Federal Arc Transmitter Showing Straight and Coupled Methods of Compensation Wave Signalling.

the same result as though connection was made directly in the antenna circuit. It has the advantage that the auxiliary hand key is insulated from the antenna circuit, thereby minimizing danger to the operator, and has the further advantage that sparking at the key contacts is reduced.

12. **Signalling With Chopper**—The frequency of the wave radiated by an arc radio transmitter is very high, much higher than can be heard by the human ear. In transmitting to a station which is receiving with a crystal or non-oscillating vacuum tube detector, it is therefore necessary to break up the radiated energy into wave trains of an audible frequency. This is accomplished by the chopper, which consists of a commutator wheel driven by a small motor. Referring to figure 225, the chopper commutator

wheel, when rotated, opens and short-circuits a "coupled compensation" loop at a speed which produces a resultant musical note in the receiver. The radio frequency energy is thus emitted at two wavelengths, as in case when using the auxiliary hand key, but the wavelength rapidly alternates between the maximum and minimum values. A continuous musical note is thus produced.

With the connections shown in figure 225, signals may be transmitted either by means of the auxiliary hand key connected in series in the circuit between loop and the chopper or by means of the "back shunt" or "ignition key" method of signalling. When the auxiliary hand key is used the radiated wave is broken into wave trains of audible frequency only when the key is closed and the receiver, therefore, gives no audible signal when the key is open. When the chopper is used with the "back shunt" or "ignition key" method of signalling, the auxiliary hand key is short-circuited by a small switch. The chopper is then effective whenever current is flowing in the antenna circuit and signalling is accomplished by permitting current to flow in the antenna circuit in accordance with the dots and dashes of the telegraphic code, as described in the paragraphs on the "back shunt" and "ignition key" methods of signalling. The small switch for short-circuiting the auxiliary hand key, when using the "back shunt" or "ignition key" method of signalling with chopper can be placed in another position to short-circuit the commutator of the chopper. This allows the auxiliary hand key to be used without breaking the signals up into audio frequency wave trains.

The chopper is used for wavelengths up to and including 800 meters. Signals transmitted by the "chopper" method may be received with the usual detector type of receiver in common use for receiving signals from damped wave transmitters. Also on shipboard the "chopper" method may be employed to signal a compass station and secure bearings. Signals of distress can also be transmitted on 600 meters so that they may be heard by all ships within range regardless of the method of reception in use.

13. Federal Marine 2-K.W. Arc Transmitter—Type AM-4151—This transmitter, which is of the panel type, is manufactured by the Federal Telegraph Company for communication at sea on wavelengths between 1500 and 2500 meters. It is rated for a power input to the arc converter of 2 K.W. under average ship conditions and will supply continuously a radio frequency current of 7 amperes at 2400 meters to an antenna circuit having a resistance not exceeding 10 ohms.

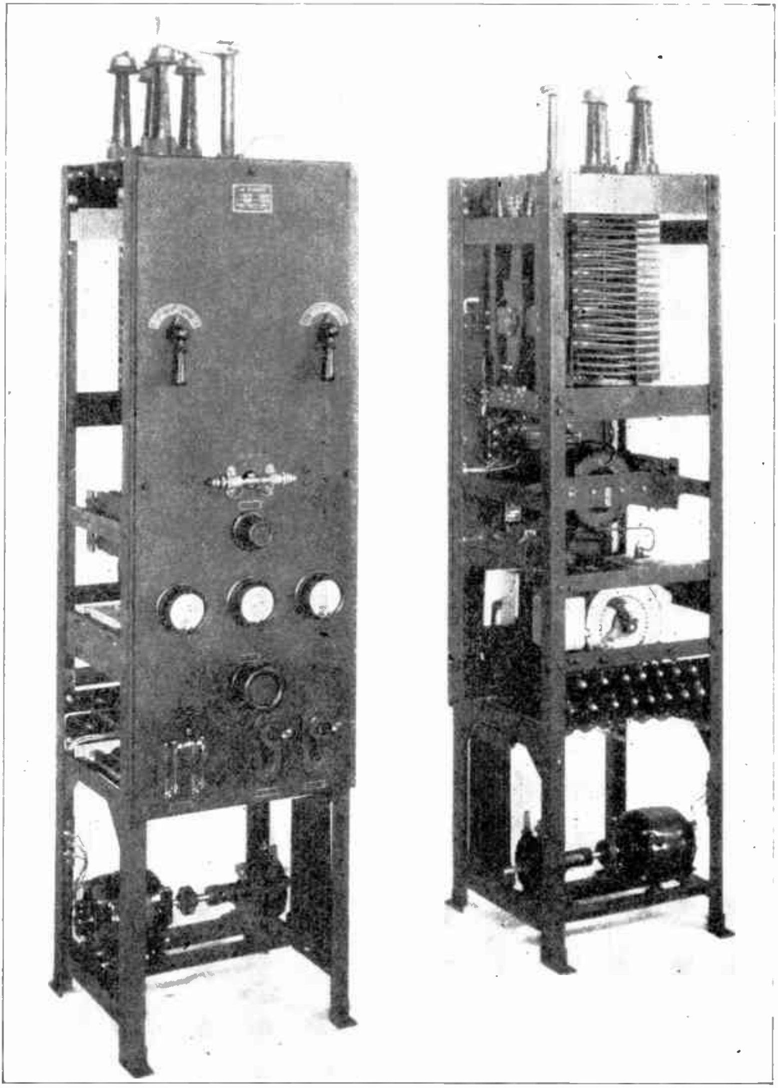


FIG. 227. 2-KW. Federal Arc Transmitter Panel, Type CM-1252—Front and Rear View.

14. **Signalling**—Various methods have ben used in the past for signalling with an arc transmiter. The most popular has been the so-called compensation method which has been described in a previous paragraph. Whereas this method is undoubtedly very simple and reliable it possesses the inherent disadvantage that it broadens the wavelength band occupied by a given transmitter and thereby increases the amount of interference which may be produced.

The development of radio has reached a stage where it is necessary to eliminate all unnecessary interference and for this reason a uniwave signalling system has been employed with the present 2-K.W. transmitter. With this system, radio frequency energy is radiated at one wavelength and only during the periods in which signals are being transmitted. The uniwave length system used employs the so-called "back shunt" method. This functions by transferring the radio frequency energy from the "back shunt" or auxiliary non-radiating circuit connected across the arc to the antenna or radiating circuit whenever the signalling key is depressed. It has been fully explained in the early part of this chapter.

Signalling by the chopper method has been eliminated with the present 2-K.W. transmitter. A ¾-K.W. spark transmitter designed to operate on a wavelength between 600 and 950 meters is employed in its place.

15. **Power Machinery**—The converter of a 2-K.W. transmitter requires a direct current power supplied at from 150 to 350 volts, depending upon the resistance of the antenna circuit. This is furnished by a motor generator set consisting of a 115-volt d.c. motor directly connected to a 2-K.W. 150-350-volt d.c. generator. The generator is separately excited from the 115-volt source supplying the motor. The generator field rheostat which is used for controlling the power supply to the arc is mounted on the transmitter panel.

All terminals for both the motor and the generator are located on an enclosed terminal board on the frame of the machine. Protective devices consisting of small condensers which by-pass any stray radio frequency currents to ground and keep them from reaching the windings of the machine are also mounted on the frame. A diagram of connections is molded on the insulating cover which protects the terminal board. This should be followed during installations.

16. **Care of Ball Bearings**—The rotor of the motor generator is mounted in ball bearings. When shipped, the bearing

races are packed in grease and should require little attention for several months. At the end of three or four months the bearings should be thoroughly flushed out with gasoline or kerosene oil and refilled with a recommended quality of grease. The grease must contain neither acid, alkali nor any fibrous material, and should not change its consistency when subjected to temperatures of 100° Centigrade or 212° Fahrenheit. After this cleaning, it is unnecessary to repack the bearings for several months although they should be inspected occasionally and kept well lubricated.

17. **Starting Equipment**—An Industrial Controller automatic starter is provided for starting the motor generator. This is equipped with overload and no-voltage protection, a push button is also provided, which permits operating the starter from some point within easy reach of the operator.

The starter proper comprises a solenoid actuating a core and piston on which is mounted the contact bar for short-circuiting the starting resistor. The bar moves vertically and makes contact with single contact fingers. This simple construction necessitates practically no adjustments, but the starter should be inspected frequently to note the wear on the contacts.

When shipped, the air dash pot on the starter piston is adjusted for an accelerating period of from 5 to 10 seconds. It can be adjusted for a longer starting period is desired by following the instructions mounted inside the starter.

18. **Overload Protection** is provided by means of an inverse time limit relay. This consists of a series solenoid actuating a plunger, the lower portion of which moves in an oil-filled cup. The oil retards the movement of the plunger and gives the inverse time limit effect.

19 **Arc Converter—The 2-K.W. Federal Arc Converter** is of the closed magnetic current type in order that there will be a negligible effect on the ship's compass due to leakage of the magnetic field. The magnetic circuit consists of a steel pole around which the field coil windings are placed, a steel plate mounted on the base, an outer steel shell and a cast iron counterpoise. The counterpoise is water cooled since it absorbs considerable heat from the arc flame.

20. **The Field Winding** is divided into four coils, the terminals of which are brought to a terminal board on the base of the arc. There are three combinations by which the coils may be connected for obtaining various field strength. In general it will be found advisable to use maximum field (all of the coils in

series) for the shorter waves and to reduce the field (three coils in series or four coils in series parallel) for the longer waves.

The positive terminal of the generator is always connected through the controls on the transmitter panel to terminal 6 on the arc terminal board.

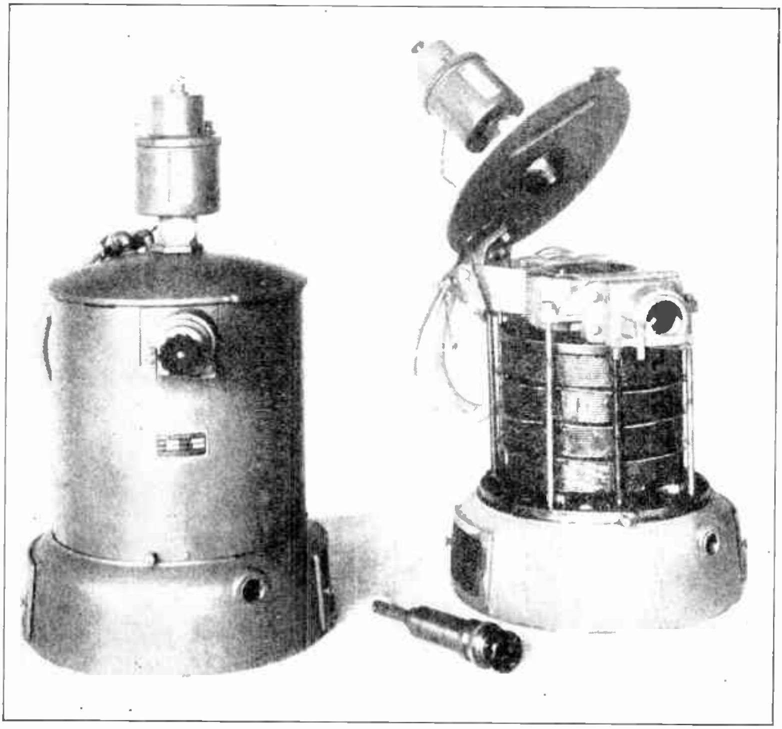


FIG. 228. Federal 2-KW. Arc Converter, Type CM-1201.

If it becomes necessary to replace any field coil it is highly important that it be connected so that the current flows through all coils in the same direction. The reversal of polarity on one coil would be sufficient to seriously impair the operation of the arc. The direction of the magnetic field is such that it blows the arc across the face of the pole tip. This may be observed by raising the counterpoise and striking the arc with the arc starting resistance in the circuit. In the event that a spare coil is not immediately available it will be found that the arc may still be operated provided the defective coil is disconnected from the circuit.

The field coils are well insulated in order to act as a choke to prevent the radio frequency current from reaching the windings of the d.c. generator.

21. **Arc Chamber**—The arc chamber consists of a water-cooled bronze casting having suitable openings for the electrodes and arranged so that it can be made gas tight. It is placed directly above the four series field coil units. The cast iron cover which carries the upper pole piece is hinged to the chamber. The raising of the counterpoise therefore provides ready access to the chamber for cleaning, or inspection. With both electrodes water cooled, the chamber can be opened as soon as the arc has been extinguished, since there is no red hot cathode to ignite the explosive mixture in the chamber.

22. **The Locking Pin** used for holding the upper section of the chamber open should also be in place with the chamber closed in order to keep it in position in case of an explosion. It is loose enough to allow the cover to raise sufficiently to break the gasket seal and relieve the chamber pressure. No explosion need ever occur should a reasonable amount of caution be used to make sure that the chamber is free from explosive mixture when the arc is struck.

23. **Burning Out Chamber**—Before closing the chamber it should be burned out. This is done by dripping a little alcohol into the chamber, lighting it with a match and then quickly lowering the counterpoise. The flame burns up any oxygen that may be in the chamber and eliminates danger of explosions due to the hydrocarbon gas.

24. **Care of Chamber**—The chamber should be inspected regularly to make sure that the copper deposits inside do not become excessive. Best arc operation is obtained with a clean chamber so that the chamber should be cleaned frequently.

It is important in closing the chamber to make sure that it is gas tight. At the cathode plenty of thick grease smeared on the outside of the cathode holder should be used. The joint at the anode and counterpoise is made with gaskets and care should be taken to see that they seat properly. A tube of graphite grease is provided for smearing on the chamber gasket to insure its being tight. It is well to move the counterpoise around a little after closing in order to make good contact all around.

The presence of water in the chamber is also undesirable since it makes the arc noisy and causes a rough note in a receiver. In case the chamber becomes filled with water due to the burning out of an anode tip, it may be drained through the pet cock provided for that purpose beneath the hinge.

25. Anode Tip and Holder—The anode is the positive electrode of the arc. It consists of a water-cooled copper tip supported by a suitable holder which is insulated from the arc chamber and grounded by means of a porcelain sleeve and bakelite flange. Little wear occurs on this copper tip so that by turning it or the holder it may be made to serve for a long period of operation, when worn it can be replaced. In changing an anode tip a new tip gasket should be used. Water in the tip softens the gasket so that it breaks up when the tip is again tightened.

The porcelain sleeve and bakelite flange should be cleaned often enough to prevent them from becoming coated with a deposit of soot and copper from the arc flame. The sleeve and flange are also replacable.

In operation care should be taken to see that there is always a supply of water circulating through the anode and that the anode is always properly aligned midway between the magnet poles. This latter condition will be met if the anode holder clamping ring is securely tightened my means of the pin spanner wrench provided for that purpose.

The anode must always be connected through the arc series field winding to the positive terminal of the d.c. generator. If connected to the negative terminal excessive wear will occur.

26. Cathode and Cathode Holder—The cathode is the negative electrode of the arc. It consists of a ¾ inch diameter water-cooled copper electrode attached to a cathode holder by means of a special nut. The cathode holder is enclosed in a cathode sheath wherein it may be moved endwise for the purpose of arc striking and arc adjusting. The arc is struck and the proper gap length attained by means of a small adjusting wheel near the end of the cathode holder. The cathode sheath together with the cathode holder and electrode is slowly rotated by means of a motor mounted in the base of the arc. This allows the arc flame to burn evenly on all points of the copper tip, resulting in more uniform operation. The speed reduction is accomplished by means of two worm gears, one mounted within the housing in the base of the arc and the other forming a part of the cathode sheath. Raising the cover exposes two oil holes through which one of the worm gears may be lubricated occasionally. The other set of gears may be lubricated by means of a grease cup on the worm gear housing and an oil cup extending through the arc casing. The driving motor should also be oiled occasionally.

After a period of operation shallow grooves are formed on the copper tips. These grooves do not generally affect the operation of the arc until they have been worn quite deep. The life of a tip under normal operating conditions is from 15 to 18 hours. At the end of this period it can still be used with but very little sacrifice in the quality of the transmitted signals. Listening to the note obtained with a nearby receiver is the best method of telling when the signals are no longer satisfactory. The note with best arc adjustment should be clear and steady with practically no breaks or bubbles.

27. **Replacing a Cathode Tip**—To replace the tip, pull down the retaining latch, remove the cathode holder from its sheath, and insert the tip in the special hexagonal hole in the base of the arc directly beneath the cathode. Place a wrench in the flats of the holder and loosen the tip and nut. Remove the tip and nut together and unscrew the tip from the nut. When putting in the new tip, it does not have to be screwed into the nut tighter than possible by hand.

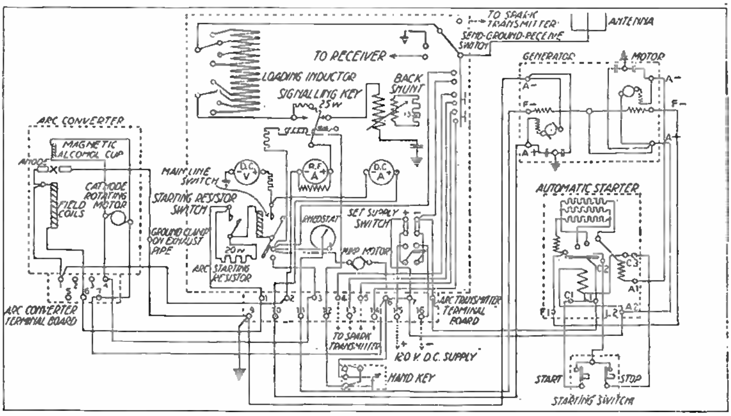


FIG. 228*a*. Diagram of Federal 2-KW. Arc Transmitter, Type AM-4151.

28. **Magnetic Feed Alcohol Cup**—The hydrogen atmosphere necessary for the functioning of the arc converter is supplied by the decomposition of alcohol. This is contained in a magnetically controlled alcohol cup mounted on the cover. When

the arc main line switch is closed preparatory to starting the arc, the solenoid on the alcohol cup is energized, through interlock contacts, thus raising a needle valve and allowing alcohol to drip into the arc chamber through a hole in the upper pole tip. The rate of the alcohol flow is regulated by a knurled nut which varies the distance which the needle valve may be raised from its seat. Opening the main line switch automatically releases the needle valve and stops the flow of alcohol. In case alcohol is wanted without energizing the solenoid the needle valve may be manually operated by means of a lever on the upper end of the valve stem. The lever should be left horizontal when the magnetic control is desired. Electrical connections are made to the solenoid through terminals No. 4 and No. 7 on the arc terminal board. The cathode rotating motor is also connected to these terminals and operated through the same interlock contacts as does the magnetic solenoid.

29. **Arc Transmitter Panel**—The arc transmitter panel mounts all of the arc starting equipment, all radio frequency circuits and the signalling system, the water circulating pump, the arc exhaust seal and all meters, switches, interlocks, etc., necessary for the operation of the arc transmitter.

30. **Set Supply Switch**—The power supply from the ship's generator or storage batteries is connected to the arc transmitter through the set supply switch. The switch is fused for 45 amperes.

31. **Arc Starting Equipment**—The arc main line switch is a special quick break switch which connects the arc converter to the d.c. generator through a starter resistor. It is provided with a trip coil which opens the switch in case of overload. The switch is non-closable on overload or short-circuit.

The arc starting resistor consists of a 20-ohm bank of resistance tubes mounted at the bottom of the panel. This resistance is necessary to keep the arc from drawing excessive current on starting and can be used for stabilizing the arc when using low power. It is designed to handle continuously a direct current of 8 amperes. The resistor may be short-circuited and full power delivered to the set by closing the arc starting resistor switch after the arc has been started. When starting up for the first time after the arc chamber has been opened, it is usually necessary to allow the arc to burn for a few minutes with the starting resistance in the circuit. This is to allow time for the production of the hydrogen atmosphere which is necessary for maintaining the oscillations.

To open the switches the operating handles should be raised until the switch trips. The switches are mechanically interlocked so that both are opened whenever the main line switch is opened.

32. **Antenna Loading Inductor and Wave Changer**—The **Antenna Loading Inductor** is mounted in the upper part of the transmitter panel. The inductor is wound on a bakelite frame with a specially designed radio frequency cable and in such a manner as to reduce the energy losses in the inductor to a minimum. A bare copper ribbon spiral is mounted on the lower end of the inductor in order to give fractional adjustment of wavelength.

33. **Caution**—When the arc is in operation the upper end of the loading inductor may be as much as 20,000 volts above ground and the operator should not approach to within six inches of the coil.

34. **A Four Point Wave Changer** for quickly changing the amount of inductance which is included in the antenna circuit is mounted beside the inductor. The wave changer consists of two sets of contacts, one for changing the number of layers of the main loading inductor and the other for changing the number of turns of the ribbon spiral. It is controlled through a set of bevel gears by a handle on the front of the panel.

It is not necessary to shut down the arc while changing wavelengths. With the radio frequency currents in the "back shunt" circuit the wave changer can be operated without affecting the operation of the arc.

35. **Back Shunt Circuit and Signalling System**—The manner in which the back shunt signalling system functions has already been described.

Referring to figure 229 it will be seen that the resistor of the back shunt circuit is inductively coupled to the back shunt inductor. It is desirable in this system of signalling to have the radio frequency energy absorbed by the "back shunt" circuit equal to the energy delivered to the antenna system. Some means must therefore be provided for making the effective resistance of the "back shunt" circuit equal to that of the antenna. In this transmitter the desired results are obtained by coupling a resistor to the back shunt inductor. The effective resistance of the circuit can be changed by varying the amount of coupling between the inductor and the coupling coil.

The control handle for changing the effective resistance of the "back shunt" circuit is located directly beneath the signalling key. Turning the handle to the right increases the coupling between the "back shunt" inductor and the coupling coil. This increases the effective resistance and decreases the current in the circuit. The coupling should be adjusted until the power delivered to the arc is approximately the same no matter which circuit

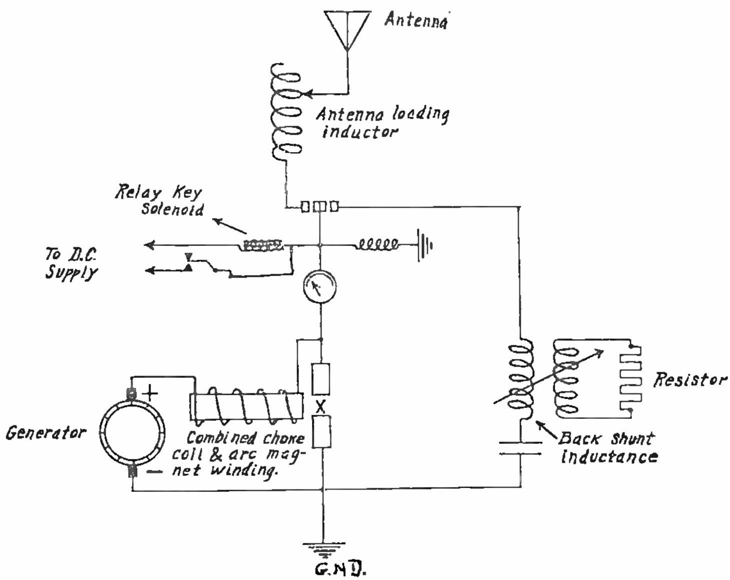


FIG. 229. Back Shunt Signalling Circuit, Type A-4151 Federal Arc Transmitter.

it is on. The correct adjustment is not critical and is obtained when the d.c. amperes to the arc are the same for both the " back shunt " and antenna circuit.

36. Send-Ground-Receive Switch—A send-ground-receive switch is mounted at the top of the transmitter panel above the loading inductor. As its name implies, the switch is for connecting the antenna to either the transmitter, the receiver or the ground. An additional transmitting position is provided to which the ¾-K.W. spark transmitter may be connected. The switch is operated through a set of mitre gears by means of a control handle mounted on the front of the panel.

On an extension to the shaft of the rotating member of the switch is an interlock which disconnects the water circulating pump motor, the cathode rotating motor and the d.c. generator field when the switch is not in the arc position. This enables the operator to have conditions as quiet as possible when receiving.

Interlocks are also provided for making it possible to operate the spark transmitter unless the switch is in the "Spark" sending position and for operating an electrical breaking device in connection with the rotary gap driving motor.

The panel on which the switch is mounted should be wiped off occasionally to keep dust from accumulating and decreasing the insulating properties of the panel.

37. **Water Circulating Pump**—The water for cooling the arc converter is circulated by a centrifugal pump mounted in the lower part of the transmitter panel. When operating the pump for the first time after filling the water tank, it is necessary to open the pet cock at the top of the pump and allow all of the entrained air to escape. *This must be done with the pump idle.* The water tank must be so installed that the water level is at least slightly higher than the pump in order to insure that all air is expelled. If the pump is not properly primed, the water may fail to circulate, resulting in the overheating of the arc converter and the possible burning out of the anode tip.

A gate valve is supplied with the tank for shutting off the water when changing a cathode or anode tip. Care should be taken to see that it is turned on before starting the arc. In case the water tank is mounted below the arc, it will not be necessary to close the valve. No water will come out if the end of the cathode or anode is held above the counterpoise.

38. **Exhaust Seal**—The arc exhaust is connected by means of a rubber hose to one end of the exhaust seal. The other end of the seal is connected to a fitting which may be placed in either the wall or deck and which leads the chamber gases to the outside air.

The exhaust seal is mounted at the bottom of the transmitter panel but can be removed and placed at any convenient point on the bulkhead. It should always be mounted vertically.

The purpose of the seal is to prevent air from entering into the arc chamber when it would combine with the chamber gases to cause an explosive mixture. When the arc is extinguished after a period of operation the hot chamber gases contract and a certain amount of air is thus drawn into the seal. The many bends in the seal and the fact that the chamber gases are much lighter prevents the air from reaching the gas chamber.

Should the seal be filled with water through accidental flooding of the chamber it should be removed and drained.

39. Water Tank—A 15-gallon tank is provided as a container for the arc cooling water. It is necessary to use fresh water in order that the anode may be insulated from ground. Salt water is a relatively good conductor and if it were used its presence in the rubber hose through which the cooling water is supplied to the anode would short-circuit the arc electrodes.

The water should be renewed occasionally in order to prevent the accumulation of sediment.

40. Tuning the Transmitter—In changing the wavelength of the transmitter two connections must be changed.

(*a*) From the signalling key to the adjusting spiral at the bottom of the antenna loading inductor.

(*b*) From the terminal board of the antenna loading inductor to the send-ground-receive switch.

Flexible connections are provided for making these connections on each of the four points of the wave changer. The manner in which the connections are adjusted so as to obtain a given wavelength is as follows:

1. Set the wave changer handle to the position where it is desired to have the given wavelength.

2. Make a connection from the switch clip now at the lower end of the wave changer arm to the lowest terminal on the antenna loading inductor. This will eliminate the adjusting spiral.

3. Make a connection from the switch clip at the upper end of the wave changer arm to some point on the terminal board of the antenna loading inductor.

If the desired wavelength is relatively long this connection should be made to one of the terminals near the tip of the inductor. If a relatively short wave is desired the connection should be made so that only a small portion of the inductor is included in the antenna circuit.

4. Start up the arc (in manner given under Operation of the Set), and measure the wavelength by means of a wave meter.

5. In case the observed wavelength is too short more layers of the inductor should be included in the antenna circuit. If the wavelength is too long a portion of the inductor should be cut out by shifting the connection to a long terminal.

6. When two terminals have been found one of which gives a wave slightly longer than desired and the other slightly shorter, connections may be made to obtain the exact wavelength by using the terminal which gives the shorter wavelength and then including a portion of the adjusting spiral in the circuit. This is done by moving the connection at the bottom of the inductor to one of

the inner turns of the adjusting spiral. After changing the amount of the spiral in use until the exact wavelength desired is obtained, the clips on the adjusting spiral should be tightened up permanently.

It should be noted that no tuning is necessary on the back shunt circuit. The constants on this circuit with the exception of the resistance are fixed so as to give satisfactory operations over the wavelength range of the transmitter (1500–2500 meters).

41. **Operation of the Set**—Assuming the transmitter to be completely installed and ready for operation, the following procedure should be followed when it is desired to carry on communication:

1. Close the set supply switch on the transmitter switch.
2. Start the motor generator set by pressing the push button of the automatic starter.
3. Place the send-ground-receive switch in the "Arc" sending position. This starts the water circulating pump.
4. Adjust the cathode so that there is about 1/32 inch motion for starting the arc.
5. Close the arc main line switch. This starts the cathode rotating motor and the alcohol feed.
6. Strike the arc by screwing in on the adjusting sleeve of the cathode until a direct current flows, then unscrewing as far as possible without breaking the arc. In starting for the first time after the chamber has been opened it will be necessary to keep the arc rather short for a minute or two until the proper hydrogen atmosphere has been obtained. As soon as the arc begins oscillating the radio frequency ammeter will indicate current in the oscillatory circuit. The arc should then be adjusted to give a maximum reading of the meter.
7. Close the arc starter resistor switch and with the arc on the antenna circuit adjust it for a maximum reading of the radio frequency ammeter. The alcohol flow should now be adjusted to what has been found satisfactory for best operation and should not be more than 10 to 20 drops per minute and probably less.

The d.c. voltage should also be adjusted to give the desired antenna current subject to the rating of the transmitter.

8. Adjust the resistance of the back shunt circuit to a value which will allow the arc to draw the same power from the d.c. generator as it would if operating on the antenna circuit. When properly adjusted the direct current to the arc should be the same for both the back shunt and antenna circuits.
9. Signals may now be transmitted by sending with the Morse

hand key. The arc should be adjusted occasionally for a maximum reading of the radio frequency ammeter when operating on the antenna circuit.

If the arc breaks or goes out it will be necessary to open the arc starting resistor switch and again strike the arc. In case the arc is struck without opening this switch, a short circuit will result and the trip coil will open the main line switch. It will then be necessary to lift the handle of this switch to the upper position and reclose it. Then strike the arc and proceed as before.

To shut down for receiving it is only necessary to throw the send-ground-receive switch from the "Arc" to the "Receive" position. This automatically opens the generator field and reduces the d.c. voltage so low that the arc breaks.

In starting up again the send-ground-receive switch should be changed back to the "Arc" position, and the arc starting resistor switch opened. Steps 6 to 9 should then be followed.

Since the adjustment of the arc determines the character of the transmitted signals it is advisable to listen in on the signals occasionally with the receiver. This will also help to give a feeling as to the proper operation of the arc.

42. **Models "K" and "Q" 2-K.W. Federal Arc Radio Transmitters**—The model "K" arc radio transmitter is for use on naval vessels and the model "Q" is for merchant ships. All the apparatus for the two sets is the same and the sets are identical in every way except for the range of the wavelengths employed.

With the model "K" sets, the chopper is used on waves below 952 meters. On 952 meters and above the set is operated as an undamped wave transmitter.

In the case of model "Q" sets for merchant ships, the chopper is used on all waves up to and including 800 meters. Above 800 meters the set is operated as an undamped wave transmitter.

43. **Motor Generator**—The direct current for the arc converter is furnished by a two-bearing Crocker Wheeler motor generator set which consists of 100–120-volt d.c. motor, directly connected to a shunt-wound, separately excited 2-K.W., 400-volt d.c. generator. The generator will deliver 2 K.W. at 250–400 volts and is wound for separate excitation from the 120-volt d.c. supply.

44. **Motor Starter**—The motor generator is started by means of a hand-operated motor starting panel. This is equipped with an overload circuit breaker which opens the motor supply circuit in case the current becomes excessive. The terminals on the starting panel are marked to insure proper connections.

To operate the motor starter, first close the circuit breaker, then move the switch arm *slowly* to the right, allowing the motor to attain maximum speed on each point. When the switch arm is in running position it is magnetically locked. It will be released in case of failure of the power supply or in case the circuit breaker is opened, either by overload or by hand. The motor may be stopped by tripping the current, the current breaker or by opening the set supply switch on the arc control panel. The starter arm will be released automatically in either case. It should never be released by hand as this would damage the contacts.

When starting the motor, the switch arm should never be returned to the starting position unless the power supply circuit is opened. Failure to observe this point will result in damaged contacts on the starter.

45. **Generator Field Rheostat**—The power output of the arc converter is regulated by adjusting the voltage of the direct current generator by means of the generator field rheostat.

46. **Arc Control Panel**—The arc control panel is the switchboard through which connections are made between the arc converter and the direct current generator. It also carries a switch through which the entire transmitter is supplied with 110–120 volts d.c. On the panel are mounted:

1. The set supply switch and fuses.
2. The arc main line switch, with overload trip coil.
3. The arc starting resistor and shorting switch.
4. The d.c. ammeter for the arc circuit.
5. The d.c. voltmeter for the arc circuit.

47. **The Arc Main Line Switch**—This is a special quick break switch which connects the arc converter to the d.c. generator. It is provided with a trip coil which opens the switch in case of overload. The switch is non-closable on overload or short circuit.

When the handle of the arc main line switch is pushed down until it locks, the arc is connected to the generator through the ammeter and arc starting resistor. To open the switch, the operating handle should be raised until the switch trips. The arc starting resistor switch is operated in the same manner. It should be closed only after the arc has been started and is in operation. These two switches are interlocked so that both are opened whenever the arc main line switch is opened. The arc starting resistor is thus automatically placed in series between the arc converter and the generator whenever the main switch is opened to shut down the arc. The switches may be operated separately by opening the arc starting switch first and then the main line switch.

Care should be observed when shutting down the transmitter to open the various switches in the following order: First, the arc main line switch and starting resistor switch; and second, the set supply switch.

48. **Arc Converter**—The arc converter has nominal rating of 2 K.W. It is designed to operate on 250–400 volts d.c.

The magnetic circuit is of the closed type. Pole tips project into the top and bottom of the arc chamber. The steel outer shell of the arc converter forms a return path for the magnetic flux.

49. **Anode Tip**—The anode tip consists of a water-cooled tip supported by a suitable holder which is insulated from the arc chamber by means of a bakelite disc. The copper tip is brazed to a short piece of brass tubing and this unit, which is known as the anode tip, is renewable when it becomes worn after a long period of operation.

50. **Care of Anode**—In operation care should be taken to see that there is always a supply of water circulating through the anode and that there are no water leaks around the anode, as any water inside the chamber causes the arc to become unsteady.

Care should be taken to see that the anode tip is always properly aligned midway between the magnet poles.

The anode must always be connected through the arc series field winding to the *positive* terminal of the d.c. generator. If connected to the negative terminal it will melt very quickly when the arc is started.

51. **Carbon**—The carbon for the 2-K.W. arc converter is ½ inch in diameter and 7 inches long. A special wrench and gauge for adjusting the carbon in the carbon holder are attached directly to one side of the arc chamber. The proper amount of projecting carbon for the most convenient operation will be automatically secured when this wrench and gauge are used for changing the carbon in position in the holder.

When the carbon and holder are placed in the arc converter, the carbon is slowly rotated by means of worm gear mechanism.

52. **Alcohol Supply**—An alcohol cup is mounted on top of the arc converter. This is provided with a needle valve and a sight feed glass by means of which flow may be adjusted and observed. The alcohol drip is controlled by a knob on top of the arc chamber.

53. **Pressure Regulator**—As alcohol is supplied continuously to the arc chamber during operation there will always be

a certain amount of gas generated within the chamber. A hose nipple is provided by means of which the excess gas may be conducted through a short piece of hose to the unit called the pressure regulator.

The pressure regulator consists of an aluminum receptacle divided into two compartments by means of a rubber diaphragm. This diaphragm serves to maintain the gases within the chamber at approximately atmospheric pressure at all times. The pressure regulator is provided with an outlet through a hose nipple with a small opening. This opening permits the excess gases to slowly leak out from the regulator through a second rubber hose.

54. **Care of Arc Converter**—The main points to be observed in caring for the arc converter are as follows:

1. The chamber should be kept reasonably clean.
2. No water leaks, however slight, should be permitted inside the chamber. The anode tip connection and gasket should be tested whenever a new tip is installed.
3. The chamber should be kept air-tight. The surfaces of the upper and lower chamber sections should always be clean and the gaskets in good condition.
4. The bakelite anode insulating disc and its gasket should be kept clean.
5. The moving parts of the cathode should be cleaned and oiled occasionally.

55. **Water Pump**—A centrifugal pump is provided for circulating water through the various water-cooled parts of the arc converter. The pump is driven by a ¼-H.P. 110-volt d.c. motor.

A set of worm gears connected to the shaft operates the carbon rotating mechanism on the arc converter.

56. **Water Tank**—A 15-gallon tank is provided as a container for the arc cooling water.

The tank is provided with three test cocks which may be used for approximately determining the water level.

57. **Back Shunt Circuit Unit**—The "back shunt" circuit unit consists of a bakelite panel upon which there are mounted an inductor, a condenser and a resistor. The inductor is a small coil of insulated copper wire. The condenser is a Dubilier Type C.D. 158 Mica Condenser, having a capacitance of .004 microfarad. The resistor consists of 2 Ward-Leonard Type D-10 resistance tubes connected in parallel. A switch is provided by means of which this resistor may be short-circuited when desired. An additional and variable resistance is obtained by placing a steel disc immediately in front of the inductor coil. When radio frequency

current flows into the coil, eddy currents and hysteresis losses in the steel disc cause an increase in the resistance of the back shunt circuit. These losses are greatest when the disc is near the coil and are a minimum when the disc is screwed back away from the coil. The resistance may be varied by turning a knob which causes the disc to be screwed in and out from the coil.

58. **In Operating the Set** the resistance of the back shunt circuit should be adjusted so that the radio frequency current delivered by the arc converter remains constant whether the arc is upon the antenna circuit or upon the back shunt circuit. This adjustment of resistance is secured by screwing the steel disc in or out and by using the switch which short-circuits the fixed Ward-Leonard tube resistor.

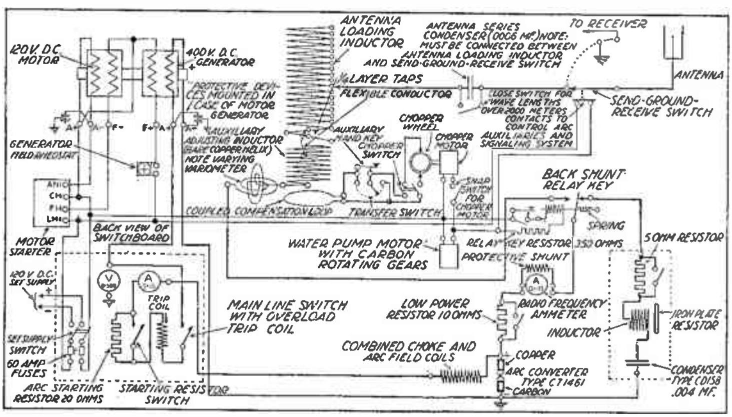


FIG. 229a. Diagram of Model "Q" Federal 2-KW. Arc Transmitter.

59. **Transfer Switch for Chopper and Auxiliary Hand Key**—A single-pole, double-throw transfer switch is supplied in order that the coupled compensation loop around the bottom of the antenna loading inductor may be connected either to the chopper or the auxiliary hand key, or to the two in series. A name plate is supplied with this switch which may be mounted with it in order to indicate the proper position of the switch for each circuit combination. A wiring diagram of the coupled compensation circuit is included on this name plate.

60. **Chopper**—The chopper consists of a commutator wheel driven by a ¼-H.P. 110-volt d.c. motor. Segments of the commutator wheel are connected at regular intervals to a central ring.

The chopper brushes are so adjusted that they both make contact with these connected segments at regular intervals during the rotation of the wheel. The two brushes are connected through a suitable switch to the coupled compensation loop which is placed around the bottom of the antenna loading inductor. The commutator wheel serves to alternately open and short-circuit this coupled compensation loop. The chopper commutator wheel, when rotated, opens and short-circuits the compensation loop at a speed which gives a musical note in the receiver. The radio frequency energy is thus emitted at two wavelengths as when using the auxiliary hand key, but in this case the wavelength rapidly alternates between the maximum and minimum values.

The chopper commutator wheel should be cleaned with fine sand paper occasionally and the brushes and springs should be kept in good condition. The oil cup on the motor should be kept filled with good lubricating oil.

61. **Note Varying Variometer**—In order that the operator may be able to slightly vary the length of his outgoing wave while calling, a note varying variometer is supplied. This variometer consists of a stationary coil and a coil which may be rotated within the stationary coil. When the rotating coil is turned in one direction, the outgoing wave is lengthened; and when it is turned in the opposite direction the wave is shortened. By rotating this coil slightly first in one direction and then in the other, the operator is able to slightly vary the outgoing wave and thereby make his call heard by the receiver.

The variometer is connected directly in series in the antenna circuit between the antenna loading inductor and the relay key.

62. **Antenna Low Power Resistor**—In order that the antenna current may be reduced when communicating with a nearby station, a resistor is supplied which may be connected in series in the antenna circuit for operation on low power. A shorting switch is mounted on the bakelite cover of the unit. This switch is closed except when it is desired to operate on low power .

63. **Send-Ground-Receive Switch**—This switch provides the means of connecting the antenna either to the transmitter or to the receiver or to the ground.

Interlock contacts are provided on the switch for the 110-volt d.c. circuit which supplies the relay key and other auxiliaries.

The switch clips should be kept in good condition and the turntable upon which the rotating insulator is mounted should be oiled occasionally.

64. **Operation of Model "K" or "Q" 2-K.W. Arc Radio**

Transmitter—Before starting the set for the first time, the various circuits should be tested to see that all electric connections have been made in the proper manner. The following steps should be taken:

1. Fill the gasoline cup and see that it feeds properly.
2. Fill the water tank ¾ full with fresh water.
3. See that the valves of the water tank are open and that the flow indicator indicates a circulation of water when the pump is started.
4. See that all moving parts are properly lubricated.

65. To Start the Set after a Long Period of Rest:

1. Close the set supply switch.
2. Place the send-ground-receive switch in the sending position. This should start the water pump and the carbon rotating mechanism which are supplied through the interlock contacts.
3. Start the motor generator by closing the circuit breaker on the starting panel and bring the motor gradually up to full speed. Adjust the generator voltage to be 250 volts by means of the field rheostat.
4. Start the alcohol flowing so that it may drip rather rapidly. Adjust the carbon on the arc so that there is about 1/32 inch motion when the arc is struck.
5. Close the arc main line switch and strike the arc. Draw it out as long as possible without causing it to break. In starting for the first time, it will be necessary to keep the arc rather short for a minute or two until sufficient alcohol has been decomposed to give a partial hydrogen atmosphere in the chamber. As soon as the arc starts oscillating, the radio frequency ammeter will indicate current in the oscillating circuit and the arc should then be adjusted to obtain a maximum reading of this meter.
6. Close the arc starting resistor switch and adjust the arc for a maximum reading of the radio frequency ammeter. The alcohol flow may now be reduced to a few drops per minute and the generator voltage adjusted to obtain the desired antenna current.

66. To Transmit Signals—After the arc is operating, signals may be transmitted by sending with the Morse hand key. In case radio frequency current through the back shunt circuit differs materially from that into the antenna circuit the resistance of the back shunt circuit should be adjusted so that the output of the arc converter is the same for both circuits.

67. Arc Adjustment—After the arc is in operation, it will only be necessary to make occasional slight adjustments of arc length. These adjustments are made to obtain a maximum reading of the radio frequency ammeter.

Only enough alcohol should be used to obtain full antenna current.

68. **If the Arc Breaks**—If the arc breaks or goes out it will be necessary to open the arc starting resistor switch and strike the arc again. In case the arc is struck without opening this switch, a short circuit will result and a trip coil will open the main line switch. It is then necessary to lift the handle of this arc and reclose the starting resistor switch.

69. **To Stop the Arc for a Short Period**—

1. Open the arc main line switch (this automatically opens the arc starting resistor switch).
2. Put the send-ground-receive switch in receiving position.

If it is desired to stop the motor generator, this may be done by opening either the set supply switch or the circuit breaker on the motor starting panel.

70 **To Start the Motor after a Short Period of Rest**—

1. Put the send-ground-receive switch in sending position and start the motor generator if it has been stopped.
2. Close the arc main line switch, strike and adjust the arc.
3. Close the arc starting resistor switch and adjust the arc.

71. **To Shut Down the Arc for a Long Period of Rest**—

1. Open the arc main line switch.
2. Open the set supply switch (this automatically releases the arm of the low voltage release coil).
3. Cut off the alcohol flow.
4. Place the send-ground-receive switch on send or ground as desired.

72. **To Use the Chopper with the Back Shunt Method of Signalling**—When it is desired to transmit signals on waves shorter than 950 meters by means of the chopper, the following procedure should be observed:

1. Throw the single-pole, double-throw transfer switch to the left and close the double-pole switch mounted on the chopper, thereby connecting the chopper to the coupled compensation loop on the loading coil.
2. Start the chopper motor by closing the snap switch.
3. Start the motor generator and arc converter in the usual manner.
4. Signals may now be transmitted by using the Morse hand key and back shunt circuit in the usual manner.

73. **To Use the Chopper with the Auxiliary Hand Key**—

1. Open the single-pole, double-throw transfer switch. Close the double-pole switch mounted on the chopper and start the chopper motor by the snap switch.

2. Connect the arc to the antenna circuit by closing the shorting switch on the Morse hand key.

3. Start the motor generator and arc converter in the usual manner.

4. Signals may now be transmitted with the chopper by using the auxiliary hand key.

74. To Transmit Undamped Wave Signals by Means of the Auxiliary Hand Key—When it is desired to send signals, using the auxiliary hand key without the chopper:

1. Throw the single-pole, double-throw switch to the right hand position, thereby connecting the auxiliary hand key directly to the coupled compensation loop on the antenna loading inductor.

2. Connect the arc converter to the antenna circuit by closing the shorting switch on the Morse hand key.

3. Start the motor generator and arc converter in the usual manner.

4. Signals may now be transmitted by the coupled compensation method with the auxiliary hand key.

75. To Change Wavelength—

1. See that the arc converter is shut down.

2. Change the antenna connection on the loading inductor to the terminal which is marked for the new wave.

3. Change the connection between the bare copper helix and the taps in the bottom layer of the loading inductor to the positions which are marked for the new wavelength.

76. Location of Trouble—If the arc flame will not strike at all—

1. Make sure generator is running and generating 250 to 400 volts.

2. Make sure arc main line switch is closed. Lift the handle and reclose the switch to be sure it is making contact.

3. See that the anode makes a good contact with its clip.

4. See that carbon is long enough. (Use gauge and wrench on side of chamber.)

5. Look for an open or loose connection in d.c. supply circuit from generator to arc converter unit.

6. Arc starting resistor tubes may be burned out.

7. See that arc field coil connections are good.

77. If the Arc Flame Burns without Producing Oscillations—

1. Make sure send-ground-receive switch is thrown to "Send."
2. Make sure of alcohol supply.
3. Make sure of connection from anode to antenna circuit.
4. Make sure of other antenna connections.
5. Try on both antenna and back shunt circuits.
6. Make sure the ground connection is good.

78. If the Arc Flame is "Fussy" and Antenna Current Low—

1. Chamber may not be air-tight, gaskets leaking.
2. Water in chamber, anode tip may be burned out, or gaskets leaking.
3. Antenna insulators may be dirty.
4. Poor connections in antenna circuit.
5. There may be water or alcohol in the chamber extension which holds the anode. Remove the anode insulating disc and see that there is no water there, and that the bakelite disc and rubber gaskets are clean.

In case the radio frequency ammeter is burned out, the arc flame may be adjusted by observing the d.c. ammeter as the direct current varies with adjustment in a manner similar to the antenna current.

79. Precautions—Do not touch any part of the antenna circuit when the equipment is in operation. It is much safer to stop the motor-generator and open the main supply switch when working on the apparatus. Contact with the 250- to 500-volt direct current may cause a painful shock, although it is not necessarily dangerous. Do not overload the transmitter beyond its maximum rating, which is 8 amperes for intermittent operation in the case of the 2-K.W.; and 12 amperes for intermittent operation in the case of the 5-K.W. transmitter.

Do not fill the alcohol container when the equipment is in operation.

Do not open the chamber or remove the carbon holder until two minutes have been allowed for the carbon to cool. Failure to observe this precaution may result in explosion, which, although not serious, should be avoided.

80. Type RH-1 2-K.W. Arc Transmitter of the Independent W.T. Company—This is a 2-K.W. arc transmitter designed for ship installations, where the antenna capacity is approximately .0012 microfarad, plus or minus .0007 microfarad. Such an average antenna will have an approximate fundamental wavelength of 450 meters and a resistance of 5 ohms at 600 meters. The motor generator and auxiliary apparatus are designed for 110-volt direct current operation, the usual supply source on shipboard.

Transmission of undamped oscillations is possible from 600 up to 2400 meters. Damped oscillations may be transmitted on wavelengths from 600 to 800 meters by using a modulating system which will be described further on.

81. **Motor Generator**—This machine is provided to convert the 110-volt ship mains to the high voltage necessary to operate the arc converter, viz.: 250 to 450 volts d.c.

With the proper care the motor generator will not give any trouble at all. On leaving the factory the ball bearings are filled with grease sufficient to last six months. About that time the bearings should be removed, washed in gasoline, and filled with grease again.

The commutator should be kept clean and smooth, using fine sand paper first, then washed with cheese cloth and gasoline. The brushes should bear evenly on the commutator bars without excessive friction.

82. **To Remove the Bearings**—When it is necessary to remove the bearings take off the outer bearing cap and, after disconnecting leads or brush rigging attached to the shield, remove the shield, leaving the ball bearing on the rotor shaft. Unscrew the butt clamps and remove them. Apply pressure evenly around the inner end of the inner race to force ball bearing off the shaft. When the bearing has been removed from the shaft it should be carefully wrapped up in clean paper to prevent any foreign matter from adhering to the grease. Before it is replaced the old grease should be washed off with gasoline and new grease replaced. In replacing the bearing, apply pressure at the outer end of inner race; never to the outer race, as this damages the bearing. A short piece of brass tubing and a babbit hammer are useful for this work.

A spare rotating element, motor field coil, generator field coil, brushes and brush holders, are provided in case of accident to any of the original parts. In substituting any of these items make careful note as to how the original parts are assembled so as no difficulties will be encountered in replacing the new elements.

83. **Arc Converter**—When working near arc converter it is safest to shut down the motor generator, so that no injury will result to the operator by coming in contact with the high voltage direct current which could prove fatal.

The arc chamber should be kept free from soot. The anode ısulating disc and gasket should be inspected from time to time ıd never allowed to become dirty enough to form a leakage path ground. If they are allowed to "arc over" they will be ıined and will then have to be renewed. The whole set should cleaned at least once a month.

It is very important that the arc chamber be gas- and water-ght. A small water or air leak in the chamber will cause the arc be unsteady and the carbon to burn down rapidly. When the ıamber is thoroughly tight, the carbon will probably build up owly at the end; this depends on the chemical content of the ydrocarbon used. If the arc is taken apart, the gaskets on the ıoulders of the poles should be examined and, if in poor condi-on, replaced by new ones before placing them against the bear-ıg surfaces on the chamber.

When it is desired to replace an anode, first close the valve in ıe water circulation system. Unscrew the anode clamping ring, aw out the anode and set it on end tip upward. Remove the p and its gaskets.

In replacing the old tip and inserting a new one, see that the aring surface of the anode, the tip and copper gasket are clean, nooth and entirely free from grit and that the gasket is in good ondition. Put the gasket and the tip in place and replace the tip ıt. The anode should be examined and cleaned with gasoline, necessary. Replace the anode in the arc chamber and tighten ıe clamping ring. See that the tip is lined up equi-distant from agnet pole tips. If it is nearer one than the other loosen the amping ring and adjust the anode position. If the tip has not en squarely replaced on the end of anode, it will be necessary remove the tip nut and see that tip is put on properly.

84. **Water Cooling System**—The cooling tank is cylindical ıd has a large hole running vertically through the center pro-ding additional cooling surface. The tank is filled from the let covered by a screw cap. The amount of water in the tank ın be noted from the right gauge.

There is a pet cock to test the sight gauge and determine if it showing the true water level. A valve is provided to open and ose the circulating circuit, as may be desired. A small red ball ithin the glass indicator rises to the top when the water is cir-ılating properly and falls when water stops circulating.

From the circulation indicator the water runs to the anode and om the anode to the duct in arc chamber, through the duct to the p of the tank. To prime the pump it is only necessary to open the pet cock near the top and let the air out. Only *fresh* water should be used. The arc will not operate using salt water as it grounds the anode. The tank should be kept from ¾ to ⅞ full at all times. During the winter alcohol mixed (1 part alcohol, 2 parts water) with the water should be used to prevent the cooling system from freezing.

85. Radio Frequency Circuit—The cathode, which is connected to the negative side of the generator line, is grounded. The anode is then connected through radiation ammeter through the low power resistor which is normally shunted by the shunting switch through the relay key to the absorbing circuit. When the relay key is in the down position, the anode is connected to the antenna loading inductance. In the 600, 800 and 2400 meter adjustments it will be noted that there is simply an inductance in series with the antenna, the constants of this circuit equalling a frequency that gives the desired wavelength.

86. Absorbing Circuit—In signalling with the back shunt method the energy converted by the arc is diverted either to or from the antenna at a rate corresponding to dots and dashes. In the key-up position, the energy is diverted from the antenna by the relay key to an absorbing circuit, which consists of a .004 mfd. condenser, an inductor and combined iron plate resistor and absorbing resistor. The antenna ammeter is also thrown from the antenna circuit to the absorbing circuit by the relay key, so this meter reads the current in each circuit depending upon the position of the key. The iron plate resistor should be adjusted so that the direct current load is nearly constant when reading. If the resistor is improperly adjusted the absorbing circuit will draw more than the radiating circuit, causing the arc to be unsteady, especially on the lower wavelengths.

87. Modulating System—This consists of a ¼-H.P. d.c. motor directly coupled to a large commutator used as a "chopper." Every sixth bar is connected together and brushes are located diametrically opposite each other. The two brushes are connected to a loop of Litzendraht which is in inductive relation to the antenna loading inductance and current is induced in this loop at times when it is shorted by the commutator circuit. The motor runs at a speed of 1700 R.P.M. and this speed and number of bars correspond to 1000 short circuits a second or a 500-cycle note, approximately. These short circuits change the wavelength appreciably and reception on a crystal or audion detector is of a 1000-cycle tone.

88. Wave Change Switch—A wave change switch is pro-

vided which permits of transmission on four wavelengths. These positions are marked by number plates and have corresponding ratchet stops. To the right of a wavelength position is an intermediate point which provides connection directly to the rotating contact of the compensating inductance in order that, after having adjusted the antenna loading inductance by steps to an approximate value, the proper amount of compensating inductance may be exactly determined in a convenient manner as explained later.

89. Operation—

1. Place send-receive switch in receive position.

2. Close switches, main switch, motor generator control switch, arc striking switch, generator field switch, resistance output, and lower power resistance shunt switch.

3. See that loading coil leads are in approximate position, also leads running to compensating inductance.

4. Place wave change switch in 2400-meter position.

5. Placing send-receive switch in send position closes circuits which perform the following functions:

(*a*) Motor generator is brought up to full speed by the closing of main line contactor, and to the two contactors of the automatic starter.

(*b*) Simultaneously, the pump and carbon rotating motor are brought to full speed. The carbon should be rotating slowly and the sight feed on the water circulating will show the red ball, indicating that the pump is working.

(*c*) The main line contactor has closed, closing the high potential circuit. The arc striking relay works, striking the arc electro-magnetically through the arc striking mechanism. A few seconds after the arc is struck, the arc starting resistor is shorted. The hydrocarbon supply magnet has operated, supplying alcohol to the arc chamber, which is evaporated, and the vapor contains hydrogen which is necessary to maintain a steady arc. Too much alcohol will be indicated by a white vapor rising in the alcohol sight glass; too little by the arc being unsteady.

(*d*) The d.c. voltmeter reads the arc voltage; the d.c. ammeter reads the arc current, and the radio frequency ammeter the absorbing circuit current, and when the key is pressed down reads the antenna current.

When throwing the send-receive switch to the send position, the arc may not ignite upon the first inward thrust of the mechanism. This may be due to excessive spacing between copper and carbon elements, and the carbon should be adjusted to proper relation to the copper by the cathode adjustment knob which moves the cathode nearer the copper anode when turned counterclockwise.

The arc striking relay has an automatic action, and when the cathode strikes the anode and returns, if the arc does not ignite, the action is repeated again until it does ignite. Of course it should be assisted by adjusting the cathode by the cathode adjustment knob.

Lock the relay key by closing the hand key on the table and measure the wavelength being transmitted, making sure on all wavelengths that you are measuring the antenna circuit and not the absorbing circuit.

Assuming that the wavelength measured was 3300 meters and after cutting out one or more sections of the antenna loading inductance it was reduced to 2300 meters, the final adjustment would be made by throwing the wave change switch to the right of the 2400-meter position and tuning with the compensation inductance until the wavelength is exactly 2400 meters as indicated by the wave meter. After final adjustment is made by the variable arm on the compensating inductance, the 2400-meter lead from the lower half of the wave change switch is brought to the inductance in exactly the same point where the variable contact was. The wave change switch can then be moved to the other wavelength position and further adjustments made with the antenna loading inductance and compensating inductance in the same manner.

On 600 meters it is best to place as much of the total inductance required in the antenna loading inductance and as little as possible in the compensating inductance.

The relay key should be kept in good order; when adjusting for the up position the lower contacts should be compressed 1/16 of an inch and a space left of 1/32 of an inch between the upper contacts; the air gap between armature and field poles should be very small. In the down position the upper contacts are compressed 3/32 of an inch and the lower contacts 1/16 of an inch apart.

The commutators of motor, generator, pump motor, and modulation motor and modulator should be kept clean and smooth and also see that the brushes are wearing evenly.

The operator should always see that the circulation indicator is indicating when the set is in operation. The water tank should be kept full to the level indicated, and the alcohol feed reservoir full as it only holds enough alcohol for ten hours' continuous operation.

All moving parts should be lubricated and parts making electrical contacts, such as switch blades, contactors, etc., should be kept smooth and clean.

Every morning the apparatus should be dusted thoroughly with cheese cloth and cleaned with alcohol at least monthly.

The copper parts should be polished if they are not lacquered.

CHAPTER 11

SPARK TRANSMITTERS

1. **Oscillatory Discharge of a Condenser**—The condensers of a radio transmitter may be charged by connecting it to a source of high voltage such as the secondary terminals of an induction coil or step-up transformer.

Consider the circuit of figure 230. The voltage of the secondary terminals of the transformer may be 10,000 to 30,000 volts. When the key of the primary circuit is closed a violent spark discharge will take place across the gap *SG*. It will continue as long as the key circuit is closed. An analysis of the discharge will show that a radio frequency current oscillates through the condenser *C* and inductance *L*. If the frequency of the alternating current of the primary circuit is 500 cycles there will be a discharge for each alternation or 1000 spark discharges per second. This will result in the flow of 1000 groups of radio frequency oscillations through the discharge circuit *LC*.

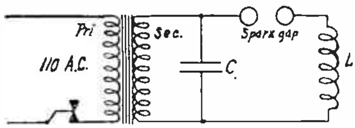


FIG. 230. Circuit for Production of an Oscillatory Discharge of a Condenser.

A spark discharge such as that described will produce a series of cycles of alternating current of constantly decaying amplitude, such oscillations being called damped oscillations on account of this decrease in amplitude.

The discharge of a condenser is explained as follows: Referring to *A* in figure 231: Just previous to the first discharge the energy is stored in an electrostatic form in condenser *C*. The potential of the condenser finally becomes so great that the air dielectric between the gap *S* is broken down so that a spark jumps from one electrode of the gap to the other. The electrostatic field is now converted into current which flows through inductance *L* creating lines of force. After a time this inductance contains all of the circuit energy in its field, and because this field produces a potential difference across the terminals of the coil opposite in sign to the original voltage, the condenser commences to charge again in the opposite direction as in *b*. After the condenser is charged, it discharges a second time. This process keeps repeating itself, the voltage reversing in sign at each charge and discharge.

Each charge is smaller than the one preceding as some of the energy is lost by the resistance of the circuit and the production of heat, light and sound. Finally the charge becomes so small

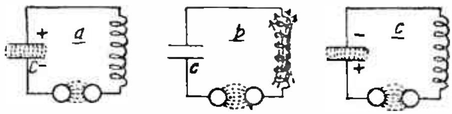


FIG. 231. Charge and Discharge of a Condenser.

that a spark can no longer bridge the gap and the oscillation current dies out. The frequency of the oscillations depends upon the size of the capacity and inductance employed. It may be calculated as follows:

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where f is the frequency, or number of discharges per second, C is the capacity of the condenser in farads and L the inductance of the coil in henrys. The number of oscillations per single spark is a function of the total damping of the circuit, that is, if the circuit has many complete oscillations per single spark discharge the wave train produced is a low damping. If the oscillations ceased after a very few oscillations the wave train is said to be highly

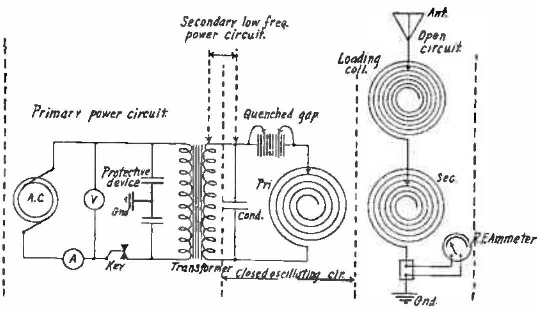


FIG. 232. Elementary Circuit of a Spark Transmitter.

damped; when the apparatus as shown in figure 230 is employed to generate radio frequency oscillations for the production of etheric waves, the circuit is denoted by the closed oscillatory circuit to distinguish it from the open or antenna circuit.

If the resistance of the oscillation circuit is too great the discharge of the condenser will not be oscillatory. This can be expressed as follows: IR is greater than $2\sqrt{L/C}$ the circuit is non-oscillatory; if the resistance is $2\sqrt{L/C}$ the circuit is just oscillatory. If the resistance is less than $2\sqrt{L/C}$ the circuit will be oscillatory. In these equations R is expressed in ohms, L in henrys, and C in farads. In actual practice it will be found that the oscillation circuits do not have anywhere near the critical value of resistance. Neglecting the value of R the frequency of the closed circuit may be decreased by either increasing the capacity of C or increasing the number of turns in L. Usually the capacity of C is fixed and the turning of the closed circuit is done by varying the number of turns in L.

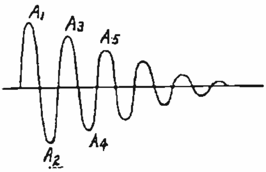


FIG. 233. Damped Oscillations with Constant Ratio of Decay.

2. Logarithmic Decrement of Oscillations—The oscillations of a damped wave train in such a circuit as has been discussed decay according to the law that the ratio of any oscillation to the one preceding is constant. This constant ratio is called the damping of the oscillation and the Naperian logarithm of the ratio of one oscillation to the preceding one is called the logarithmic decrement. Referring to figure 233 the amplitude of A' is to A^3 as A^3 is to A^5 or in terms of logarithms

$$\frac{A'}{A^3} = \epsilon\delta,$$

where ϵ = base of the Naperian system of logarithms,
δ = a constant termed logarithmic decrement.

Transposing, $\delta = \log \frac{A'}{A^3}\cdot$

If the value of the logarithmic decrement is known the number of complete oscillations comprising a wave train can be determined before their amplitude has fallen below a certain fraction of the first oscillation. It has been found that if the oscillation radiated by a spark transmitter has less than 24 complete oscillations per single spark discharge such transmitter will emit a broad interfering wave. A decrement of .2 corresponds to such a wave train and the oscillations are said to be highly damped. A group of oscillations having many more than 24 complete oscillations would have feeble damping. There are various formulæ for the calculation of decrement mathematically but fortunately there is manufactured a meter called the Kolster decremeter which gives a direct reading to the decrement of the emission from a spark transmitter. Such an instrument is employed by radio inspectors of the U. S. Government in their inspection of various types of mobile spark transmitters.

3. Spark Gaps—The purpose of the spark gap in a radio transmitter is (*a*) to act as sort of a value to prevent the condenser discharging until it has reached a certain potential (*b*); then to allow the stored-up energy to break down the air gap and circulate through the closed oscillation circuit in the form of radio frequency oscillations (*c*) to restore the gap to its non-conducting state when the energy has been transferred to the antenna circuit.

There are three types of spark employed with commercial radio transmitters. They are:

(1) Non-synchronous rotary gap.
(2) Synchronous rotary gap.
(3) Quenched gap.

The non-synchronous gap as employed with spark transmitters on vessels operated by the United States Shipping Board consists of an aluminum housing on which is mounted, at the upper portion, an insulating ring to which are attached twelve stationary electrodes of hard drawn copper. A rotating aluminum disc insulated from the shaft carries fourteen moving electrodes of h.d. copper. This rotating disc is driven by a shunt-wound motor connected to the radio auxiliary power circuit. The moving electrodes are rotated at a speed of 4000 R.P.M. and produce 5600 breaks per second. The gaps are enclosed by a ribbed aluminum cover with an observation hole protected by a red sight glass. The stationary and moving electrodes are arranged to be easily renewable.

4. Theory of Operation—This non-synchronous gap is designed so that a pure 1000 spark note is obtained and is accomplished by making the break frequency approximately 5600 per second, which is high as compared to 1000 per second. In consequence of this high break frequency it is always possible for at least one spark per alternation (500-cycle a.c. supply or 1000 alternations per second) to occur. If there should be several sparks per alternation, these must occur at the rate of 5600 per second. This higher discharge rate produces a musical tone which is inaudible as compared to the dominant 1000 spark tone, and therefore has no disturbing effect. Application of the Vernier principle makes it possible to obtain this high rate. That is, the spacing of the revolving electrodes is less than the spacing of the stationary electrodes and because of this unequal spacing there are a number of sparks around the circumference of the gap, while one of the revolving electrodes is passing from one stationary electrode to the next one. In this gap 14 revolving and 12 stationary electrodes are provided. The following formula gives the spark frequency.

$$\frac{Es \times Er \times RPS}{2}.$$

Es is the number of stationary electrodes.
Er is the number of revolving electrodes.
RPS is the number of revolutions of rotor per second.
2 is the factor which depends on the number of gap in series.

In order to obtain satisfactorily the characteristics described above, the 500-cycle circuits must be adjusted to resonance. This adjustment is readily made when the 500-cycle circuit contains a reactance regulator with several steps; otherwise it must be accomplished by the speed of the motor generator.

5. Synchronous Rotary Gap—The disc of a synchronous gap is mounted on the shaft with the alternating current generator. The disc is fitted with as many rotating electrodes as there are

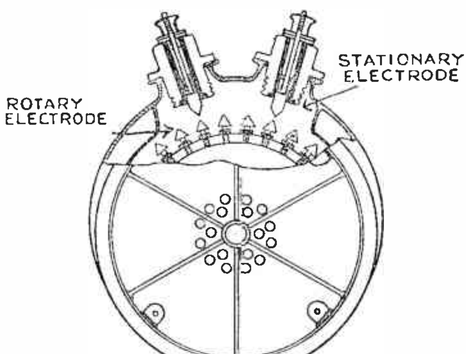


FIG. 234. Sectional View of a Synchronous Rotary Spark Gap.

field poles of the generator. If the frequency of the generator is 500 cycles the condenser will be charged and discharged 1000 times per second and will produce a musical pitch. Figure 234 is a back view of the rotary gap supplied with the R.C.A. 2-K.W. 500-cycle transmitters. There are two stationary and 30 rotating electrodes. The rotating disc is enclosed in a steel muffling drum which also acts as a support for the two stationary electrodes. This drum is designed so that it can be moved through an arc of approximately 25 degrees by an adjusting rod. This permits the adjustment for a synchronous discharge, that is, a discharge on the peak of an alternation, thus resulting in a musical spark note.

6. **The Quenched Spark Gap**—The quenched gap gets its name from the effects produced when a spark gap of this type is employed in the closed circuit of the transmitter. The ideal gap is one which permits the closed circuit to oscillate for a period of time sufficient for the oscillations in the antenna circuit to build up their maximum amplitude and then quench out those in the closed circuit.

Both the non-synchronous and synchronous gap permit a different degree of quenching providing the circuits are loosely coupled, the latter possessing this quality to a higher degree than that of the non-synchronous. The quenched gap has the further advantage of permitting a very close coupling between the primary and secondary circuits, while at the same time quenching the primary oscillations very strongly. This prevents the oscillations in the aerial circuit from being retransferred to the closed circuit which would cause two waves to be radiated as will be shown later. With proper quenching the primary circuit comes to rest after a few oscillations and the gap becomes non-conducting, thus preventing a retransfer of energy to the primary circuit.

The principal difference between the quenched gap and those just discussed is that instead of one or two spark gaps cooled by a rotary member we use many very small gaps in series, subdividing the spark into many short sparks.

The complete unit of a quenched gap usually consists of approximately 15 units of the self-cooled quenched type with silver sparking surfaces. Each unit is self-contained and may be renewed independently of the rest by hand. In removal of any one unit the circuit is automatically and instantly closed by the gap holder springs making contact.

Each gap unit consists of two annular brass discs secured by a central insulated bolt and separated from one another by an annular fish paper gasket. A brass washer and fish paper gasket serve to insulate the bolt and distribute the pressure.

The sparking surface consists of two annular silver rings spaced .013 of an inch apart. Cooling is effected by a rectangular flange of copper fixed to the central plates. The quenching action of a gap depends largely upon the speed with which heat created by the spark can be removed and dissipated. The gasket when heated by operation makes the sparking chamber air-tight.

When a gap unit is first put in operation, the air enclosed and the spark cause a certain amount of oxidation of the silver sparking surfaces. When the gap has sealed, the spark reduces this oxide, and the surfaces regain the white color of pure silver. This seasoning process is usually carried out at the factory of the manufacturer. Therefore, a unit should not be opened until one is sure that it needs to be cleaned. A gap test rod, provided with the set, is used to short-circuit successive gap units. Active units will give a healthy snappy spark at the instant of making or removing the short-circuit. Inactive units will give only a small sluggish spark or even no spark at all.

The advantages of the quenched gap are: Noiseless in operation, has no moving parts, permits the use of low voltage transformers, allows maximum transfer of energy to the antenna circuit because of closer coupling and permits the radiation of a wave of low decrement.

The note of the quenched gap is regulated by variation of the number of gaps or regulation of generator voltage. If properly adjusted a synchronous discharge can be obtained resulting in a pure musical note.

7. **Reaction of Coupled Circuits**—The commercial spark transmitters on American vessels employ an oscillation transformer with inductive coupling to transfer the energy to the open circuit. It may be found that the energy is being radiated on two different wavelengths. For example, if the circuits are tuned to 600 meters it may be found with a wave meter that there is energy radiated on a wavelength higher than 600 meters and also on a wavelength lower than 600 meters. These two wavelengths are caused by the reaction of the lines of force of the secondary of the oscillation transformer in the antenna circuit upon the primary of the closed circuit and vice versa. The mutual induction of the two coils causes the effective self-induction of the secondary coil either to increase or decrease, depending for the instant upon which of the two circuits is driving the other. The result is the radiation of the two waves. This represents an undesirable condition; as the receiver can only respond to one wavelength at a time, the energy in the other wave is lost. Interference is also increased as the transmitter is occupying two frequency channels.

This condition usually is caused by improper quenching of the spark gap or too tight coupling between primary and secondary of the oscillation transformer. Usually by loosening the coupling the two waves will merge into one, thus permitting exact resonance between primary and secondary circuits.

8. Commercial Spark Transmitters—On vessels operated by the U. S. Shipping Board and several privately owned vessels one finds a type of transmitter known as the Navy Standard 2-K.W. set. Of the 2-K.W. transmitters the following types are found:

CK 617 Kilbourne & Clark Manufacturing Co.
CR 655 Wireless Specialty Apparatus Co.
CM 1080 Marconi Wireless Telegraph Co. (now R.C.A.)
CM 305 Marconi Wireless Telegraph Co. (now R.C.A.)

Types CK-617, CR-655 and CM-1-80 are practically alike, having like power control panel, meters, circuit breakers, switches and automatic starters. The same is true of the wave changer which consists of oscillation transformer, loading coils, spark gap and condensers.

Type SE-1205A is another 2-K.W. set, but differs somewhat from the others in the arrangement of the power control panel. With this type a separate panel to control the charge and discharge of the storage batteries is used.

The motor generators are usually mounted on the engine room grating and remotely controlled by the operator. The automatic starter consists of a counterweighted shunt-wound magnetic contactor controlled by a push button for closing the main circuit and series-wound magnetic contactors for short-circuiting the starting resistors. A description and the theory of operation of this starter will be found in Chapter 3, Motors and Generators.

Inasmuch as the power apparatus comprising a spark transmitter such as motor generators, transformers, etc., have already been described in previous chapters, no further description will be given here.

9. Inductive Coupler—This consists of one fixed and one movable spiral of copper strip placed on a rectangular insulating frame formed by two end cheeks which are the base of the wave charging switch. The movable coil slides on a central guide and is actuated by a slotted bell-crank arm and handle placed to the right of the apparatus.

Tappings from primary and secondary coils are brought to contacts on the wave change switch and the primary terminals are connected to the radio transformer and condensers.

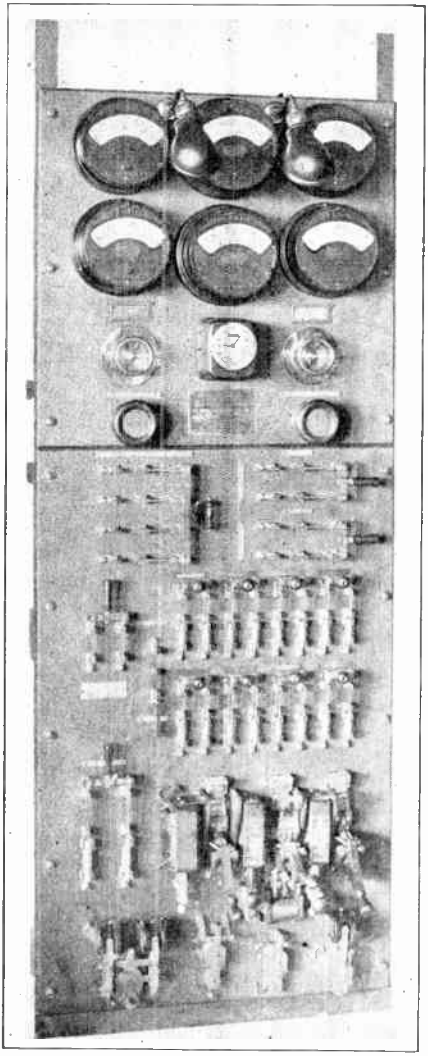


FIG. 235. Power Control Panel of Navy Standard 2-KW. Spark Transmitter.

The terminals of the secondary spiral are connected to the ground through the aerial ammeter.

10. **Wave Change Switch**—This consists of two rotating contact arms working over contacts arranged on two cheek plates of insulating material. The front switch has three contacts arranged on the upper semi-circle which connects with tappings, on the inductance spirals. The front switch arm is connected by a movable connector to the power change switch and spark gap.

The back switch has three contacts arranged on the lower semi-circle connecting with the tappings on the secondary inductance spiral. The back switch arm has two contacts diametrically opposite and these connect the lower fixed contacts with three others arranged on the upper semi-circle. These latter connect to the inner ends of the three antenna loading spirals.

The rear arm of the switch can be rotated independently of the front arm by loosening and sliding back the clamp bolt. This permits the varying of the secondary inductance independently of the primary, which is necessary at times when the antenna is affected by storm or accident.

11. **Antenna Loading Coils**—These consist of four spirals mounted directly above the inductive coupler and each is provided with a rotating contact finger which can be moved over the whole length of the spiral. Under normal operating conditions these coils are so connected that only three are variable, the fourth being connected as a whole in the circuit; by changing the bus bars this coil can be made variable as required by the characteristics of different antennæ.

12. **Send-Receive Switch**—This switch performs the following functions: In sending position:

(1) Closes a break in the field circuit of the alternator.

(2) Closes a break in the solenoid of the chopper switch on the switchboard.

(3) Closes a break in the circuit which operates detector protective relay.

(4) Closes one spare set of contacts.

(5) Grounds the terminal which connects to the receiver primary.

(6) Connects antenna to loading coil of transmitter.

In receiving position:

(7) Opens contacts 1, 2, 3, 4, 5 and 6 as closed above.

(8) Connects receiver lead to antenna.

The switch is in the sending position when the main switch blade is parallel to the base. In this position it closes contacts

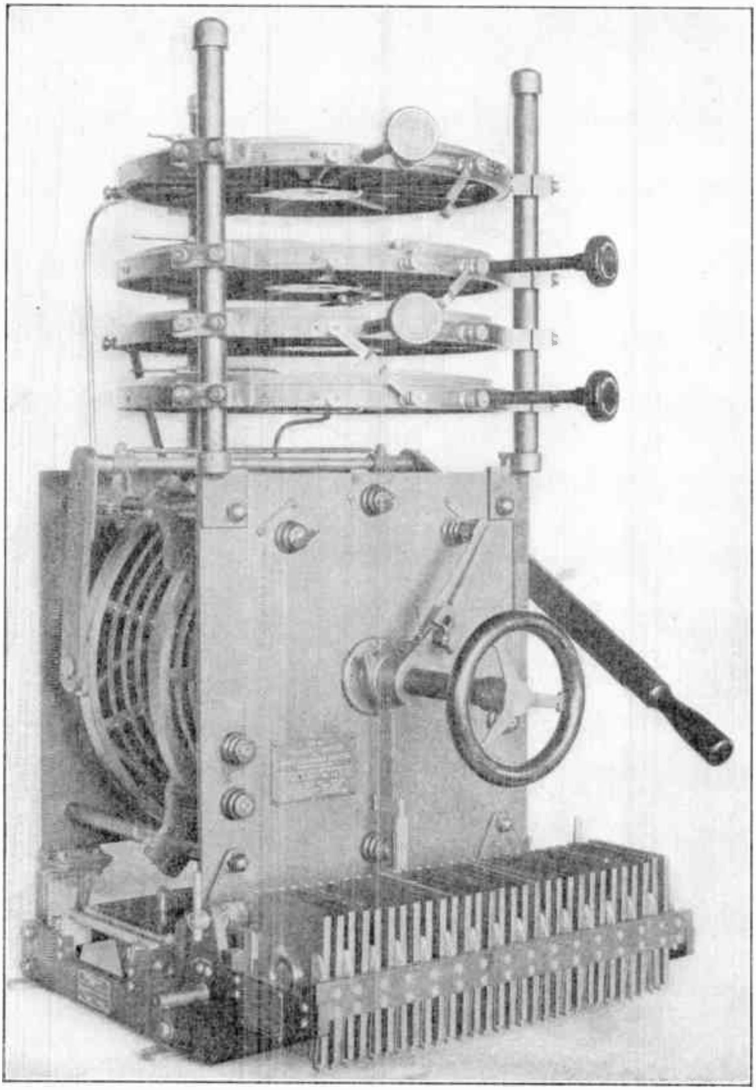


FIG. 236. Wave Changer—Oscillation Transformer, Load Coils and Quenched Spark Gap of Navy Standard 2-KW. Spark Transmitter.

11 and 12 by short-circuiting the spring clips. The aerial is connected to the transmitter by the spring contacts on the "Ant. C'C'T" post making contact with the "OSC. C'K'T" post. The generator field and spare circuit are closed by the contacts on the rotating cylinder.

13. **Tuning the Transmitter**—Start the generator by the remote control push button switch. Adjust the generator voltage to the lowest value and short-circuit seven or eight gaps by means of the clips on the gap switch rods. The gaps between a clip on the short arm and on the long arm are short-circuited when the clips make contact with the studs. Throw the antenna switch to the sending position and close the auxiliary switch on the switchboard. When this is done the clapper switch on the switchboard should close. Adjust the generator voltage till the gaps just spark over, and, with the antenna circuit grounded, proceed to tune the primary to the wavelengths desired. When the primary circuit is tuned wavelength markers should be placed on the primary inductance at the proper places. The primary leads should be clipped to the inductance at these marks. Then close the aerial circuit and proceed to tune the aerial circuit as follows:

On account of the fact that the unused turns of the oscillation transformer secondary and of the antenna loading inductances are short-circuited, and hence have an effect on the used turns, it is necessary to tune the longest wavelengths first, as the amount of inductance short-circuited is determined by the position of this slider.

Loosen the coupling as much as possible by pressing down on the coupling lever handle. Throw the wavelength switch to the highest wavelength point. Tune this wavelength by rotating the knob on the bottom loading coil till the aerial ammeter shows maximum current under these conditions. In case there is too much inductance in the circuit, change the connector between the first and second antenna loading coils so that the outside end of the first loading coil is connected to the middle of the second loading coil, instead of to the inside of that coil. Then tighten the coupling very slowly, watching the aerial ammeter constantly. It will be found that there are several coupling points which give maximum aerial current. All these should be marked on the coupling scale. Choose the point which gives the highest current value and vary the inductance in the aerial current to see whether it is possible to further increase the antenna current. When the highest current is found by this operation, tighten the coupling slowly again in order to find a closer coupling point which will give a higher antenna current, or at least a maximum point. Retune the aerial circuit, adjust the coupling, retune the aerial circuit, and so on until the best result is obtained. If the gap is in perfect condition the note on this hump will be good; if not, it will be impossible to get a good note on this hump, and the previous hump should be used till the gap is in good condition. In all cases, several trials should be made in order to locate the best possible coupling point. When this is found, note the position of the coupling lever on the scale accurately.

Throw the wavelength switch to the next lowest wavelength and proceed to tune it in like manner and note the final position of the coupling lever for the best coupling point. Proceed in this manner over all the wavelengths desired, noting the best coupling points.

Then choose a position of the coupling handle which will be most convenient for all the wavelengths, probably that at which the lowest wavelength is in tune. If the coupling for any wavelength is tighter, that is, if the coupling coils are too close to each other, inductance must be added to the oscillation transformer secondary till the coupling is again at the chosen point. It must be remembered that when inductance is added to or subtracted from the oscillation transformer secondary, it must be subtracted from or added to the loading coils. This makes it necessary to go over all the adjustments again. When the set is finally tuned, it must be possible to change from one wavelength to any other simply by turning the hand wheel on the wavelength switch without further adjustment of coupling or aerial inductance.

14. **Sparking of Loading Coils**—The loading coils will spark considerably by the voltage built up in them if the proper distribution of the secondary inductance in each loading coil permits the variable contact to engage approximately the same number of turns. The secondary of the oscillation transformer will require more turns as the wavelength increases. A minimum decrement will result and the breakdown of insulation of the loading coils will be prevented.

In severe cases where the insulation of the loading coils has broken down and the adjustments as described above do not relieve the trouble it may be necessary to cut away portions of the insulation that are carbonized. If only small discharges have taken place the insulation should be cleaned and a light coating of vaseline applied. If it becomes impossible to eliminate sparking by these adjustments the transmitter should be operated at reduced power.

RADIO APPARATUS ADJUSTMENT RECORD

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

Name of Station I M L A Y

Inspected by L. C. Herndon. *Radio Inspector.*

Date of Inspection October 24, 1925

Type of Equipment: SPARK Lowenstein Navy Std. ARC VACUUM TUBE - -

Power 2 K.W.

Auxiliary: Type and Source of Power Main set on battery. Gould VCP 13 210 A.H. Cap.

Adjustment of equipment as indicated on this record and approved by the Supervisor of Radio MUST NOT BE CHANGED without the authority of the Secretary of Commerce

ADJUSTMENTS FOR AUTHORIZED WAVE LENGTHS

SPARK — Wave Lengths	600	706	800				
Primary condenser (mfds.)	.016	.016	.016				
Primary turns	2-1/2	3-1/8	4				
Secondary turns	6-1/2	7-2/3	8				
Loading coil No. 1 turns Top	0	0	0				
Loading coil No. 2 turns Variable →	9-1/4	7	7				
Loading coil No. 3 turns Variable	→	5-7/8	7				
Loading coil No. 4 turns Variable	→	→	4-7/8				
Loading coil No. 5 turns							
Loading coil No. 6 turns							
Coupling: Type Scale	2	2	2				
Antenna current	15	15	14				
Decrement	.035	.03	.03				

ARC — Wave Lengths							
Large loading coil turns							
Small loading coil turns							
Variometer degrees							
Antenna condenser							
Antenna current CW							
Antenna current ICW							

VACUUM TUBE — Wave Lengths							
Oscillator adjustment dial							
Oscillator circuit condenser							
Frequency dial							
Plate taps							
Grid taps							
Antenna tuning coil							
Antenna loading coil							
External loading coil No. 1							
External loading coil No. 2							
Coupling: Type							
Plate voltage							
Filament voltage							
Filament current							
Plate current (oscillator)							
Plate current (modulator)							
Antenna current CW							
Antenna current ICW							
Antenna current PHONE							

REMARKS: Tuned with 1.5 K.W. input.

FIG. 236*a*. Department of Commerce Radio Apparatus Adjustment Record Showing Number of Turns Used in Inductance Coils for Various Wavelengths.

15. **Final Adjustments**—After all the wavelengths have been adjusted bring up the motor speed till the frequency meter shows 500 cycles. Then increase the generator voltage till the note breaks into a full 1000-spark note. If the lower is low, cut in more gaps and raise the voltage till the wattmeter shows normal power and the note is clear. Readjust the motor speed, if necessary, till the frequency meter shows 500 cycles. It will then be necessary to go over the tuning again to see that the circuits are in proper resonance, and that the wavelengths are right. This retuning will help to clear up the note in case it was impossible to do it by means of the motor speed and generator voltage alone. When all the circuits are in exact resonance, when the motor speed is right, and the generator voltage has been adjusted properly, the note emitted by the transmitter will be a clear 500-cycle (1000-spark) note of good quality. It it is rough and scratchy, it is an indication that these circuits are not in proper resonance, or that the gap is not fully seasoned. It may be cleared up by a slight readjustment of the coupling or of the inductance in the aerial circuit or both.

16. **Rotating Gap**—If it is desired to use the rotary spark gap instead of the fixed gaps of the transmitter, it may be connected in circuit by proceeding as follows:

(1) Pull the single pole switch connecting the power change switch with the primary wave changing switch forward until it rests upon the fixed gaps; this will disconnect the fixed gaps from the circuit.

(2) The terminals of the rotary gap can now be plugged in either pair of terminals mounted on electrode insulators on each lower side of the primary wave changing switch.

(3) Close the D.P.S.T. switch marked "Radio Auxiliary," thus starting the motor.

The set is now ready to operate and can be adjusted and tuned in the same manner as the fixed gaps until the best note is heard and a maximum reading observed on the aerial ammeter.

17. **Care of the Quenched Gap**—Gap units are opened by removing the center bolt with the special wrench provided and then breaking the unit apart by a twisting movement. The sparking surfaces of an opened unit will indicate conditions as follows:

1. If the silver surface is black in color, there has been a breakage of air into the gap.

2. If the silver surface has a blue-black appearance, there has been a slight leakage of air and deposit of silver oxide.

3. If the silver surface has a brown color and is spreckled or pitted, the gap has been overloaded.

4. If there are rough edges on the inner and outer circumferences of the sparking surface, the gap has been overloaded.

Gaps showing the first three conditions can usually be brought back to operating condition by running them for about twenty minutes with an input of about 75 per cent of the rated power, with new gaskets and with antenna disconnected. If the fourth condition exists, the rough edges can be scraped off with a knife, after which the gap can be restored as mentioned. If the unit has been operated for some time in a leaky condition, the deposits may be too thick to be removed except by the use of an abrasure. For this purpose use No. 000 sand paper pasted to a flat block of wood. Do not use the sand paper alone, as it is essential that the silver surface be kept true. Never use emery in any form. All blackening should be removed from the inside of the unit and from the bolt. Do not be too ready to open the unit. Remember that every cleaning removes a certain amount of silver, increases the gap length, increases the power which the unit must handle, and shortens its life.

Spark gaskets supplied with the set are selected for the proper thickness. It is well to be sure, however, that they lie between .041 and .039. The thickness of the gasket determines the length of the gap. If the gasket is too thick the power per gap will be too high and unnecessary heating and deterioration will result. If the gasket is too thin, the power will be low and it may not be possible to obtain rated output from the set.

To assemble a gap unit, lay the plate that has the tapped hole, silver side up, on the assembly base, with the alignment pins properly inserted. Lay a large gasket on the plate, centering it inside the pins. Lay the other plate on top, silver side down, and put a small gasket in the center bore. The gasket under the head of the center bolt is quite as important as the main gasket, and must not be forgotten. Insert the center bolt, bring it up as far as possible by hand, and screw home with the wrench. Remember that the unit was made for the average operator to use, and do not be too strong.

18. **Seasoning Gap Unit**—The unit is replaced in the rack by dropping it between the contact springs, and is tested and seasoned by running it for about an hour with the key locked and no antenna, the closed circuit being in tune and the power and frequency normal. After this seasoning process, it is essential to take the unit out of the rack and tighten up the center bolt. The

unit should then be perfect. If it is still impossible to obtain a clear note, the unit is beyond repair.

19. **Replacing Secondary Coil**—To replace an injured transformer secondary coil, it is necessary to take out the laminations at end of the core, so that the secondary and insulating tube can be taken off as a unit. Be careful to connect the new coil so that the turns progress in the same direction as in the other coils. In replacing the end laminations, be careful to put a shellaced lamination between two plain ones, or vice versa. This is necessary in order to keep down the eddy current losses. Be careful not to bruise the edges of the laminations in sliding the assembled transformer back into case. The primary terminals are to be connected through the protective device and hand key to the proper terminals on the panel, as shown in the wiring diagram. The secondary terminals include the usual protective spark gap, the third ball being connected to the core of the transformer. This ball must be connected to the main ground when the set is installed.

20. **Care of Motor Generator**—The shunt-wound d.c. motor is mounted on the same shaft and in the same frame with a single-phase, 500-cycle, inductor type alternator. Since both field and armature coils of the alternator are stationary, there are no brushes on the alternator side.

The machine is fitted with two ball bearings. (See Chapter 7 for care of ball bearings.)

21. **To Replace a Rotating Element**—First remove the end shields and bearings. Place the bearings on the new shaft and insert the new rotor in the machine. Then put on end shields and replace the brushes and connections, taking care to get them back exactly where they were.

22. **To Replace a Generator Armature Coil**—First remove the rotating element, disconnect and remove the defective coil and then insert the new coil and slot insulation. The inside of the coil tapers slightly, and the coil should be placed so that its big end is in the bottom of the slot. Connect the coil, taking care to make the connections the same as they were originally. Replace the slot key, solder the connections securely, insulate with two layers of ¼-inch linen tape, paint with insulating varnish, and assemble the machine.

23. **To Remove a Generator Field Coil**—First remove the outer set of armature coils and the core as a unit. This is done by removing the bolts which hold the core to the frame. All leads must first be disconnected from the terminal blocks. The field coil is ring shaped and can be slid out easily.

24. **To Remove a Motor Field Coil**—Remove the rotating element and then remove the pole shoe by loosening the holding down screws. Disconnect the defective coil and replace it with a now one, putting the long lead next to the frame. Replace the pole shoe, taking care to get it in its original position. Solder the connections to the coil and re-assemble the machine.

25. **To Replace a Motor Armature Coil**—Remove the defective armature from the machine and replace it with a spare armature. Locate the injured armature coil, unsolder its leads from the commutator rises, and also those of all the coils which have one of their sides in the slots included between the sides of the injured coil. Remove all the wedges from the slots in which the injured coil lies and from those between and lift out the coil sides. This is necessary because the coils overlap all the way around the armature. Put the new coil in by reverse process, taking care to get it in the proper relation to the others without injuring any of them. Solder the leads to the commutator rises and be careful to make good tight joints, as otherwise injurious sparking will result.

26. **To Replace a Motor Brush**—First remove the old one by disconnecting the pigtail and pulling back the pressure arm. Insert the new brush and trim it to fit the commutator by pulling a piece of No. 0 sand paper between the brush and the commutator. Never use emery cloth or paper.

27. **To Replace a Motor Brush Holder**—Remove the old holder by removing the nuts on the brush stud and the connection and unfasten the holder stud from the insulating bridge. Put the new holder in place, leaving a clearance of about 1/8 inch between the holder and the commutator. Before tightening nuts and making connections, be sure that the new holder inclines at the same angle as its neighbor.

28. **To Replace a Brush Holder Spring**—Remove the holder and stud and the pin through the spring drum by using a small punch and hammer. Insert the new spring and pin, rivet the latter with the punch, and re-assemble.

29. **To Replace a Brush Holder Stud**—Proceed as indicated above.

30. **Trouble and Repairs**—Everything depends upon the operator for the quick and successful location and repair of trouble. Mechanical or electrical faults may develop. If the trouble is mechanical, the operator can usually find it immediately, and its nature determines the remedy. Duplicates of those parts which are most liable to give out are usually supplied with the equipment.

There are two classes of electrical trouble, open circuits and short circuits. The blowing of a fuse on the opening of the circuit breaker, usually, though not always, indicates a short circuit. Short circuits of high potential energy are indicated by sparks which the operator can see or easily locate. If these sparks have passed through or along the surface of the insulating material, the abnormal strain has been caused by some misplaced conductor, such as a flexible lead, and the remedy is to remove it to its proper position. Open circuits are indicated by no reading on one or more of the meters. Since energy enters the equipment at one point and leaves at another, the meter or meters which do not read, tell the operator how far back toward the source of supply the trouble is. The circuits must then be traced from the antenna terminal until the loosened or broken connection is located.

CHAPTER 12

COMMERCIAL RADIO RECEIVERS AND ASSOCIATED APPARATUS

1. **Introduction**—The idea in this chapter is to take up in detail the types of receivers most generally used for the reception of radio telegraph signals. No attempt is made at all to cover receivers employed in the reception of radio broadcasting for entertainment. The writer has found that the commercial operator requires an instruction book that he can carry from station to station and ship to ship and such a book should contain a brief description with circuits of receivers and associated apparatus as employed generally at these stations. Thus the operator may use the same for reference in order to quickly locate trouble and make repairs.

Although many of these receivers are alike in principle of operation, they differ considerably in constructional details and electrical constants. It will be noted that the description of the SE-143 and SE-1220 Navy Receivers are quite similar, although their electrical constants and wavelength ranges are quite different.

Type 106–106-C–106-D R.C.A. Radio Receivers—Wavelength Range of These Receivers is from 200 to 3500 Meters.

The type 106 receiver is an inductively coupled oscillation transformer, consisting principally of a primary and secondary circuit. The period of the primary and secondary circuit and inductive relation between the two circuits can be varied. Provision is made for varying either the capacity or inductance in each circuit within certain limits. The inductance is tapped and the condenser is continuously variable.

2. **Primary Circuit**—The primary circuit consists of an inductance made variable by a switch and a variable capacity which may be inserted in the circuit if the capacity of the aerial circuit is too large for the desired wavelength. The "primary tens" switch varies the number of turns included in the primary in steps of 10 turns to each point, and, at the same time, disconnects "hanging on" end turns which are not in use. The "primary

units" switch varies in steps of one turn to each point, so that with both switches any number of turns on the entire inductance may be used. When the primary condenser is not in use, it should be rotated to the position past 180 degrees marked "out." This automatically short-circuits the condenser.

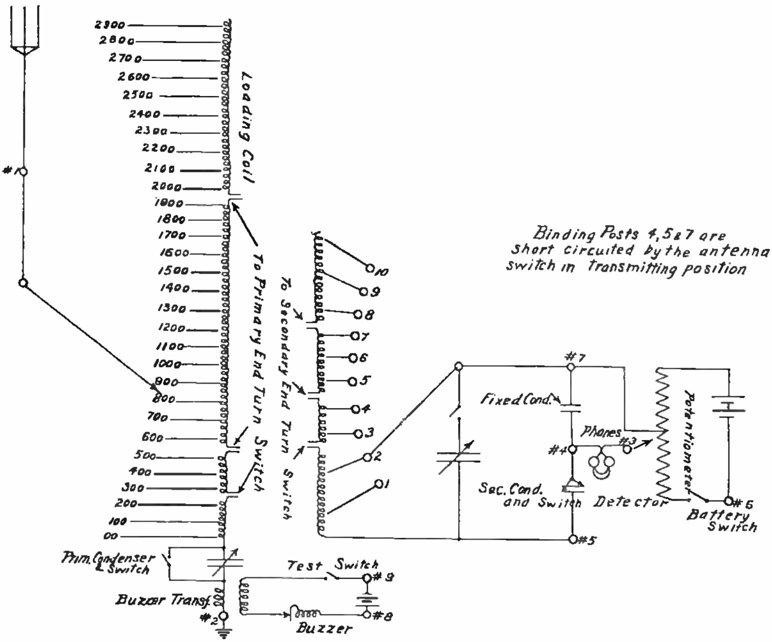


FIG. 237. Schematic Diagram of R.C.A. Type 106 Receiver.

3. **Secondary Circuit**—The secondary circuit consists of a variable inductance and a variable condenser. The transformer secondary switch varies the secondary inductance in appropriate steps and cuts off the unused portion of the coil. The secondary condenser is used for obtaining wavelength adjustments finer than those obtained by varying the inductance and for wavelengths above 2000 meters. When not in use, this condenser should be rotated past the zero point to the position marked "out." This automatically disconnects the condenser from the circuit. A crystal detector is mounted on the front of the receiver which can be used in an emergency. Battery binding posts are provided on the receiver, making it possible to use an external

battery connected to a potentiometer. The potentiometer regulates the potential across the detector. The zero point of the potentiometer is in the middle so that the polarity of the voltage across the crystal may be easily reversed.

4. **Coupling**—The secondary coil is arranged so that it will slide inside of the primary coil and variation of distance between them is made by the coupling handle.

5. **"Modifier Circuit"**—The modifier or tickler system consists of a fixed winding or "stator" of the variometer in series with the grid of the secondary circuit. The variable or "rotor" winding is connected in series with the plate of the detector tube and primary of the audio frequency amplifying transformer. The modifier is mounted within a small box placed on top of the receiver. A bakelite dial controls the position of the rotating windings. By providing regeneration in the detector circuit the audibility of weak signals can be greatly intensified. Continuous wave signals can be received by increasing the feed-back in the detector circuit until the tube oscillates. A fixed condenser is connected across the primary windings of the first audio frequency transformer, to serve as a low impedance path

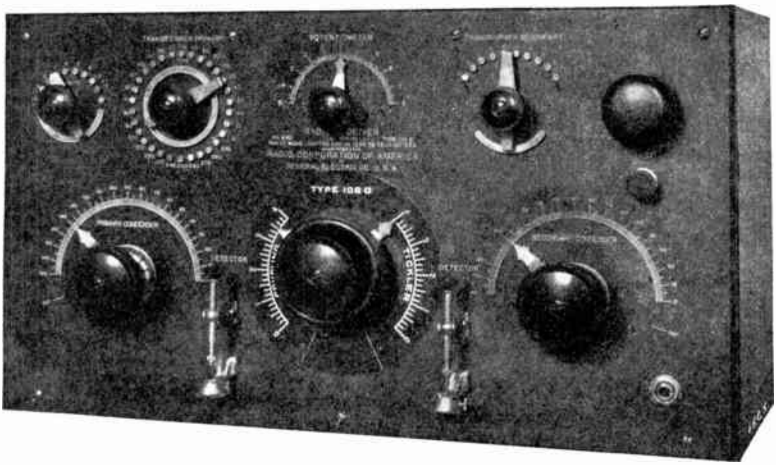


FIG. 238. Front View of 106-D Regenerative Receiver.

for the radio frequency current in the detector plate circuit, and assists in the feed-back necessary for regeneration and oscillations. The stator windings of the tickler system are tapped, allowing two different values of inductance. This is controlled by a snap switch on the modifier panel.

6. **Adjustment of Receiver**—Light the filaments of detector and amplifier tubes and adjust to normal brilliancy. Set the modifier dial at zero. Set the primary condenser at "out." Adjust the coupling to about seven on the scale. Set the secondary condenser at "out." If a test buzzer is connected, push test switch and make sure receiving circuits are functioning. Release the test switch and vary the primary and secondary inductances until the desired signal is heard with maximum response, then decrease the coupling by rotating the coupling handle to the left, until

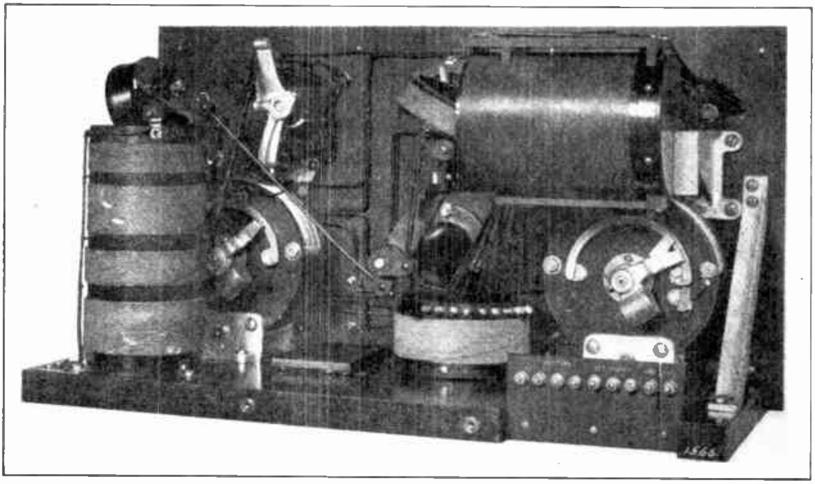


FIG. 238*a*. Interior View of 106-D Regenerative Receiver.

signal is just audible. Adjust primary and secondary condensers until signal is at a maximum. Generally the loudest signal is reached with a maximum secondary inductance and minimum secondary capacity. If the signal is too weak to read, increase regeneration by rotating dial of modifier. If the signal is from a spark transmitter it will be necessary to keep the tube from oscillating; otherwise the signal will be "mushed up," making it difficult to read through interference. If the signal is from a self-rectifying continuous wave transmitter the signal may be heard either with or without the detector tube oscillating. Continuous wave signals can only be heard with the detector tube oscillating.

To avoid interference, the operator should work with the loosest coupling possible. Greater selectivity may be had by using small secondary inductance and adjusting the secondary condenser until maximum response is obtained. If the wavelength of signal desired is shorter than can be obtained with the above adjustment, place the primary "tens" switch at zero, primary "units" switch at ten, rotate the primary condenser until signal is heard, using the lower points of secondary inductance. If a maximum signal is not obtained up to 180 degrees of primary condenser, more primary inductance will be needed. Follow the same method as with longer wavelengths. Selectivity may be still further increased, partly sacrificing intensity, by using a large amount of primary inductance, having the primary condenser in circuit.

7. **Type 106-D Regenerative Receiver**—The 106-D receiver is the 106-B receiver converted for operation with a vacuum tube detector. The secondary coil is placed in a fixed position. A small coupling coil placed within the primary inductance is

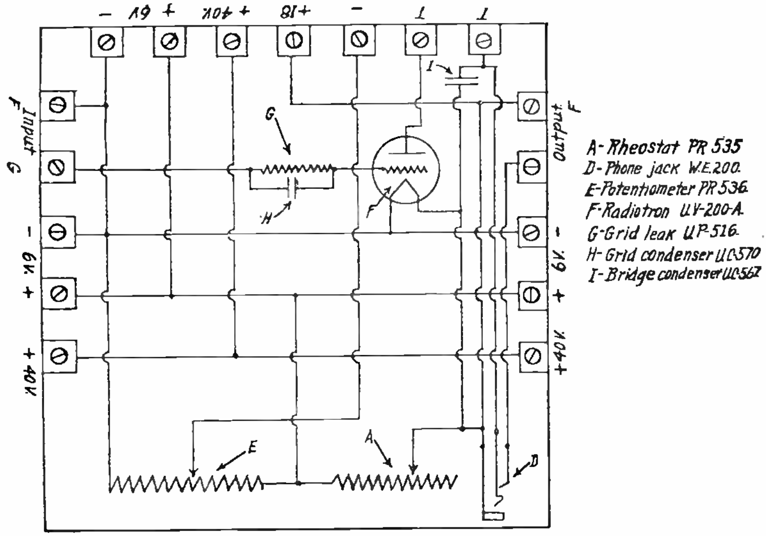


FIG. 239. Diagram of Model AD-1527 Detector Unit.

used to transfer energy from one circuit to the other. It can be rotated by the external coupling knob on the receiver, thereby increasing or decreasing the amount of coupling between the primary and secondary circuit. Regeneration is accomplished by a rotating tickler coil placed within one end of the secondary inductance. The position of the tickler coil is controlled by an external knob on the front of the receiver.

A phone jack extending through the front of the receiver panel makes it possible to plug the telephones in on the crystal detector.

8. **Model AD-1527 Vacuum Tube Detector Unit**—The AD-1527 vacuum tube detector unit is contained within a metal case and consists of the following: One rheostat, one potentiometer, one grid leak and condenser, one bridging condenser, a phone jack and tube socket. The potentiometer is connected in shunt to the 6-volt battery with the rotating arm connected to the negative "B" battery. This connection permits a variation of the plate potential applied to the detector tube. The detector box is provided with three terminal blocks as shown in figure 239. A wiring diagram of the detector unit is shown in figure 239.

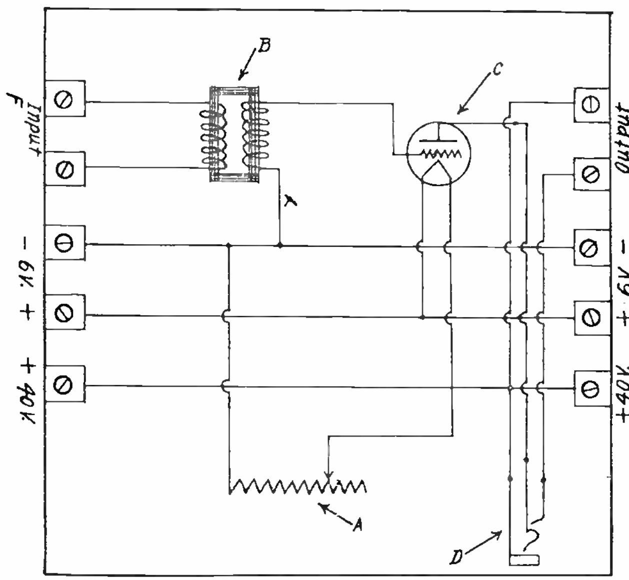


FIG. 239*a*. Diagram of Model AA-1528 Audio Frequency Amplifier.

9. **Model AA-1528 Amplifier Unit**—The AD-1528 amplifier is an individual audio frequency amplifier unit containing a fila-

ment rheostat, audio frequency amplifying transformer and telephone jack. The amplifier units are so constructed that plate and filament circuits are completed in each succeeding step when bus wires are in place. Plate and filament batteries are connected only to the detector box and these circuits are carried to the amplifiers through the bus wires. The terminals on the output side of the last step are always left disconnected. Figure 239-a shows a wiring diagram of the AA-1528 amplifier unit.

10. Model **AA**-1400 **Detector-Amplifier Unit**—The detector-amplifier AA-1400 is a compact and easily operated detector-amplifier unit. It consists of a vacuum tube detector and two stages of audio frequency amplification enclosed in a neat metal case.

An important feature of model AA-1400 is the individual filament control system. A detector and two stages of amplification are furnished with separate rheostats, thus enabling the operator to obtain individual stage control of the received energy. The left telephone jack is for plugging in on the detector tube only, the middle jack furnishes detection and one stage of audio frequency amplification, while the right hand jack gives maximum amplification output, i.e., detection with two stages of amplification. Re-

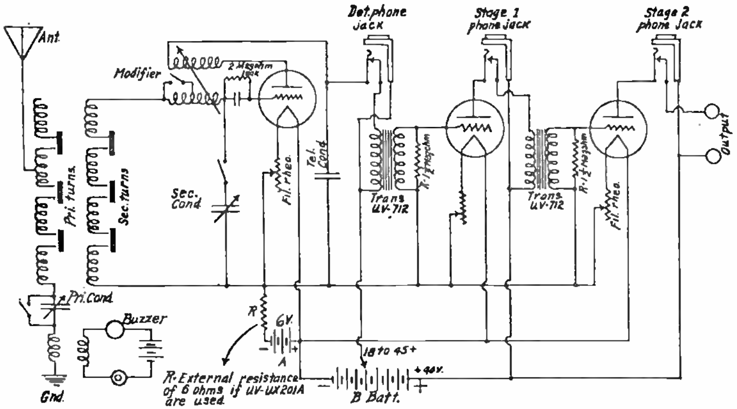


FIG. 239*b*. Diagram of 106-C Regenerative Receiver Fitted with Model AA-1400 Detector-Amplifier Unit.

ception may be continued in emergency with the detector, or the detector and one stage of amplification, when the "A" battery has become discharged to such an extent that it will not properly operate the filaments of the three tubes, although this practice should not be generally followed.

The electrostatic shielding afforded by the metal case of this instrument eliminates all disturbances caused by the proximity of the hand or body to the instrument.

Originally designed for the UV-200 and UV-201 vacuum tubes, the filament rheostats in the model AD-1527 vacuum tube detector, model AA-1528 amplifier and model AA-1400 detector-amplifier are of low resistance and allow the passage of too much current for the new type of thorium or XL filament tubes. Therefore, it is advisable to connect an external resistance of 6 to 20 ohms in series with the negative side of the filament discharge line. A correct adjustment of this resistance will permit the operator to have the separate filaments under control by the individual rheostats. Not more than five volts should be impressed across the filament terminals of the UV or UX-201-A tubes; otherwise current in excess of ¼ ampere will pass, causing a rapid exhaustion of the thorium drawn in the tungsten filament, thus decreasing the useful life of the tube.

11. **Radiomarine Corp. of America Charging Panel UP-858**—The charging panel UP-858 permits the use of two "A" batteries for heating the filaments of the vacuum tubes in the detector and amplifier units. It is so designed that by changing the position of the four-pole, double-throw switch on the charging panel, one battery may be placed on charge while the other is on discharge and vice versa. If it is desired to discharge one battery without charging the other at the same time, the double-pole ship's power switch should be opened.

If the ship is equipped with two engine room dynamos, care should be taken to ascertain that both machines are connected with the same polarity. Batteries should not be placed on charge unless it is definitely known that the engine room dynamo is running. Should engine room generator stop for any reason while batteries are on charge, the double-pole ship's power switch on the charging panel must be pulled immediately. Both switches on the charging panel must be opened before leaving the radio room to go ashore.

Two 6-volt Exide batteries, type 3-LX-9-1, of 100 ampere hour capacity are furnished with the charging panel and vacuum tube equipment. The four resistances showing in figure 240 are connected in parallel. Each unit is of approximately 88 ohms resistance. The total effective resistance is therefore 22 ohms, permitting a charging rate of 5 amperes if the ship's generator has an output of 120 volts. If the charging voltage is lower the charging rate is reduced, making it necessary to charge the batteries longer. Under normal conditions a charge of from 5 to 7

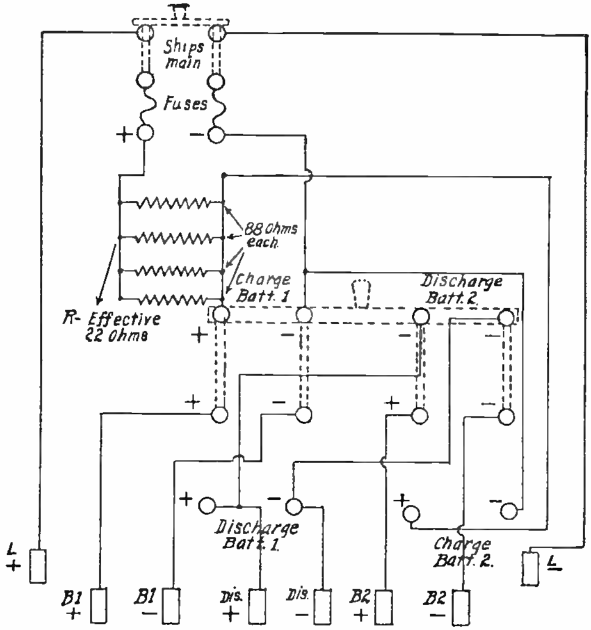


FIG. 240. Circuit of Charging Panel UP-858.

hours should restore the battery to its rated capacity. Should any one of the resistance units burn out, the charging rate will be reduced depending upon the number of units inoperative and the charging voltage. If all the units were to burn out a bank of eight 50-watt lamps in parallel will permit the correct charging current to flow.

12. Installation of "C" Battery with Amplifier Units AA-1528 or AA-1400—

1. Remove wires running from negative 6-volt terminal on unit to terminal "F" on audio frequency amplifying transformers. Connect both "F" terminals together and continue wire to 3 or 4½ negative terminal of "C" battery.

2. Connect positive terminal of "C" battery to negative terminal of 6-volt battery.

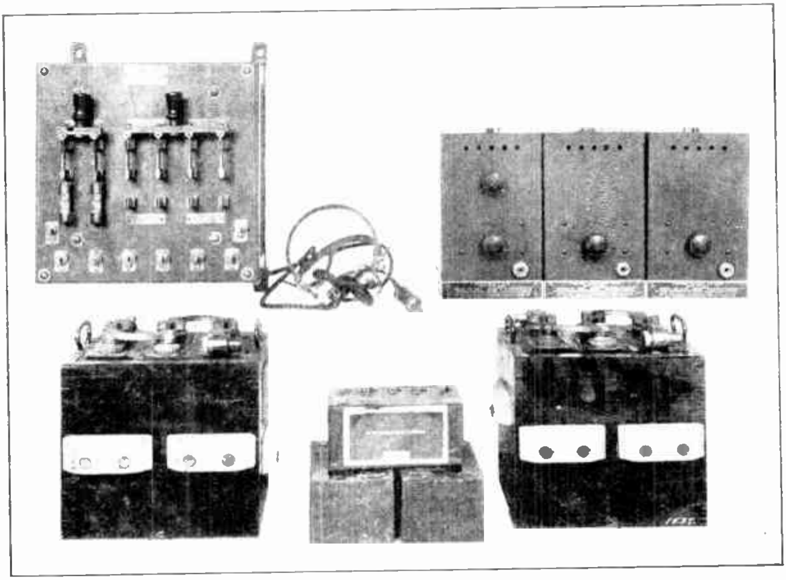


FIG. 241. Model UP-858 Charging Panel Detector and Amplifier Units "A" and "B" Batteries.

The "C" battery will reduce the milliampere drain on the "B" battery and thus prolong the life of the latter. When the tuner and amplifier are used for broadcast reception, a marked improvement in volume and quality will result.

Type IP-501 Regenerative Receiver. Wavelength Range 300 to 8,000 Meters, Which May Be Extended with IP-503 Long Wave Loading Unit, 300 to 19,000 Meters. Made by The Wireless Specialty Apparatus Co.

The type IP-501 regenerative receiver is designed for the reception of either continuous wave or spark signals. The receiver is equipped with six binding posts, normally short-circuited for 300 to 6,800 meters, to which loading coils may be attached for the reception of wavelengths up to 23,000 meters. The proper loading coils are primary, 50; secondary, 50; tickler, 30 millihenries. This receiver possesses a high degree of selectivity, but it is also provided with an untuned or "standby" circuit.

A switching mechanism permits the use of either of two tuned circuits on an untuned or tuned secondary.

The coils used in the receiver are bankwound inductances of high-frequency cable, wound on threaded bakelite tubes. The assembled coils are impregnated in vacuum and baked. The individual sections are automatically connected, entirely disconnected and opened, or entirely disconnected and individually short-circuited by a mechanism operated by the inductance

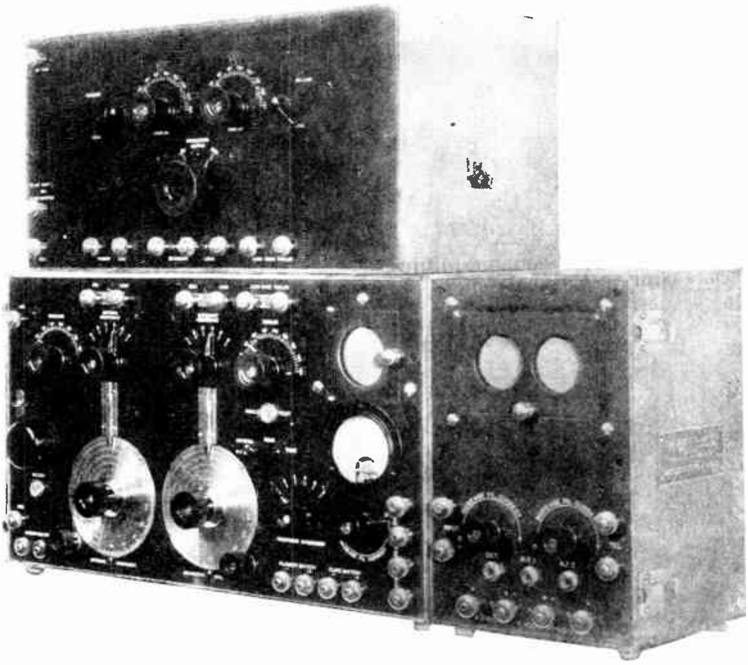


FIG. 242. Wireless Specialty Company 1P-501 Radio Receiver and 1P-503 Long Wave Loading Unit.

switch. By this means every coil in the receiver has a natural period when connected with its leads and switch points which is less than the shortest wavelength in the range of the receiver. This eliminates the reception of parasitic signals, reduces the absorption of the desired signal by the coils, forces the energy into the detector and minimizes interference on all wavelengths.

The condensers are of the self-balanced plate type. Insulating bushings are entirely absent in their construction. Their calibration is constant and their losses extremely low.

The receiver is mounted under a one-half inch bakelite-dilecto panel. The containing box is 5/8 inch oak. A switch is provided for vacuum tube reception, and also to protect the detector during transmission.

The IP-501 receiver is similar in design and construction as the Navy SE-1420 receiver. The inductances and condensers are of the same values and arranged in the same network.

13. **IP-503 Long Wave Loading Unit**—The IP-503 long wave loading unit consists of three loading coils of sufficient inductance to load the primary, secondary and tickler circuits of the IP-501 receiver to extend the wavelength range up to 19,000 meters.

A wavelength control switch on the panel of the unit permits three ranges of wavelengths. In the position marked "Low" the coils are short-circuited, thus permitting the normal range of the receiver from 300 to 8,000 meters. Figure 242*a* shows the schematic of the loading inductances for the three wavelength ranges.

14. **Installation of IP-503 Long Wave Loading Unit**—

1. Mount this unit on top of IP-501 receiver.

2. Remove short-circuiting straps from binding posts on IP-501 receiver marked "Pri. Load," "Sec. Load" and "Long Wave Tickler."

3. Connect these binding posts to posts directly above and similarly marked on long wave loading unit.

4. Connect antenna lead to post marked "Antenna" on long wave loading unit.

5. Connect binding post on IP-501 receiver marked "Ant." to binding post on long wave loading unit marked "To Antenna Post on IP-500 or IP-501."

6. Connect to ground the post marked "Gnd." on long wave loading unit and also the post marked "Gnd." on the IP-501 receiver.

15. **Operation of Long Wave Loading Unit**—

1. For wavelengths up to 8,000 meters, set wavelength switch at position marked "Low," thus entirely short-circuiting the long wave loading unit.

2. For wavelengths above 8,000 meters, set wavelength switch

on long wave loading unit at position marked "Medium" or "High." Cut in all "antenna inductance" and "secondary inductance" of IP-501 receiver. Rotate "antenna condenser" and "secondary condenser" of IP-501 receiver until desired signal

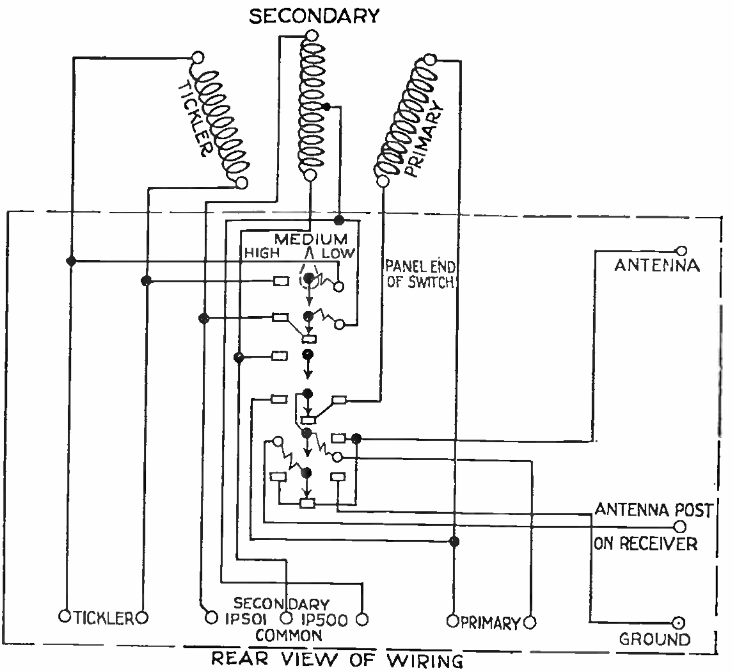


FIG. 242*a*. Wiring Diagram of 1P-503 Long Wave Loading Unit. Rear View.

s heard. Vary coupling and tickler of long wave loading unit nd make other adjustments in accordance with preceding intructions covering IP-501 receiver until maximum signal strength s obtained.

3. Lock coupling and tickler coils of long wave loading unit to revent vibration or rolling of ship from throwing them out of djustment.

16. IP-Triode "B" Amplifier—This two-step amplifier is compact unit of the resonance low-frequency type. It provides maximum of amplification due to the transformer design. The input impedance of each tube is automatically controlled by the filament rheostat.

The apparatus consists of two vacuum tube receptacles, two filament control rheostats, and two amplifying transformers. Shock-proof mountings protect the vacuum tubes from "noise" due to mechanical vibration.

The apparatus is mounted on the rear of a bakelite-dilecto panel and enclosed by an oak box. At the bottom of the panel are terminals for connecting the 6-volt filament and the 40-volt plate batteries. At the lower left of the panel are two input binding posts for connection to the receiver equipment. At the right of the panel are two binding posts for connecting telephones.

17. Installation of IP-Triode "B" Amplifier with IP-501 Receiver—

1. Connect two terminals marked "Input" to binding posts on IP-501 receiver marked "Telephones."

2. Connect "A," "B" and "C" batteries to four terminals at bottom of amplifier in accordance with markings on these terminals. Be sure that batteries are connected with correct polarity.

18. Operation—

1. Insert two UV-201-A radiotrons in tube sockets back of screened door. Before doing this be sure the filament rheostat is Off.

2. Set filament rheostats at point on scale corresponding to setting of detector tube rheostat when adjusted for five volts.

Plug telephones into jack marked "Det." if it is desired to use the detector tube only; jack marked "AF1" for one stage of audio frequency amplification or "AF2" for two stages of audio frequency amplification.

Two 6-volt Exide batteries, type 3 LX-9-1, and R.C.A. charging panel, UP-858, are used to complete the installation of the IP-501 receiver and IP-triode "B" amplifier. Any standard type of "B" battery may be used for plate supply.

Navy Type SE-1420 Radio Receiver. Wavelength Range 250 to 8,000 Meters.

The type SE-1420 receiver is designed for the reception of spark signals, using crystal detector, and for the reception of arc and other undamped signals, using a vacuum tube. The vacuum tube detector can also be used for the reception of spark signals. The receiver is a compact unit containing the radio frequency circuits and vacuum tube apparatus in a single case. Binding posts are provided for the connection of a crystal detector. This receiver possesses a high degree of selectivity coupled with maximum sensitivity.

19. **Primary Circuit**—The primary circuit consists of two primary cylindrical loading coils, a primary coupling coil and variable air condenser of .00008 mfd. to .0045 mfd. capacity,

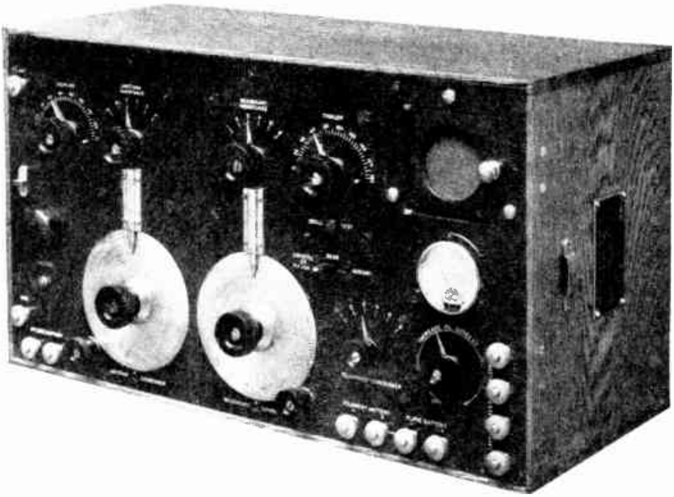


FIG. 243. Navy Type SE-1420 Radio Receiver.

inductance switches, and automatic coil cut-outs. The inductance is variable in six steps by a rotary control switch. This switch automatically connects, entirely disconnects and opens or entirely disconnects and short-circuits the individual sections of inductance. This arrangement minimizes interference on all wavelengths within the range of the receiver.

The primary condenser is connected in series with the antenna circuit. It is of the self-balanced type with constant calibration and extremely low losses. Fine variation of the condenser is provided by a rotary control knob which is gear connected and gives a vernier motion to the condenser.

The condenser dial is engraved with degree graduations from 0 to 180° and with rows of concentric circles. A mechanism actuated by the inductance switch moves a pointer to the successive circles on which may be marked the wavelength calibration of the receiver for the particular antenna with which it is used. This assists in identifying stations.

20. Secondary Circuit—The secondary circuit consists of a cylindrical inductance coil shunted by a variable air condenser. Both the secondary and primary coils are bank-wound inductances, wound of high frequency cable on threaded bakelite dilecto tubes impregnated and baked. The secondary inductance is variable in six steps by means of a rotary control switch. The condenser is of similar construction to the primary condenser, but with a capacity of about .00006 mfd. to .00032 mfd. This condenser like the primary condenser is also equipped with a fine control mechanism.

21. Coupling—The primary circuit is inductively coupled to the secondary by means of a movable primary coupling coil. The movement is governed by a rotary control switch provided with pointer and 180-degree scale mounted upon the receiver panel. The coupling between the primary and secondary is purely electromagnetic and continuously variable, passing from the maximum coupling value through zero to a small reverse coupling. It is thus possible to secure a point of minimum coupling between primary and secondary circuits on all wavelengths within the range of the receiver. The capacity coupling between primary and secondary circuits is entirely eliminated by heavy sheet copper boxes separately enclosing the two circuits. Interference is greatly reduced by this means.

22. Tickler System—The tickler system of this receiver consists of a coil coupled to the secondary at the short wave end of the secondary coil, and connected in series with the plate circuit of the vacuum tube. The coil is arranged in controllable inductive relation to the secondary coil, permitting control of the coupling between grid and plate circuits of the vacuum tube. This is accomplished by a rotary control on the panel with a scale graduated from 0 to 180 degrees. This allows reception of regenerative spark or undamped signals.

23. Buzzer Circuit—The buzzer circuit consists of a buzzer and push button mounted on the panel, on an external battery of about two volts connected to the binding posts on the panel marked "Buzzer Battery." The buzzer is capacitively connected to the antenna and is used for testing the adjustment of the crystal detector. It may also be used to indicate when the vacuum tube is oscillating, in which case a low hissing sound will be heard in the telephone receivers.

24. Telephone Condenser—Provision is made for variation

of telephone capacity in this receiver by a rotary control switch mounted on the panel. This allows variations in six steps.

25. **Vacuum Tube Apparatus**—The vacuum tube is mounted inside the receiver case. A screened door in the upper right hand

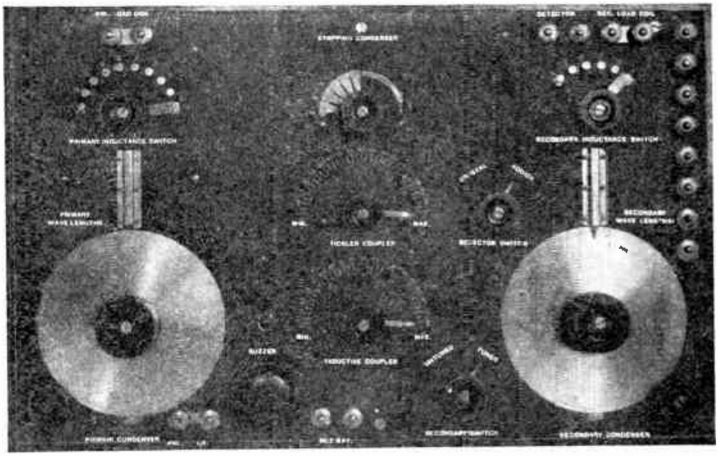


FIG. 243*a*. Navy Type SE-143 Radio Receiver.

corner of the panel allows a view of the tube and permits easy removal or replacement. The vacuum tube and standard type socket connection are supported on a shock-proof mounting that reduces "noises" due to vibration. The tube is provided with a filament ammeter and a filament current control rheostat mounted on the panel directly below the tube. Binding posts are provided on the receiver panel for connecting the filament and plate batteries. A key switch allows the receiver circuits to be connected to either the vacuum tube or the crystal detector. A neutral position is also provided for protecting the detector circuits during transmission. In this type of receiver the vacuum tube is of the biased grid type which eliminates the grid condenser and grid leak ordinarily employed. (This method of detection has been explained in Chapter 4.) Extremely fine regeneration is provided.

26. **Operation**—If the crystal detector is to be used, throw the detector switch on the receiver panel to Crystal, and adjust the crystal to maximum sensitivity by means of the buzzer test. If the vacuum tube detector is to be used, throw the detector switch on the receiver panel to Audion. Before doing this, be

sure the filament rheostat is Off. The rheostat handle should now be turned in the direction marked Increase Fil. Current until the filament ammeter reads the correct value of current at which the tube is operated. When it is desired to pick up a spark station the tickler should be set at about 120 degrees. Vary antenna, inductance and antenna condenser until maximum signal is heard. Then tune to resonance by means of the secondary inductance switch and secondary condenser. Adjust the telephone condenser until maximum signal is heard.

Maximum selectivity on spark signals is secured by using the loosest coupling consistent with an easily readable signal, and with antenna and secondary circuits tuned to resonance.

27. **Continuous Wave Signals**—For the selective reception of continuous wave signals loosen the tickler coupling as much as possible. Use loosest coupling between primary and secondary circuits. Adjust antenna circuit to resonance with the received wave, employing in general a similar process to that used for picking up spark signals. In this case, however, it will be found necessary to change the tune of the primary circuit very slowly, swinging the secondary condenser through resonance at each slight change in the primary. When the secondary circuit is oscillating passage through the resonance point is marked by a slight click. The best note of the station will be heard at a setting slightly below or above the resonance point.

Summary—Procedure for Obtaining Oscillations.

1. Adjust coupling to about 45 degrees.
2. Raise filament current to correct value.
3. Set telephone condenser so that about one-half capacity is connected in.

28. **Test for Oscillations**—A clicking sound will be heard in the telephones if the bulb is oscillating:

1. When push button marked Oscl'n Test is pressed in.
2. When primary circuit is brought into resonance with secondary circuit with medium inductance coupling.
3. When tickler coupling is tightened (periodic clicks).
4. If buzzer is operated and tube is oscillating, a soft hissing sound will be heard.

29. **Failure to Obtain Oscillations**—This may be due to:

1. Reversed plate battery.
2. Insufficient tickler coupling.
3. Reversed feed-back. (Reverse tickler connections.)

30. **Care**—

1. See that all connections are tight.
2. Clean the panel occasionally with a clean dry cloth.

Type SE-143 Navy Short Wave Receiver. Wavelength Range 250 to 6400 Meters.

This receiver consists of a primary circuit tuned with series condenser, inductively coupled with the secondary circuit. The secondary circuit, when the secondary switch is in the "Tuned" position, is shunted by a variable condenser; in the "Untuned" position, the variable condenser is cut out, and an extra secondary winding, which can be very tightly coupled with the primary, is cut into the secondary circuit. For use with oscillating audion detector a tickler coil is provided, variably coupled with the secondary winding.

The primary inductance is variable by ten taps. The inductance varies from 50 microhenries to 3880 microhenries. The primary condenser is of the variable air type and is variable from a minimum capacity of .00008 cicrofarad to a maximum capacity of .00314 microfarad.

To connect the receiver for operation, the antenna lead must be run to the binding post marked "Ant." and the ground lead to the post marked "Gr." The antenna lead to the receiver must be well insulated, and not bunched with other leads, or run for any distance in close proximity to a steel bulkhead or other metal mass.

To the posts marked "Detector" a crystal detector may be connected and used for spark reception only. Leads from "RA," "RE," "Tickler" and "Aud. Tel." are then run to the corresponding posts on the audion control panel, and finally the telephone receivers are connected to the posts marked "Telephone." The leads from "RA," "RE" and "Tickler" to the audion control panel should be as short as possible and must not be bunched. Especially should the "RA" lead be kept well separated from the others.

31. **Operation**—If it is desired to receive spark signals on the crystal detector, the detector switch must be set on "Crystal" with the secondary switch in the "Untuned" position, and the inductive coupler set at "Max." The detector is first adjusted to a sensitive condition on signals from the receiver buzzer.

If the wavelength of the desired station is known, the primary and secondary circuits may be at once set to this wavelength, and the secondary switch thrown to the "Tuned" position and the coupling varied until the best signal is heard in the phones. Slight retuning of both primary and secondary circuits by means of the primary and secondary condensers will generally be found necessary for the best signal, owing to the effect of the coupling and the possible slight inaccuracy of the distant stations' wavelength setting. Finally, the stopping condenser should also be adjusted until the clearest and loudest signal is obtained.

Spark signals may also be received on the audion by simply throwing over the detector switch from "Crystal" to "Audion."

If the desired station is of unknown wavelength, it will be easiest picked up by leaving the secondary switch in the "Untuned" position, the inductive coupler in the "Max." position, moving the primary inductance switch from point to point, and at each point rotating the primary condenser through 180 degrees. In this way all tunes within the range of the receiver will be

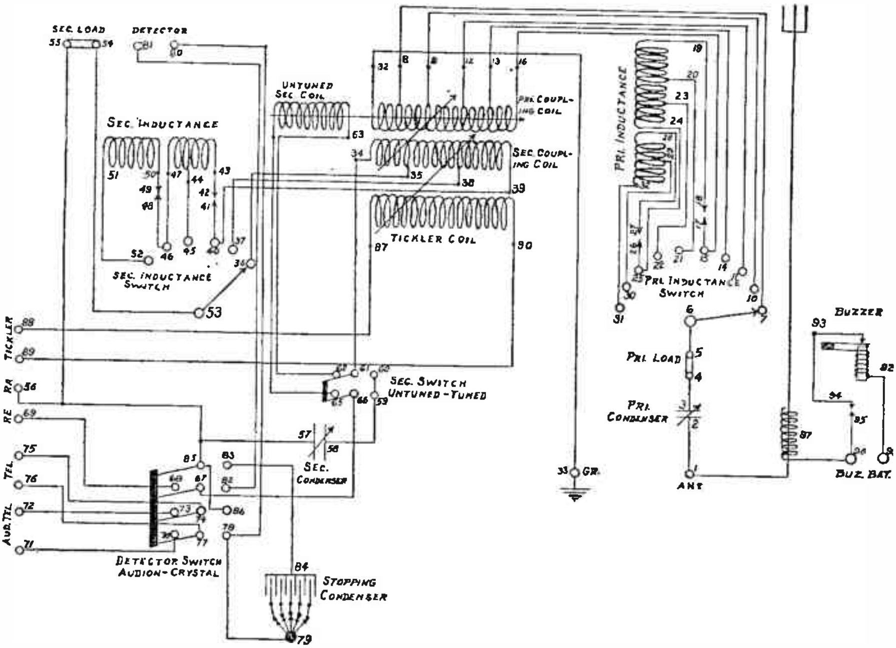


FIG. 243*b*. Wiring Diagram of Navy Type SE-143 Radio Receiver.

quickly passed over. As soon as the station is heard, decrease the coupling as far as possible without losing the signal, retune the primary by variation of the primary condenser, and then throw the secondary switch over to the "Tuned" position. Next carefully tune the secondary circuit, first approximately by setting it on the same wavelength marking as that indicated by the primary, and then more closely by slow movement of the secondary condenser. Finally, readjust coupling for maximum strength of signal. It is usually necessary to slightly readjust both primary and secondary circuits after any considerable change of coupling.

For arc or other undamped wave signals, it is necessary to use the oscillating audion. The detector switch must be set on "Audion" and the secondary switch on "Tuned."

After tuning the primary and secondary circuits approximately to the desired wavelength, and leaving the inductive coupler at about 50 degrees, vary the tickler coupler until good oscillations are obtained in the secondary circuit. The presence of oscillations may be readily discovered by either short-circuiting the "Tickler" posts or touching the "RA" terminal, a click being heard if the circuit is oscillating properly. When the station is heard, readjust the coupling of the primary and secondary for best signal, similarly to the adjustment for spark signals.

An arc station of unknown wavelength may be picked up by a similar process to that employed for unknown spark signals. But in this case it will be found necessary to change the tune of the primary circuit very slowly, swinging the secondary condenser through resonance at each slight change in primary. When the secondary circuit is oscillating, passage through resonance point is marked by a slight click, and the best note of the station will be heard at a setting above or below the resonance point.

U. S. Navy Medium Wave Receiver, Type SE-1220. Wavelength Range 300 to 6800 Meters.

This receiver is designed primarily for the reception of spark signals; secondarily for the reception of undamped waves, using an audion control box detector. A four-pole, double-throw switch in the receiver permits of the use of either crystal detector or audion, both of which may be permanently connected to the receiver.

The receiver circuit with detector switch on "Crystal" is shown schematically in figure 244.

32. **Tuning**—The antenna is tuned by means of the series variable condenser *C1* and the 10-step variable inductance *L1*. The secondary is tuned by the shunt variable condenser *C2* and the 6-step variable inductance *L2*. A double-pole, double-throw switch in the receiver permits of the use of either the tuned secondary or the untuned secondary. The latter consists of a coil coupled to the primary and placed in series with the secondary

inductance; the secondary condenser is cut out of the circuit when the untuned secondary is used.

33. Coupling—The coupling between primary and secondary circuits is purely inductive. The coupler is designed to afford either loose or close coupling on long or short waves with a point of minimum coupling for any wavelength.

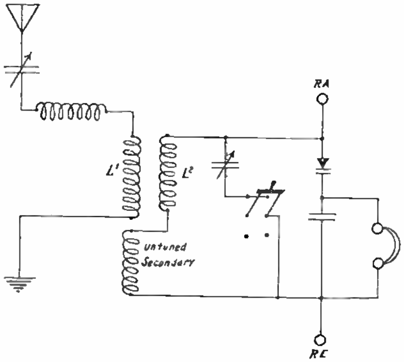


FIG. 244. Schematic of Type SE-1220 Receiver with Detector Switch on Crystal.

34. Primary Circuit—The primary circuit of this receiver has a wavelength range of 300 to 6,800 meters when used with an antenna of .0008 mfd. capacity. The primary circuit consists of a large, air dielectric, variable condenser, minimum capacity about .00008 mfd. and maximum capacity about .0045 mfd.; a primary cylindrical loading coil, a primary rectangular section loading coil, a primary coupling coil, inductance switches and coil cutouts.

The cylindrical loading coil is wound with a fine bank winding of 408 turns—3 × 16 × 38 Belden litzendraht, and has an inductance of about 15 millihenries.

The primary coupling coil is double bank-wound with 47 turns of 3 × 38 Belden litzendraht, and has an inductance of .42 millihenries.

The primary cylindrical loading coil is wound in three sections, an air gap of one-half inch separating the first 135 turns from the remaining 273. This sectionalizing scheme is adopted in order to cut down both the distributed capacity and the natural period of the coil.

The primary rectangular section loading coil consists of 23 layers of 3 × 16 × 38 litzendraht, 21 turns per layer, making a total of 483 turns. This loading coil is placed inside the primary cylindrical loading coil, at the long wave end.

The primary condenser is of the balanced plate type. The fixed and movable plate systems are in two sections arranged 180 degrees from each other to balance the movable plate system mechanically. A knob is mounted on the receiver panel to the left and below the handle of the variable condenser, and permits of fine adjustment of the primary condenser through gears connected to the movable plates. A small sector of 7 degrees is cut from each end of the movable plates of the condenser. A sector of 10 degrees is cut from each end of the fixed plates of the condenser. This increases the ratio of maximum to minimum wavelength of each coil, by reducing the end plate capacity of the condenser to a minimum. The movable plate system carries a German silver dial on which the antenna wavelengths may be marked either in pencil or in India ink. An external loading coil may be inserted into the antenna circuit by connecting to the binding posts marked "Load Coil" after removing the short-circuiting link.

35. **Secondary Circuit**—The secondary circuit has a wavelength range of from 300 to 6,800 meters. There is an overlap of at least 35 percent on each of the steps of secondary coil.

36. **Tuned Secondary**—The tuned secondary circuit consists of a cylindrical inductance coil shunted by an air dielectric variable condenser. This coil is 5 inches in diameter, 7.5 inches long, is wound with a double bank winding of 188 turns of 3 × 16 × 38 Belden litzendraht, and has an inductance of 4.25 millihenries. This coil is wound in three sections; a 7/16 inch air gap separates the first 43 turns from the second section and a 3/16 inch air gap separates the second section (70 turns) from the third section (75 turns). This sectionalizing scheme cuts down both the distributed capacity and natural period of the coil.

The secondary air dielectric condenser has a minimum capacity of about .00006 mfd. and a maximum capacity of about .0032 mfd. The movable plate system carries a German silver dial on which the wavelengths and condenser degrees are marked. The fixed and movable plates are cut back like the plates of the primary condenser in order to obtain a high ratio of maximum to minimum wavelength on any inductance tap, by reducing the end plate capacity to a minimum. A knob is mounted on the receiver panel to the right of and below the handle of the variable condenser for fine adjustments such as are necessary in short wave arc or tube work.

Extra secondary loading coils may be inserted between the posts marked "Load Coil" after removing the short-circuiting link.

37. **Untuned Secondary**—The untuned secondary consists of the secondary, without the secondary condenser, in series with a coil mounted over the primary coupling coil. This arrangement gives close coupling between the primary and secondary circuits, for stand-by work, both on long and short waves. The additional coil is 6 inches in diameter and ⅝ inch long and is wound with a four bank winding of 72 turns $3 \times 16 \times 38$ Belden litzendraht. A double-pole, double-throw switch permits of the use of either the tuned or untuned secondary. When the tuned secondary is used the additional coupling coil is short-circuited; when the untuned secondary is used the secondary condenser is cut out of the circuit. The untuned secondary is so designed that its presence in the secondary circuit does not cause any detuning of the primary. Thus it is possible to pick up a station on the untuned secondary, switch to the tuned side and adjust the secondary circuit to resonance with the incoming signal without changing the primary condenser setting more than a few degrees.

38. **Coupling**—The primary is inductively coupled to the secondary by means of a movable primary coupling coil. Precautions were taken in the design of this receiver to cut down the residual capacitive coupling between the primary and secondary circuits. There is no fixed inductive coupling between the two circuits since all the coils in the receiver are mutually perpendicular. It is possible to secure a point of minimum coupling between primary and secondary circuits on all wavelengths within the range of the receiver. Medium and tight coupling can be obtained on short waves; medium coupling on long waves.

For stand-by work the untuned secondary of the receiver is to be used with the inductive coupler set at about 100 degrees. After the primary is tuned for maximum signal, and if interference or static is present, the tuned secondary should be used and the coupling loosened to the lowest point consistent with a good readable received signal.

39. **Tickler Coil**—The tickler is connected in series with the plate circuit of the detector tube and is coupled to the secondary at the short wave end of the secondary coil to provide sufficient coupling to the secondary on short waves.

40. **Buzzer Circuit**—The buzzer circuits consist of a battery, a buzzer and a push button switch, all in series.

The buzzer is coupled to the antenna and shock excites the antenna into oscillation at its own natural period. Outside batteries (1 to 3 volts) are connected to the terminals marked "Buz. Bat." The buzzer is intended to test the adjustment of the crystal and may be used to indicate whether the detector tube is oscillating. (A low hissing sound will be heard in the telephone if the buzzer is operated while the bulb is oscillating.)

41. Operation. Stand-by Work—

1. Set the TUNED-UNTUNED switch on UNTUNED side.
2. Set inductive coupler at about 100 degrees.
3. Adjust stopping condenser to its maximum value.
4. Vary the primary condenser and inductance till maximum signal is obtained.

42. Selective Work—

5. Throw switch to TUNED side and adjust secondary capacity and inductance till maximum signal is obtained.

As a rule it will be found that the use of the untuned secondary does not detune the primary circuit, so that only a slight readjustment of the primary, if any, is necessary after throwing from the untuned to the tuned side of the secondary.

Sharpest tuning, or maximum selectivity on spark signals, is obtained by cutting all the stopping condenser out of the circuit and using the loosest coupling giving a loud signal, with both antenna and secondary circuits tuned to resonance with the incoming wave. The point of minimum coupling of this receiver is between 5 and 20 degrees on the coupling scale.

When the knob of the inductive coupler is turned counterclockwise, so that the primary coupling coil rotates beyond its position of minimum coupling, the direction of the e.m.f. induced in the secondary is opposite the direction of the e.m.f. induced when the coupling coil is rotated clockwise beyond its position of zero inductive coupling (phase difference of 180° between the two voltages).

This feature is incorporated in the receiver so as to provide a means of bucking whatever residual capacitive coupling may exist between the antenna and secondary circuits, by providing a counter e.m.f. to the e.m.f. due to static coupling.

Broadest tuning is best accomplished by the use of from 90 degrees to maximum coupling on the inductive coupler with all the secondary capacity disconnected from the circuit. This can be done by setting the tuned-untuned switch on the untuned side and increasing the stopping condenser to its maximum value.

43. Regeneration—Spark signals may be amplified on all wavelengths by setting the switch on the audion control box on the contact marked "Osclr" and increasing the tickler coupling to the point just before oscillations begin. An amplification of 3 to 10 times may be obtained by this method.

For selective reception of undamped waves, loosen the tickler coupling as much as possible, without stopping oscillation, and adjust primary and secondary circuits for loosest coupling; adjust antenna circuit till it is in resonance with the received wave (maximum signal due to the antenna tuning and independent of heterodyne note). It may be necessary to reverse the tickler leads to secure regeneration.

44. Care—

1. Clean and brush all contacts occasionally.

2. Clean switch blades occasionally; if they do not make good contact, tighten them.

3. See that no metal objects rub against any of the leads.

4. Clean the front and rear of the panel occasionally with clean, dry cloth.

5. Clean buzzer contacts with crocus cloth.

6. Make sure that all binding posts make good contact with the leads.

7. Clean anti-grid safety gap with crocus cloth and clean paper.

Navy Short Wave Receiver, Type CM-294. Range of Wavelengths 250 to 3100 Meters.

45. **Primary Circuit**—The primary circuit of the receiver is composed of a variable condenser, loading inductance and coupling inductance, and suitable binding posts for making connections with antenna, ground, and additional loading inductance, if necessary. The primary variable condenser is of .002 mfd. capacity and is in series with the antenna and primary inductances. The distribution of the primary inductance between the loading and coupling coils is such that the overall coupling coefficient is approximately constant for all taps. Suitable switching mechanism is provided in order to change to the desired step of inductance. In making changes of inductance, both loading and coupling inductances are changed at each step. The primary variable condenser is of .002 mfd. capacity; is of the balanced type insuring permanence of setting. The design is such that concentrated electrostatic fields are eliminated. Connection to the rotor plates is made by a double spring contact against a contact arc. The contact between springs and arc is such that no noise is produced in receiver telephone by a movement of the condenser when

circuit is excited by an oscillating audion. Two binding posts marked " Pri. Load " are provided for the insertion of additional loading inductance in the primary circuit when necessary. A protective gap is located across the antenna and ground binding posts.

46. Secondary Circuit—The secondary circuit of the receiver is formed of a variable condenser, loading and coupling inductances, suitable terminals, and switching arrangements. A stopping condenser, variable in steps, is also provided for use in connection with the crystal detector circuit. The variable condenser used in the secondary circuit is exactly the same as the one used in the primary circuit and is of .002 mfd. capacity. It is connected in parallel with the secondary inductances however, instead of in series as is the case in the primary circuit. This condenser is fitted with a fine adjustment mechanism, which gives a ten-to-one ratio. This fine adjustment is accomplished by means of gears, and is operable from front of panel. The inductance of the secondary circuit is distributed between loading and coupling coils as described in primary circuit. The relation between the values of the inductance in the primary and secondary circuit is such that the proper value of overall coupling coefficient is obtained on all taps.

The secondary circuit is provided with switching arrangements so that either a crystal detector circuit or an oscillating audion circuit may be used. When the switch is in the oscillating audion position, the receiver is adapted for connection with the Navy standard audio control box by means of the row of binding posts at the right.

When using the oscillating audion in connection with the receiver on very low wavelengths, it is recommended that close coupling between primary and secondary be used, also that the tickler coupling be minimum and the value of bridging condenser be very small. The best results will be obtained by the proper use of this combination.

47. Coupling Device—The coupling device used on the short wave receiver is of special design and is of such construction that it occupies a minimum amount of space. The primary coil is permanently mounted to the panel at an angle of 45 degrees to the axis of the shaft. The secondary or the inside coil can rotate inside the primary coil through an angle of 180 degrees. The shaft on which the secondary coil is mounted projects through the panel fitted with pointer and handle; the pointer travels over a degree scale. Connection to the movable secondary coil is made through a connection spool. The wires from the secondary coil are fastened to the spool, which is fastened to the shaft and rotates with it; connection from the spool to the circuit is made through phosphor bronze springs. By this method of making connection to the movable coil the leads from the coil are always in one position, and there is no wear on them caused by twisting wires, etc. The 180 degree movement is taken up completely in the phosphor bronze springs.

48. **Wave Change and Indicating Device**—This device consists of a dial or disc attached to the rotating portion of the variable condensers, and a pointer actuated by a cam on the inductance switch shaft. The shafts of the variable condensers are fitted with a special form of hollow shaft which are slotted to permit the travel of the pointer through them. The dial is made fast to the hollow shaft and rotates with it. On one-half of the dial is engraved a degree scale, and on the other half are engraved lines, corresponding to taps of inductances on the inductance switch. The dials are removable so that wavelength indications may be engraved on this portion of the dial.

49. **Operation**—This receiver is designed to receive signals, using either a crystal detector or an oscillating audion. A description of the procedure for operating the receiver on both detector and audio follows:

50. **Crystal Detector**—To set receiver to receive signals using a crystal detector:

1. Set cam switch to "Crys. Det." position.
2. Set coupling at about 45 degrees.
3. Set tickler at zero degrees.
4. Set stopping condenser switch on first position.
5. Start test buzzer and adjust detector for sensitive setting.
6. Tune in signal.

51. **To Tune Receiver to Signal of Unknown Wavelength**—Set secondary tuned-untuned switch to "Untuned" position.

Use close coupling between primary and secondary circuits (up to 120 degrees setting of coupler).

Tune primary circuit to signal.

The signal may then be tuned in on the secondary circuit by setting secondary tuned-untuned switch to "Tuned" position, adjusting secondary circuit to the same wavelength as the primary circuit.

The strength of the signal may be increased by the proper adjustment of stopping condenser and degree of coupling.

52. **To Tune Receiver to Signals of Known Wavelengths**—Set secondary tuned-untuned switch to "Tuned" position.

Use close coupling between primary and secondary circuits (up to 120 degrees setting of coupler).

Set secondary circuit to wavelength desired by setting wavelength indicating device pointer to the proper wavelength indication on dial.

Set primary circuit to same wavelength in same manner as for secondary. (The primary circuit of this receiver is to be calibrated on shipboard when connected to ship's antenna.)

Make final adjustments to resonance with signal by slight variations of both primary and secondary condensers.

53. **Tuning Receiver to Receive Signals through Interference**—Tune receiver to the signal it is desired to receive in the manner described in the preceding two sections.

Loosen coupling between primary and secondary circuits until secondary circuit is slightly detuned from signal.

Bring secondary circuit into resonance with signal by varying secondary condenser (use fine adjustment handle for varying condenser).

Repeat this operation until as loose coupling as possible is being used, the signal being still readable.

Adjust value of stopping condenser, so maximum response to signal is indicated in telephones.

54. **Oscillating Audion**—To set the receiver to receive signals using an oscillating audion:

1. Set cam switch to "Audion" position.
2. Set tickler to "Max."
3. Use medium coupling (about 90 degrees on coupling scale).
4. Raise audion filament current to proper amount and adjust voltage of plate battery. (Using 201-A as detector, filament current should be adjusted to .25 ampere and plate battery to 45 volts.)
5. Set switch blades of audion control box on "Osclr." A grid leak of about ¼ to 5 megohms should be connected between grid and positive terminal of filament, if not already installed. (5 megohms is best when using 201-A tube as detector.)
6. Set stopping condenser switch on audion control box so that half the capacity is in. Same with bridging condenser.

55. **Tests for Oscillation**—A clicking sound will be heard in the telephones when the system is oscillating under the following conditions:

1. When tickler is short-circuited (switch marked "Test" above tickler binding posts on audio control box panel).
2. When the grid binding post on audion control box is touched.

3. When secondary inductance switch on receiver is moved from one contact to another.

If the buzzer is started when audion is oscillating, a soft hissing noise will be heard in the telephones instead of the true note of the buzzer.

Periodic clicks will be heard in telephones if tickler coupling is too tight and grid leak is not great enough.

56. Failure to Obtain Oscillations—Failure to obtain oscillations may be due to:

1. Reversed filament battery.
2. Reversed plate battery.
3. Reversed tickler leads.
4. Reversed leads from "audion" binding posts on receiver to "RA," "RE" terminals on audion control box.
5. Value of bridging condenser too small.
6. Improper value of stopping condenser.
7. Tickler too loosely coupled to secondary.
8. Value of plate current not sufficient.
9. Bad cells in plate battery.
10. Defective vacuum tube.

57. Notes on Tuning When Using Oscillating Audion—In order to obtain oscillations on very low wavelengths, it is necessary to use tight coupling between primary and secondary receiver circuits (180 degrees on coupling scale); loose coupling between tickler and secondary circuit, and small values of stopping condenser and bridging condensers.

On the longer wave within the range of the receiver, closer tickler coupling can be used to advantage, also looser coupling between primary and secondary circuits. On these longer waves, it is necessary to use larger values of bridging and stopping condensers.

58. Maintenance—This receiver is designed to operate with the minimum of attention. As all parts are finely finished care should be exercised in order to keep the finish as perfect as possible.

Dust should be wiped off the instrument with a fine cloth.

No emery cloth, crocus cloth, sand paper or other abrasive materials should be used on any part of the receiver.

The protective gap should be cleaned occasionally by running a piece of paper between the two parts in order to remove any accumulations of dust.

U. S. Navy Audion Control Box, Type SE-1071.

59. **Description**—This instrument is designed to function as the detecting system for standard Navy receivers, especially for short wave receivers, types SE-143, SE-143-A; medium wave receivers, types SE-1220 and CM-294; long wave receivers, types SE-95-A, SE-899 and CN-240.

The audion control panel is encased in a cherry or walnut wood box about 14½ inches high, 7⅜ inches wide and 6 inches deep. The entire system is composed of the following units, each of which may be assembled independently and then mounted without the necessity of further adjustment after having been secured to the panel: Shock-proof vacuum tube support, filament ammeter, filament rheostat, plate voltage switch, detect-oscillate switch, grid condenser, bridging condenser, grid leak, potentiometer, filter system.

60. **Shock-Proof Vacuum Tube Support**—The vacuum tube is supported from the panel by a system of conical springs arranged so as to minimize the amount of vibration transmitted to the bulb due to any sudden shock or persistent disturbance. The bulb socket is attached to a micarta base to which are secured three conical springs. These springs support an angular brass disc which acts as a damping vane. On the brass disc equally spaced between the springs just described are attached three brass rods which hold the entire vacuum tube support system to the panel. All the springs are stuffed with cotton so as to increase the damping of the springs without increasing their metallic mass.

61. **Filament Ammeter**—The filament ammeter is a small flush type instrument developed expressly for use in the audion control box. The zero mark is displaced from the extreme left hand position so as to furnish a positive indication of a reversed filament battery connection without injury to the position of the ammeter. The moving coil system is dead-beat and the calibration of the instrument is quite accurate.

62. **Filament Rheostat**—The filament rheostat consists of about 7 feet of number 24 advance wire and has a resistance of about 10 ohms. The moving switch blade carries an insulated arm which separates 2 contacts in the plate battery circuit, thereby opening the plate circuit in the "Off" position of the rheostat switch blade.

63. **Grid and Bridging Condenser**—Each of these condensers is built up of alternate layers of mica and copper foil. The ca-

pacity of the grid condenser at each step is approximately as follows:

Step 1—0.000250 mfd.
Step 2—0.000500 mfd.
Step 3—0.000750 mfd.
Step 4—0.001000 mfd.
Step 5—Shorted.

The capacity of the bridging condenser is variable by steps from 0.000500 mfd. to 0.002500 mfd.

64. **Grid Leak**—The grid leak used in this control box consists of a thin film of tantalum deposited on the inner walls of a glass tube about ½ inch in diameter and 2 inches long. This grid leak has a resistance of 600,000 ohms or .6 megohm. If a UX-201-A tube is used as the detector the value of this grid leak resistance should be increased to 5 or 6 megohms. The grid leak is permanently connected between the grid and the positive filament battery terminal.

65. **Potentiometer**—To secure variations of plate voltage a graphite sector of about 30,000 ohms is connected across the 125-volt line. A sliding contact button, moving on one surface of the sector and connected to the plate element of the vacuum tube, permits of continuous variations of the voltage impressed between the plate and the filament.

66. **Note**—When the plate voltage switch is thrown to the "Storage Bat." side the potentiometer is disconnected from the plate circuit and no variation of plate voltage is obtained. This procedure is adopted to prevent the storage battery or emergency dry battery from discharging continuously through the graphite arc.

67. **Filter System**—In order to eliminate noises in the receiver telephone due to line surges and commutator ripples, a high impedance choke coil or "filter coil" is connected in each side of the line supply. Each filter coil consists of about 17,000 turns of No. 36 S.S.C. wire and has a resistance of about 2700 ohms. A one microfarad condenser is connected across the line and another is connected between the positive terminal of plate battery and the movable switch blade of the potentiometer.

68. **Installation and Wiring**—

(*a*) Connect the binding posts on the left-hand side of the audion control box to the corresponding binding posts on the receiver. For this purpose use either the metal links supplied with the audion control box or short leads of flexible stranded copper wire.

(*b*) Connect the telephones to the binding posts marked "Tel." at the lower right-hand side of the audion control panel.

(*c*) Connect a 6-volt Edison storage battery to the terminals marked "Fil. Bat. +."

(*d*) Connect the ship's d.c. supply to the binding posts marked "125 V. Gen.+."

(*e*) Connect a 60- or 90-volt "B" battery to the terminals marked "Storage Battery +."

(*f*) Connect the "Storage Battery" binding posts of the audion control box to the ground.

69. Operation—

1. Light filament of vacuum tube, but do not burn at excessive brilliancy. The following is a list of proper filament currents and plate voltages for the standard type of detector tubes:

Tube.	Filament Current.	Plate Voltage.
W. E. C. W-933	1.0 to 1.2	25 to 60 volts
Gen'l Elec. CG-890	.9 to 1.05	20 to 50 volts
Radiotron UX-201-A	.25	22 to 45 volts
Radiotron UX-200-A	.25	not critical 25 to 45 volts

70. Note—If Radiotrons UX-200-A or UX-201-A are employed as detector tubes it is advisable to connect a rheostat of not less than 6 ohms resistance in series with the negative side of the filament supply lead.

2. Set the detect-oscillate switch on "Detect."

3. Set the grid and bridging condenser switch blade on about step 3.

4. Set plate voltage switch at the proper position: on "125 V. Gen." if it is desired to use the ship's supply as plate battery; on "Storage Bat." if it is desired to use "B" battery as a source of plate voltage.

71. Note—When the plate voltage switch is on the "125 V. Gen." side, the potentiometer is connected in circuit and a variable voltage may be impressed between the plate and the filament.

When the plate voltage switch is set on "Storage Bat." the potentiometer is cut out of circuit and no voltage variation is obtained.

5. Tune receiver to the incoming signal. Vary grid and bridging condensers, and plate voltage (when using the 125-volt supply) till signal of maximum intensity is obtained.

72. Regeneration—

6. Spark signals may be amplified by setting the "Detect-Os-

cillate" switch on "Oscillate" and increasing the tickler coupling in the receiver to the point just before oscillations begin.

7. For receiving continuous wave signals, set "Detect-Oscillate" switch on "Oscillate." Vary tickler coupling for maximum signal. It will usually be found that for a given amount of inductive coupling there is a value of tickler coupling which gives maximum intensity of heterodyne note.

8. Always set tickler coil in the receiver at its position of minimum coupling when the "Detector-Oscillate" switch is in the "Detect" position, because the tickler coil is then shorted, and unless loosely coupled, will cause an increase in the secondary resistance with a consequent diminution of signal intensity.

9. When using a U. S. N. two-stage amplifier, type SE-1000, 1000A, 1000-B or 1000-C, with this control box, set the plate voltage switch on "Storage."

73. Note—The amplifier cannot be used if the plate voltage for the tube of the audion control box is supplied from any other source but a standard "B" battery or emergency battery, because the commutator ripples in the ship's supply which cannot be heard

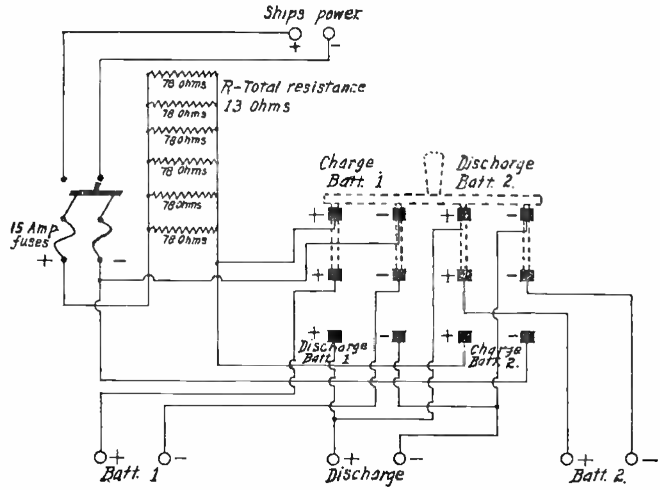


FIG. 245. U. S. Shipping Board Charging Panel (Liberty Elec. Corp.).

when using only one vacuum tube are amplified to such extent that they mask the incoming signals.

10. Failure to obtain oscillations may be due to:

1. Reversed tickler coupling.
2. Insufficient filament current.
3. Insufficient plate voltage.
4. Improperly adjusted grid and bridging condensers.
5. Defective vacuum tube.

74. U. S. Shipping Board Charging Panel—This charging panel is used to control the charge and discharge of two Edison storage batteries of six volts each. These batteries are known as type B-2, 37.5 ampere-hour capacity and are employed to operate the filament of the vacuum tube used in the audion control panel, to emergency power equipment. A wiring diagram of the Shipping Board charging panel (manufactured by the Liberty Electric Corp.) is shown in figure 245.

By the use of the four-pole, double-throw switch the operator may discharge one battery while the other is charging. By opening the switch marked " Ship's Power " the charge may be discontinued. At any time trouble develops and the batteries do not charge, the fuses in the ship's line should be examined. 15-ampere fuses should be used in this line.

Six resistances of 78 ohms each are connected in parallel in the positive side of the charging line. The effective resistance of this parallel arrangement is 13 ohms, allowing a charging rate of approximately 8 amperes when the ship's dynamo or charging terminals are 120 volts.

Loading Coils for Navy Standard Receivers, Types SE-143, SE-1220 and SE-1420.

The longest wavelength employed by any government or commercial station is that of the French Government Station at Bordeaux, France, call letters LY, operating on a wavelength of 18,900 meters. The U. S. Naval Station at Annapolis, Maryland, employs a wavelength of 17,150 meters. The longest wavelength used commercially by the Radio Corporation of America is at the Radio Central Station situated at Rocky Point, Long Island, call letters WQL. This station operates on a wavelength of 17,500 meters. There are numerous other stations operating on long wavelengths for the transmission of commercial traffic, time signals, weather reports and press. These stations all employ a continuous wave for transmission.

Inasmuch as these wavelengths are above the normal operating range of most commercial receivers it becomes necessary to insert loading coils in the primary, secondary and tickler circuits to enable the operator to copy the schedules of such stations.

The Navy radio receivers, types SE-143, SE-1220 and SE-1420, are fitted with external binding posts whereby loading coils may be inserted in all three circuits. The following size honeycomb coils have sufficient inductance to extend the wavelength range of these receivers to cover all stations operating on long wavelengths.

HONEYCOMB COILS FOR LOADING S-143, SE-1220 AND SE-1420 RADIO RECEIVER.

Primary.	Secondary.	Tickler.
750 to 1000 turns	600 to 1000 turns	600 to 750 turns

The maximum capacity of the secondary condenser in the SE-1220 and SE-1420 is .0032 microfarad. If a honeycomb coil of 600 turns (40,000 microhenries inductance approx.) is employed as a secondary loading coil the oscillation constant (LXC) becomes 128 or a natural wavelength of approximately 21,400 meters. A 600-turn coil is the smallest size honeycomb coil which may be used successfully to load the secondary circuit of these receivers. A 1000-turn honeycomb coil will extend the range to approximately 33,500 meters.

The minimum capacity of this condenser at 10 degrees is approximately .00014 mfd. Employing a 600-turn honeycomb coil, the oscillation constant becomes 5.6 or a natural wavelength of 4460 meters. The minimum wavelength is therefore 3540 meters below the normal maximum wavelength range (8000 meters) of the receiver, thus providing a sufficient overlap.

The secondary condenser of the SE-143 receiver has a slightly smaller maximum capacity (.00314 microfarad); therefore, a 600-turn honeycomb coil will extend the range of the secondary circuit of this receiver to 21,100 meters and a 1000-turn honeycomb coil to approximately 33,000 meters.

The inductance of the secondary windings of the receiver has been neglected in these approximations. The maximum inductance is about 3670 microhenries and is so small that it has but little effect on the tuning of the receiver at long wavelengths. In actual practice it may be noted that when a long wave station is once tuned in the secondary inductance may be varied from the 1st to the 6th tap, causing only a change in the beat note of the received signal.

The primary condenser in the Navy Standard Receivers SE-143, SE-1220 and SE-1420 is in series with the antenna inductance and ground. It may be placed in shunt to the loading coil and primary inductance by making the following changes in wiring:

1. Remove antenna lead from terminal "Ant." on receiver and

connect antenna lead to left binding post of primary load terminal.

2. Place jumper across terminal on receiver marked "Ant." and "Gnd." The ground lead should be left on receiver terminal marked "Gnd."

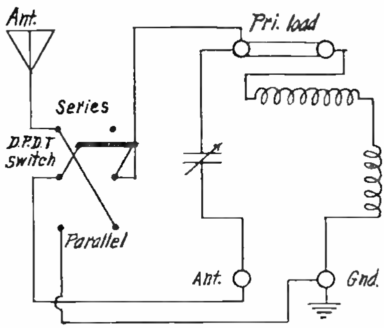


FIG. 246. Series-Parallel Connections of Primary Condenser for Navy Standard Receivers.

Figure 246 shows an arrangement whereby the primary condenser can be used either in series with antenna primary inductance and ground or in shunt to same, depending upon the position of the double-pole, double-throw switch. This is especially

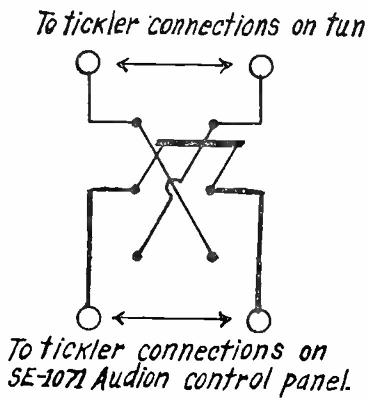


FIG. 247. Tickler Polarity Reversing Switch for SE-143 and SE-1220 Radio Receivers.

useful when a loading coil is employed in the primary circuit for long wave reception.

In practice it has been found necessary to reverse the tickler connections of the SE-143 and SE-1220 receivers to secure oscillations on long wavelengths and reverse the same again when operating on short wavelengths. A double-pole, double-throw switch may be also used to accomplish this operation. The connections for this arrangement are shown in figure 247.

Western Electric Superheterodyne Radio Receiving Outfit, Type 6004-C.

75. **General**—This receiving outfit is designed to operate on an antenna tuned to 500 kilocycles (600 meters) while the radio transmitter is operating on a broadcasting frequency. It employs the 4-C receiver with the 2-A tuning unit for tuning the antenna and the 20-A filter for filtering out the transmitter frequency. Figure 248 shows the circuits of this receiver.

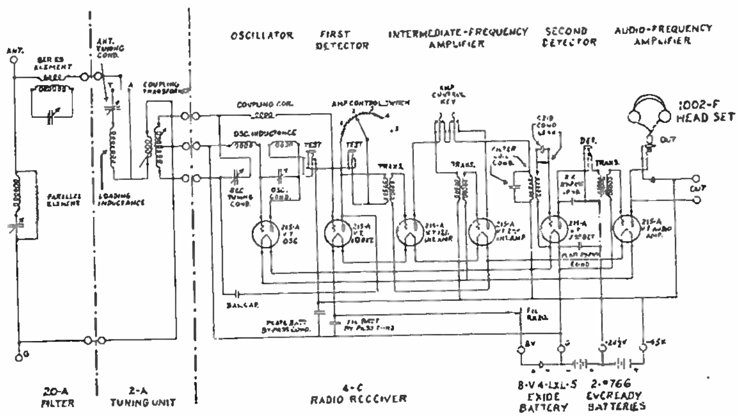


FIG. 248. Schematic Circuit of Western Electric Receiving Outfit, Type 6004-C.

76. **4-C Radio Receiver**—The 4-C receiver is a double-detection (superheterodyne) receiver employing six 215-A tubes It is designed for operation with a loop antenna or with an outside antenna.

The first tube is an oscillator, which is adjusted to a frequenc 45 kilocycles above or below the received frequency. The oscil lator output and the received signal are applied together to th grid of the second tube, which is a detector. The output of thi detector is amplified by two 45-kilocycle amplifiers when it is again detected to produce the modulation frequency of the received signal. The last tube is used as an audio frequency amplifier. The output from the last tube is obtained directly from the plate of the tube through the jack on the front of the panel or terminals on the back. The output circuit must carry the d.c. plate current of the tube, which is about .001 ampere.

FIG. 248*a*. Western Electric 4-D Radio Receiver (Double-Detection).

The filaments of all of the tubes are lighted in series by an 8-volt battery controlled by a filament rheostat on the panel. A 45-volt dry battery is used for the plate supply to the oscillator, the amplifier tubes and the first detector. A mid-tap of 22½ volts is used to supply the second detector tube. Ammeter jacks marked "Test" are placed in the plate circuits of the oscillator and the first detector for testing purposes. The jack marked "Det." is connected to the plate circuit of the second detector so that the output circuit plug can be plugged in it to get the output from the detector directly. Plugging in this jack opens the interstage transformer at the plate of the detector. The amplifier control key short-circuits the second 45-kilocycle amplifier when it is thrown to the position marked "1," and puts it in the circuit at the position marked "2." The amplifier control switch controls a shunt resistance across the primary of the input transformer to the first amplifier tube. The tuning condenser is used to tune the input circuit to the received radio frequencies and the oscillator condenser is used to tune the oscillator to a frequency about 45 kilocycles different from the received radio frequency.

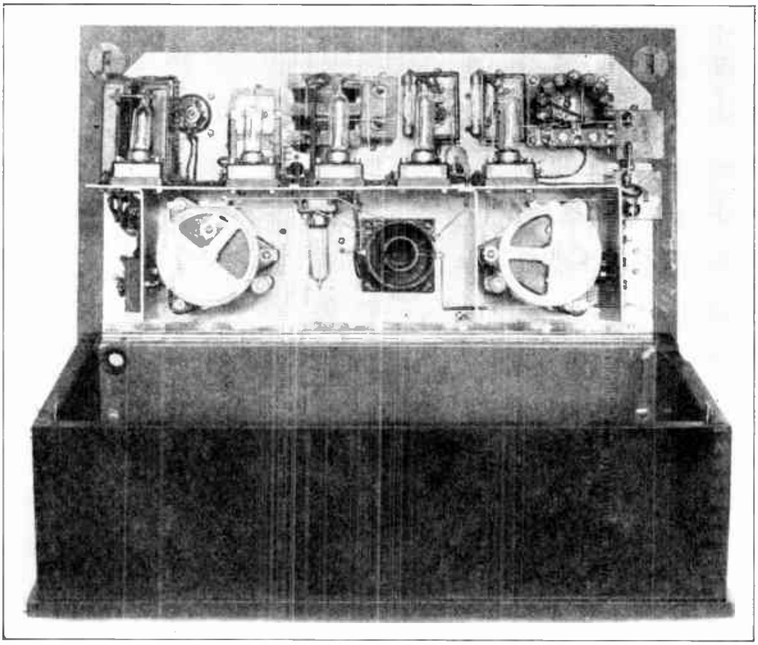


FIG. 248*b*. Interior View of 4-D Receiver.

77. **2-A Tuning Unit**—The 2-A tuning unit is used for connecting an antenna to the 4-C receiver. It is a variable coupler with a secondary having a middle tap. The three secondary taps are connected to the loop terminals on the receiver. The primary is tuned with a loading coil and a variable condenser in the antenna circuit. Coupling to the secondary is controlled by a knob with an indicator on the front of the panel and an aperiodic-tuned switch is provided which connects the antenna to either the tuned circuit just described when on the point marked "T" or the primary coil alone when on the point marked "A." The aperiodic circuit is used for preliminary tuning of the receiving set after which more selectivity can be obtained by tuning the primary circuit.

78. 20-A Filter—The 20-A filter is provided for use with a receiving set under the transmitting antenna. It should be tuned to offer a high impedance to the transmitter frequency and a low impedance to the frequency it is desired to receive. With careful adjustment of these circuits it should be possible to receive a frequency differing only 10 per cent from the transmitting frequency. The circuits are adjusted by first adjusting the receiver to the frequency to be received. The filter circuits are then adjusted until the signal the transmitting frequency is reduced to a minimum. This will change the tuning of the primary circuit on the 2-A tuning unit which must again be tuned to the desired signal.

CHAPTER 13

MARINE AND AIRCRAFT RADIO BEACONS AND DIRECTION FINDERS

1. **Radio Direction Finders**—The radio compass or direction finder was developed in this country by F. A. Kolster and successfully introduced by him as an aid to navigation. Since its introduction and increasing use the United States Lighthouse Service has established automatic radio beacons on light vessels and at lighthouses in the vicinity of harbor entrances and places dangerous to navigation, the exact locations of which are clearly shown on all sailing charts. These stations send out characteristic radio signals similar to light flashes, thus enabling the master of a vessel fitted with a radio compass to take bearings as often as desired.

2. **Fundamental Principles**—It has long been known that an antenna consisting of a loop or closed coil has "directional" properties. Consider the coil of wire in figure 249 marked (*a*) as being supported vertically and its edge pointing in the direction of a radio transmitting station. A radio wave from the transmitter will pass through that portion of the loop marked *F* the merest fraction of time before it does that marked *R*. The result of this is that a difference of potential will exist between the two sides of the loop, thus producing a radio frequency current in the coil and condenser circuit. If this circuit is resonant to the

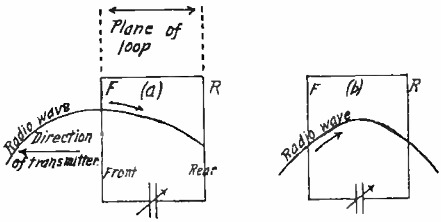


FIG. 249. Radio Wave Striking Loop Antenna.

frequency of the incoming wave a maximum e.m.f. will exist across the terminals of the condenser.

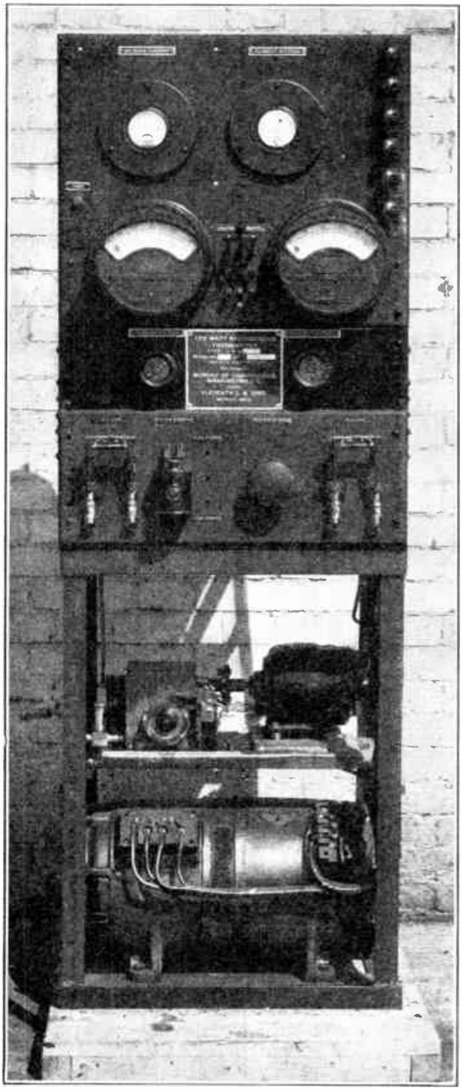


FIG. 249a. U. S. Bureau of Lighthouse 100-Watt Radio Beacon Transmitter with Automatic Signalling Device.

As the wave advances there will be an instant when both *F* and *R* are subject to the same potential as the amplitude of the wave cutting both wires is the same. This is represented by *b* in figure 249.

As the wave continues to advance, the *R* wire will have a greater e.m.f. than that of *F* and again a current will flow in the loop circuit. As the end of the wave passes over the loop the current will fall to zero only to repeat the cycle of events just mentioned upon the arrival of the next wave.

Now consider the loop turned so as to be at right angles to the transmitting station. The wave arriving from the station will strike both the *F* and *R* wires at the same time. This results in e.m.f.s of equal potential but opposite in sign being induced in the loop, the result of which they cancel, and no current will flow.

If the terminals of the loop and condenser were connected to a vacuum tube detector and amplifier the signals from the transmitting station would have been heard the loudest when the loop was pointing in the direction of the station, i.e., when the plane of the loop lay in the direction of the source of transmission. As the loop is turned from this position, through 180 degrees, the signal will gradually disappear, and when the plane of the loop is at right angles to the source of transmission the signal intensity will be zero. If the loop is continued in rotation the signal will gradually reappear, being at a maximum when the plane of the loop again lies in the direction of the source of transmission. Referring to figure 249, the *R* turn has now become *F* and *F* become *R*. The signal intensity thus varies in accordance with the figure-of-eight characteristics as shown in figure 250, the direction *A* or *B* indicating maximum signal intensity.

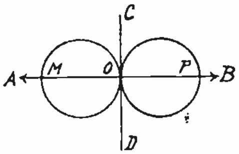


FIG. 250. Theoretical Directional Characteristic of Loop Antenna (Figure-of-Eight).

3. **Capacity of Loop Circuit to Ground**—An important factor that has to be considered in the use of the loop antenna in its application as a direction finder is the effect produced in the coil by virtue of the coil structure having an appreciable capacity to earth. Also the detector and amplifier circuits are electrically unsymmetrical with respect to earth. This results in a distortion of the ideal figure-of-eight signal intensity characteristic obtained by rotation of the coil about its vertical axis. The critical position of "no signal" no longer exists and the directive qualities of the loop have been distorted.

An examination of figure 251 will show how this is brought about. The grid of the vacuum tube is actuated by an e.m.f. directly from the tuned input circuit consisting of the coil L and condenser C. The dotted lines C_g represent the capacity of the coil and apparatus to ground. Because of the electrically unsymmetrical relation of the coil system with respect to earth, an appreciable current will be set up in the loop circuit by the incoming wave acting through the earth capacities C_g. The potential produced by this current across the condenser C will likewise operate on the grid of the vacuum tube.

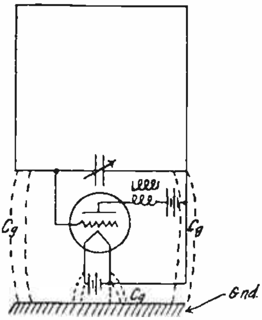


Fig. 251. Loop Circuit Showing Capacity to Ground.

The ideal figure-of-eight signal intensity characteristic is therefore distorted by these additional effects, the degree of distortion depending upon their relative magnitudes. The signal variation characteristic which results from these effects is shown in figure 252. The position of minimum or zero signal intensity is no longer at right angles to the plane of the loop, nor does it coincide with the axis of the loop as in the ideal case.

The complete solution of the problem depends upon obtaining exact electrical symmetry of the loop system, including the vacuum tube apparatus with respect to earth. This is accomplished by balancing out this so-called "antenna effect" with a condenser connected as shown in figure 253. It can also be improved by inductively coupling the loop circuit to the vacuum tube.

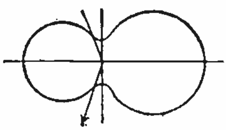


Fig. 252. Loop Characteristic Showing Effect of Current Set Up in Coil by "Antenna Effect."

4. Determination of Sense—As already explained, the loop system when properly balanced will give a critical zero signal, thus giving the line of direction which is of course at right angles to the point of zero signal. However, the loop is subject to a possible 180 degree error, owing to the fact that there are two points at which the signal disappears, obtained by rotating the loop half a turn. When taking bearings from a coast station the general direction of which is known, the two points of zero signal do not matter, as the correct one is easily recognizable.

The occasion may arise wherein the location of the signalling station is necessary, such as locating and proceeding to the aid of a ship in distress. To obtain the true direction it is necessary to unbalance the loop by exaggerating the antenna effect. This is accomplished by connecting a small antenna to one side of the loop through a disconnecting or uni-directional switch. Normally the uni-directional switch is open when taking a bearing, but when

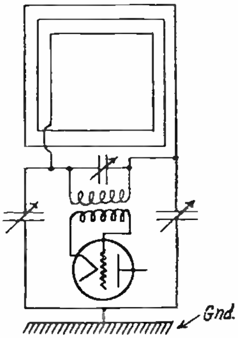


FIG. 253. Method of Balancing Out "Antenna Effect" of Coil and Apparatus to Earth.

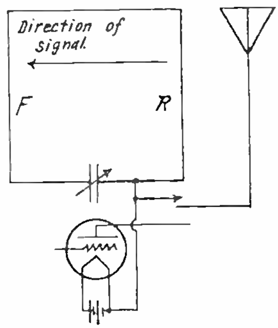


FIG. 254. Loop Unbalanced by "Sense Antenna."

the true direction is desired, the operator closes the switch and turns the loop to the position of maximum signal at which point the plane of the coil lies in the direction of the signalling station and points toward it as indicated by an index pointer provided for that purpose.

Referring to figure 254, the loop is turned so as to pick up the signal from the advancing wave as indicated by the arrow. Attached to one side of the loop is the small antenna previously mentioned. This antenna is connected to the rear side of the loop and picks up just enough energy to offset that picked by the front of the loop and the result is that no signal is heard.

Now, if the loop, with its small antenna attached, is rotated 180 degrees there will be communicated to the grid of the tube the combined energy of both loop and small antenna. The effect is that the combined e.m.f.s will greatly overbalance the feeble e.m.f. induced by the rear of the loop. Thus when the side of the loop with the antenna attached is turned so that a signal is heard at a maximum it establishes the direction of the transmitter. If the loop is turned in any other direction the signal will be lost or considerably weakened.

5. **Wave Front Distortion**—When a direction finder is installed on shipboard there are certain distributing effects due to

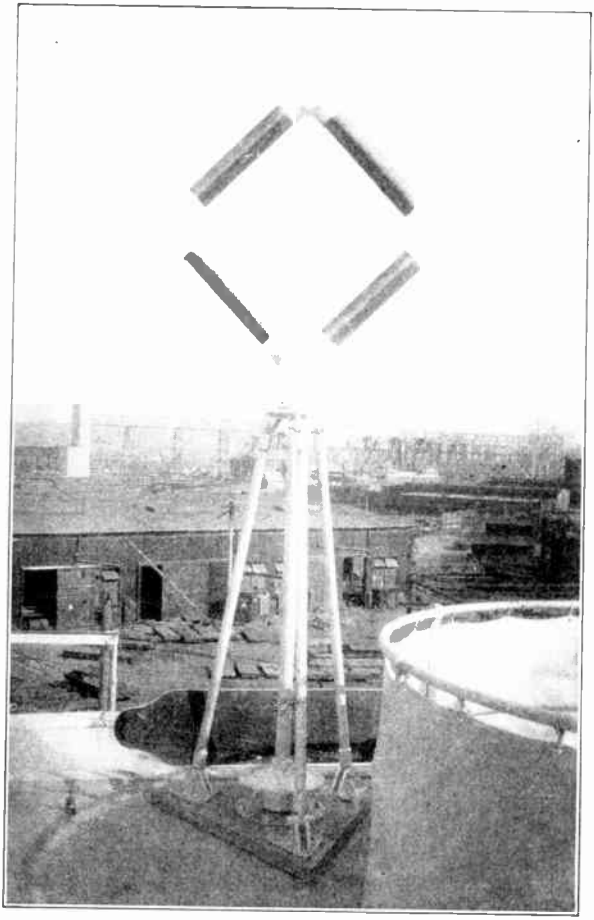


FIG. 255. Loop Employed with Radio Direction Finder of the Radiomarine Corporation of America.

the ship's equipment, the most serious of which are due to currents induced in the d.f. by wires, forming closed circuits, stays, whistle cords and the like and which have a natural wavelength considerably less than the working wavelength. These currents are in phase opposition to the currents induced by the signal direct and therefore have the effect of decreasing the apparent sensitivity of the direction finder. Since the masts, stays, etc., are in various directions from the direction finder, they also have the effect of shifting the apparent direction of the arrival of the signal. This latter effect is more prominent when the wave is approaching from approximately 45 degrees from the ship's center line. In the fore-and-aft direction and directly abeam the error is at a minimum.

Currents induced in the direction finder by masts, grounded stays and any metal objects, which can act as a vertical antenna and which have a natural wavelength considerably less than the working wavelength, are 90 degrees out of phase with the current due to the signal. Therefore, no value of signal current can be obtained to cancel these antenna currents as the vectorial addition is always to make the resultant greater than either component. The effect apparent to the observer is the broadening of the minima, in two opposite quadrants, in taking of bearings in which the resultant mass effect causes currents to be induced in the direction finder. Usually these induced currents are not of sufficient magnitude to cause an appreciable shift in the apparent bearing of the signal.

In order to compensate for the apparent shift in direction of signal and adjustment to obtain a sharp minimum signal at all angles it becomes necessary to calibrate the direction finder. Calibration is done by taking simultaneous sight and radio bearings on a radio transmitter. This is accomplished by sailing completely around a radio beacon on a light vessel at a distance from one and a half to two miles while taking the sight and radio bearings. After calibration, a deviation or correction curve is plotted and applied to an automatic compensator which makes the instrument direct reading and eliminates the necessity of applying a correction to the bearings.

6. Proceeding with Calibration—Since the received wave is distorted or bent by the metal objects on the vessel it becomes necessary to place such objects in a permanent condition, i.e., either insulated or grounded. The latter method is most practical as it is easiest and cheapest. However, this cannot be done to the whistle cord, fore-and-aft stays or any such stays that form a closed loop around the d.f. loop. Therefore these are always broken up into small lengths by insulators so that each length has a fundamental wavelength lower than that of the range of the direction finder receiver.

Usually a direction finder is equipped with two scale pointers. One is mounted under the compensating cover and is known as

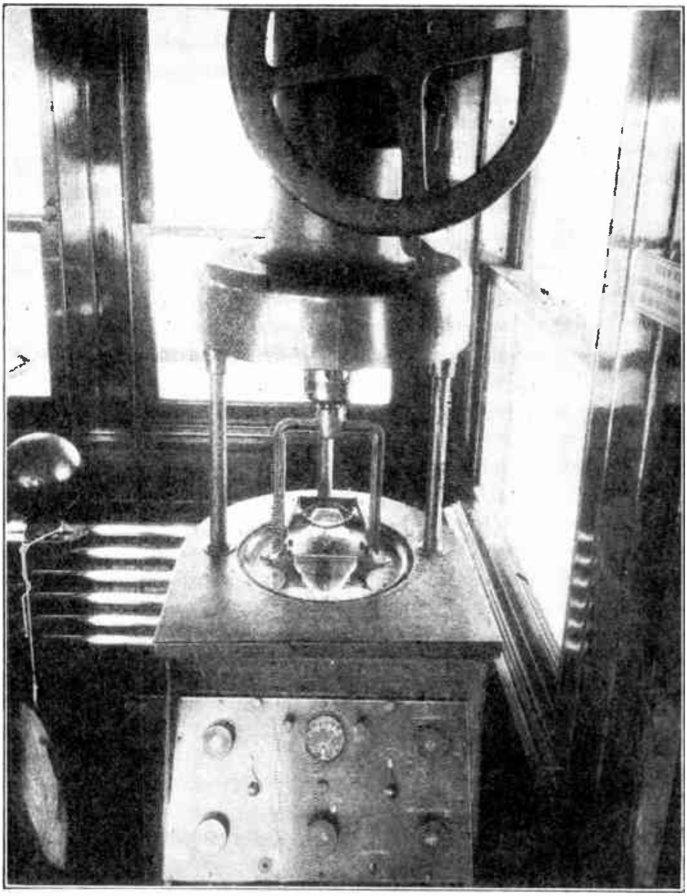


Fig. 256. R.C.A. Direction Finder Mounted in Chart House of Vessel.

the upper scale. This indicates the actual position of the loop. The other is at the bottom end of the extension shaft and indicates the true bearing after compensation is completed. During calibration only the upper scale is used and it is adjusted so that scale reads zero when plane of loop is 90 degrees from the lubber line and the glass indicator reads on the lubber line.

Radio and sight bearings are taken as near to 10 degrees apart as possible and each bearing recorded and numbered as follows:

Bearing Number.	Upper Scale.	Pelorus (Sight Bearing).	Correction.
1	72	76½	+ 4½

where 72 is the position of the d.f. loop, 76½ is the correct bearing as per pelorus, + 4½ is the correction to be added to the d.f. bearing to give the true bearing.

When the d.f. loop is rotated by means of the hand wheel, the characteristic signals from a beacon station will be heard with a gradually varying degree of loudness until the plane of the coil is at right angles to the direction of the incoming waves at which point the signals should die out entirely. This position of silence is critical and sharp and therefore indicates with great acccuracy the line of direction of the source.

After the ship has been swung and the required number of bearings taken they are recorded and a curve drawn. In practically all calibration curves there are four angles where no correction is necessary and the form of the curve resembles a sine wave. Theoretically, the curve is a sine wave for practically all cases with a given amplitude and phase angle for each installation. Considerable emphasis should be given this fact in drawing the curve from the data obtained, as it will help in judging what points are in error.

7. **Compensation for Error**—The compensator as employed with R.C.A. direction finder consists of an arm mounted at the top of the lower scale pointer shaft which has a roller fitted in the end. This roller bears on a circular band that is held semirigid by 24 screws spaced 15 degrees apart; by screwing or unscrewing as the occasion necessitates the shape of the cam is changed which causes the roller to move outward or inward at the appropriate points, thereby changing the position of the arm which in turn rotates the lower scale to read the true bearing.

These twenty-four screws are numbered from 1 to 24 inclusive and are mounted directly under the upper scale.

Record should be made of the numbers on the upper scale that are immediately over the screws. Consult the calibration curve at the point indicated by screw number 1 and note the correction. As in the table below, screw number 1 is under 6 on upper

Screw Number.	Upper Scale.	Correction.	Lower Scale.
1	6	+ 2	8
2	21		
3	36		
4	51		

scale and 6 degrees shows a 2 degrees plus error, $6+2=8$, so that when the loop is at an angle of 6 degrees the pelorus indicates a plus two degrees error. It then becomes necessary to set the upper scale pointer on 6 and adjust screw number 1 until the lower pointer reads 8 which is the pelorus or true bearing at this particular angle. After this one is completed move upper scale to figures over screw 2 and adjust screw 2 until the lower scale pointer reads plus the error indicated by the chart and so on until the 24 screws have been adjusted. It should be noted that a minus as well as a plus error has to be compensated for, depending upon the angle of the loop for a particular reading.

While the d.f. is being operated the antenna employed for transmission and reception is placed in a neutral position, i.e., ungrounded.

The direction finder system as described in this chapter is employed on American vessels; however, there is another system known as the Bellini-Tosi, which is a development of the British Marconi Co. Equipment of this type is found on foreign vessels. Inasmuch as this book is primarily for American operators and descriptive of American apparatus, no details of the system will be given.

8. **Radio Compass Stations on Shore**—Radio compass stations on shore are direction finders established to furnish ships, upon request, radio bearings taken by one or more such stations. This system requires that the ship requesting the bearings become the signalling station, while the direction finder station or stations take the bearings and then communicate them to the ship. Such stations in the United States are established and controlled by the Navy Department. They are divided into two classes:

(*a*) Single stations, operating independently and furnishing a single bearing.

(*b*) Harbor entrance groups. All stations in harbor entrance groups are connected to and controlled by the master station; all stations of the group take bearings simultaneously and these bearings are transmitted to the ship requesting them by the master station.

Where only one radio compass station is available, the mariner may fix his position by two or more bearings from the station with the distance run between, or may use the bearings as a line of position, or as a danger bearing, or the bearing may be crossed with a line of position obtained from an observation of an astronomical body to establish a " fix."

The maximum distance for which bearings from these stations are accurate is 150 miles, but accurate position cannot be plotted on a Mercator chart when the station is more than 50 miles distant without first correcting the bearing to allow for angular distortion due to the projection. This correction can be found by reference to tables or curves prepared for that purpose.

9. **Wavelengths**—Radio compass stations maintained by the U. S. Navy maintain a watch and transmit on a wavelength of 800 meters (375 kc.). Only this wave should be used to call and work these stations. Accuracy of bearings will probably be affected if the ship's transmitter is not adjusted to this wavelength. In order to obtain the best results, it is important that the ship should not transmit with too much power. Signals should, however, be fairly strong and clear; great care must be taken to keep the note and strength steady and to pay strict attention to spacing.

10. **Obtaining a Bearing**—The following procedure should be followed by a vessel desirous of obtaining a bearing from U. S. Navy radio compass stations.

To obtain a bearing from independent radio compass stations, call the station from which the bearing is desired in the usual manner and request bearings by means of the conventional signal given hereafter. Simultaneous bearings from two or more compass stations can be obtained by making the call include the other compass stations desired.

To obtain bearings from the harbor entrance group compass stations carry out the procedure previously given. The compass control station only will answer.

(*a*) A ship calling the radio compass or compass-control station should make the abbreviation QTE? (What is my bearing?). This request will be answered by the radio compass station or control station, and when ready to observe the radio bearing it will send the signal K (invitation to transmit), indicating to the ship that it is to commence testing, i.e., repeating its call letters for a period of *50 seconds*. The signal should be made slowly with the dashes considerably prolonged. (See previous instructions regarding power, etc., to be used.)

(*b*) The testing should be made on 800 meters; upon the completion of the test the ship should await reply from the radio compass station.

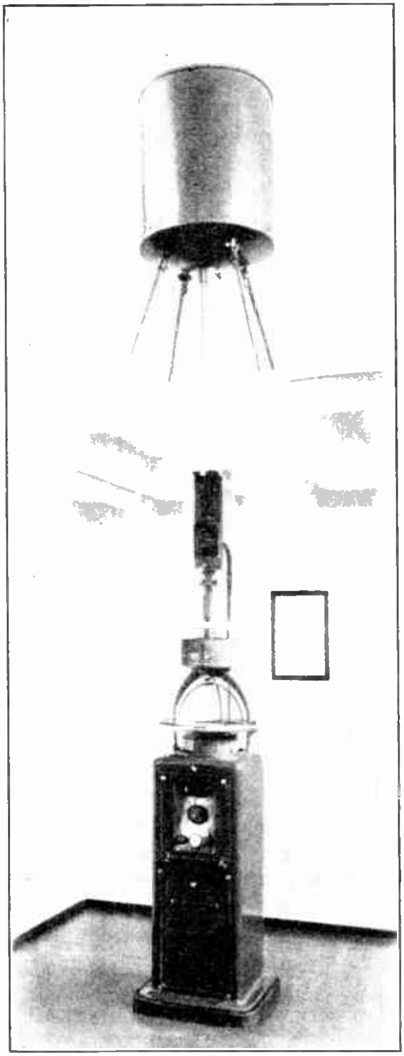


FIG. 257. Kolster Radio Compass, Type AM-4490.

(*c*) The radio compass station or control station will then reply, repeating the abbreviation QTE (Your bearing from —— was —— degrees) followed by the bearing in degrees of the ship station from the radio compass station, and then the time group giving the time of observation in local standard time. In the case of more than one radio compass connected by land line only, the station originally called will answer. This station will combine all the bearings taken by itself and associated stations into one message, which gives each bearing observed immediately after the name of the station making the observation. The ship then acknowledges receipt of the bearings and repeats the figures back to the compass station for verification.

11. **Example**—A ship (call letters KVA) desires to get bearings from the Delaware Bay entrance group (call letters NSD). The following procedure is used:

— . — . — NSD NSD NSD de KVA KVA KVA — . . . — QTE . . — — . . ar.

— . — . — KVA de NSD K.

— . — . — NSD de KVA — . . . — QTE? KVA KVA KVA.

(Ship repeats call letters KVA for 50 seconds, prolonging the dashes.)

— . . . — KVA ar.

— . — . — KVA de NSD — . . . — QTE.

Cape May 120 Cape Henlopen 110 Bethany Beach 085 at 0126 — . . . — NSD ar.

— . — . — NSD de KVA — . . . — 120 110 085 at 0126 . . — — . . ar.

— . — . — KVA de NSD R . . . — . — NSD.

This method is the only authorized procedure for calling, answering and testing, and should be followed exactly. Such signals as MO or V and other test signals are not authorized for radio compass traffic. The testing period of 50 seconds should not be exceeded.

12. **Danger from Reciprocal Bearings**—Attention is invited to the fact that when a single bearing is furnished there is a possibility of an error of approximately 180 degrees, as the operator at the compass station cannot always determine on which side of the station the vessel lies. Certain radio compass stations, particularly those on islands or extended capes, are equipped to furnish two corrected true bearings for any observation. Such

bearings when furnished vessels may differ by approximately 180 degrees, and whichever bearing is suitable should be used.

13. **Caution**—Mariners receiving bearings which are evidently the approximate reciprocal of the correct bearing should never attempt to correct these bearings by applying a correction of 180 degrees, as such correction would not include the correction necessary on account of deviation at the compass station. An error as large as 30 degrees may be introduced by mariners applying an arbitrary correction of 180 degrees to such bearings. Vessels receiving bearings manifestly requiring an approximate 180-degree correction should request the other bearing from the radio compass station if not previously furnished.[1]

Aircraft Radio Beacon Development by the Bureau of Standards.[2]

A number of demonstrations have recently been given of the aircraft radio beacon system which has been under intensive development by the Bureau of Standards. The beacon system marks out an invisible but infallible course along which aviators can fly regardless of fog or other weather conditions. To make use of this system, an airplane need only be provided with a small receiving set carrying an indicator. An occasional glance at the indicator tells the pilot whether he is following the course, or how far off if he has deviated from it. The troublesome trailing wire antenna and headphones used in earlier stages of development have been eliminated. The experimental work is still in progress, but the system is sufficiently perfected that routine use of it on the regular airways is beginning.

With the radio beacon made practical and dependable, air route operations enter a new era of regularity and safety. Most of the trips which are now omitted or undertaken only at great risk can be confidently made. It has been the rule to undertake flights only when weather conditions were favorable enough so that the pilot could see points on the ground, and in the early days of our air mail service flying schedules were frequently interrupted on account of weather conditions.

A method of aerial navigation called "instrument flying" has been tried from time to time. When the pilot cannot see the earth below he forgets the outside world and, concentrating all his at-

[1] For further details on Radio Compass Stations, locations, methods of obtaining bearings from foreign stations, etc., see "Radio Aids to Navigation," published by Hydrographic Office.

[2] By courtesy of Geo. K. Burgess, Director Bureau of Standards, Department of Commerce.

tention on his instruments, navigates his craft from the information they convey. One instrument tells him his elevation, another his speed, another whether he is turning or flying straight away, and his compass indicates his general direction. But accurate as all these instruments may be, they do not tell him if he is drifting sidewise due to a cross wind, nor do they tell him exactly at what speed he is traveling because there may also be a head or tail wind to slow him down or to speed him up. Thus while instrument flying may enable a pilot to keep his craft at a safe altitude and in a generally correct direction, the hazard of getting far away from the course into strange, unfamiliar, and possibly dangerous areas is ever present.

What "instrument flying" has hitherto lacked is precisely supplied by the radio beacon system, because with its use the pilot can always know his location. The radio beacon system includes the double-beam directive beacon and smaller stations known as "marker beacons."

14. **Early Work**—The first work on the double-beam directive type of radio beacon was done by the Bureau of Standards in 1921 for the Army Air Service. The method consisted of transmitting radio waves alternately for two directive coil antennas placed at an angle with each other. Each antenna transmits a set of waves which is directive, i.e., it is stronger in its own plane than in other directions. When an airplane flies along the line exactly equidistant from the two beams of waves, i.e., on the bisector of the angle between the planes of the two antennas, the pilot hears the signals from the two with equal intensity. If the airplane deviates from this line the signals from one antenna are louder and the other weaker. Equality of received signals thus indicates a fixed line in space and provides a means to guide an observer on any kind of craft along that line. A different signal is used on each antenna, so as to distinguish between them.

In the early work a switch was used to throw the radio-frequency power from one antenna to the other. Tests made at Washington on the ground and on ships showed that a course was effectively marked out, permitting navigation without aid of landmarks, compass, or other navigational device. The apparatus was next set up at Dayton, Ohio, and tests made in the air. The method was successful in airplane flights, and had the important advantages that it required no special apparatus to be carried on the airplane, and that no error was introduced by wind drift.

15. **Principle of Operation**—If two loop antennas are arranged at an angle of 135 degrees and the energy from a trans-

mitting set impressed first on one and then the other once every second, there will be propagated intermittent waves directly from each coil. The intensity of the emitted waves with respect to the plane of each coil will vary in accordance with a figure-of-eight. (See previous paragraph on directive properties of a loop antenna.) Should an airplane or vessel fitted with an ordinary receiving set be located or any bisector of the angles formed between the two coils it will receive signals of equal intensity from both of them. Thus a definite course may be held in thick or foggy weather simply by navigation so that the signal strength from the two coils remains equal.

Referring to figure 258, the two loop antennas are arranged so as to be energized alternately by a radio transmitting set *W*. This is done by means of a special switch *S*, which is thrown rapidly from one loop to the other. Intermittent radio waves are thus propagated from each loop, the intensity with respect to the plane of the loop varying in accordance with a figure-of-eight as shown by the circles *A'*, *A'* and *T'*, *T'*. The loop aerials are represented by the lines *as* and *tt*. Thus a receiving set located anywhere along the line *OY* would receive a signal proportional to the length of the line *OM* from loop *tt* and another a few seconds later of intensity proportional to the length of the line *OQ* from loop *aa*. It is apparent, therefore, that along the line *OY* the signals from coil *tt* are more than twice as strong as those from coils *aa*. A receiving set located along the line *OX* will receive signals of equal intensity from both coils since (as it is the bisector of the angle formed by the two coils) the distance *OP* is the same for both coils. A similar condition exists along the lines *OV*, *OK* and *OL*. Therefore, if the receiving set is moved to any other points than those along these lines, signals of unequal intensity will be received from the two coils. Thus a ship or airplane fitted with an ordinary receiving set navigating so as to keep the signals received from *aa* and *tt* of equal intensity will be going toward or away from the point *O* or position where the two-loop antenna transmitting set is located.

In the following four years, the Army engineers at Dayton, Ohio, developed the beacon further; in particular, they devised a signal-switching arrangement such that the signals from the two antennas merged into a steady dash when on the course, giving an added criterion besides that of equal signal intensity to enable the observer to tell whether he was on or off the course. They also introduced a goniometer, or mutual inductance device, to permit orienting the course in any desired direction without moving the antennas. The beacon as thus developed is described in "Stationary and Rotating Equisignal Beacons," by W. H. Murphy and L. M. Wolfe, *Journal Soc. Automotive Engineers*, 19, p. 209, Sept., 1926.

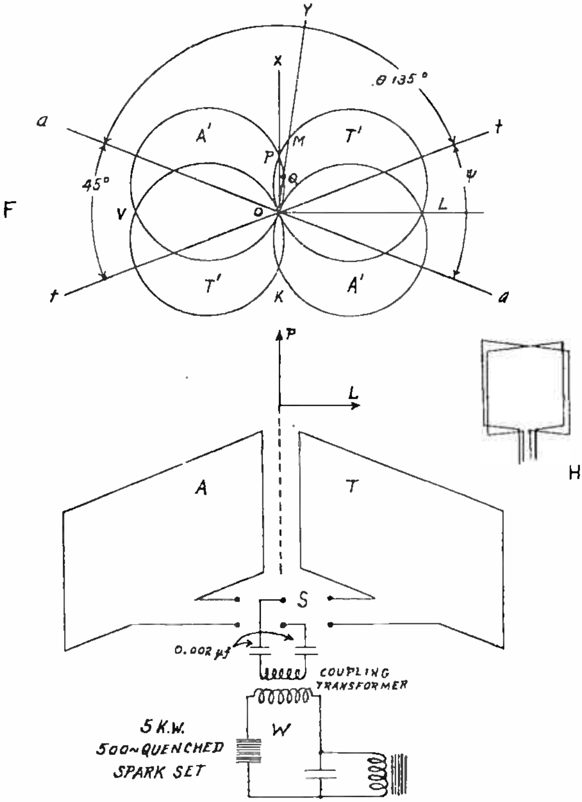


FIG. 258. Characteristic of Signal from Directive Radio Beacon Transmitter.

16. Development for the Department of Commerce—Shortly after its formation in July, 1926, the Aeronautics Branch of the Department of Commerce began a program of establishing aids to navigation on the nation's airways. The aids determined upon were: Upper air weather information, airways lighting for night flying, and radio aids. It was recognized that radio offered important advantages in the way of communication between the ground and air and also direct navigational assistance. As there had been little or no experience in the use of radio under the conditions of flight on the civil airways in the U. S. (the Air Mail Service did not employ radio on its airplanes), it was not immediately evident what form these radio aids should take.

The Aeronautics Branch assigned the necessary experimentation and development in this field to its research division, which was organized in the Bureau of Standards. As a first step, a conference was called, June 22, 1926, to secure information and advice from various organizations which had experience bearing upon this problem. The recommendations made have been of value to the Department in the developments since that time.

The development of radio aids for the airways was immediately begun, the principal features to be radio telephony from ground to aircraft, and a radio beacon system. One of the major considerations in narrowing the choice of radio aids to these two was the idea of minimizing the apparatus which would have to be carried aboard the airplanes. The system adopted requires only a simple receiving set to be carried by an airplane. With this set it receives radio telephone information on weather conditions, etc., and also the radio beacon signals to guide it along its course. All of the complicated and expensive apparatus is on the ground at the transmitting end, to be maintained by the Government. A description of the general system, and discussion of the considerations affecting it, are given in "Applications of Radio in Air Navigation," by J. H. Dellinger, *Engineers and Engineering,* 43, p. 301, Nov., 1926; *Mechanical Engineering,* 49, p. 29, Jan., 1927.

The experimental work done in 1927 made it apparent that this system is entirely practicable and that all technical requirements will be met by placing the radio telephone transmitting stations and the main beacon stations at the principal airports, something like two hundred miles apart. The Department of Commerce has begun the purchase of apparatus to make a number of the installations.

It has been demonstrated that the use of radio telephony to transmit weather and other important navigational information to the airplanes while in flight is thoroughly practicable. In public demonstrations in May, 1927, Hon. W. P. MacCracken, Assistant Secretary of Commerce for Aeronautics, and Dr. G. K. Burgess, Director of the Bureau of Standards, held conversations from their desks with other officials in airplanes. In one case the whole two-way conversation was broadcasted to the radio public from station WRC.

This discussion is limited to the work on the radio beacon system. When the specific development of the beacon for the civil airways was begun in 1926, several improvements over the existing form of the beacon were sought. These included some matters of design detail (involving the goniometer, interlocking switch, etc.), an automatic device for setting the course successively on several courses (for use at airports where several courses intersect), and means of replacing the telephone receivers by a visual indicator. The work has been done at two field stations, one at College Park, Md., a suburb of Washington, and the other at Bellefonte, Pa., chosen because of its location on the New York-Cleveland airway in particularly hazardous mountain terrain. These two stations are equipped with radio beacon and also radio telephone and telegraph transmitting apparatus. They serve as development laboratories and as model and demonstration stations, and are in addition available to give radio service to the air routes on which they are located.

At College Park there is a directive radio beacon which is equipped to send signals of the aural interlocking variety, and also to send signals modulated at two low frequencies necessary for the visual indicator system that the Bureau has developed. The College Park stations are equipped with other special types of equipment for the sending of signals for experimental purposes. At Bellefonte the directive radio beacon is being remodeled so that it can send signals for use of the visual system in addition to the aural system.

The beacons operate in the frequency band 285 to 315 kc., and the telephone stations in the band 315 to 350 kc. These are allocated to air service by the 1927 International Radio Convention. For the present the beacons are adjusted to the frequency of 290 kc., and the telephone stations to 333 kc.

17. **Visual Indicator Systems**—The Bureau's work of the pastyear or so has been largely directed to the effort to replace the aural method by a practical visual method. The use of telephone receivers and determination of location by distinguishing certain aural signals requires skill and entails a certain strain upon the pilot. This would be eliminated if a method could be devised which required no listening but only an occasional glance at the instrument board.

The army engineers worked out a visual system in 1925, which superposed an arrangement of relays and lights on the interlocking signal beacon. This was not found to be practical under flight conditions.

The Bureau of Standards has experimented with a number of possible visual indicator systems, most of them involving the use of two different modulating frequencies for the two crossed loop antennas. The modulated radio frequency is on the antennas continuously, instead of throwing from one to the other antenna as in the aural system. This permits the use of continuously indicating instruments on the airplane. If the airplane gets off to one side of the course, the intensity of one of the modulated waves will increase and the other decrease, owing to the directive nature of the two coil antennas.

It is required that a device be used in connection with the receiving set on the airplane which will give a visual indication of the relative amounts of the two modulated waves. This requires some form of tuning to these two modulation frequencies. In several devices tried, the tuning was secured by means of tuned circuits attached to the output of the receiving set. Modulation frequencies of 500 and 1000 cycles were used.

One form of indicator consisted of a pair of neon glow lamps. One of these was in each tuned circuit. They were so adjusted as to just light up when the airplane was on the course and they received equal voltage. Because of their critical response voltage, they gave a rather sharp indication when the voltage of either tuned circuit dropped. In another form of indicator the two tuned circuits were connected differentially to a rectifier and direct-current galvanometer. When the airplane was on the course and currents are the same in the two tuned circuits, the d.c. outputs balanced and the galvanometer needle remained in the center of the scale. For deviation to either side the galvanometer needle moved correspondingly. These forms of indicator were found too critical and too complicated for practical use.

The form most recently developed, which is likely to be adopted, consists of two vibrating steel reeds. Their vibration gives the visual indication and they themselves provide the necessary tuning to the two modulation frequencies. The indicator is very simple and practical, merely being connected to the receiving set in place of telephone receivers. When the beacon signal is received the two reeds vibrate. The tips of the reeds are white, with a dark background behind them, so that when vibrating they appear as a vertical white line. The reed on the pilot's left is tuned to a frequency of 85 cycles and the one on the right to 65 cycles. It is only necessary for the pilot to watch the two white lines produced by the vibrating reeds. If they are equal in length, he is on his correct course. If the one on his right becomes longer than the other, the airplane has drifted off the course to the right (into the region where there is more of the 65 cycles). If he drifts off the course to the left, the white line on the left becomes longer.

18. Beacon Transmitting Apparatus—The directive radio beacon station is usually located at an airport, just off the landing field. It employs two loop antennas crossed at an angle of 90° with each other. Each of these emits a set of waves which is a maximum in its plane and a minimum at right angles thereto. Both antennas transmit 290-kilocycle waves but modulated at two dif-

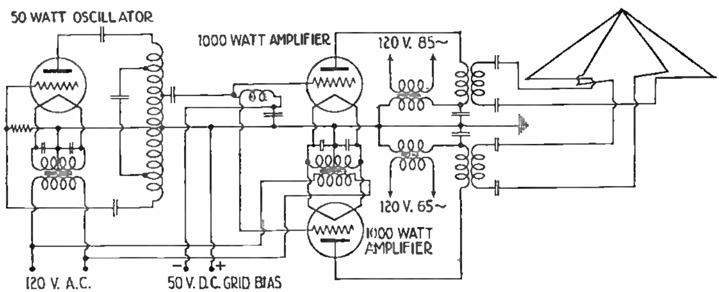


Fig 258*a*. Diagram of Radio Beacon Transmitter Developed by Radio Section, Bureau of Standards.

ferent frequencies. A master oscillator producing 290-kilocycle current feeds two power amplifiers. These are modulated by two different low frequencies. Their outputs go separately to the two loop antennas.

Figure 258-*a* is a circuit diagram of the transmitter in simplified form. The two loop antennas terminate in tuning condensers and coils as shown. They are both tuned to 290 kc., and so adjusted that there is no coupling between them. The coils are coupled to the plate circuits of the two 1000-watt amplifiers. The plate circuits are untuned, which reduces intercoupling between the two tuned loop antennas through the plate circuits of the power amplifiers. A radio-frequency voltage is supplied to the grids of the two amplifiers from the 50-watt oscillator operating at 290 kc. with direct voltage (not shown) applied to the plates.

The plates of the amplifier tubes are supplied with high-voltage alternating current through transformers, one being connected to a source of 85-cycle voltage and the other to a source of 65-cycle voltage. These are the two modulation frequencies, to which the reeds of the visual indicator are tuned. Each power amplifier passes radio-frequency current every alternate half cycle, the frequency being 85 or 65 cycles. This occurs each time the plate is positive. The completely modulated output from one amplifier supplies power to one of the antennas only, and the other amplifier supplies only the other antenna.

The use of a common master oscillator prevents any shift in the indicated course due to tuning of the receiving set, which might occur if two master oscillators were used in case they differed slightly in frequency.

As mentioned, the description is illustrative only. In practice means must be provided to prevent the production of harmonics, which are not permissible.

A number of other methods for modulating the carrier frequency at the low frequencies required are possible and have been used. The method just described involves the supplying of plate power directly to the amplifier tubes at the low frequencies desired. This method was not found entirely practicable because the constancy of the low frequencies depends upon the steadiness of the frequency of the power source available, which in most cases varies somewhat. Even with a steady source available, alternators with synchronous motors of special design to drive them would be necessary.

Vacuum tube oscillators controlled by tuning forks which supply sufficient voltage to enable grid or plate modulation of intermediate amplifiers have been developed, and solve the difficulty of keeping the low frequencies steady. In the grid modulation method the modulating frequency is impressed upon the grid of one of the amplifier tubes. With the plate modulation method the low-frequency voltage is applied to the grids of modulating tubes, the plates of which are connected to the output of one of the amplifiers in a circuit arrangement analogous to that of the ordinary method of plate modulation employed in broadcasting stations. Both methods give satisfactory performance although the plate modulation scheme has some advantage in that less distortion of the wave form is introduced.

When the beacon is to be used for air routes in several directions, a goniometer, not shown in Fig. 258-*a*, must be introduced. This is a coupling arrangement connected between the antennas and the amplifiers, rotation of which is equivalent to rotating the antennas. It has two pairs of coils, each pair consisting of an 8-turn rotor and a 32-turn stator. The stator coils are fixed at right angles to each other, and so are the rotors. Rotation of the rotor coils with respect to the stators orients the course marked out by the beacon in any desired direction. At airports where several courses intersect the beacon course can be set successively on the several courses for fixed time intervals.

19. **Receiving Equipment**—The beacon system can be used with any receiving set which operates at the frequencies used, merely replacing the telephone receivers by the simple reed indicator unit. There are, however, a number of special conditions involved in receiving on an airplane, and the bureau has developed special receiving sets in order to use the beacon system under the most advantageous conditions.

The use of a trailing wire as an antenna has long been recognized as a source of difficulty in airplane reception. Besides its obvious inconvenience and possible dangers, it is particularly unsuitable to radio beacon reception because it has a directional effect introducing apparent variation of the course and making it more difficult for a pilot to utilize the beacon signals. The trailing wire has been eliminated through the development of a receiving set having the necessary sensitivity and other characteristics necessary to receive on a short antenna through the ignition interference. The antenna now used is a metal pole extending vertically from the cockpit, having a total length of 10 feet. It has numerous advantages, not the least being that it practically eliminates direction errors in the beacon course which have been observed at night.

The receiving set weighs less than 15 pounds; its power supply is a 6-volt battery weighing 15 pounds. The receiving set operates in the frequency range from 285 to 350 kilocycles. A circuit

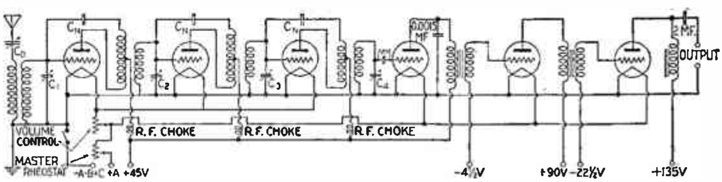


Fig. 258*b*. Diagram of Radio Receiver Employed on Aeroplane to Receive Radio Beacon Signals and Weather Reports.

diagram is given in Fig. 258-*b*. It is used to receive either the beacon signals or radio telephone or telegraph messages at will.

It is highly selective as well as sensitive, and is provided with interstage shielding as well as shielding against extraneous interference. The selectivity of the set design is supplemented by the great selectivity of the reed vibrators, which help greatly in reducing interference. It uses 3-volt tubes, selected for freedom from microphonic noises. The set has remote control arrangements for tuning and volume, so that the set itself can be out of the way in the tail of the airplane.

The indicator for the beacon signals is mounted on the instrument board in front of the pilot. It functions essentially the same

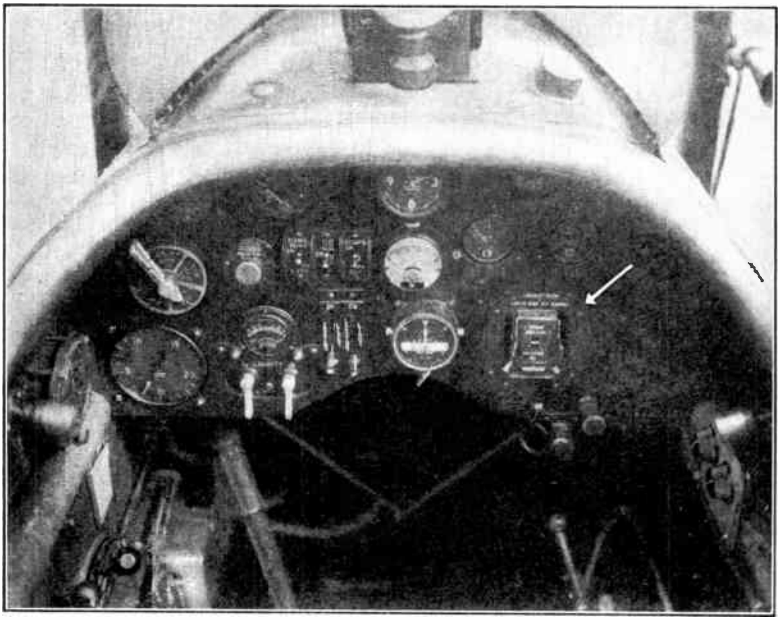


FIG. 258e. Instrument Board on Aeroplane Showing Visual Indicator Which is Actuated by Radio Beacon Signals.

as a telephone receiver except that its vibrating portions are tuned while a telephone receiver responds almost equally to all frequencies. The indicator consists of a set of coils, through which passes the audio output current of the receiving set, acting on a pair of short steel strips or reeds. These two reeds are tuned to the two modulation frequencies of the beacon signals. When the two are received with equal intensity the two reeds vibrate with equal amplitude. Their vibration is made evident by the motion of white tabs on their ends. These tabs are all that the pilot sees of the instrument, apparently lengthening out into white lines against a dark background when the indicator is in operation. By piloting the airplane so that the two lines are always of equal length, he remains on the indicated course.

While there are no commercial receiving sets at present available which are suitable for use on aircraft at the new frequencies for the air services, close cooperation is being maintained between the bureau and several commercial companies working on various problems related to radio aids for air navigation. It appears that suitable receiving sets and auxiliaries will soon be offered on the market.

20. Supplementary Features—The directive beacons at College Park, Md., and Bellefonte, Pa., operate on 1 kilowatt. Such beacons, located about 200 miles apart, would give satisfactory beacon service when the course usually flown is practically a straight line between them. When the course varies in direction, lower power beacons at the turning points could be used. Where the course is straight for a considerable distance such as 200 miles, it is planned to utilize a supplementary feature called "marker beacons." The directive beacons successfully guide a pilot along the course but give him no information of the distance traversed along it. This lack is supplied through the installation of non-directive beacons, placed along the airway at short intervals (perhaps 25 miles). These marker beacons are of very low power (a few watts), and emit a characteristic signal which the airplane pilot will receive for one or two minutes. They tell the pilot when he is passing over a specified place, so that he can locate himself and always know his position. In fact, through keeping track of these marker beacons, the pilot will be able to gauge wind conditions and note any change in direction or velocity as he proceeds during flight. The marker beacons operate a 60-cycle reed vibrator mounted alongside the directive beacon indicator on the airplane's instrument board. Each marker beacon will send the characteristic signal assigned for its location, which will coincide where possible with the characteristic flash signal of the light beacon at the same location. Thus the marker beacon signals will come to the pilot in a logical and automatic manner.

The reed indicator can also be used to transmit messages to the pilot when necessary, merely by interrupting the transmitting current at a slow rate in accordance with a code understood by the pilot. Additional reeds, tuned to other frequencies, can be used if desired to send special information.

The audio-frequency tuning of the reed vibrators also helps to avoid interference between the directive beacons. When one beacon station uses modulating frequencies of 65 and 85, the

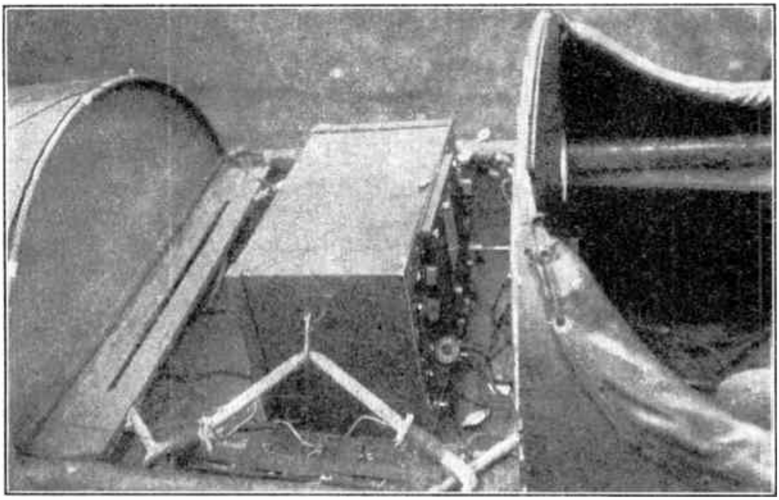


FIG. 258*d*. Radio Receiver Installed on Aeroplane for Reception of Beacon Signals and Weather Reports.

next station could use 75 and 95, etc. Indicators consisting of several pairs of reeds are easily installed on the instrument board of an airplane.

21. **Application of the System**—Flights have been made under practical conditions up to 135 miles, in which the beacon signals actually determined the course. Parts of these flights were made under conditions of low visibility, when the pilot had only the beacon indicator to determine his direction. To a large extent the device is unaffected by interference. It is affected little by airplane engine ignition interference. Such interference does not change the operating characteristic of the indicator signal, but merely reduces the distance range from the beacon station. The system was recently demonstrated to various prominent Government officials.

This development insures the full success of the Department of Commerce program of aids to air navigation. It is the intention of the department to establish radio telephone and radio beacon stations along the civil airways throughout the country, probably at the principal airports. To utilize both services, airplane operating companies will require only to provide a moderate amount of engine ignition shielding and to install a very simple radio receiving set on each of their airplanes.

Opinion recently expressed by the leading aviators converges on the necessity of a course indicator that will guide airplanes in conditions of low visibility. The radio beacon provides this and when the Department of Commerce has completed its development and established the system over the country, airplanes in flight will always have the beacon signals available to keep them constantly informed of their location. Indeed, when a pilot leaves his regular course either accidentally or to avoid a stormy area, the radio beacon will show him the way back.

CHAPTER 14

DEVELOPMENT OF AMATEUR SHORT WAVE APPARATUS

1. **Brief History**—Previous to 1924 amateur operation, with a few exceptions, was confined to a wavelength of 200 meters with a few special (Z stations) employing a wavelength of 375 meters. The generally accepted theory at that time was that wavelengths below 200 meters were of little use for long distance communication, due to a large absorption factor. However, a small group of amateurs had started a little activity on wavelengths below 200 meters. Boyd Phelps of Minneapolis, Minnesota, some time prior to 1920 had operated a spark transmitter at 33 meters, using a wavemeter calibrated down to 10 meters. Unfortunately Phelps had no one to communicate with on such a short wavelength, and as far as the author knows it was not until 1920 that any two-way communication was established on wavelengths below 200 meters. For instance, at this time Harry Lyon of Hyattsville, Md., communicated with Robert Kruse of Washington, D. C., on a wavelength of 190 meters. The following year Kruse communicated with Lyons at Hyattsville on a wavelength of 160 meters with a vacuum tube transmitter. During August, 1921, J. C. Ramsay, 1XA, of Brookline, Mass., worked two-way communication with Boyd Phelps, 1HX, of Hartford, Conn. These two also employed vacuum tube transmitters operating on a wavelength of 112 meters. During the latter part of 1921, this same Ramsay of 1XA had worked Frank Conrad, 8XK, in Pittsburgh on 112 meters. Some time prior to this Phelps at Hartford had been working two-way communication with Conrad at Pittsburgh on a wavelength in the vicinity of 90 meters.

Despite what this small group of amateurs were doing on short wavelengths, we find in December, 1922, that amateurs by the hundreds were making application for vacuum tube transmitter licenses to operate above 200 meters, still thinking that such transmitters would not operate below that wavelength. Previous to this John Reinartz of South Manchester, Conn., had described in QST of June, 1921, a regenerative receiver operating over a wavelength range of from 370 to 130 meters and in the June, 1922, issue there appeared another receiver of similar construction covering a range of from 212 to 174 meters. This latter receiver by Reinartz was considered an improvement over the original.

In June, 1922, Secretary Hoover of the Department of Commerce called a radio conference, the outcome of which permitted amateur stations to operate on a wavelength of from 150 to 200 meters, with a few stations licensed to operate on 250 meters. Throughout 1922 the files of QST indicated that amateur apparatus in general was being designed to operate down to 175 meters. However, considerable opposition to waves below 200 meters was registered by the traffic handlers of the American Radio Relay League.

During March, 1923, Kruse was exploring 100 meters in order to investigate transmission effects as discovered by a limited group of less than 10 experimenters. This was followed up in April by a story "Getting Down to 100 Meters" in preparation for a CQ party on this wavelength. QST of May, 1923, published a list of "calls heard" in which there appeared 26 stations operating between 80 and 190 meters. In July, 1923, the schooner "Bowdoin" of the MacMillan Arctic Expedition was fitted with apparatus for communication with amateurs on 200 meters, as there were not sufficient stations working on waves below that figure. During July F. W. Dunmore and Francis Engel, at the Bureau of Standards in Washington, D. C., worked on 100 and 105 meters with amateurs in Pennsylvania and Ohio. Fading tests were conducted on 190 to 375 meters during August, 1923, in which 260 stations were involved. In October of the same year Messrs. Brown, Darne and Basim of 3BWT, at Washington, D. C., described in QST a 100-meter, 200-watt vacuum tube transmitter. In the December issue of QST of the same year, K. E. Hassel, of 9ZN, ran an article on short wave tuner design that went from 250 to 90 meters. From this emerged the "Low-Loss" short wave tuners now so familiar to all in the radio industry.

2. Transatlantic Amateur Communication Established—The Atlantic Ocean was bridged in two-way amateur operation for the first time in history on the night of November 26, 1923, when 1MO in West Hartford, operated by Fred Schnell, exchanged messages with French 8AB, owned and operated by Leon Deloy in Nice, France. The transmitter employed by 1MO was built with the assistance of John Reinartz of South Manchester, Conn., 1XAM-1QP, and tuned by him to a wavelength of 100 meters. Reinartz himself, on the same night, was successful in making contact with French 8AB.

During this time the radio engineers of the Navy had been following with great interest the development of short wave communication by amateurs, as their interest in short waves was by no means a new one. As early as 1917 one of the standard waves for a small Navy spark set was 150 meters which occasionally transmitted over extraordinary long distances.

Of the Navy engineers, Dr. A. Hoyt Taylor was a leader and successfully conducted short wave tests with 1XAM and other amateur stations. Writing at that time in QST of May, 1924, Dr. Taylor says: "Perhaps the most outstanding thing about high-frequency or short wave work today is the amazing ranges obtained at frequencies in the neighborhood of 3000 kilocycles (100 meters). The intensity of signals received on these frequencies is so great that I am forced to conclude that these waves do not follow at all the ordinary laws of transmission. To me this would indicate that there is so complete a reflection of these waves at some upper and probably ionized layer of atmosphere, etc."

During these tests with amateurs in 1924, Dr. Taylor established the skip distance theory of short waves, the phenomena of which will be shown later.

In July, 1924, H. S. Shaw, of Cambridge, Mass., described in QST a piezo-electric oscillator. This marked the beginning of piezo-electric controlled transmitters.

During August, 1924, F. E. Bliley, 8XC, was working traffic on 50 meters and QST was getting excited about amateurs working below 150 meters illegally. However, the Third National Radio Conference of that year recommended for amateur use certain wavelength bands ranging from 4.7 to 200 meters. Following the recommendations of the conference, the Bureau of Navigation, Department of Commerce, issued new amateur regulations authorizing the use of the following wavelengths, with restrictions as to type of emission. The wavelengths were 150 to 200, 75 to 85.7, 37.5 to 42.8, 18.7 to 21.4, and 4.69 to 5.35 meters.

In the meantime, on September 20, W. B. Magner, 6BCP, of San Pedro, Cal., succeeded in exchanging signals with Frank Bell, 4AA, at Waihemo, New Zealand, and on the following night traffic was exchanged between 6CGW of Long Beach, Cal., and 4AA of New Zealand. This work was done on wavelengths above 100 meters, Bell, 4AA, having used 130 meters, 6BCP 157 meters, and 6CGW 150 meters.

With the official opening of the short wave bands various schemes were suggested as to how to operate on the different wavelength bands. Kruse and Clive Meredith published a story in QST doubting the necessity of loading the antenna and leaning towards fundamental, sub-fundamental and harmonic operation.

Daylight tests on 40 meters were very successful and Reinartz of 1XAM during March, 1925, worked W. J. Lee, 4XE, at Orlando, Fla. Using 40 meters Reinartz was also successful in communication with T. Lewis, 6TS, at Santa Monica, Cal. Mr. W. H. Schick, 2MU, of Brooklyn. N. Y., was also successful in working 6TS during the daylight period on 40 meters.

In April, 1925, QST published an article by John Reinartz in which he advanced a theory of reflection of radio waves from the Heaviside layer. A theory of refractive bending of radio waves was also advanced at that time by Kruse.

At this time there occurred a total eclipse of the sun and amateur stations operating on 20–40–80 meters were engaged in making observations during this period. However, no unusual phenomena occurred which would indicate that the eclipse affected short wave transmission.

In the fall of 1925, Traffic Manager F. H. Schnell of A.R.R.L. at the request of Dr. A. Hoyt Taylor made a cruise to the Far East with the Navy and demonstrated the possibilities of short waves for long distance work to and from ships.

The increased use of short wavelengths brought a demand for a tube having a small value of inter-electrode capacity. Such a tube was marketed by the DeForrest Company in February, 1926, and called the " H " tube.

In November, 1926, there was conducted a short wave test by the General Electric Company at Schenectady and members of the A.R.R.L. 9500 reports were received on 15–26–33–50, 65, and 109 meters. The results of these tests were used to plot curves showing the various ranges of day and night signals.

The first real DX on 5 meters by amateurs was accomplished during the summer of 1926. On July 11, Boyd Phelps at Grasmere, Staten Island, 2EB, was heard by Kruse at Glastonbury, Conn., a distance of 120 miles. This was done at 2 p.m. with 5 watts of power in the antenna. It was noted at that time that the signal was affected by a fog bank originating at the transmitting station. It caused the signal to waver and finally disappear.

During these tests there were only two fair days and it was only on the fair days that any signal was heard. In the meantime, west coast stations, 6TS, 6CNC, and others had operated at waves between 1 and 5 meters covering distances that ran up to 20 miles or so.

Foreign experimenters were also engaged in 5-meter tests and Italian 1ER were heard and copied by Captain Filipini at a distance of 1600 miles.

In July, 1927, at a Hudson Division Convention a ¾ meter transmitter was demonstrated by Phelps and Kruse.

In October, 1927, five meter signals from 2EB, operated by Boyd Phelps at Jamaica, N. Y., and from 9EHT, operated by Norvel Douglas at Lawrence, Kansas, were heard by Kruse at New Orleans, San Diego and Grand Canyon.

Thus has been the exploitation of short waves and the development of short wave apparatus by the American amateur. In other parts of the world other amateurs have been equally successful. At this time amateurs in all quarters of the globe are able to establish communication with each other. In fact, amateur short wave communication has become so universal that the International Radiotelegraph Convention held in Washington during 1927 set aside certain short wavelength bands to be known as the international amateur bands (40- and 20-meter bands).

Having discussed briefly the history of short waves, we will now consider what happens to these waves when they leave the antenna of a short wave transmitting station.

3. **Reflection of Short Waves**—When long distance communication was accomplished on wavelengths below 200 meters with small power, engineers began to consider that the atmosphere might have something to do with this phenomenon. This is indicated by remarks made by Dr. Hoyt Taylor as previously quoted. John Reinartz had also made observations leaning towards a reflection of short waves from an ionized region. At the present time the height of this region as well as its activity is pretty well known. Experiments conducted by R. A. Heising of the Bell Telephone Laboratories fix this ionization of the atmosphere as beginning at an altitude of about 16 miles and extending upward, and experiencing diurnal and seasonal variations. This diurnal and seasonal variation of the reflecting area produces effects on radio waves according to their frequency. It has been found that the ratio of night to day signal decreases as the frequency is increased and that finally the day signal will be the stronger, depending upon the distance and frequency.

It is not within the scope of this book to discuss at length the production of the ionized regions of the atmosphere; therefore, we will go on and show what happens to the short wavelengths after they leave the antenna of the transmitting station.

For an example, we will show what happened to a 20-meter wave that was transmitted from one of the General Electric Company's stations during the G.E.-A.R.R.L. tests.[1] As the wave leaves the transmitting antenna its signal intensity rapidly decreases due to spreading and energy absorption by the ground and other obstacles within its path. At 60 miles it showed a field strength of 10 microvolts per meter, its lowest useful level. As the distance is increased beyond 60 miles no signal can be heard; at a distance of approximately 850 miles the signal transmitted during the day becomes unexpectedly strong again. Continuing to greater distances the signal gradually falls off in intensity and reaches the useful limit of 10 microvolts per meter in the vicinity of 4000 miles by day. On a summer night the signal does not reappear after the 60-mile extinction until 4000 miles are reached, after which the signal falls off gradually to a very low value at 6500 miles.

4. **Ground Wave and Reflected Wave**—The signal which is heard up to 60 miles may be considered the ground wave limit of the transmitter. The day signal which reappears at 850 miles may be considered the sky wave. It is accounted for by a bending back to earth of a portion of the energy from the ionized regions of the atmosphere.

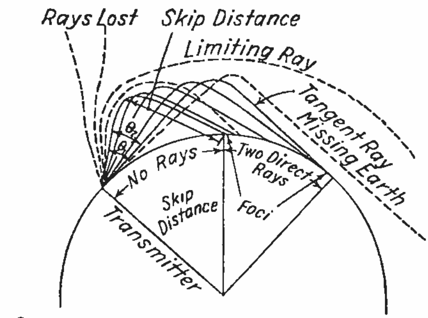
5. **Skip Distance**—The distance from the transmitter to the nearest point at which the refracted sky wave returns to earth is known as the skip distance. For a given wavelength the skip distance is at a minimum in the middle of the day and at a maximum on a winter night. As already stated, experiments show that the skip distance for a given time of day or night decreases with increasing wavelength. This may be explained by saying that the longer the wavelength the closer the sky wave returns to the transmitter and at a given wavelength a receiver may always be within range of both ground and sky wave.

It was also found that a radio wave starting out at a low angle will be only slightly bent or refracted and comes to earth at a great distance from the transmitter. On the other hand radio waves propagated at high angles will come to earth progressively nearer the transmitter until finally a critical angle is reached from

[1] A complete report of these tests was described by Chester W. Rice in QST of July and August, 1927.

which the refracted wave comes down at the nearest distance to the transmitter. For higher angles the points of return recede from the transmitter until eventually a second critical angle is reached at which the wave does not return to earth, but instead goes out into space and is lost. This effect is shown diagrammatically in figure 259.

6. **Multiple Reflections**—At a given wavelength there may be more than one reflection of the wave. A part of the refracted energy that strikes the ground will be reflected towards the sky and will return to earth again at twice the initial distance from the transmitter. Observations made at the Naval Laboratory at Bellevue, D. C., indicate that reflections of certain wavelengths at a certain time of day and year may occur such that a signal from a transmitter may be heard when the receiver is situated beyond the zone of ground wave reception and closer than the normal skip distance. In fact, several signals with time interval may be received from one impulse at the transmitter and the time interval shows that the waves travelled various distances other than the normal straight line distance between transmitter and receiver.



θ_1 Angle at transmitter corresponding to the first critical angle

θ_2 Angle at transmitter corresponding to the second critical angle

FIG. 259. Diagram Showing the Various Possible Paths of Radiation of Short Wavelengths.

7. **Echo Signals**—Signals which have passed around the world in the reverse direction from transmitter to receiver or have passed more than once completely around the world are known in the art today as "echo" signals because they make themselves manifest in the receiver as echoes make themselves manifest in acoustic phenomena.

Signals from short wave transmitters have been photographically recorded after having passed approximately 2½ times around the world. It has been noted that they are of sufficient intensity to cause serious interference and may prevent the receiving operator from making a perfect copy of the message.

Observations by the Naval Research Laboratory at Bellevue, D. C., indicate that echo signals manifest themselves first as direct signals over the great circle from transmitter to receiver and second as an echo going a long way around the world (probably in the same great circle) but in the reverse direction (therefore arriving at an appreciable time interval later than a direct signal), have been observed on various frequencies between 28,000 kilocycles (10.7 meters) and 8,700 kilocycles (34.46 meters), but are usually restricted on the lower frequencies to a very limited time of day and time of year. The predominant period for observation of echo signals is in the spring or fall and the best periods of the day are in the morning or late afternoon hours. When the signal goes more than once around the world it is generally observed as coming from the same direction as the direct signal. Its time lag over the direct signal is the means of identifying it and this time lag is approximately .137 second, which corresponds to the time it would take an electro-magnetic wave to traverse the periphery of the world on the Heaviside layer at a distance of, roughly, 100 to 150 miles away from the surface of the earth. In other words, the time differences do not correspond to a ground wave but they correspond to the circumference of the Heaviside layer which is somewhat larger than the earth.

The time intervals are such as to throw the dots and dashes of a message into a complete jumble and in some cases have made it impossible to copy a message. The effect sounds as though two operators were sending the same message, one slightly behind the other.

In order to overcome the interference from echo signals the Bellevue Laboratory has employed long low single wire antennas erected so as to be directive in the direction of the transmitter it was desired to receive.

8. Choosing the Wavelength—From the foregoing discussion it can be seen that for long distance work on short waves low angle radiation is most effective, since the high angle radiation returns progressively near the transmitter or does not return to earth. High or low angle radiation depends upon whether the antenna is excited at its fundamental frequency or on a harmonic frequency. The method of feeding the antenna is a secondary consideration.

9. The Marconi Antenna—The form of antenna first made use of by Marconi in his early experiments used a ground and for that reason is known as the Marconi antenna. The distribution of current and voltage in a vertical Marconi antenna operating at its fundamental frequency is shown in *a*, figure 260. A grounded antenna can only be operated on its odd harmonics. *b* in figure 260 shows the distribution of current and voltage when such an antenna is operated on its third harmonic. The frequency is three times the fundamental frequency and the wavelength is one-third of the fundamental wavelength. Other modes of oscillation have wavelengths 1/5, 1/7, 1/9, etc., of the funda-

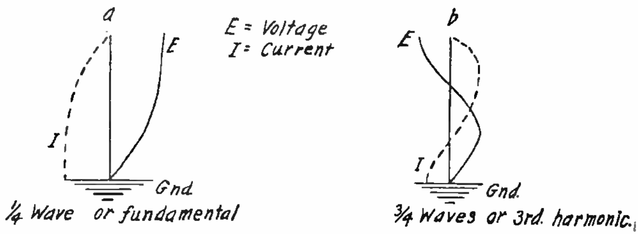


FIG. 260. Marconi Antenna Systems.

mental. Note from the figures that there is always a maximum voltage at the top of the antenna. A point of no voltage is spoken of as the nodal point. A point of maximum voltage would be a voltage loop or anti-nodal point. A point of maximum current is called the current loop and the point of no current, the current node.

10. **Hertz Antenna**—Antenna systems employing a counterpoise instead of a ground are known as Hertz antennas. Hertz in his early experiments employed an ungrounded antenna. A Hertz antenna can be made to oscillate at its fundamental frequency or at an even or odd harmonic of the fundamental. Figure 261 shows the distribution of current and voltage in a Hertz

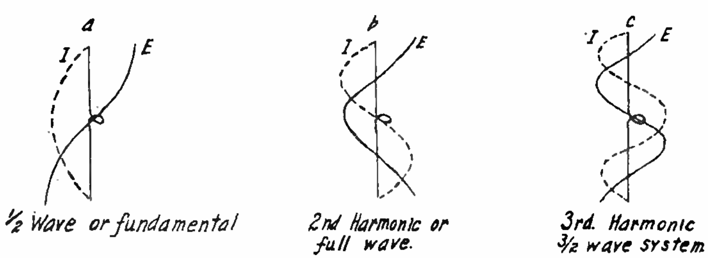


FIG. 261. Hertz Antenna Systems.

antenna when it is made to oscillate at its fundamental, second harmonic and third harmonic frequencies.

11. **High and Low Angle Radiation**—The Hertz antenna shown in figure 261 operating at its fundamental (half-wave an-

tenna) will radiate mainly at a low angle. As already shown, low angle radiation is desirable when it is desired to transmit over a considerable distance as the wave is only slightly bent or refracted and comes back to earth at a great distance from the transmitter.

If the antenna is made to oscillate at the second harmonic the angle of propagation will be increased, thus decreasing the range of the transmitter. The higher the harmonic at which the antenna is made to oscillate the higher will be the angle of radiation until finally at the seventh or eighth harmonic the wave projected upwards will be split up into several parts and there will be several maxima of radiation. This same is true of a grounded antenna when operated as 7/4 or 9/4 wave antenna corresponding to the seventh or ninth harmonic.

12. **Horizontal and Vertical Antenna**—Many tests have been conducted by various experimenters to determine the relative effectiveness of the horizontal and vertical antenna at short wavelengths. The results of these tests indicate that for DX (DX meaning long distance) purposes a vertical half-wave antenna with its lower end supported ¼ wavelength above the earth is superior.

13. **Feeding the Antenna**—There are two groups of methods generally employed by amateurs for feeding energy to the antenna system. They are known as the current feed and the voltage feed systems. The choice of a system depends upon the physical conditions existing at the station.

14. **Current Feed**—One system of current feed is shown in figure 262. Here the antenna has a gap cut at its center indi-

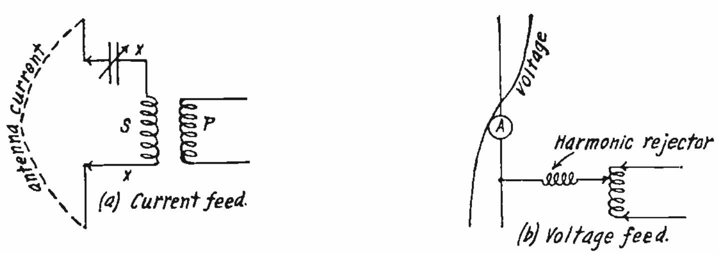


FIG. 262. Current and Voltage Feed Systems.

cated as *X* and to the two sides of this gap is connected the current-feeding device which consists of the secondary coil of the transmitter. A series condenser may be employed in either branch or both to keep the secondary from loading the antenna to a wavelength higher than which it is desired to operate. Referring to figure 261 of the Hertz antenna system the secondary could be placed at any point in the system when there is a current loop. Figure 263 shows several different current-feed methods.

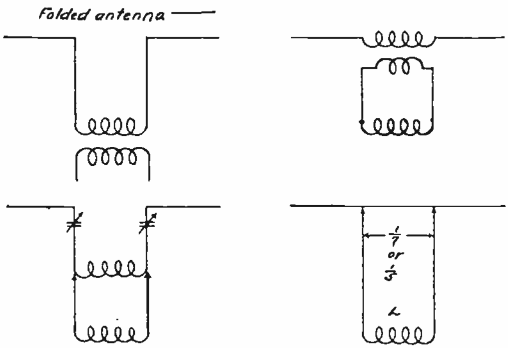


FIG. 263. A Group of Current Feed Systems.

15. **Voltage Feed**—One of the voltage feed systems is illustrated in *b* of figure 262. The single wire transmission line type of feeder requires that the feeder be connected to the antenna at a voltage loop. This method has several disadvantages, the main one being that the antenna is practically a fixed wavelength arrangement. Also any system of feeding an antenna through a 1-wire r.f. line is likely to make much the same troubles that are caused by direct coupled transmitter. To avoid this the feeder line should be inductively coupled to the driver with one end of the coupling coil grounded. This arrangement is shown in figure 264.

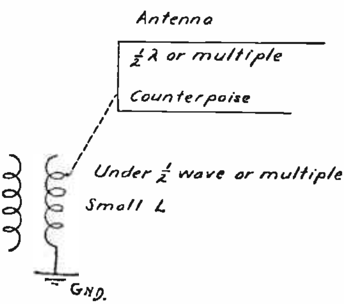


FIG. 264. One Wire Voltage Feed with Inductive Coupling.

16. **"Zeppelin" Antenna**—The most popular of voltage feed systems employed by amateurs is the non-radiating two-wire transmission line feeding a straight wire antenna system known as a "Zeppelin" antenna. (See figure 265.) This system was mentioned by Dr. Greenleaf Pickard in QST of June, 1925, who at that time stated it was suggested by H. Begge-

row for Zeppelin airships. The antenna wire is cut to one-half of the desired wavelength in length and placed in any desirable location or position. (The wavelength in meters multiplied by 3.28 gives the wavelength in feet. For example, a 40-meter half-wave antenna would be $\frac{1}{2} \times 40 \times 3.28 = 65.6$ feet long.) The two-wire transmission line must be ¼ wavelength long or any odd number of quarter wavelengths, such as ¾ wavelength. The feeder wires should be spaced about 1/200 wavelength. The system is so arranged that the currents in the feeders are exactly out of phase and radiation from the transmission line is zero.

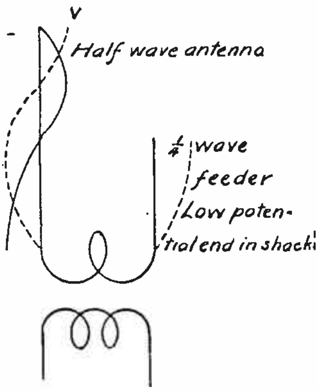


FIG. 265. Zeppelin Antenna System.

Note: In either case if feeders are a bit short use series inductance, or if too long use series capacity on both sides.

17. **Getting on the Air**—Amateurs are mainly divided into two groups. In one of these groups we find the amateur who desires to experiment and test out his own ideas and ideas suggested by those engineers more advanced in the art. Sometimes we find in this group one or more who develop ideas of their own which often prove of great benefit to the science. This group at times acts as a whole body in order to assist in making observations on transmission phenomena. A good example of this is the reports furnished by amateurs during the fading tests of 1923 and more recently the General Electric-A.R.R.L. tests on short waves.

18. **Traffic Handlers**—In the second group we find those who are engaged in the orderly transmission and reception of messages. These messages are accepted from the general public and transmitted free of charge. Sometimes such a message passes through several relay stations before reaching its destination.

Sometimes both groups of experimenters and traffic men unite in order to establish communication with some community which has been cut off from the outside world by an earthquake, flood or tornado. In the past both groups have been instrumental in keeping members of the Arctic and Antarctic exploring expeditions in touch with their families many thousands of miles away.

19. **The Amateur in the World War**—In all this has developed a trained corps of competent radio operators who can be

of service to the Army and Navy when called upon in advent of war. No one can realize this any more than the writer who, while serving in the Radio Intelligence Section of the First Army in France during the World War, came in contact with many of such amateurs. Of the hundreds of operators received in France as graduates of war-time radio schools few were capable of being immediately placed in actual operation of intercept and gonio (radio compass) stations. It was generally necessary to put these men through another schooling in order to increase their speed in reception and to train them in the enemy's method of procedure. This of course meant delay in expanding the work of the intelligence section and at the same time required the services of skilled men as instructors whose time could have been of much value in actual operation of field stations.

Each group of men received from the States were closely examined to determine if there were any former amateurs or commercial operators. If any were found they were received with much concealed joy by the C.O. and his staff because practice had shown that these men could be placed at once on field stations at the front and would produce results. With their previous experience in handling traffic they were quick to get on to methods employed by the German field stations in dispatching traffic and could make solid copies of code messages through all kinds of interference.

The value of this work and the skill of the operators engaged in it is attested to by General Russel, late Chief Signal Officer of the U. S. Signal Corps. In circular No. 129 issued in France, December 20, 1918, General Russel says in writing of the work of the Radio Section, Signal Corps: "The following incidents which have been reported to this office by the Assistant Chief of Staff, G-2, A.E.F., are recorded and copies furnished in order that the excellent work of the men of our radio section in the field may be known and duly appreciated.

"On a certain occasion, some remarkably clever interceptions of German code messages were made that enabled the Americans associated with the British and French code men to work out a solution of the new code. The cleverness of this work is apparent when it is known that a failure to get correctly any one of three code messages would have defeated the accomplishment of this end. When it is known that these code messages are the hardest kind of messages to copy, and that in order to be sure of getting the valuable messages it has been necessary to copy several hundred useless ones per day over long periods of time, and that copying is done under difficult conditions and through interference which confuses all but the best operators, it is possible to appreciate the fine work which has been done. In this one case a few minutes' inattention, a single mistake in call letters or the missing of a few groups in one of the messages would have made the others useless. The American operators are the only ones who copied all three messages with sufficient accuracy to be useful."

20. Building the Receiver—In starting in the amateur game one usually begins by building a receiver designed to cover the wavelength bands authorized for amateur use. In this way he can listen in and see what is doing on the air and get practice in learning the code. After tuning around in the different bands he becomes accustomed to the methods of procedure in calling and transmitting messages.

With diligent practice one can within three or four months copy ten words per minute (five letters to the word), the speed required in order to secure an amateur operator's license which permits him to operate a licensed amateur station. After securing the operator's license he can proceed with the building of a transmitter and get it on the air and communicate with other amateurs in all parts of the globe.

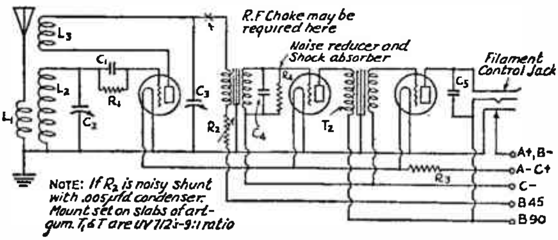
Generally speaking, a short wave receiver designed for amateur use should be able to tune from 5 to 90 meters. This will cover all the short wave bands authorized for amateur use. Such a receiver will permit the broadcast listener to tune in on short wave broadcast stations both foreign and domestic. A short wave receiver may be a simple regenerative affair or elaborate one so as to include a stage of tuned r.f. amplification employing a shielded grid tube. Again the receiver may be of the double detection type better known as a super-heterodyne. In fact, any super-heterodyne may be revamped so as to cover a wide band of short wavelengths. This is easily done by employing a plug-in coil in both tuned input and oscillator.

The audio frequency end of the receiver should be designed to meet the pleasure of the operator. If it is desired to hear only code signals a peaked transformer may be used. On the other hand, if the operator desires to tune in the short wave broadcasting stations the audio end should be designed so as to have a flat frequency characteristic ranging from approximately 30 to 7,000 cycles. This can be satisfactorily done by choosing a good make of audio transformer such as a Silver-Marshall, Amertran, Thoradson, or General Radio.

21. Short Wave Regenerative Receiver—The simplest and most economical of all short wave receivers is the regenerative type employing plug-in coils, with the antenna inductively or capacitively coupled to the tuned circuit. There are various kits for sale on the market at reasonable prices which can be easily assembled by the amateur set builder.

The receiver about to be described is designed primarily for the amateur in order to cover the various wavelength bands authorized for amateur use.

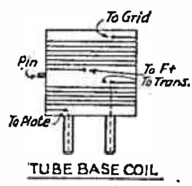
The coils are wound on forms salvaged from the bases of burned-out UX tubes. A receiver of this type was described by



REFERENCE TABLE	
C1	.0001 µfd Mica Fixed Condenser
C2	.00015 µfd Midget Variable Cond. 1 plate
C3	do
C4	.0005 µfd Mica Fixed Condenser
C5	do
R1	10 Megohm Grid leak (Noiseless)
R2	0 - 50,000 Ohm Bradleyohm
R3	Rheostat or Amperite
R4	1/10 Megohm Gridleak
L1	2 turns bell wire around coil socket base
L2	Grid coil on plug in tube base
L3	Tickler " " " " "

Wave Band	L2 Turns	L2 Wire Gage	L3 Turns	L3 Wire Gage
80	37	28	25	30
40	16	22	20	30
20	7	22	10	30
10	3	20	5	30
5	1	20	3	30

SHORT WAVE RECEIVER USING TUBE BASE COILS AND MIDGET CONDENSERS BY P. H. Quinby - 9DXY - St. Louis, Mo.



TUBE BASE COIL

NOTE: Remove old tube & leads from base. Drill small holes for leads. Wind both coils same direction. Run ends of coils thru prongs & solder.

ADVANTAGES: High L:C Ratio. No heavy end plates in condensers. High amplification with low noise level. Combined capacity and resistance control of regeneration. Good form factor in inductance. Economical efficient plug in system. Better signal spread over dial. Simplicity-Compactness.

FIG. 266. Circuit Diagram of Tube Base Short Wave Receiver with Reference Table.

P. H. Quinby in QST of March, 1928. The construction of this receiver as worked out by Mr. Quinby is as follows:

First of all it is necessary to secure five tube bases as five coils are required to cover all the amateur wavelength bands. The glass and old leads are removed from the inside of the base. Small holes are drilled for the leads which are soldered to the prongs.

22. Removing Glass from Base—In order to remove the glass from the tube put the whole tube in boiling water for about five minutes, then twist the glass part and it will come loose from the base. Hold the tube prongs downward and touch the ends of the prongs to the tip of a very hot soldering iron. After a moment, the solder can be flipped out with a snap of the wrist which will leave the leads running through the prongs free.

Figure 266 shows the circuit diagram of the receiver.

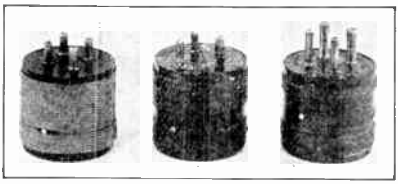


Fig. 266*a*. Tube Base Coils.

Figure 266-*a* shows three of the coils wound so as to cover the short wave bands.

Reference Table.

C_1—100 micro-microfarad fixed condenser.
C_2—15 micro-microfarad midget variable condenser.
C_3—15 micro-microfarad midget variable condenser.
R_1—10 megohm grid leak (noiseless).
R_2—0–50,000 ohm Bradleyohm or Frost Resistance.
R_3—20 ohm rheostat.
R_4—100,000 ohm grid leak.
L_1—2 turns bell wire around socket base. Ant. coil.
L_2—Grid on plug-in tube base. Sec. coil.
L_3—Tickler on plug-in tube base.

COIL SPECIFICATIONS.

Wave Band.	Secondary Coil.		Tickler Coil.	
	No. of Turns.	Size Wire.	No. of Turns.	Size Wire.
80	37	28 D.C.C.	25	30 D.C.C.
40	16	22 "	20	30 "
20	7	22 "	10	30 "
10	3	20 "	5	30 "
5	1	20 "	3	30 "

Both secondary and tickler coil are wound in the same direction with about ¼-inch separation between the two windings. The outside winding of the secondary goes to the grid. The inner secondary terminal is soldered to the pin that engages in *F* + on the socket. The outside of the tickler winding is soldered on to the pin that engages in *P* on the socket. The other terminal of the tickler winding is soldered to the pin that engages in the *F* — of the socket. The *F* — terminal of the socket connects to *P* of the 1st audio transformer.

The antenna is inductively coupled by winding two turns of bell wire on the socket base. This does for all wavelengths. The antenna may be capacitively coupled to the secondary by a midget condenser of one or two plates. If dead spots occur when the antenna is inductively coupled the antenna circuit should be detuned by loosening the coupling. This is accomplished by pulling the tube-base away from the socket. If the antenna is capacitively coupled dead spots can be eliminated by decreasing the value of the coupling condenser or cutting down the length of the receiving antenna.

23. **The Detector Tube**—A UX-112-A amplifier tube with a 9 or 10 megohm grid leak makes a good detector tube for short waves. It is non-microphonic and passes easily into oscillation with about 60 volts on the plate.

24. **Fringe Howl**—There is a tendency for some tubes to howl when regeneration is increased to the point of oscillation. This howl can be eliminated in most cases by connecting a fixed resistance across the secondary of each audio transformer. The value of this resistance lies between 25,000 and 100,000 ohms. In the receiver just described this resistance is indicated by R_4.

25. **Commercial Short Wave Receiver Kits**—There are available on the market several short wave receiver kits which are easily assembled by the amateur set builder. One such kit

of particular merit, designed and sold by Silver-Marshall, Inc., of Chicago, is known as "Round the World Four." This kit employs one stage of untuned radio frequency amplification preceding the detector tube. A description of the kit follows.

26. Description—Silver-Marshall "730 Series" screen grid short wave kits are available in two models, both of which are designed around a type 732 Essential Kit. Both are identical in external appearance, being housed in the same type of aluminum shielding cabinet, 14 inches long, 6 inches wide and 6 inches high, and weighing 14 pounds. The 730 "Round the World Four" is a four-tube non-radiating short wave receiver consisting of one stage of screen grid r.f. amplification, a regenerative detector

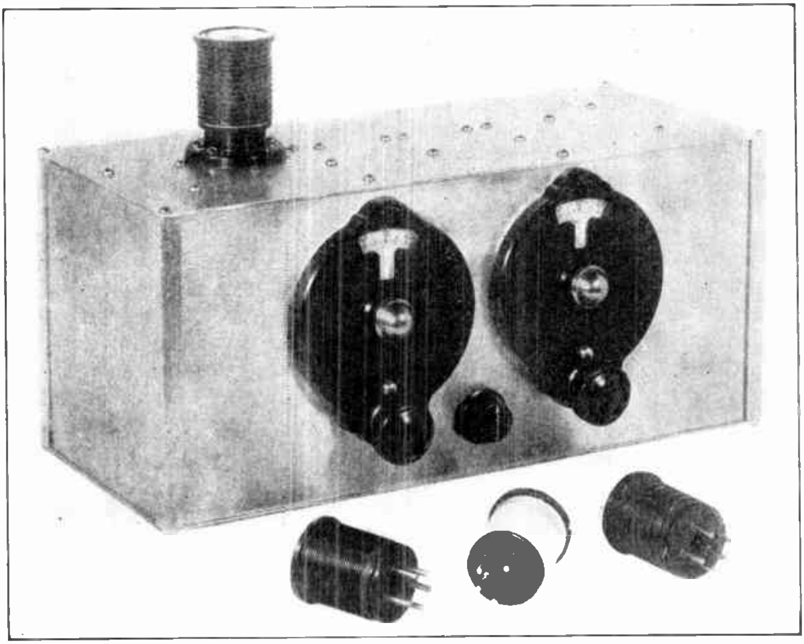


FIG. 266*b*. Silver-Marshall "Round the World Four" 4-Tube Screen Grid Short Wave Receiver.

and two stages of extremely high-gain audio amplification. Four inductance coils, which may be successively plugged into a 5-prong tube socket on top of the cabinet, provide four tuning ranges on the left-hand (tuning) dial (131-T: 17.4 to 32 meters. 131-U: 31 to 58 meters. 131-V: 56 to 110 meters. 131-W: 105 to 204 meters). The right-hand vernier dial controls regeneration. The small lower knob regulates the detector filament voltage, and at the extreme anti-clockwise position turns the entire set off. The loud speaker range is practically unlimited, being restricted only by atmospheric conditions, operating location, and transmitter power. Ordinarily, under favorable conditions, European short wave broadcast stations may be received, and amateur code sta-

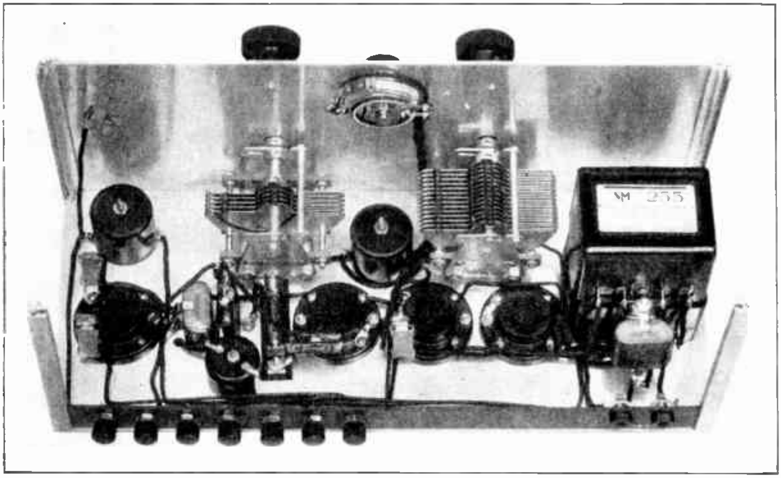


FIG. 266*c*. Assembly of Silver-Marshall "Round the World Four" Receiver.

tions on every continent may usually be tuned in—all in a single evening.

In Chicago, low power amateur telephone stations from Maine to California are received loudly and clearly.

The 731 "Round the World Adapter" is essentially a two-tube device used for short wave reception, when connected by an adapter to any broadcast receiver. Or it may be connected to a standard power audio amplifier, or used directly with head-phones. The 731 adapter is exactly the same in appearance as the 730 four-tube set, and is substantially the 730 set except that the two-stage audio amplifier is omitted (but may be added at any time if desired). The wavelength range, tuning characteristics, distance range, etc., are the same for Model 731 as for Model 730.

Type 732 Essential Kit contains the essential parts for the r.f. portion of the S-M "Round the World" circuit. It may be assembled into a two-, three-, or four-tube receiver, as desired, either in the S-M type 734 aluminum shielding cabinet, or upon a wood baseboard, or in any other fashion.

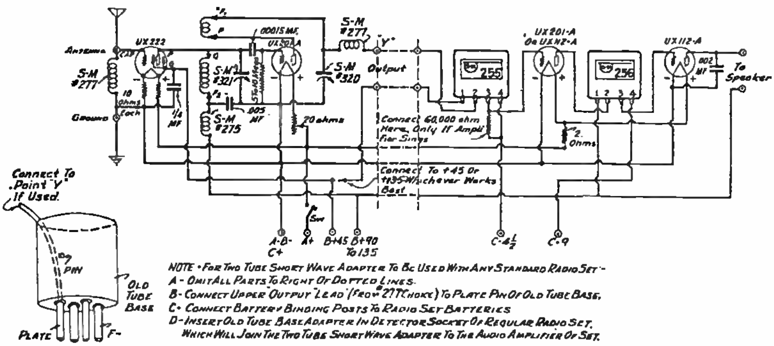


FIG. 266*d*. Circuit Diagram of Silver-Marshall "Round the World Four" 4-Tube Screen Grid Short Wave Receiver.

27. Requirements of a Modern Amateur Transmitter—In order to meet the changes in amateur operating conditions occasioned by the enforcement of the new International Radio Laws and Regulations, the Board of Directors of the American Radio Relay League authorized a program of investigation towards development and modification of amateur transmitting and receiving apparatus suitable to meet these new conditions.

In the August, 1928, issue of QST, Ross A. Hull, Associate Technical Editor of QST in charge of the A.R.R.L. Technical Development program, describes what the requirements are of a self-excited transmitter suitable for 1929 performance and tells how these requirements can be met.

Mr. Hull states briefly that the requirements of a self-excited transmitter are as follows: "The frequency 'flutter' due to irregularities of plate supply must not exceed about 1/30 of 1 per cent (approximately 250 cycles at 40 meters). In addition, the frequency of the signal must be relatively constant. The signal must not 'shimmy' as the antenna vibrates, it should not 'chirp' as it is keyed, nor can it 'creep' appreciably as the line voltage fluctuates or the tube heats. In short, the frequency of the first dot transmitted should be within 1/10 of 1 per cent (about 750 cycles at 40 meters) of the hundredth dot, even if the plate has

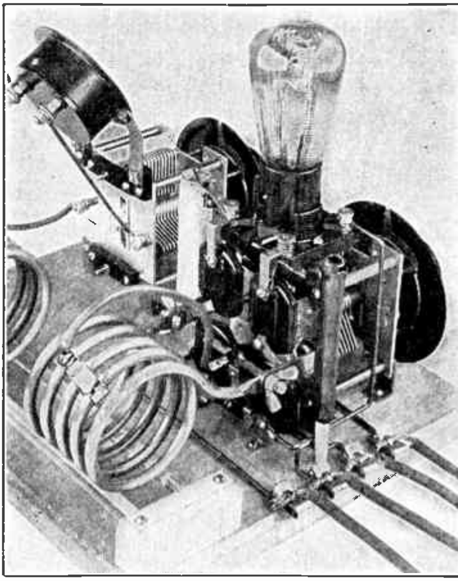


FIG. 267. A "Close-up" Showing the Heavy Tank Leads and Solid Construction. (Courtesy of QST.)

The plate and grid fixed condensers are mounted immediately under the tube socket. Below them are the two filament by-pass condensers and the center-tapped filament resistor. On the far side of the tube socket is the plate choke supported from the plate terminal. On the near side is the grid leak pushed over a wooden peg in the base-board. Heavy flexible wire is used for the filament lead to the inductance, a clip being permissible in this case on account of the low current to be passed by it. Relatively enormous currents flow in the coil-condenser circuit and in this case connections between the two must be made with wing nuts, or some similar device, in order to avoid serious losses.

reddened or the line voltage drifted in the meantime. At the end of a few hours of operation the frequency should not have strayed much farther."

The problem of plate supply must be considered if one is to build a transmitter which will meet the requirements enumerated above. Raw a.c. is out of the question and one must decide on a d.c. generator or batteries or resort to rectification of a.c. with suitable choke coils and condensers.

Key clicks are also taboo. A key filter circuit is shown in figure 269 which effectively eliminates key clicks.

Another matter of great importance is the elimination of antenna swaying and the vibration of the set or any of its radio frequency wiring. The effect of coupling between tank circuit and antenna must also be studied. This will be discussed later when instructions are given for tuning the transmitter.

The investigation of the A.R.R.L. Technical Development program showed that a circuit having a low inductance-capacity ratio (termed a Hi-C circuit) has characteristics which make its use in the self-excited transmitter very desirable. In such a circuit the circulating currents increase rapidly as the inductance is reduced and the capacity increased. "A successful Hi-C plate circuit will require the use of ¼-inch copper tubing (or strip of similar surface area) for the coils of the transmitter of 50 watts or less, and at least ⅜-inch tubing or its equivalent for the higher powers.

The voltages developed across a Hi-C circuit are much lower than in circuits of the usual constants. This will permit the use of good receiver type condensers with transmitters operating with

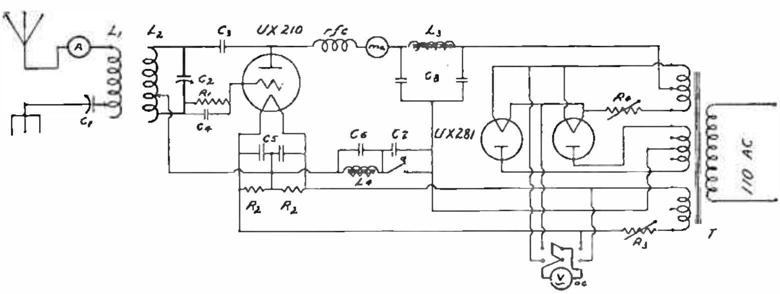


FIG. 267*a*. Circuit of "High C" Hartley 7½-Watt Transmitter.

T—Acme 200-watt power transformer; L_1 and L_2 for various bands; C_1, C_2—500 micro-microfarad capacity receiver-type variable condenser of good quality; C_3—500 micro-microfarad fixed condenser (Sangamo); C_4—250 micro-microfarad fixed condenser (Sangamo); C_5—2000 micro-microfarad fixed condenser (Sangamo); R_1—10,000 ohm grid leak; R_2—50, 100 or 200 ohm fixed resistors or Christmas tree lamps; *r.f.c.*—radio frequency choke (see text); C_6—2 mfd. condenser—1000 volt test; C_7—1 mfd. condenser—1000 volt test; C_8—4 mfd. each (see list of parts); R_3—2 ohms—2 ampere capacity; R_4—2 ohms—4 ampere capacity; L_3—Acme 30 henry 300 m.a. choke; L_4—30 henry "B" eliminator choke.

plate voltages of 1000 or less, while nothing more than "double spacing" should be used for transmitters employing UX-852 or UV-204-A tubes.

28. Building the Transmitter—The Hartley circuit is used extensively by amateurs for short wave work and is easily adjusted and placed in operation. Figure 267-*a* shows the connections of a Hartley circuit suitable for 1929 performance. The UX-210 7½-watt power tube adapts itself very well to a low-powered set for the beginner and will be used in this transmitter. Plate supply is obtained from rectified a.c. which is sufficiently filtered to give a pure C.W. note. Rectification is obtained by using two UX-281 tubes in a full wave rectifying circuit. De-

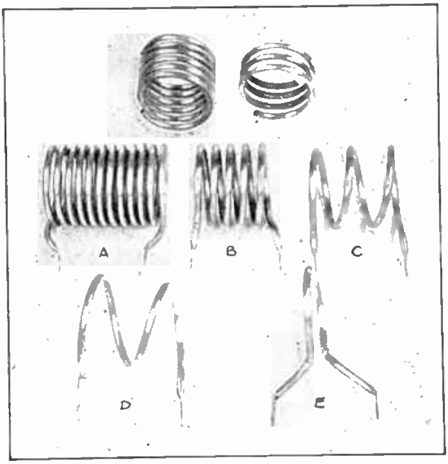


FIG. 268. Plate and Antenna Coils for Five Bands.

tails of the filter circuit are shown in figure 267-*a*. The low-frequency power circuit can be wired up in the usual manner with No. 14 rubber-covered wire.

The inductances shown in figure 268 are designed to be tuned by a 500 micro-microfarad condenser (.0005 mfd.). Coils *A*, *B*, *C*, *D* and *E* are used for the 3500–4000 kc. (80 meter). 7000–7300 kc. (40 meter). 14,000–14,400 kc. (20 meter), 28,-000–30,000 kc. (10 meter) and 56,000–60,000 kc. (5 meter) bands respectively. They have an inside diameter of 2⅜ inches and are made by winding ¼-inch soft copper tubing over a length of 2⅜ inches outside diameter water pipe by hand. To facilitate the winding process holes should first be drilled in the pipe and tubing, one end of the copper tubing being secured to the iron pipe with a machine screw before the winding is started. The ends of the coils are hammered flat and drilled to fit under the wing nuts which hold them to the condenser leads. Two antenna coils—to be seen above the plate coils—serve for use with coils *A, B, C* and *D*. Their size will be determined to some extent by the type and constants of the antenna. Short stiff leads should be used between coils and condenser if the inductance is not connected directly to the condenser. In fact, the whole assembly should be made as compact and rigid as possible. A heavy

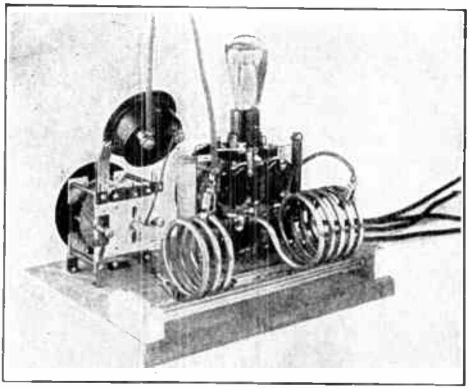


FIG. 268*a*. A Rear View of the "1929 Type" Low-Powered Hartley Photo. (Courtesy of QST.)

The tube socket being mounted on top of the plate tuning condenser, its plate and grid terminals are particularly convenient to the leads between the condenser and the coil on to which they are connected through the plate and grid condensers. And the left is the antenna tuning unit, consisting of a coil —which is moved along the glass rods for variation of antenna coupling—a condenser, and a thermo-couple ammeter. The meter, though mounted on the condenser, must be insulated from it. The plate choke can be seen between the two variable condensers. Aside from their use in supporting the antenna coil, the glass rods also serve to prevent the plate coil from vibrating.

flexible wire may be used for the filament lead to the inductance, a clip being permissible in this case on account of the low current to be passed by it.

The radio frequency choke coil can be made by winding 160 turns of No. 28 or 30 d.c.c. wire on a ¾-inch diameter wooden rod. The size of the wire and tube is not extremely critical and smaller wires and other size tubes may be employed. A small choke of 25 turns should be connected in the grid lead to prevent generation of a frequency which is controlled by the grid-to-plate capacity as discussed in Chapter V.

29. Tuning the Transmitter—When the transmitter has been assembled and all leads tightened up and made stationary the plate supply can be turned on and the filaments adjusted to 7½ volts. It is best to start at low power and with grid excitation giving half the rated plate current. The antenna coil should be disconnected during the preliminary adjustments for frequency and power. The ratio of turns between grid and filament clip and the turns between the plate and filament clip should be somewhere between 1 to 4 or 5.

After the primary or tank circuit has been adjusted to the desired frequency the antenna coil can be connected and coupled loosely to the tank circuit coil. A coupling of 4 or 5 inches will do for low power. After resonance is secured in the antenna circuit as indicated by maximum deflection of the antenna current meter (or by maximum brilliancy of a flashlight bulb in the antenna lead) the power can be increased and adjustments made for normal plate current. The antenna coupling should then be reduced and the circuits resonated until the antenna current is about 75 to 85 per cent of the peak value. The operator should listen in on his receiver for a harmonic of the transmitter in order to determine on which side of resonance the best note is secured. In most every case the correct adjustment will be obtained when the antenna is tuned to a lower frequency (a higer wavelength) than the tank circuit. Having determined this, the operator should make several test letters and note if the antenna meter follows the key and if it does not in all probability the antenna is too closely coupled to the tank circuit. Before calling a final check of the frequency should be made in order to insure that it is within the band authorized for amateur use.

30. Material and Parts Necessary to Build the Transmitter—

1 Acme 200 C.W. transformer 550–750 volts plate winding with oscillator and rectifier filament winding.
1 Acme 30 henry choke coil, 300 milliamperes capacity.
8 1 mfd. 1750-volt condensers.
1 Thermocouple ammeter, 0–1 amps.
1 Milliammeter, 0 to 200 milliamps.
1 0–15 a.c. voltmeter.

2 500 micro-microfarad receiver type variable condensers of good quality.
1 500 micro-microfarad fixed condenser.
1 250 micro-microfarad fixed condenser.
2 2000 micro-microfarad condensers.
3 UX sockets.
1 10,000 ohm grid leak tapped at 5000 ohms.
2 2 ohm rheostats each capable of handling 1.5 amperes without undue heating.
2 50, 100 or 200 ohm fixed resistors or Christmas tree lamps.
1 UX 210 power tube.
2 UX 281 half wave rectifier tubes.
1 Transmitting key.
25 feet of ¼-inch soft copper tubing.

Key filter material:
1 30 henry "B" eliminator choke.
1 2 mfd. condenser, 1000 volts.
1 1 mfd. condenser, 1000 volts.
1 double-pole, double-throw switch for a.c. voltmeter connections.

31. **The Antenna System**—The simplest and most easily adjusted antenna for this set is a simple antenna—counterpoise system, the fundamental wavelength of which is a bit higher than the working wave. While it is probable that surrounding conditions will influence your particular antenna, it is also probable that if it is in a fairly open space a length of 35 feet from the far end to where it connects to the set for the antenna and a similar length for the counterpoise will be about correct. This should give a system having a (loaded) fundamental of approximately 45 meters which will be about right for operation in the 40-meter band with a series condenser in the antenna lead. For work in the 80-meter band the antenna and counterpoise should each have a length of approximately 62 feet from the insulator at the far end up to the transmitter.

32. **Operating the Antenna on a Harmonic**—With the transmitter just described it was shown how the antenna system was excited at just below its loaded fundamental wavelength by employing an antenna series condenser. If it was desired to operate in the 20-meter band it would be necessary to shorten both antenna and counterpoise and retune the primary circuit. However, one may desire to work in both 40- and 20-meter band on the same antenna. This can be accomplished by harmonic excitation of the antenna and was first suggested to amateurs by

Boyd Phelps in QST of March, 1922, in an article entitled, "Radio Below 200 Meters."

Harmonic operation may be accomplished as follows: The antenna circuit of the transmitter is tuned to 40 meters as indicated by maximum glow of the flashlight bulb and remains as is. Adjustments are then made to the primary circuit until it is tuned to 20 meters, care being taken not to overload the tubes as indicated by excessive heating. When the primary circuit is tuned to approximately 20 meters the flashlight bulb will start to glow again and at a certain setting of the primary condenser may light nearly as bright as when the primary was operating at 40 meters. If the wavelength of the open circuit is measured it will indicate approximately 20 meters, showing that the antenna system is oscillating on its second harmonic frequency or one-half the wavelength of the fundamental. In a previous paragraph it was shown that it was undesirable to operate a Hertz system on an even harmonic as it was productive of a voltage loop at the center of the system which in most cases means at the coupling coil, thus producing losses. The logical thing then to do is to load the antenna circuit with inductance until it has a fundamental wavelength of 60 meters (the loading coil can be shortened out for 40-meter operation) and the primary tuned to 20 meters as before. When the flashlight bulb glows this time the system is operating on its third harmonic and should be very efficient in producing low angle radiation for long distance communication. One should not be deceived by the small antenna current when operating on a harmonic. Sometimes with no visible current it is possible to do wonderful DX work.

33. **Securing a License**—It is unlawful for anyone in the United States (including Alaska, Porto Rico, Virgin Islands and Hawaii) to operate a radio transmitter for the purpose of amateur communication or experimentation without first securing an operator's and station license. The applicant for an amateur first grade operator's license is required to be able to receive and transmit in the International Morse Code at the rate of ten words per minute, five letters to the word. In addition, a knowledge of the radio communication laws of the United States and International Convention is required.

Before applying for an operator's license the applicant should get a copy of the "Radio Act of 1927," obtainable for five cents (not in stamps) from the Superintendent of Documents, Government Printing Office, Washington, D. C., and study especially the following sections: Section 1; Section 5, paragraphs

C, D, E, F, G, and H; Section 11, paragraphs A and B; Section 12, paragraph 2; Section 20, Section 23, paragraph 2; Section 27, Section 28, Section 31, Section 32 and Section 33. The applicant is not required to quote word for word the text of these portions of the law, but should memorize the most important parts such as the requirements of a station operator upon hearing a distress call, penalty for transmission of a false distress call, secrecy of messages, the penalty for operating a station without an operator's or station license and penalty for violation of any regulation made by the licensing authority.

A copy of the International Radiotelegraph Convention should also be secured and those parts studied relative to procedure of calling and answering a station, and International regulations governing testing.

The United States and possessions are divided into nine radio districts, each district being presided over by a radio supervisor. A list of their addresses follows:

District.	Addresses.
1	Custom House, Boston, Mass.
2	Sub-Treasury Bldg., New York, N. Y.
3	Fort McHenry, Baltimore, Md.
4	Post Office Bldg., Atlanta, Ga.
5	Custom House, New Orleans, La.
6	Custom House, San Francisco, Calif.
7	L. C. Smith Bldg., Seattle, Wash.
8	Commerce Bldg., Detroit, Mich.
9	Engineering Bldg., Chicago, Ill.

Alaska is under the jurisdiction of the 7th district, Hawaii under the 6th, and the Virgin Islands and Porto Rico under the 4th district.

To apply for an operator's license write the Supervisor of Radio for the district in which you live (this information can be generally obtained from some amateur or broadcasting station in your city or town; if in doubt write to Chief, Radio Division, Department of Commerce, Washington, D. C., who will forward your communication to the right supervisor), requesting application forms for operator's license and the date and place nearest your location at which you may appear for examination. If an applicant lives in some remote town or city from the place of examination the supervisor will issue a temporary operator's license which is valid for a period not exceeding one year, providing he can send and receive at the required rate and has a knowledge of the laws and regulations. The holder of a temporary license is expected to appear during the year for a regular amateur class examination.

After securing the operator's license application should then be made to the same supervisor's office for forms for a station license which should be properly filled out by the applicant and the notary's oath executed and then forwarded to the supervisor who will then issue the station license and call letters.

Regulations governing the operation of amateur stations:

An amateur station is a station operated by a person interested in radio technique solely with a personal aim and without pecuniary interest. Amateur licenses will not be issued to stations of other classes.

Amateur radio stations are authorized for communication only with similarly licensed stations, except as indicated below, and on wavelengths or frequencies within the following bands:

Kilocycles.	Meters.	Kilocycles.	Meters.
401,000 to 400,000	0.7477 to 0.7496	8,000 to 7,000	37.5 to 42.8
64,000 to 56,000	4.69 to 5.35	4,000 to 3,500	75.0 to 85.7
30,000 to 28,000	9.99 to 10.71	2,000 to 1,500	150.0 to 200.0
16,000 to 14,000	18.7 to 21.4		

and at all times unless interference is caused with other radio services, in which event a silent period must be observed between the hours of 8:00 p.m. and 10:30 p.m., local time, and on Sundays during local church services.

Amateur radio telephone operation will be permitted only in the following bands:

Kilocycles.	Meters.
64,000 to 56,000	4.69 to 5.35
3,550 to 3,500	84.5 to 85.7
2,000 to 1,715	150.0 to 175.0

Amateur television and operation of picture transmission apparatus will be permitted only in the following bands:

Kilocycles.	Meters.
60,000 to 56,000	5.00 to 5.35
2,000 to 1,715	150.00 to 175.00

Spark transmitters will not be authorized for amateur use.

Amateur stations must use circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize key impacts, harmonics and plate supply modulations. Conductive coupling, even though loose, will NOT be permitted, but this restriction shall not apply against the employment of transmission line feeder systems to Hertzian antennas.

Amateur stations are not permitted to communicate with commercial or government stations unless authorized by the licensing authority except in an emergency or for testing purposes. This restriction does not apply to communication with small pleasure craft such as yachts and motor boats holding limited commercial station licenses which may have difficulty in establishing communication with commercial or government stations.

Amateur stations are not authorized to broadcast news, music, lectures, sermons or any form of entertainment, *or to conduct any form of commercial correspondence.*

No person shall operate an amateur station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

34. **Interference**—One of the most serious difficulties that an amateur encounters upon his entrance into the transmitting game is the matter of interference to broadcast listeners, better known to the amateur fraternity as B.C.L.'s.

The revised amateur regulations of March 6, 1928, require that a silent period be observed on all WAVELENGTHS between the hours of 8:00 p.m. and 10:30 p.m., local time, and on Sunday during local church services *if* interference is caused with other radio services. Therefore, if any amateur is informed by a B.C.L. or by a letter from the Supervisor of Radio that he is interfering with broadcast or other reception, he must immediately suspend operation of his transmitter during the hours from 8:00 p.m. to 10:30 p.m. local time.

35. **Key Thumps**—Key thumps, sometimes called key clicks, are one of the most prevalent causes of interference to broadcast reception by amateur transmitters. The thump or click is due to the sudden shocking of the tube caused by an instantaneous rush of high voltage to the tube when the key is closed and the inductive kick with accompanying spark discharge when the key is opened.

36. **Elimination**—Various devices have been devised by members of the A.R.R.L. towards eliminating this source of interference. One of the simplest means of doing this is by connecting a choke coil, condenser and resistance in the keying circuit. The keying is done in the center tap connection of the filament winding. See figure 269.

Radio frequency chokes in the 110-volt a.c. supply will also prevent considerable interference by choking out induced currents which might travel all over the neighborhood by means of these conductors.

Cooperation with B.C.L.'s—In the past it has been shown that cooperation between B.C.L.'s and the amateur helps tremendously towards solving the problem of interference. In most cases the Supervisor of Radio will furnish the amateur with the address of the complainant and request him to visit the latter at his convenience to ascertain the kind of receiver the B.C.L. is using and note the character of the interference.

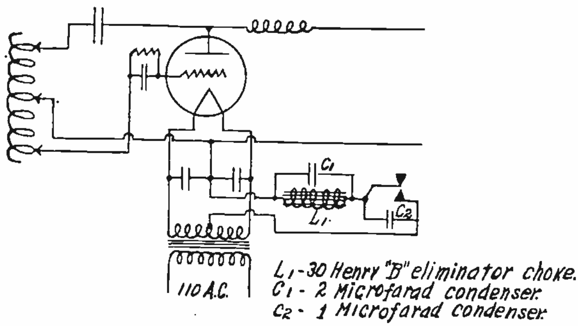


FIG. 269. Key Filter Circuit.

To make sure the interference is coming from the amateur transmitter he should arrange with another licensed amateur to come to his station and transmit a pre-arranged signal while he is at the home of the B.C.L., or tell the B.C.L. to listen for a certain character. If the interference is recognized as coming from the transmitter the owner of the same should recommend to the B.C.L. a means of making his receiver more selective, such as the employment of a wave trap, cutting down the length of the antenna or revamping the circuit in the receiver. On the other hand, if the interference is of the inductive type such as originates from street cars, motors, generators, faulty insulation of power lines, heating pads, electric signs, violet ray, and X-ray machines, battery chargers of the vibrator type, precipitators and other industrial devices, the amateur should so inform the B.C.L. and explain to him how interference is generated by these devices and recommend a method of locating and remedying the same and offering to assist in this procedure if convenient. Of the hundreds of complaints made by broadcast listeners to the Federal Radio Commission or Supervisor of Radio in which amateurs are accused of creating certain disturbance to broadcast reception it has been found upon investigation that in the majority of cases the interference was caused by one or more of the devices of the type listed above and that interference caused by amateur transmission is a rare occurrence, especially so with the increased use of modern selective receivers employed for broadcast reception.

37. The American Radio Relay League—Every amateur should join the American Radio Relay League which is a non-commercial association of radio amateurs, bonded for the promo-

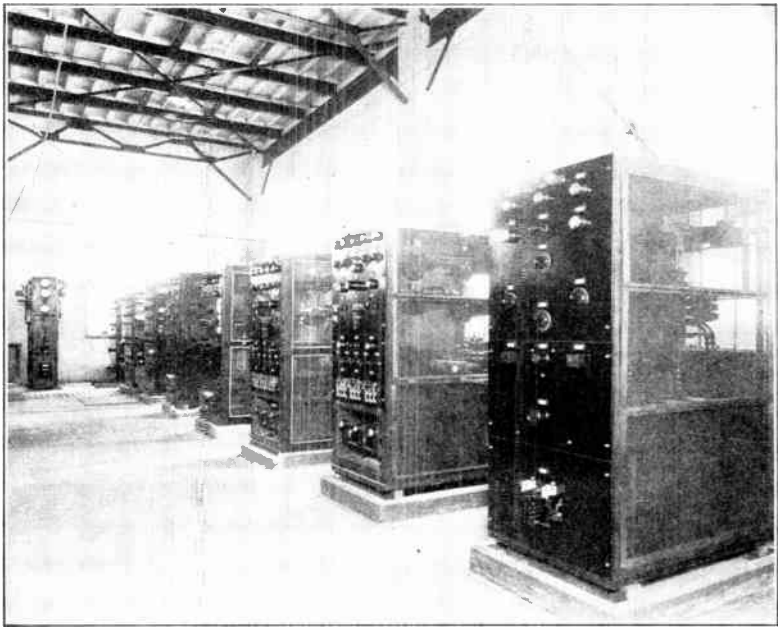


FIG. 270. A Group of High Frequency Transmitters Operated by the Radio Corporation of America at Rocky Point, L. I.

tion of interest in amateur radio communication and experimentation, for the relaying of messages by radio, for the advancement of the radio art, and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

Of, by and for the amateur, it numbers within its ranks practically every worth-while amateur in the world and it can be truly said that it has a history of glorious achievement as the standard-bearer in amateur affairs.

The only essential qualification for membership is a bona fide interest in amateur radio. Ownership of a transmitting station and knowledge of the code are not prerequisite. Membership in the league entitles one to a year's subscription to QST, a monthly publication describing the activities of amateur transmission, and technical articles dealing with the latest developments of the radio art. Correspondence should be addressed to the Secretary, Executive Headquarters, Hartford, Conn.

CHAPTER 15

RADIO LAWS OF THE UNITED STATES AND INTERNATIONAL TELEGRAPHIC CONFERENCE

1. **Introduction**—In the United States we have two radio acts as enacted by Congress, one of which is designed to promote safety at sea through the employment of apparatus and operators to transmit and receive distress calls and other calls relating to perils and aids to navigation. It is known as the Ship Act and is quoted here exactly as enacted by Congress and approved July 23, 1912, to amend Section I of an act entitled, "An Act to Require Apparatus and Operators for Radio Communication on Certain Steamers," approved June 24, 1910. The amended act applies to vessels licensed to carry as well as those actually carrying 50 or more persons, etc.

Following the quotation of this Ship Act there will be found certain regulations which have been established by the Secretary of Commerce in order to secure the proper execution of this act by officers of the Radio Division, Department of Commerce.

Ship Act of July 23, 1912.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, . . .

"Section 1. That from and after October first, nineteen hundred and twelve, it shall be unlawful for any steamer of the United States or of any foreign country navigating the ocean or the Great Lakes and licensed to carry, or carrying, fifty or more persons, including passengers or crew of both, to leave or attempt to leave any port of the United States unless such steamer shall be equipped with an efficient apparatus for radio communication, in good working order, capable of transmitting and receiving messages over a distance of at least one hundred miles, day or night.

2. "**Auxiliary Power**—An auxiliary power supply, independent of the vessel's main electric power plant, must be provided which will enable the sending set for at least four hours to send messages over a distance of at least one hundred miles, day or night, and efficient communication between the operator in the radio room and the bridge shall be maintained at all times.

3. "**Operators and Penalty**—The radio equipment must be in charge of two or more persons skilled in the use of such apparatus, one or the other of whom shall be on duty at all times while the vessel is being navigated. Such equipment, operators, the regulation of their watches, and the transmission and receipt of messages, except as may be regulated by law or international agreement, shall be under the control of the master, in the case of a vessel of the United States; and every willful failure on the part of the master to enforce at sea the provisions of this paragraph as to equipment, operators, and watches shall subject him to a penalty of one hundred dollars.

"That the provisions of this section shall not apply to steamers plying between ports, or places, less than two hundred miles apart.

4. "**Cargo Operators**—Section 2. That this Act, so far as it relates to the Great Lakes, shall take effect on and after April first, nineteen hundred and thirteen, and so far as it relates to ocean cargo steamers shall take effect on and after July first, nineteen hundred and thirteen: Provided, That on cargo steamers, in lieu of the second operator provided for in this Act, there may be substituted a member of the crew or other person who shall be duly certified and entered in the ship's log as competent to receive and understand distress calls or other usual calls indicating danger, and to aid in maintaining a constant wireless watch so far as required for the safety of life."

The remaining sections of the act of June 24, 1910, which are unchanged, read as follows:

5. "**Intercommunication**—Sec. 2. That for the purpose of this Act apparatus for radio communication shall not be deemed to be efficient unless the company installing it shall contract in writing to exchange, and shall, in fact, exchange, as far as may be physically practicable, to be determined by the master of the vessel, messages with shore or ship stations using other systems of radio communication.

6. "**Penalty**—Sec. 3. That the master or other person being in charge of any such vessel which leaves or attempts to leave any port of the United States in violation of any of the provisions of this Act shall, upon conviction, be fined in a sum not more than five thousand dollars, and any such fine shall be a lien upon such vessel, and such vessel may be libeled therefore in any district court of the United States within the jurisdiction of which such vessel shall arrive or depart, and the leaving or at-

tempting to leave each and every port of the United States shall constitute a separate offense.

"Sec. 4. That the Secretary of Commerce shall make such regulations as may be necessary to secure the proper execution of this Act by collectors of customs and other officers of the Government."

7. **Regulations Applied to Ship Stations Governed by the Ship Act of 1912**—1. On vessels coming under the ship act, an emergency power supply, independent of the vessel's main electric power plant, must be provided which will enable radio messages to be sent for at least four hours over a distance of at least 100 miles day or night. The emergency power supply and equipment should be located and installed in such manner as to afford maximum protection against accident.

2. The radio transmitting apparatus, operated from the emergency power supply, should be capable of functioning within two minutes after unexpected notice to the operator.

3. The complete equipment must be maintained in an efficient condition at sea.

4. The complete emergency equipment should be tested before each sailing and daily at sea by the operator or an inspector and a note of its performance entered in the radio log.

5. Radio inspectors or other duly authorized officers of the Government will occasionally call for test messages, to be sent by means of the emergency apparatus, while the vessel is at sea.

6. An "induction coil" connected to "plain aerial" is not recommended as emergency apparatus, on account of the high voltages produced which frequently damage the antenna insulation and on account of "vibrator troubles."

7. A motor generator or rotary converter operated by storage battery is probably the most satisfactory means available at present of energizing the transmitting apparatus.

8. Any auxiliary engine for wireless purposes must operate on a fuel which will fulfill the requirements of Rule XI, Section 5, of the General Rules and Regulations of the Steamboat-Inspection Service.

9. Every ship station shall carry a reasonable number of spares of such parts of both the main and emergency radiotelegraph equipments as are subject to undue wear, deterioration, or liability to accident.

10. One extra pair of head telephones, extra cords, and extra detectors must always be kept on hand.

11. A storage battery voltmeter, hydrometer, a supply of elec-

trolyte, and distilled water should be a part of the regular equipment, but are not prescribed in terms by statute. The absence of these and similar inexpensive emergency articles will be brought to the attention of the master and of the company installing the apparatus by the radio inspector, in writing, and if after a reasonable interval they have not been supplied, the inspector will communicate the fact to the Commissioner of Navigation.

12. The vessel's electric power for the operation of the main equipment shall, at all times while the steamer is under way, be available for the radio operator's use. On steamers where the dynamo is not run continuously there should be an efficient means of communication between the radio room and the dynamo room, in order that the radio operator may signal for power, as the law provides that he may not leave his post of duty.

13. Efficient communication between the radio room and the bridge must be maintained. A speaking tube or telephone will comply with this requirement. A bell and messenger service will not be acceptable unless there are special conditions justifying this equipment. The speaking tube or telephone must terminate in the radio room and on the bridge, or in the chart room if readily accessible from the bridge. If the radio room is adjacent to or accessible from the bridge so that orders may be transferred direct, no means of communication will be required. Any arrangement calling for the services of a third person to transmit the message will not be satisfactory. The radio inspectors will notify the ship authorities whether the means of communication provided is satisfactory at the time of inspection.

14. On vessels of the United States it is the statutory duty of the master to see that one operator is on duty at all times. The radio service of the ship is under the supreme authority of the master.

15. Masters should require operators on duty to communicate with the officer on the bridge every half hour.

16. Operators must make entries on the radio log *every* 15 minutes, as evidence that a continuous watch is being maintained. The entries must, if possible, consist of call letters of other stations communicating and a few words of the intercepted messages.

17. When vessels are in port the key to the radio room must at all times be on board in charge of the proper officer and the radio equipment shall be in such condition as to facilitate government inspection.

8. Reporting of Violations—The regulations established by law, or by the authority of law, or of the International Convention, will be enforced by the Secretary of Commerce through collectors of customs, radio inspectors, and other officers of the government.

The service regulations of the radiotelegraphic convention in force provide that "no station on shipboard shall be established or worked by private enterprise without authority from the government to which the vessel is subject." Such authority shall be in the nature of a license issued by said government. Stations on foreign ships will be licensed by their governments, respectively. Inspectors will report to the Commissioner of Navigation stations on foreign ships not so licensed.

A radio inspector is authorized in exceptional cases to act outside of his district for the convenience of commerce. In such cases he will communicate before or after acting with the inspector in whose district he has acted. Radio inspectors are authorized to communicate directly with collectors of customs and to cooperate with them in the enforcement of the law.

Violations of the laws and regulations will be reported to the chief customs officer of the district in which the offense occurs, who will report the case to the Secretary of Commerce (Bureau of Navigation), according to the procedure followed in violations of the navigation laws. Misdemeanors will be reported to the United States district attorney in the usual manner.

Collectors of customs and radio inspectors are enjoined that the reports required by paragraph 170 must be precise statements of the facts as the basis for possible proceedings by the United States attorney.

Violations by the master of a vessel of the United States of the provisions of the second paragraph of section 1 of the Ship Act will be reported to the collector of customs directly, and the usual procedure in cases of fines and penalties will be followed.

9. **Inspection of Ship Stations**—The radio inspectors and customs officers, as far as practicable, shall visit steamers subject to the act before they leave port and ascertain if they are equipped with the apparatus in charge of the operators prescribed by law and regulation.

When the radio apparatus is certified as complying with the requirements of law by the competent authorities of a foreign government, such certificate will be recognized by this department, but the radio inspector or customs officer may, if he deem it necessary or desirable, satisfy himself that the apparatus is in good working order.

Whenever practicable, the radio inspector shall satisfy himself on his visit before the departure of a steamer subject to the act of June 24, 1910, as amended July 23, 1912, that the radio apparatus is efficient and in good working order within the meaning of the act. If the apparatus does not comply with the law, the radio inspector will furnish the master with the stub of Form 771, "Inspection Record," on which will be noted the particulars in which the apparatus does not comply with the law. Where apparatus is found to be in compliance with the law, the stub of Form 771 will not be detached.

Masters of vessels entering a port of the United States and expecting to leave under the act of June 24, 1910, as amended July 23, 1912, should file Form 753a, "Radio Declaration" (Appendix A) in duplicate with the customs officer at the time of entry. The customs officer will furnish one copy to the radio inspector in order that proper inspection of the radio equipment may be made before departure.

For each departure of a steamer under the act of June 24, 1910, as amended July 23, 1912, the master is required to furnish to the customs officer a certificate in the form of Appendix B (Form 753b), "Master's Certificate of Radio Apparatus." Such certificates shall be retained in the files of the collectors of customs. The collector of customs will arrange for the collection of these certificates at all times.

Where a steamer subject to the radio law is without the apparatus and the operators prescribed, or either of them, and is about to attempt to leave port, the radio inspector or customs officer visiting the vessel shall (*a*) furnish the master with a memorandum (stub of Form 771) of the particulars in respect of which the law has not been complied with and the penalty; (*b*) if convenient, notify the vessel's agents or the proper person in charge of the apparatus so that the necessary corrections may be made before sailing.

If a steamer clears in violation of the law, the radio inspector or customs officer shall submit to the collector of customs of the port a written report, stating the exact nature of the violation, the section of the act violated, and the penalties involved and all of the circumstances in connection therewith which will be of service to the collector and to the Secretary of Commerce in determining what action shall be taken. A copy of the report will be forwarded to the Commissioner of Navigation.

Statements should be obtained from operators, ships' officers, or other witnesses at the time the violation is discovered and should accompany the report to the collector of customs.

The collector of customs will report the case to the Secretary of Commerce in the usual manner as a navigation fine case.

Merchant vessels chartered by the United States Government are subject to the act of 1927, in every case, if the radio apparatus is owned and operated by a commercial company.

Merchant vessels chartered by the United States Government for the transportation of persons or supplies are subject to the requirements of the Ship Act (act of July 23, 1912), if the vessel is controlled and operated by the owners. Vessels commanded wholly or in part by government officers are not subject to the Ship Act.

Government vessels or vessels chartered by the government are subject to the act of 1927, if the radio equipment is owned and operated by private interests.

The Ship Act does not authorize the refusal of clearance in case of violation of its provisions, but specifically provides for the imposition of a fine in a sum not more than $5,000.

The act does not apply to a vessel at the time of entering a port of the United States. Radio inspectors and customs officers may, however, accept as evidence of the efficiency of the apparatus and the skill of an operator messages shown to have been transmitted and received by him over a distance of at least 100 miles, by day, during the voyage to the United States.

10. **Operators on Foreign Vessels**—The act of July 23, 1912 amending the act of June 24, 1910, is designed to promote safety at sea through the employment of apparatus and operators to transmit and receive distress calls and other calls relating to perils and aids to navigation. It provides that in the case of American and foreign vessels subject to its provisions "the radio equipment must be in charge of two or more persons skilled in the use of such apparatus." This act does not require that the operators shall be licensed and the penalty prescribed in Section 3 of the act is not incurred by the master of a vessel whose operators are "skilled in the use of such apparatus," even though they may not be licensed.

The International Radiotelegraphic Convention (Service Regulations) provides that the service of the station on shipboard shall be carried on by a telegraph operator holding a certificate issued by the government to which the vessel is subject.

The act of July 23, 1912, as stated, requires that on foreign ships the operators must be "skilled in the use of such apparatus," but does not require that they must be licensed. To facilitate commerce and simplify administration, operators presenting Amercan licenses or foreign certificates are accepted as "skilled in he use of such apparatus," except where there may be special 'easons to doubt the operator's skill or reliability. Where op- :rators on American or foreign ships do not have such licenses ›r foreign certificates, radio inspectors or customs officers under he act of July 23, 1912, may accept other competent evidence of .kill or may examine such operators.

11. **The Radio Act of 1927**—The Radio Act of 1927 became :ffective February 23, 1927, and was enacted primarily for the egulation of "all forms of interstate and foreign radio trans- nissions and communications within the United States, terri- ories and possessions; to maintain the control of the United States over all the channels of interstate and foreign radio trans- nission; and to provide for the use of such channels, but not the ›wnership thereof, by individuals, firms or corporations, for lim- :ed periods of time, under licenses granted by Federal authority, nd no such license shall be construed to create any right, beyond he terms, conditions, and periods of the license.

It provided for the creation of a body of five members known s the Federal Radio Commission. Briefly, the duties of the Com- nission are to (*a*) classify radio stations; (*b*) prescribe the ature of the service to be rendered by each class of licensed sta- :ons; (*c*) assign bands of frequencies or wavelengths to the arious classes of stations, and individual stations, and determine he power which each station shall use and the time during which : may operate; (*d*) determine the location of classes of stations or ndividual stations; (*e*) regulate the kind of apparatus to be used vith respect to its external effects and the purity and sharpness f the emissions from each station and from the apparatus there- n; (*f*) make such regulations not inconsistent with law as it nay deem necessary to prevent interference between stations and o carry out the provisions of this act with certain provisions, tc. Authority is also granted for various other purposes which re of little interest to the commercial operator.

12. **Duties of the Secretary of Commerce**—Quoting from Section 5 of the act: From and after one year after the first neeting of the Commission created by this act, all the powers and uthority vested in the Commission under the terms of this act, xcept as to the revocation of licenses, shall be vested in and xercised by the Secretary of Commerce; except that thereafter ne Commission shall have power and jurisdiction to act upon nd determine any and all matters brought before it under the :rms of this section.

It shall also be the duty of the Secretary of Commerce:

(*a*) For and during a period of one year from the first meeting of the Commission created by this act, to immediately refer to the Commission all applications for station licenses or for the renewal or modification of existing station licenses.[1]

(*b*) From and after one year from the first meeting of the Commission created by this act, to refer to the Commission for its action any application for a station license or for the renewal or modification of any existing station license as to the granting of which dispute, controversy, or conflict arises or against the granting of which protest is filed within ten days after the date of filing said application by any party in interest and any application as to which such reference is requested by the applicant at the time of filing said application.

(*c*) To prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such persons as he finds qualified.

(*d*) To suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy him that the license (*a*) has violated any provision of any act or treaty binding on the United States which the Secretary of Commerce or the Commission is authorized by this act to administer or by any regulation made by the Commission or the Secretary of Commerce under any such act or treaty; or (*b*) has failed to carry out the lawful orders of the master of the vessel on which he is employed; or (*c*) has willfully damaged or permitted radio apparatus to be damaged; or (*d*) has transmitted superfluous radio communications or signals or radio communication containing profane or obscene words or language; or (*e*) has willfully or maliciously interfered with any other radio communications or signals.

(*e*) To inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this act, the rules and regulations of the licensing authority, and the license under which it is constructed or operated.

(*f*) To report to the Commission from time to time any violations of this act, the rules, regulations, or orders of the Commission, or of the terms or conditions of any license.

(*g*) To designate call letters of all stations.

(*h*) To cause to be published such call letters and such other announcements and data as in his judgment may be required for

[1] Congress has since extended the life of the Commission until March 16, 1929.

the efficient operation of radio stations subject to the jurisdiction of the United States and for the proper enforcement of this act.

The Secretary may refer to the Commission at any time any matter the determination of which is vested in him by the terms of this act.

Any person, firm, company, or corporation, any State or political division thereof aggrieved or whose interests are adversely affected by any decision, determination, or regulation of the Secretary of Commerce may appeal therefrom to the Commission by filing with the Secretary of Commerce notice of such appeal within thirty days after such decision or determination or promulgation of such regulation. All papers, documents, and other records pertaining to such application on file with the Secretary shall thereupon be transferred by him to the Commission. The Commission shall hear such appeal de novo under such rules and regulations as it may determine.

Decisions by the Commission as to matters so appealed and as to all other matters over which it has jurisdiction shall be final, subject to the right of appeal herein given.

No station license shall be granted by the Commission or the Secretary of Commerce until the applicant therefor shall have signed a waiver of any claim to the use of any particular frequency or wavelength or of the ether as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

Section 1 of this act shall not apply to any person, firm, company, or corporation sending radio communications or signals on a foreign ship while the same is within the jurisdiction of the United States, but such communications or signals shall be transmitted only in accordance with such regulations designed to prevent interference as may be promulgated under the authority of this act.

Such station licenses as the licensing authority may grant shall be in such general form as it may prescribe, but each license shall contain, in addition to other provisions, a statement of the following conditions to which such license shall be subject:

(*a*) The station license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies or wavelength designated in the license beyond the term thereof nor in any other manner than authorized therein.

(*b*) Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of this act.

(*c*) Every license issued under this act shall be subject in terms to the right of use or control conferred by Section 6 hereof.

Section 12. The station license required hereby shall not be granted to, or after the granting thereof such license shall not be transferred in any manner, either voluntarily or involuntarily, to (*a*) any alien or the representative of any alien; (*b*) to any foreign government, or the representative thereof; (*c*) to any company, corporation, or association organized under the laws of any foreign government; (*d*) to any company, corporation, or association of which any officer or director is an alien, or of which more than one-fifth of the capital stock may be voted by aliens or their representatives or by a foreign government or representative thereof, or by any company, corporation, or association organized under the laws of a foreign country.

The station license required hereby, the frequencies or wavelength or lengths authorized to be used by the licensee, and the rights therein granted shall not be transferred, assigned, or in any manner, either voluntarily or involuntarily, disposed of to any person, firm, company, or corporation without the consent in writing of the licensing authority.

Section 18. If any licensee shall permit any person who is a legally qualified candidate for any public office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the licensing authority shall make rules and regulations to carry this provision into effect: Provided, That such licensee shall have no power of censorship over the material broadcast under the provisions of this paragraph. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

Section 19. All matter broadcast by any radio station for which service, money, or any other valuable consideration is directly or indirectly paid, or promised to or charged or accepted by, the station so broadcasting, from any person, firm, company, or corporation, shall, at the time the same is so broadcast, be announced as paid for or furnished, as the case may be, by such person, firm, company, or corporation.

Section 20. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

Section 22. The licensing authority is authorized to designate from time to time radio stations the communications or signals of which, in its opinion, are liable to interfere with the transmission or reception of distress signals of ships. Such stations are required to keep a licensed radio operator listening in on the wavelengths designated for signals of distress and radio communications relating thereto during the entire period the transmitter of such station is in operation.

Section 23. Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency or wavelength specified by the licensing authority, with apparatus capable of transmitting and receiving messages over a distance of at least one hundred miles by day or night. When sending radio communications or signals of distress and radio communications relating thereto, the transmitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference which may thus be caused.

All radio stations, including government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies or wavelengths which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, shall assist the vessel in distress, so far as possible, by complying with its instructions.

Section 24. Every shore station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

Section 25. At all places where government and private or commercial radio stations on land operate in such close proximity that interference with the work of government stations cannot be avoided when they are operating simultaneously such private or commercial stations as do interfere with the transmission or reception of radio communications or signals by the government stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time.

The government stations for which the above-mentioned division of time is established shall transmit radio communications or signals only during the first fifteen minutes of each hour, local standard time, except in case of signals or radio communications relating to vessels in distress and vessel requests for information as to course location, or compass direction.

Section 26. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

Section 27. No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substance, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: Provided, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

Section 28. No person, firm, company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

Section 29. Nothing in this act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Section 31. The expression "radio communication" or "radio communications" wherever used in this act means any intelligence, message, signal, power, pictures, or communication of any nature transferred by electrical energy from one point to another without the aid of any wire connecting the points from and at which the electrical energy is sent or received and any system by means of which such transfer of energy is effected.

Section 32. Any person, firm, company, or corporation failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the authority of this act or of any international radio convention or treaty ratified or adhered to by the United States, in addition to any other penalties provided by law, upon conviction thereof by a court of competent jurisdiction, shall be punished by a fine of not more than $500 for each and every offense.

Section 33. Any person, firm, company, or corporation who shall violate any provision of this act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by this act, or shall knowingly swear falsely to a material matter in any hearing authorized by this act, upon conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than $5,000 or by imprisonment for a term of not more than five years or both for each and every such offense.

Section 34. The trial of any offense under this act shall be in the district in which it is committed; or if the offense is committed upon the high seas, or out of the jurisdiction of any particular State or district, the trial shall be in the district where the offender may be found or into which he shall be first brought.

Regulations Governing the Issuance of Radio Operators' Licenses.

13. **Commercial Extra First Class**—To be eligible for examination applicants for this class of license must have held a commercial first class license, and must have been actually engaged as an operator at stations open to public correspondence for at least 18 months during the two years previous to his application.

A speed in transmission and reception of at least 30 words per minute, Continental Morse Code, and 25 words per minute, American Morse Code (five characters to the word), must be attained, the American Morse Code to be copied on a sounder.

Holders of licenses of this class are authorized to operate any licensed radio station.

14. **Commercial First Class**—Applicants for this class of license must pass a code test in transmission and reception at a speed of at least 20 words per minute in Continental Morse Code (five characters to the word).

The practical and theoretical examination shall consist of comprehensive questions under the following headings:

	Credits
(a) Experience	20
(b) Diagram of receiving and transmitting apparatus	10
(c) Transmitting apparatus	20
(d) Receiving apparatus	20
(e) Operation and care of storage batteries	10
(f) Motors and generators	10
(g) International Regulations governing Radio Communication and the United States Radio Laws and Regulations	10
	100

A percentage of 75 will constitute a passing mark for this class of license.

Holders of this class of license are authorized to operate any licensed radio station.

An applicant's experience will be determined from a personal question sheet and from satisfactory letters or references submitted, on the following basis: Three months' or more experience as a licensed operator at a commercial station handling traffic by means of the Continental Code or as an operator at a United

States Government station handling commercial traffic, full credit, 20 per cent. Less than three months' service at a commercial station, 10–15 per cent at the discretion of the examining officer. Graduates who present satisfactory letters from recognized radio schools, other than correspondence schools, which are equipped with modern radio apparatus for the practical instruction of students, 10 per cent. Experience as a licensed operator at a first class amateur station and graduates from correspondence schools, 5 per cent.

15. **Commercial Second Class**—Applicants for this class of license must pass a code test in transmission and reception at a speed of at least 12 words per minute in Continental Morse Code (five characters to the word).

The practical and theoretical examination will cover the same subjects as required for the first class license.

A percentage of 65 will constitute a passing mark.

Holders of this class of license are authorized to operate only licensed radio stations not open to general public correspondence. (See amendment.)

Applicants desiring to operate broadcasting stations only will be given an examination pertaining specifically to broadcasting apparatus. (See amendment.) The license will show on the face this limitation. (See amendment.)

Credit for experience is rated as follows: Three months' service under a commercial operator's license at any class of commercial stations, including broadcasting stations, full credit of 20 per cent. Holders of commercial licenses having less than three months' commercial experience, instructors of recognized radio schools and of radio courses at colleges, operators having only experience at Federal Government stations not open to general public service, 15 per cent. Graduates of resident radio schools, those having had special training at colleges and holders of amateur first grade licenses, 10 per cent. Correspondence school graduates, 5 per cent.

16. **Operator Permits**—In special cases where no interference with communications of other stations is involved, consideration will be given to applications for the operation of particular stations, without technical examination.

17. **Amateur License**—Applicants for this grade of license must pass a code test in transmission and reception at a speed of at least 10 words per minute in Continental Morse Code (five characters to the word).

An applicant must pass an examination which will develop knowledge of the adjustment and operation of the apparatus which he desires to use and of the International Regulations and Acts of Congress insofar as they relate to interference with other radio communications and impose duties on all classes of operators.

A percentage of 70 will constitute a passing mark.

This license is valid for the operation of licensed amateur radio stations only.

18. **Temporary Amateur Licenses**—Amateurs who cannot be examined at time of application may be given temporary licenses valid for the operation of a particular station until such time as examination for a regular license can be held, but not to exceed a period of one year.

18a. **Amateur Extra First Grade**—Licenses of this grade will be issued to persons passing the required special examination with percentage of at least seventy-five and code speed in sending and receiving at least twenty words a minute, five characters to the word; who have had at least two years' experience as licensed radio operators; and who have not been penalized for violation of the radio laws subsequent to the date of these regulations.

19. **Renewals—Commercial Extra First Class**—These licenses may be renewed without examination, provided the records show 12 months' satisfactory service in a land or ship station open to general public service, at least 6 months of which must have been during the last 12 months of license period. Holders of these licenses employed as radio inspectors, radio instructors, or in similar occupations requiring exceptional qualifications where the duties require the testing, or demonstrating, or otherwise using commercial radio apparatus and the telegraph codes, may be issued renewals of their licenses without examination, provided such employment has covered a period of 18 months out of the two-year license period. Where the applicant has not regularly used the telegraph codes he will be given the code examination as for an original license, and if he has used only one code he will be examined in the code not used.

20. **Other Renewals**—Renewal licenses may be issued to operators of other classes without examination, provided the operator has had three months' satisfactory service during the last six months of the license term. One year satisfactory service out of two years of the license term may be accepted for renewal at the discretion of the examining officer.

21. **Amendment to Regulations Governing the Issuance of**

Radio Operator Licenses—Under Section 3, amend the fourth and fifth paragraphs to read as follows:

Holders of this class of license are authorized to operate only licensed radio stations not open to general public correspondence. This fact should be indicated by having all licenses of this class bear across their face, preferably in red, the following restriction: "This license not valid for the operation of any general public service station."

Applicants desiring to operate broadcasting stations only will be given an examination pertaining specifically to broadcasting apparatus. The licenses so issued will indicate this limitation by showing across their face, preferably in red, the following restriction: "This license valid only for the operation of a broadcasting station."

Under Section 7, add the following:

Holders of commercial first class radio operator licenses who have not had sufficient service at commercial stations to permit the unconditional renewal of such licenses but indicate satisfactory service at broadcasting stations for the length of time necessary for renewal and are unable to pass the required code test or to present themselves for a code test may be issued restricted renewals of their existing licenses. The licenses so issued should bear across their face, preferably in red, the following restriction: "This license not valid for the operation of any limited or general public service station."

Holders of commercial second class radio operator licenses who have passed the regular commercial second class examination but have not had sufficient service at stations regularly using the Continental Code to permit unconditional renewal of such licenses, but indicate satisfactory service at broadcasting stations for the length of time necessary for renewal and are unable to pass the required code test or to present themselves for a code test, may be issued restricted renewals of their existing licenses. The licenses so issued should bear across their face, preferably in red, the following restriction: "This license not valid for the operation of any limited or general public service station."

Applicants holding restricted commercial operators' licenses or broadcast operators' licenses ay be issued renewals of such licenses provided the service records indicate three months' satisfactory service during the last six months of the license term. One year satisfactory service out of the two-year term of the license may be accepted at the discretion of the examining officer. Renewal commercial class licenses so issued should bear the endorsement "This license not valid for the operation of any limited or general public station" and renewal broadcast licenses should bear the endorsement "Valid only for the operation of a broadcasting station."

Applicants who have passed the regular commercial examination but who hold renewal licenses "This license is not valid for the operation of any limited or general public service station" may be issued unconditional renewals of such licenses, provided they have the required service as indicated above, and pass the code test required by the regulations for the class of license held by them.

22. Service—Service obtained at a station other than that licensed by the United States Government cannot be considered as sufficent for renewal. Holders of American licenses operating on foreign vessels cannot have this service credited for renewal of license.

Renewal of commercial licenses by applicants operating in the Federal Service at stations which do not require licensed operators, may have such experience accepted for renewal in the usual manner provided the stations at which applicants have been operating are open to public correspondence.

Operators employed in commercial land stations engaged in point to point service may secure renewal of their licenses in the usual manner, providing they have the same responsibility in care of apparatus and the apparatus is similar to that employed on shipboard and the service is conducted in like manner.

Application for renewal must be made before date of expiration of the license, preferably within two or three weeks prior to the date of expiration. An operator employed on a ship whose license expires at sea is required to submit an affidavit attesting to that fact. This affidavit may be submitted to the Radio Division through the supervisor of radio or examining officer, attesting to the facts, which will be considered by the Radio Division, which will advise the supervisor of radio or examining officer in regard to the issue of a renewal of the license without examination. An operator who is about to leave on a trip, during which time his license will expire, should make application for renewal prior to sailing, providing the date of expiration is within one month from the date of sailing. An affidavit is also required of an applicant requesting a duplicate license to replace one that has become lost or destroyed.

Service records must be completed and signed only by masters, employers of the duly authorized of either.

Any improper alteration of the service record or the forgery of masters' or employers' signature constitutes a violation of the regulations, and the operator may suffer suspension of license for a period not exceeding one year, at the discretion of the Secretary of Commerce.

23. **Re-examination**—An applicant for commercial radio operator's license who fails to pass the examination may be examined at the same sitting for a commercial operator's license of a lower grade. Should he fail to make immediate application for examination in the lower grade, he should be required to wait three months before again making application for a commercial operator's license.

The ranking order of commercial operator's license is as follows:

Commercial extra first,
Commercial first,
Commercial second,
Commercial second—authorizing operation of broadcast stations only.

All examination papers, except amateur, whether the applicant qualified or not, will be forwarded to the Department of Commerce, Radio Division, for filing.

Applicants preparing for the commercial first class examination should learn to draw a diagram of a modern shipboard transmitter and receiver with an auxiliary power supply capable of operating the transmitter for four hours. Figure 178 in Chapter 8 will meet this requirement. Any of the other complete tube transmitter circuits shown in that chapter combined with receiver, auxiliary batteries and charging circuit will likewise do.

In order to be able to answer the questions given under "Transmitting Apparatus" the applicant should study chapters 1, 2, 5, 8, 9, 10, and 11. A knowledge of the operation of the various systems as described in these chapters is essential.

In the subject of receiving questions, chapters 1, 4, 7, and 12 should be studied, especially chapters 4 and 7.

Sufficient information relative to motors and generators is given in chapter 2; storage batteries and charging circuits in chapter 3; and Radio Laws and Regulations in chapter 15.

The abbreviated "Q" signals should be learned and the applicant able to give fifteen and their meaning.

Applicants desirous of taking the commercial second class examination are required to have a knowledge of the same subjects, but not so comprehensive in scope.

The applicants who desire to secure an operator's license to operate a broadcasting station should be able to draw the diagram of a complete radiotelephone transmitter as shown in chapter 6 or 9. Chapters 4, 5, 6 and 9 should be studied in detail. Knowledge of the various tube transmitting circuits, modulating systems, harmonic suppressors, etc., are essential. A knowledge of the care and operation of motor generators and storage batteries is also required. The radio laws should be studied with especial attention to the important regulations issued by the Federal Radio Commission governing broadcast stations.

Applicants taking the amateur first class examination are required to draw a diagram of the transmitting and receiving set they propose to operate. An explanation is required as to how the transmitter generates radio frequency oscillations and how they are detected and made audible at the receiving station. The applicant should describe how he places this apparatus in operation for transmitting and receiving. The radio laws should be studied giving special attention to those sections pertaining to interference, secrecy of messages, signals of distress, false signals and calls, operating without an operator's or station license, and the penalties involved for those convicted of violation of these laws and regulations. Sufficient information is contained in chapters 14 and 15 to enable an applicant to prepare himself for the amateur first class license. Article 5 Ter quoted below should also be studied by all amateurs prior to taking examination for the first class or Extra first class amateur operator's license. The article follows:

ARTICLE 5 TER (INTERNATIONAL RADIOTELEGRAPH CONVENTION)

5. (1) The exchange of communications between private experimental stations of different countries shall be forbidden if the Administration of one of the interested countries has given notice of its opposition to this exchange.

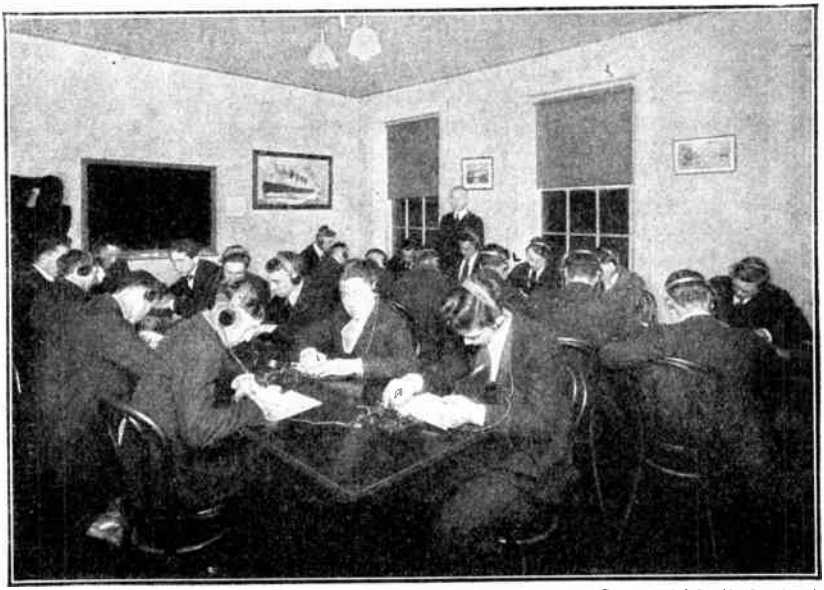
(2) When this exchange is permitted the communications must, unless the interested countries have entered into other agreements among themselves, be carried on in plain language and be limited to messages bearing upon the experiments and to remarks of a private nature for which, by reason of their unimportance, recourse to the public telegraph service might not be warranted.

(3) In a private experimental station authorized to carry on transmission any person operating the apparatus, either on his own account or for another, must have proved his ability to transmit text in International Morse Code signals and to read by ear texts

thus transmitted. He can be replaced only by authorized persons possessing the same qualifications.

(4) Administrations shall take such measures as they deem necessary to verify the qualifications, from a technical point of view, of all persons handling the apparatus.

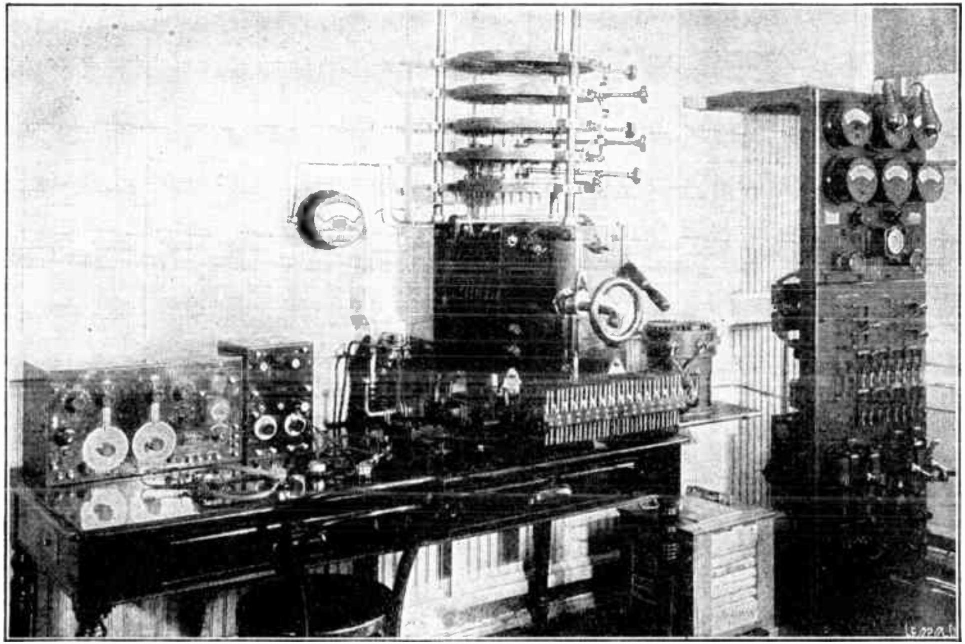
23a. Radio Schools and Institutes—Throughout the United States there are several radio schools and institutes equipped with



(Photo by courtesy of Commercial Radio Institute)

FIG. 271. A code class in a radio school.

modern radio apparatus for the practical instruction of students. Many of such schools are recognized by the Radio Division, Department of Commerce, and their graduates when presenting satisfactory letters of identification at the time of examination are credited with ten per cent for experience. Referring to paragraph 14, it will be seen that unless an applicant has credit for experience it will be extremely difficult for him to pass an examination for the first class commercial operator's license. Eighty per cent represents the maximum percentage he can obtain without credit for experience and should he miss six points in the technical examination he will fall below the passing mark of seventy-five per cent.



(Photo by courtesy of Commercial Radio Institute, Baltimore, Md.)

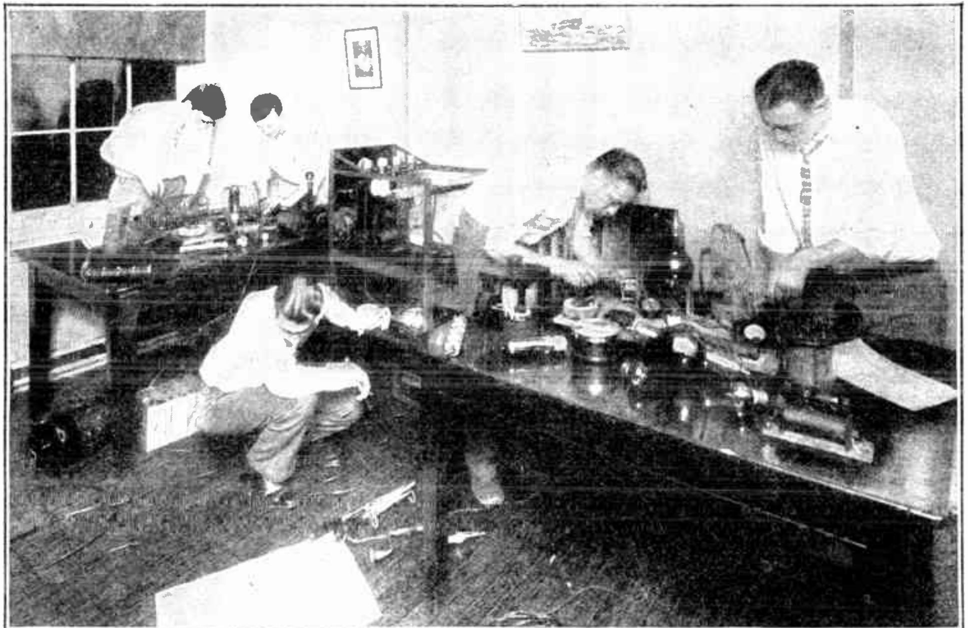
FIG. 272. A well-equipped radio school.

The layman or amateur who expects to enter the radio profession as a commercial or broadcast operator should give serious consideration to the idea of entering a recognized radio school or institute in order to prepare for the Government examination. Such schools usually have day and night classes. In addition to practical instruction, the student receives lectures on theory, also code practice one or two hours each day transmitting and receiving traffic similar to that encountered in commercial practice. The length of time required to complete the course depends upon the interest, efforts and adaptability of the student. Usually, from nine to twelve months are required of those having no previous knowledge of elementary electricity and magnetism. A licensed amateur with one or two years' experience might complete a commercial course in one or two months less than that stated above.

Radio stations on shipboard are maintained primarily for the protection of life and property at sea. The responsibility of the radio operator is quite apparent. One can never tell what may happen in an emergency. The radio apparatus may be rendered inoperative by a collision, fire, or by constant pounding of a vessel out of control at about the time the master orders the distress call transmitted. The practical operator can meet such an emergency by quickly locating the defects and making temporary repairs, thereby making it possible to summon aid to the stricken vessel. Ten or twelve months of practical instruction at a radio school is time well spent when the responsibility of the position is considered. It also means something to those interested in advancing themselves to a better position ashore after a period at sea.

24. Regulations Governing Broadcasting Stations—Applicants who expect to apply for examination for license to operate a broadcasting station in addition to having a knowledge of the Radio Act of 1927, should also study the following regulations pertaining to the operation of this class of station. The three most important regulations of interest to operators as issued by the Federal Radio Commission are known as "General Orders." They are quoted directly as issued by the Commission.

25. General Order No. 7—The Federal Radio Commission hereby fixes a maximum of one-half kilocycle as the extreme deviation from authorized frequency which will be permitted to any broadcasting station operating under permit or license issued under the terms of the Radio Act of 1927. The Department of Commerce is hereby requested to notify its proper agents immediately of this order, and to direct them to report promptly any apparent violations thereof. Maintenance of the assigned fre-



(Photo by courtesy of Commercial Radio Institute, Baltimore, Md.)

FIG. 273. Students learning radio by actual practice in building and assembling apparatus.

quency, within the limits herein prescribed, is the duty of each radio broadcasting station, and violation of this order will be deemed by the Federal Radio Commission cause for revocation of license under Section 14 of the Radio Act of 1927.

To facilitate the execution of this order, each radio broadcasting station is hereby directed, effective 12:01 a.m., local time, Monday, May 9, to announce twice each day, at the beginning and end of its program, that it is broadcasting on a frequency of .... kilocycles by authority of the Federal Radio Commission.

26. **General Order No. 8**—For the purpose of facilitating a more accurate check on station frequencies both by the Federal Radio Supervisors of the Department of Commerce and by the public, each radio broadcasting station licensed under the Radio Act of 1927 is hereby directed to announce its call letters and location as frequently as may be practicable while it is broadcasting, and in any event not less than once during each fifteen minutes of transmission.

It is understood, however, that this requirement is waived when such announcement would interrupt a single consecutive speech or musical number, and in such cases the announcement of the call letters and location shall be made at the beginning and end of such number.

This order becomes effective at 12:01 a.m., Wednesday, May 11, 1927, and will remain in force until further notice.

27. **General Order No. 16**—The Federal Radio Commission finds that while the broadcasting of music performed through the agency of mechanical reproductions, such as records or perforated rolls, is not in itself objectionable, the failure clearly to announce the nature of such broadcasting is in some instances working what is in effect a fraud upon the listening public. The Commission, therefore, hereby orders that, effective August 21, 1927, all broadcasts of music performed through the agency of mechanical reproductions shall be clearly announced as such with the announcement of each and every number thus broadcast, and that proved failure to make such announcement shall be deemed by the Commission cause for action under Section 32 of the Radio Act of 1927.

28. **Regulations Governing Experimental Stations**—A commercial second class license or higher, or a special permit issued for such purpose is required for the operation of experimental stations.

29. **Responsibility of Operator in Charge**—Radio operators on ships have the status of an officer without executive authority

and are usually furnished officers' quarters. The radio service of the ship is under the authority of the master of the vessel, and any instructions given by him must be carried out. However, in the event of such instructions conflicting with United States laws and regulations or International Laws, the operator shall advise the master of the circumstances for his further consideration. Failure to carry out the lawful orders of the master liables the operator to a suspension of his license for a period not to exceed two years.

30. **Transmitting a Distress Call**—The distress signal should never be transmitted by an operator unless ordered to do so by the master who at the time should furnish the operator with the position of the vessel, the nature of the disaster and kind of assistance required. The distress call should be transmitted at a moderate speed with the name of the vessel spelled out and each word and group of figures repeated.

31. **Answering a Distress Call**—Upon hearing a distress call transmitted by another vessel the operator should copy all details and if he believes he is close to the vessel requiring aid he should answer the call, providing no interference is caused some other ship engaged in answering the call, acknowledging receipt of the distress message and giving his position. In all probability several vessels will answer the distress call and the operator who transmitted the distress call will designate the vessel or vessels he desires to communicate with relative to securing aid. In the meantime the operator receiving the call should communicate all details of the disaster to the master of his vessel and from then on work under his instructions.

32. **Interference**—Usually when a distress signal is transmitted considerable interference results from other vessels relaying such call or trying to tell some other ship who has not heard the call to "QRT SOS." Unless an operator is engaged in answering the distressed vessel he should not start up his transmitter for this purpose but leave it to the operator of the distressed vessel or those with whom he is communicating to silence those stations who are interfering.

As provided in the International Laws the operator will give the clear signal when he desires other stations to resume traffic.

33. **Payment of Salary**—Operators are paid directly by the steamship company and are required to sign on the ship's articles at the agreed rate of pay and receive payment of their salary in the same manner and at the same time as other members of the crew.

34. **Key to Radio Room**—Upon going ashore the operator must always leave the key to the radio room with the Chief Officer or next in authority.

35. **Station License**—When taking over a station the operator should ascertain if the apparatus is properly licensed. On vessels the radio station license is usually kept by the master with other documents of the ship. However, this is unnecessary as the ship's station license should be posted in the radio room where it can be seen by government inspectors and others in authority. If any doubt exists as to the license status of the station, information may be obtained directly from the service company or the office of the Supervisor of Radio or a sub-office.

A government tuning card should be posted in the radio station and the operator should check over the various wavelength settings to see if the correct number of turns of the inductance are engaged as specified on the adjustment card.

36. **Operator's License**—The operator's license should also be posted in the station in plain view of radio inspectors and others concerned. This is necessary to facilitate government inspections as required by law.

Under the Radio Act of 1927, the operator is held responsible for the condition of the apparatus and should he willfully allow the apparatus to become damaged, or deteriorated from lack of attention he is liable to suspension of his license for a period not to exceed two years.

Important General Regulations Taken from the International Radio Telegraph Convention, Effective January 1, 1929.

37. **Article 1**—In the present regulations, supplementing the definitions given in Article Zero of the Convention:

The term "mobile station" means any mobile station.

The term "mobile stations" means all mobile stations, whatever their location.

The term "ship station" means a station on board a vessel not permanently moored.

The term "aircraft station" means a station on board an aircraft.

The term "coast station" means a land station used for communication with ship stations. It may be a fixed station used also for communication with ship stations; it is then considered as a coast station only for the duration of its service with ship stations.

The term "aeronautical station" means a land station used for communication with aircraft stations. It may be a fixed station used also for communication with aircraft stations; it is then considered as an aeronautical station only for the duration of its service with aircraft stations.

The term "station" means any station, without regard to its use.

The term "land station" has a general meaning; it is used when the intention is to cover at the same time communications with ship stations, with aircraft stations, and with any other mobile stations. The term then covers a coast station, in so far as concerns communication with ship stations, an aeronautical station in so far as concerns communication with aircraft stations and any station on land used for communications with any other mobile stations.

The term "broadcasting service" means a service carrying on the dissemination of radiotelephone communications intended to be received by the public, directly or by the intermediary of relay stations.

The term "fixed service" means a service carrying on radio communications of any kind between fixed points, exclusive of broadcasting and special services.

The term "mobile service" means a radio communication service carried on between mobile stations and land stations, and by mobile stations communicating with one another, exclusive of special services.

The term "special services" means the services of radiobeacons, radio compasses, transmission of time signals, notices to navigators, standard waves, transmissions having a scientific object, etc.

The term "radiobeacon" means a special station, the transmissions of which are intended to enable a receiving station to determine its bearing or a direction with rescept to the radiobeacon.

The term "radio-compass station" means a station provided with special apparatus intended to determine the direction of the emissions of other stations.

The term "broadcasting station" means a station used for the dissemination of radiotelephone emissions intended to be received by the public.

The term "private experimental station" means:

1. A private station intended for experiments with a view to the development of radio technique or radio art;

2. A station used by an "amateur," i.e., by a duly authorized

person interested in radio technique solely with a personal aim and without pecuniary interest.

The term "administration" means a government administration.

38. **Article 4: Classification and Use of Radio Emissions**—

1. Radio emissions shall be divided into two classes:

A. Continuous waves,

B. Damped waves,

defined as follows:

Class A.—Waves the successive oscillations of which are identical under permanent conditions.

Class B.—Waves consisting of successive trains in which the amplitude of the oscillations, after having reached a maximum, decreases gradually.

Waves of Class A include the following types, which are defined below:

Type A1: Unmodulated continuous waves. Continuous waves, the amplitude or frequency of which is varied by means of telegraphic keying.

Type A2: Continuous waves modulated at audible frequency Continuous waves, the amplitude or frequency of which is varied in a periodic manner at audible frequency, combined with telegraphic keying.

Type A3: Continuous waves modulated by speech or by music. Continuous waves, the amplitude or frequency of which is varied according to the characteristic vibrations of speech or music.

The above classification, into waves of Types A1, A2, and A3, shall not prevent the use, under conditions fixed by the Administrations concerned, of modulated and/or manipulated waves, by methods not falling within the definitions of Types A1, A2, and A3.

These definitions do not relate to systems of transmitting apparatus.

Waves will be designated in the first place by the frequency in kilocycles per second (kc/s). Following this designation there will be indicated, in parentheses, the approximate length in meters. In the present Regulations, the approximate value of the wavelength in meters is the quotient of the number 300,000 divided by the frequency expresesd in kilocycles per second.

2. Waves emitted by a station must be maintained upon the authorized frequency, as exactly as the state of the art permits, and their radiation must also be as free as practicable from all emissions not essential to the type of communication carried on.

3. The interested administrations shall fix the tolerance allowed between the mean frequency of emissions and the recorded frequency; they shall endeavor to take advantage of technical improvements progressively to reduce this tolerance.

4bis. The width of a frequency band occupied by the emission of a station must be reasonably consistent with good current engineering practice for the type of communication involved.

4. In cases where frequency bands are assigned to a specified service, stations in that service must use frequencies sufficiently remote from the limits of these bands, so as not to produce serious interference with the work of stations belonging to services to which are allocated immediately neighboring frequency bands.

39. **Article 6**—The radio service of a mobile station shall be placed under the supreme authority of the master or of the person responsible for the vessel, aircraft, or other mobile station.

The master or person responsible, as well as all persons who may have knowledge of the text or simply of the existence of radio telegrams, or of any information whatever obtained by means of the radio service, shall be bound to maintain and ensure the secrecy of correspondence.

40. **Article 9: General Procedure in the Mobile Service**—1. In the mobile service, the following detailed procedure shall be obligatory, except in the case of distress calls or of distress correspondence, to which the provisions of Article 21 are applicable.

2. (1) Before proceeding with a transmission, the sending station must make sure that no excessive interference will be caused to other communications in progress within its range on the frequency to be used; if there is probability of such interference occurring, it shall await the first break in the transmission with which it might interfere.

(2) If, in spite of this precaution, a radio transmission in progress is interrupted by the call, the latter must cease at the first request of a land station open to the international service of public correspondence or by any aeronautical station whatsoever. The station requesting this cessation must indicate the approximate duration of the suspension imposed upon the station whose call has been stopped.

3. In mobile service radiotelegraph correspondence the following procedure shall be used for calling a station:

(1) The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed not more than three times by its own call signal.

In making this call the calling station shall use the wave on which the station called keeps watch.

(2) The station called shall reply by transmitting not more than three times the call signal of the calling station, the word DE, its own call signal, and, if it is ready to receive traffic, the letter K (invitation to transmit), followed if deemed useful, by the appropriate abbreviation and by a number indicating the strength of the signals received.

(3) If the station called is unable to receive, it shall replace in the reply formula the letter K by the signal . — . . . (wait), followed by a number indicating in minutes the probable duration of the wait. If it is probable that this delay will exceed ten minutes, the delay must be explained.

(4) When there are several radiotelegrams to be transmitted in the same direction, they may be transmitted in series with the consent of the station which is to receive them.

(5) This latter station, in giving its consent, shall indicate the number of radiotelegrams which it is ready to receive in a series, and this indication shall be followed by the letter K.

(6) In principle, a radiotelegram containing more than 100 words shall be considered as forming a series, or shall terminate a series then under way.

(7) As a general rule, long radiotelegrams in plain language, code, or cipher, shall be transmitted in sections, each section containing 50 words in the case of plain language and 20 words or groups where code or cipher is used.

(8) At the end of each section the signal . . — — . . (?) meaning: "Have you received the radiotelegram correctly up to this point?" shall be transmitted. If the section has been correctly received, the receiving station shall send the letter K and the transmission of the radiotelegram shall be continued.

(9) The transmission of a radiotelegram shall be terminated by the signal . — . — . (end of transmission) followed by the call signal of the sending station and the letter K.

In case of transmission in series, the call signal of the sending station and the letter K shall be sent only at the end of the series.

(10) Acknowledgment of receipt of a radiotelegram shall be sent by means of the letter R followed by the number of the radiotelegram; this acknowledgement of receipt shall be preceded by the following formula: call signal of the sending station, word DE, call signal of the receiving station.

Acknowledgment of receipt of a series of radiotelegrams shall be sent by means of the letter R followed by the number of radiotelegrams received as well as by the numbers of the first and of the last telegram composing the series. This acknowledgement of receipt shall be preceded by the formula given above.

(11) The conclusion of work between two stations shall be indicated by each of them, by means of the signal . . . — . — (end of work) followed by it own call signal.

4. (1) If the calling station intends to transmit its traffic with a type of wave and/or on a frequency other than those employed for the call, it shall send after its own call signal the service indications defining the type of wave and/or the frequency which it proposes to use for its transmission. The absence of these service indications shall signify that it does not intend to change the type of wave or frequency.

(2) If the station called wishes the calling station to send on a type of wave and/or frequency other than those used for the call, it shall add to the reply formula service indications defining the type of wave and/or the frequency which it desires to be used. The absence of these service indications shall signify that it does not desire that type of wave and/or the frequency used for the call be changed.

(3) If the calling station has indicated that it is going to use for transmission a type of wave and/or frequency other than those with which the call was made, the station called in the reply formula shall precede the letter K by abbreviations, indicating that from then on it would listen on the type of wave and/or the frequency announced and that it itself, will use the said type of wave and/or frequency for the entire period of communication.

(4) If the calling station is a land station which, according to the provisions of the present regulations, may employ a wave other than those which it is possible for the mobile station to transmit, it may, after having established contact, use this wave to transmit its traffic. In such case the procedure shall be as follows:

The land station shall call the mobile station by using the wave on which the latter is keeping watch; and after having obtained an answer shall inform it by means of the appropriate abbreviation that it must listen thereafter on the wave which it intends to use.

If the mobile station can receive the wave indicated, it shall send the letter K. If not, it shall inform the land station by means of the appropriate abbreviation that it is impossible to receive the proposed wave and the two stations shall agree to adopt another working wave.

(5) The land station shall continue to use the wave which it

has employed until after the transmission of the signal . . . — . — (end of work), followed by its call signal. This signal, followed by its call signal, shall be repeated by the mobile station on the international calling wave assigned to its service.

(6) When the land station which receives a request to change the type of wave and/or the frequency can not, or does not desire to comply with this request, it shall not transmit the signal K, but shall propose, by employing the appropriate abbreviations, the use of another type of wave and/or another frequency.

5. (1) On the wave of 500 kc/s (600 m.) (or on an authorized wave, in the case of communications with an aircraft station), the periods of continuous work between two stations must not exceed approximately ten minutes; after each of these periods a pause must be observed in order to permit, if necessary, another station to send a priority call or to transmit a priority message.

(2) On the other waves assigned to the maritime mobile service the length of the period of continuous work shall be controlled by the coast station. In the case of communications between two ship stations, the receiving station shall determine the length of the periods of continuous work.

(3) In communications between aircraft stations the length of the periods of continuous work shall be controlled by the receiving aircraft station, subject to the intervention, for that purpose, of the aeronautical station. In communications between aeronautical stations and aircraft stations, the aeronautical station shall control the length of the periods of continuous work.

6. When a station receives a call without being certain that such call is intended for it, it shall not reply until the call has been repeated and is understood. When, on the other hand, a station receives a call which is addressed to it, but is uncertain of the call signal of the calling station, it must answer immediately using the signal . . — — . . instead of the call signal of this latter station.

7. When it is necessary to make test signals in order to adjust the apparatus before proceeding with a call or a transmission, the signals must not be made for more than about ten seconds and they must be composed of a series of V's followed by the call signal of the sending station.

If a station sends test signals at the request of another station to permit the latter to adjust its receiving apparatus, these signals must likewise be composed of a series of V's in which the call signal of the transmitting station shall appear several times.

41. Article 9 bis—1. Stations desiring to enter into com-

munication with mobile stations, without, however, knowing the names of the mobile stations which are within their range of action, may use the signal of inquiry CQ, in place of the call signal of the station called in the calling formula, this formula being followed by the letter K (general call for all mobile stations with request for reply).

In regions where traffic is heavy, the use of the call CQ followed by the letter K shall be forbidden except in combination with urgent signals.

The call CQ not followed by the letter K (general call for all mobile stations without request for reply) shall be employed for radiotelegrams of general information, time signals, regular meteorological information, general safety notices, and information of all kinds intended to be read by anyone who can receive them.

42. **Article 11: Interference**—1. The exchange of unnecessary signals shall be forbidden to mobile stations. Tests and experiments shall be allowed in these stations only to the extent that they do not disturb the service of other stations.

Each Administration shall decide, with a view to their authorization, whether the proposed tests or experiments will be likely to interfere with the service of other stations.

8. Tests and adjustments in any station, must be conducted so as not to interfere with the service of other stations engaged in authorized correspondence. The test and adjustment signals must be chosen so that no confusion can be produced with a signal, abbreviation, etc., of special meaning defined by the Regulations.

2. Any station transmitting for tests, adjustments, or experiments must, during the course of these transmissions, send its call signals at frequent intervals.

9. An Administration or private operating company making a complaint regarding interference must, in order to support and justify this complaint, declare that it regularly uses receiving apparatus of a type equivalent to the best employed in the current practice of the service concerned.

43. **Article 12: Reporting of Infractions**—1. If an Administration has knowledge of a breach of the Convention or of these Regulations, committed in one of the stations of the mobile service which it has authorized, it shall determine the facts, fix the responsibility, and take the necessary measures.

2. Infractions of the mobile service rules must be reported by the stations detecting them to the Administration to which they

are subject by means of a form similar to that shown in Appendix 4.

3. In the case of repeated infractions on the part of the same station, representations must be made to the Administration of the country to which the station is subject.

44. Article 18: Conditions to be Observed by Mobile Stations—1. Mobile stations must be established in such a way as to conform, with reference to frequencies and types of waves, to the general provisions constituting the subject matter of Article 5. In accordance with these provisions, the use by mobile stations of damped waves (Type B) of a frequency below 375 kc/s (wavelength above 800 m.), shall be forbidden beginning January 1, 1930.

In addition, no new installations of transmitters of type B waves shall be made in mobile stations beginning January 1, 1930, except when these transmitters working on full power shall expend less than 300 watts measured at the input of the supply transformer at audible frequency.

Finally, the use of type B waves of all frequencies shall be forbidden beginning January 1, 1940, except for transmitters fulfilling the same conditions regarding power as above.

2. Every station installed on board a vessel or an aircraft following a maritime route, such vessel or aircraft being compulsorily equipped with radio apparatus in accordance with an international agreement, must be able to send and receive on a wave of 500 kc/s (600 m.) type A2 or B. Ship stations must, in addition, be able to use the wave of 375 kc/s (800 m.), type A2 (or B subject to the provisions of paragraph 1 above).

Aircraft stations must be able to send and receive the wave of 333 kc/s (900 m.) types A2 or A3 (or B subject to the provisions of paragraph 1 above).

3. In addition to the fixed waves stipulated above, mobile stations equipped to send waves of Types A1, A2 or A3 may use all the waves authorized in Article 5.

The use of waves of type B shall be authorized only for the following frequencies (wavelengths):

Kc/s	Meters	Kc/s	Meter
375	800	500	600
410	730	665	450
425	705	1,000	300
454	660	1,364	220

The use of the type B wave of 665 kc/s (450 m.) shall be forbidden henceforth in regions where this wave may interfere with broadcasting.

The use of the Type B wave of 1000 ks/s (300 m.) for traffic shall be forbidden, henceforth, between 6:00 p.m. and midnight, local time, and shall be absolutely forbidden, at all times, beginning January 1, 1930 at the latest. This same type B wave of 1000 kc/s (300 m.) may, however, continue in use indefinitely without restriction as to hours by stations on board fishing vessels, for radio-compass bearings among themselves, provided they do not interfere with broadcasting.

4. All apparatus in mobile stations established for the transmission of type A1 waves between 125 and 150 kc/s (2400–2000 m.) must permit the use of at least three frequencies chosen from this band, and must permit a rapid change from one to another of these frequencies.

5. All stations on ships compulsorily equipped with radio apparatus must be able to receive the wave of 500 kc/s (600 m.) and in addition all the waves necessary for the proper accomplishment of the service which they carry on.

Beginning January 1, 1932 they must be able to receive easily and efficiently on the same frequencies, waves of types A1 and A2.

6. Transmitting apparatus used in the mobile service must be provided with devices permitting reduction of power. This provision shall not apply to transmitters, the input power of which does not exceed 300 watts.

7. Receiving apparatus must be such, that the current which it produces in the antenna shall be as small as possible and shall not disturb neighboring stations.

The transmitting and receiving apparatus of all mobile stations must be such as to allow changing of frequency as rapidly as possible. All installations must be such that communications once being established the time necessary to change from transmission to reception and vice versa shall be as short as practicable.

45. **Article 19: Calling and Listening Waves**—1. In the band between 360 and 515 kc/s (830–580m.) the only type B waves permitted shall be the following: 375, 410, 425, 454 and 500 kc/s (800, 730, 705, 660, and 600 m.).

The general calling wave, which must be used by all ships compulsorily equipped and by coast stations, shall be 500 kc/s (600 m.) (A1, A2 or B).

Besides the wave 500 kc/s (600 m.) the use of waves of all types between 485 and 515 kc/s (620–580 m.) shall be forbidden.

The wave of 500 kc/s (600 m.) shall be the internationall calling and distress wave. It may be used, but with discretion, for other purposes, if it does not interfere with distress, urgent, safety, or call signals.

Coast stations must be able to use at least one wave besides that of 500 kc/s (600 m.). This additional wave shall be underlined in the nomenclature to indicate that it is the normal working wave of the station. The additional waves thus chosen may be the same as those of ship stations or may be different. In any case, the working waves of the coast stations must be chosen in such a way as to avoid interference with neighboring stations.

Besides the normal working waves underlined in the nomenclature, coast and ship stations may use in the authorized band additional waves which they deem suitable. These waves shall be given in the nomenclature without being underlined.

4. (1) In order to increase safety of life at sea (ships) and over the sea (aircraft), all stations in the mobile *maritime* service must, during their hours of service, take the necessary measures to assure the watch on the distress wave (500 kc/s–600 m.) for three minutes twice per hour, beginning at the 15th minute and at the 45th minute after each hour Greenwich mean time.

(2) Stations carrynig on a service of radiotelegraph correspondence, press news, etc., with ships at sea must observe silence during the intervals indicated above. Only the transmissions provided for in Article 21, paragraphs 25 to 27, may be made during these intervals.

(3) As an exception, however, land and ship stations equipped to correspond by means of continuous waves may continue to work during these periods; if they are in a position to maintain at the same time a satisfactory watch on the distress wave as provided for in subparagraph (1) of the present paragraph.

6. The following rules must be observed in the operations of stations in the mobile service using type A1 waves of the band 100 to 160 kc/s (3000–1875 m.) which is assigned to the mobile service.

(*a*) Every coast station carrying on communications on a long continuous wave must listen on the wave of 143 kc/s (2100 m.) unless it is otherwise indicated in the nomenclature. The coast station shall transmit all its traffic on the wave or waves especially assigned to it.

(*b*) When a mobile station desires to establish communication on a long continuous wave with another station of the mobile service it must employ the wave of 143 kc/s (2100 m.) unless it is otherwise indicated in the nomenclature. This wave, designated as the general communication wave, must be employed:

1. For calls and answers thereto.

2. For sending signals preliminary to the transmission of traffic.

(*c*) A mobile station after having established communication on the general communication wave, with another station in the mobile service, may transmit its traffic on any wave in the authorized band on condition that it does not disturb the work of a coast station or work in progress on the calling wave.

(*d*) As a general rule, every mobile station, equipped for service on long continuous waves and not engaged in communication on another wave, must, in order to permit the exchange of traffic with other stations of the mobile service, return to the wave of 143 kc/s (2100 m.) for 10 minutes from the beginning of the 35th minute to the beginning of the 45th minute of each hour, Greenwich mean time, during the specified hours, according to the class to which the station in question belongs.

(*e*) Coast stations shall transmit their traffic lists at specified times, published in the nomenclature, on the wave or waves which are assigned to them.

Besides the times thus fixed for this transmission of their traffic lists, coast stations may call mobile stations individually, at any other time, according to circumstances or according to work which they have to carry on. These individual calls may be made on the wave of 143 kc/s (2100 m.) in regions where there is no congestion of traffic.

(*f*) The special provisions concerning the service carried on by land stations using long continuous waves shall be shown in detail in a special reference in the nomenclature.

46. Article 21: Distress, Alarm, Urgent and Safety Signals—*Distress Signal*—1. The distress signal shall consist of the group . . . — — — . . . which indicates that the ship, aircraft, or other mobile station sending it, is threatened by grave and imminent danger, and requests immediate assistance.

Distress Call—2. The distress call shall consist of the distress signal sent three times, followed by the word DE and the call signal of the mobile station in distress, sent three times. This call has absolute priority over all other transmissions. All mobile or land stations hearing it must immediately cease all transmissions capable of interfering with the distress calls or messages and must listen on the wave used for the distress call. This call must not be addressed to a particular station.

The same rules apply to the radiotelephone distress call which consists of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression "m'aider" [help me]).

Distress Message—3. The distress message shall include the distress call followed by the name of the ship, aircraft, or other mobile station in distress, and information concerning its position, the nature of the distress and the kind of assistance desired.

4. As a general rule and when a ship or aircraft on or over the sea is involved the position must be expressed in latitude and longitude (Greenwich) using figures for degrees and minutes, accompanied by one of the words NORTH or SOUTH, and by one of the words EAST or WEST. A period shall separate the degrees from the minutes. Where necessary, the true bearing and the distance in nautical miles from a known geographic point may be given.

5. The distress call and message shall be sent only by the authority of the master or person responsible for the ship, aircraft, or other mobile station.

6. A ship in distress shall transmit the distress call on the wave of 500 kc/s (600 m.) preferably of type A2 or B. This call must be followed as soon as possible by the distress message.

7. The distress call and message must be repeated at intervals until an answer has been received, especially during the periods of silence specified in Article 19, paragraph 4. The intervals must, however, be long enough for stations preparing to reply to the call to have time to start their sending apparatus. In the case where the ship in distress receives no answer to a distress call or message sent on the 500 kc/s (600 m.) wave, the call and the message may be repeated on any other available wave on which attention might be attracted.

8. Furthermore, a mobile station which is aware that another mobile station is in distress may transmit the distress message on condition that:

(*a*) The station in distress is not itself in a position to transmit it.

(*b*) The master (or his relief) of the vessel, aircraft, or other mobile station believes that further help is necessary.

9. Stations which receive a distress message from a mobile station which unquestionably is in their immediate vicinity, must at once acknowledge receipt thereof (see paragraphs 15 and 16 below), taking care not to interfere with the transmission of the acknowledgments of receipt of the said message sent by other stations.

Stations which receive a distress message from a mobile station which unquestionably is not in their immediate vicinity, must listen for a short period before acknowledging receipt thereof in order to permit the stations nearer the mobile station in distress to answer and acknowledge receipt without interference.

Distress Traffic—10. Distress traffic shall include all messages relative to immediate relief of the mobile station in distress.

11. All distress traffic must include the distress signal, sent before the time of filing.

12. The control of distress communications devolves upon the mobile station in distress or upon the mobile station which by application of the provisions of paragraph 8, subparagraph (*a*), sent the distress call. These stations may delegate the control of the distress communications to another station.

13. All stations which are within the range of the distress communications but which do not take part in them must refrain from using the distress wave until the distress communications are finished. As soon as these communications are established on the distress wave, mobile stations not taking part in them may continue their normal service on other authorized waves of type A1, if by so doing they are still able effectively to receive the distress traffic.

14. When distress communications are ended and silence is no longer necessary, the station which has controlled these communications shall send a message on the distress wave addressed to CQ, indicating that the distress communications are ended. This message shall take the following form:

> Call CQ (three times), word DE, call signal of the station transmitting the message, distress signal, time of filing the message, name and call signal of the mobile station which was in distress, words "distress traffic ended."
>
> This message shall be repeated, where necessary, on the other waves on which the distress traffic has been sent.

Acknowledgment of Receipt—15. Acknowledgment of receipt of a distress message shall be made in the following form:

> Call signal of the mobile station in distress (three times), word DE, call signal of the station acknowledging receipt (three times), group RRR, distress signal.

16. Every mobile station which acknowledges receipt of a distress message must make its name and position known as soon as possible (in the form shown in paragraph 4), taking care not to interfere with other stations more favorably situated to render immediate relief to the station in distress.

17. If a mobile station employing continuous waves not included in the band 485 to 515 kc/s (620–580 m.) hears a distress message sent on the waves of 500 kc/s (600 m.), during other than the obligatory silence periods on the wave of 500 kc/s (600 m.), and if the ship, aircraft or other mobile station is not in a position to render assistance, the said station must take all possible steps to attract the attention of other mobile stations in the vicinity, which are working on waves not included in the band mentioned above.

18. Repetition of the distress call or message, by mobile stations other than the one in distress, shall be permitted only on authorization from the master (or his relief) of said stations, taking care not to cause interference by useless repetition.

19. A station repeating a distress call or message shall add to the end thereof the word DE followed by its own call signal transmitted three times.

20. In a case where a station receives a distress call or message but is not in a position to render assistance and has reason to believe that there has been no acknowledgement of receipt of the distress message, it must repeat the message on full power on the distress wave and take all the necessary steps to advise the authorities who are capable of useful intervention.

Automatic Alarm Signal—21. The composition of the automatic alarm signal must comply with the following conditions:

(*a*) It must be possible to send this signal by hand or by an automatic apparatus, without difficulty and with a precision as to the measure of time, which must not be greater than that of a watch or a clock indicating seconds.

(*b*) Its composition must be clear, distinct, and easily recognized by a person ignorant of the Morse Code; and it must be adaptable to the easy and cheap manufacture of an automatic receiving apparatus which:

1. Shall respond to the alarm signal even when numerous stations are working as well as when there is atmospheric interference;

2. Shall not be started by powerful signals or by atmospherics when these are not accompanied by the alarm signal;

3. Shall possess a sensitiveness equal to that of a crystal receiver-detector connected with the same antenna;

4. Shall give warning when its operation ceases to be normal.

(*c*) The said composition must be different from the signal used for adjustment and functioning of the variometer.

(*d*) Before an automatic alarm receiver shall be approved for use in ships under the jurisdiction of an Administration, the Administration must be satisfied by practical tests made under suitable conditions of interference, that the apparatus complies with the provisions of these Regulations.

(*e*) The following alarm signal shall hereafter be recognized:

> A series of twelve dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two dashes, one second.

(*f*) This special signal must have for its sole purpose, the operation of the apparatus used to give the alarm. It must be used solely to announce that the distress signal is about to follow.

(*g*) The adoption of the type of alarm signal mentioned in (*e*) shall not prevent and Administration from authorizing the use of an automatic apparatus which would comply with the conditions fixed above and would be operated by the regulation distress signal (. . . — — — . . .).

Urgent Signal—22. The urgent signal shall consist of several repetitions of the group XXX, sent by distinctly separating the letters of each group and the successive groups; it shall be sent before a call. This signal shall indicate that the calling station has a very urgent message to transmit concerning the safety of the ship, aircraft, or other vehicle in which it is located; of a ship, aircraft, or other vehicle in sight; or finally, of the safety of any person on board or in sight therefrom. In the aircraft radio service the indication of PAN shall be used as an urgent signal, by radiotelephony and by radiotelegraphy, when an aircraft station wishes to give notice of damage which compels the aircraft to land without requiring immediate assistance. In the case of radiotelegraphy, the three letters must be well separated in order that the signals AN be not transmitted as the signal P.

The urgent signal shall have priority over all other communications except those of distress, and all mobile or land stations which hear it must avoid interfering with the transmission of such urgent traffic.

As a general rule, the urgent signal may be employed only if the sending mobile station addresses it to a specific station.

23. Mobile stations which hear the urgent signal must continue to listen for a least three minutes. At the expiration of this period and if no urgent message has been heard, mobile stations may resume their normal service.

Land and ship stations nevertheless, which are in communication on authorized waves, other than that used for the transmission of the urgent signal and of the call which follows it, may continue their normal work without interruption.

24. The urgent signal shall be transmitted only with the authorization from the master or the person responsible for the ship, aircraft, or other mobile station.

Safety Signal—25. The safety signal shall consist of the transmission of the group TTT, with the letters well separated, followed by the word DE and by the call signal of the station sending it. It shall indicate that this station is about to transmit a message concerning the safety of navigation or giving important information relative to meteorological warning messages.

26. The safety signal and the safety message shall be sent on the wave of 500 kc/s (600 m.) and if necessary, on the normal listening wave of ship and aircraft stations.

27. The safety signal shall be sent once during the first silent period (Article 19, par. 4) and near the end of that period. All stations hearing it must continue to listen on the normal calling wave (ship stations) or on the authorized wave (aircraft station) until the message preceded by the safety signal shall have ended. The transmission of this message shall begin immediately after the end of the silent period.

47. **Article 24 quater: Order of Priority in the Establishment of Communications in the Mobile Service**—The order of priority in the establishment of communications in the mobile service shall be as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by an urgent signal.
3. Communications preceded by the safety signal.
4. Communications relative to radio-compass bearings.
5. All other communications.

48. **Article 25: Calling**—1. As a general rule, responsibility for establishing communication with the land station rests with the mobile station; the latter may call the land station, for this purpose, only after arriving within the range of action of said station.

In principle, a land station having traffic for a mobile station which has not indicated its presence, must call this station only if it has reason to believe that the said mobile station is within range and is keeping watch.

2. Land stations may, however, transmit their traffic list, consisting of the call signals of all mobile stations for which they have traffic on hand, at fixed intervals which have been established

by agreements between the governments concerned. Land stations which transmit their calls on the wave of 500 kc/s (600 m.) shall transmit the call signals of their traffic list in alphabetical order; land stations which use continuous waves shall transmit these call signals in the most convenient order.

In all cases, mobile stations which, during this transmission, hear their call signal must answer so soon as practicable, complying with provisions paragraph 1, and following so far as practicable the order in which they were called. The time at which land stations transmit their traffic lists as well as the frequencies and types of waves which they use for this purpose shall be indicated in the nomenclature.

The land station shall inform each mobile station concerned of the frequency and type of wave to be used for work with it, as well as of the approximate time at which the traffic may begin.

3. When a land station receives calls from several mobile stations at practically the same time, it shall decide the order in which these stations may transmit their traffic to it, its decision being based only on the requirement of permitting each calling station to exchange with it the greatest possible number of radiotelegrams.

4. When a land station answers a call from a mobile station it may, if deemed necessary, ask the mobile station, by means of appropriate abbreviations, to indicate the number of radiotelegrams on hand.

If information concerning the position, route, speed or ports of call of the ship, aircraft or other mobile station appears necessary to the land station, the latter asks for it by means of a free service advice, addressed to the master, or to the person in charge of the ship, aircraft or other mobile stations who furnishes it or not at his discretion. The mobile station must give such information to the land station only when it has been requested and furnished as stated above.

5. In communication between coast and mobile stations, the mobile stations shall follow the instructions of the coast station, in all questions relating to the order and time of transmission, as well as to the suspension of work. This provision shall not apply to cases of distress.

6. In communication between mobile stations, except in cases of distress, the station called shall control the work as indicated in paragraph 5 above.

7. When a station called does not answer to a call sent three times at intervals of two minutes, the call must cease and it may

be resumed only after an interval of fifteen minutes. The calling station, before resuming the call, must make certain that the station called is not at that moment in communication with another station.

The call may be repeated at shorter intervals if it is not likely to interfere with communications in progress.

8. When the name and address of the management of a mobile station are not shown in the nomenclature or are no longer in accord with the data given in the latter, it devolves upon the mobile station to furnish the land station to which it sends traffic all the necessary information, using for this purpose the appropriate abbreviations.

49. **Article 26: Time of Filing Radiotelegrams**—To indicate the time of filing radiotelegrams accepted in mobile stations, the person in charge shall employ Greenwich Mean Time, and shall use a notation according to the twenty-four hour system. This time shall always be expressed and sent by means of four figures (0000 to 2359).

The Administrations of countries located outside zone "A" (Appendix 17), however, may authorize ship stations following the coasts and their countries to use zone time to indicate, by a group of four figures, the time of filing, and in this case the group must be followed by the letter F.

50. **Article 27**—1. In principle, a mobile station using waves of types A2, A3 or B shall send its radiotelegrams to the nearest land station.

When, however, the mobile station may choose among several land stations, situated at approximately the same distance it shall give the preference to that located on the territory of the country of destination, or of the normal transit of the radiotelegrams to be sent. When the station chosen is not the nearest, the mobile station must cease work or change the type or frequency of the emission upon the first request made by the land station in the interested service which is actually the nearest, the request being based upon the interference which the work in question causes the latter.

2. A mobile station using Type A1 waves included in the authorized band may transmit its radiotelegrams to a land station which is not the nearest. It is, however, recommended in this case that preference be given to the land station established on the territory of the country of destination or of the country which it appears could most reasonably effect the transit of the radiotelegrams to be sent.

3. A coast station, to which one or more waves included in the band 125–150 kc/s (2400–2000 m.) are allocated, shall have the right of preference on such wave or waves.

Any other station in the mobile service transmitting public traffic on such wave or waves and thereby causing interference to the said coast station must suspend its work at the request of the latter.

4. Except in the case of distress, communications between ship stations must not interfere with the work of coast stations. When this work is thus interfered with, the ship stations causing it must stop sending or change waves, upon the first request of the coast station with which they interfere.

5. If the sender of a radiotelegram filed in a mobile station has designated the land station to which he desires his radiotelegram sent, the mobile station must in order to effect this transmission to the designated land station, wait if necessary until the conditions specified in the preceding paragraphs shall have been fulfilled.

6. A mobile station which does not have fixed working hours must inform the land station with which it is in communication the time of closing and the time of reopening its service.

Every mobile station whose service is about to close by reason of arrival in port must notify the nearest land station.

51. **Article 27 bis**—In case of distress, the wave of 500 kc/s (600 m.) must be used preferably with type A2 or B. When it is not possible to use one of these types of waves, type A1 or A3 may be used. No provision of the present Regulations shall prevent the use by a mobile station in distress of any means at its disposal to attract attention, indicate its position, and obtain assistance.

52. **Article 27 ter**—1. In the case where waves other than the normal wave may be used, the ship station shall follow the instructions of the coast station with which it is in communication. In principle, the normal wave of 500 kc/s (600 m.) must not be used for the transmission of long radiotelegrams in regions where the radio work is heavy.

2. During their hours of service, stations using for their work waves of type A2, A3 or B, and open to the international service of public correspondence, must continue to listen on the wave of 500 kc/s (600 m.), except when they are exchanging traffic on other waves.

3. As a general rule, it is recommended that public correspond-

Q CODE:[1] LIST OF ABBREVIATIONS TO BE USED IN RADIO TRANSMISSIONS.

I. *Abbreviations to be used in all services.*

Abbreviation.	Question.	Answer.
QRA......	What is the name of your station?.....	The name of my station is ......
QRB......	At what approximate distance are you from my station?	The approximate distance between our stations is ...... nautical miles (or ...... kilometers).
QRC......	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the ...... private company (or by the government administration of ......).
QRD......	Where are you going?...............	I am going to ......
QRE......	What is the nationality of your station?.	The nationality of my station is ......
QRF......	Where do you come from?...........	I come from ......
QRG......	Will you indicate to me my exact wavelength in meters (or frequency in kilocycles)?	Your exact wavelength is ...... meters (or ...... kilocycles).
QRH......	What is your exact wavelength in meters (frequency in kilocycles)?	My exact wavelength is ...... meters (frequency .... kilocycles).
QRI......	Is my tone bad?....................	Your tone is bad.
QRJ......	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK......	Are you receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL......	Are you busy?......................	I am busy. Or, (I am busy with ......). Please do not interfere.
QRM.....	Are you being interfered?............	I am being interfered with.
QRN......	Are you troubled by atmospherics?....	I am troubled by atmospherics.
QRO......	Must I increase power?..............	Increase power.
QRP......	Must I decrease power?..............	Decrease power.
QRQ......	Must I send faster?..................	Send faster (...... words per minute).
QRS......	Must I send more slowly?............	Send more slowly (...... words per minute).
QRT......	Must I stop sending?................	Stop sending.
QRU......	Have you anything for me?..........	I have nothing for you.
QRV......	Must I send a series of V's?..........	Send a series of V's.
QRW.....	Must I advise ...... that you are calling him?	Please advise ...... that I am calling him.
QRX......	Must I wait? When will you call me again?	Wait until I have finished communicating with .... I will call you immediately (or at ...... o'clock).
QRY......	Which is my turn?..................	Your turn is No. ...... (or according to any other indication).
QRZ......	By whom am I being called?.........	You are being called by ......
QSA......	What is the strength of my signals (1 to 5)?	The strength of your signals is ...... (1 to 5).
QSB......	Does the strength of my signals vary?...	The strength of your signals varies.
QSC......	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD......	Is my keying bad?..................	Your keying is bad. Your signals are unreadable.
QSE......	Are my signals distinct?.............	Your signals run together.
QSF......	Is my automatic transmission good?....	Your automatic transmission fades out.
QSG......	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH......	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI......	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ......	What is the charge to be collected per word for ...... including your internal telegraph charge?	The charge to be collected per word for ...... is ...... francs, including my internal telegraph charge.

[1] The abbreviations take the form of questions when they are followed by question marks.

I. *Abbreviations to be used in all services*—Continued.

Abbreviation.	Question.	Answer.
QSK......	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at ...... (o'clock).
QSL......	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM......	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN......	Can you receive me now? Must I continue to listen?	I cannot receive you now. Continue to listen.
QSO......	Can you communicate with ...... directly (or through the intermediary of ......)?	I can communicate with ...... directly (or through the intermediary of ......).
QSP......	Will you relay to ...... free of charge?.	I will relay to ...... free of charge.
QSQ......	Must I send each word or group once only?	Send each word or group once only.
QSR......	Has the distress call received from ...... been attended to?	The distress call received from ...... has been attended to by ....
QSU......	Must I send on ...... meters (or ...... kilocycles) waves of Type A1, A2, A3 or B?	Send on ...... meters (or on ...... kilocycles) waves of Type A1, A2, A3 or B. I am listening for you.
QSV......	Must I shift to the wave of ...... meters (or of ...... kilocycles) for the balance of our communications and continue after having sent several V's.	Shift to wave of ...... meters (or of ...... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW......	Will you send on ...... meters (or on ...... kilocycles) waves of Type A1, A2, A3 or B?	I will send on ...... meters (or ...... kilocycles) waves of Type A1, A2, A3 or B. Continue to listen.
QSX.....	Does my wavelength (frequency) vary?	Your wavelength (frequency) varies.
QSY......	Must I send on the wave of ...... meters (or ...... kilocycles) without changing the type of wave?	Send on the wave of ...... meters (or ...... kilocycles) without changing the type of wave.
QSZ......	Must I send each word or group twice?..	Send each word or group twice.
QTA......	Must I cancel telegram No....... as if it had not been sent?	Cancel telegram No. ...... as if it had not been sent.
QTB......	Do you agree with my word count?....	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC......	How many telegrams have you to send?.	I have ...... telegrams for you or for ......
QTD......	Is the word count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE......	What is my true bearing? (or) ... . What is my true bearing relative to....?	Your true bearing is ...... degrees (or) Your true bearing relative to ...... is ...... degrees at ...... (o'clock).
QTF......	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on the bearings taken by the radiocompass stations which I control is ...... latitude ...... longitude.
QTG......	Will you transmit your call signal for one minute on a wavelength of ...... meters (or ...... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for one minute on the wavelength of ...... meters (or ...... kilocycles) in order that you may take my radiocompass bearing.
QTH......	What is your position in latitude and longitude (or according to any other indication)?	My position is ...... latitude ...... longitude (or according to any other indication).
QTI......	What is your true course?............	My true course is ...... degrees.
QTJ......	What is your speed?................	My speed is ...... knots, or ...... kilometers per hour.
QTK......	What is the true bearing of ...... relative to you?	The true bearing of ...... relative to me is ...... degrees at ...... (o'clock).

I. *Abbreviations to be used in all services*—Continued.

Abbreviation.	Question.	Answer.
QTL......	Send radio signals to enable me to determine my bearing with respect to the radio beacon.	I am sending radio signals to permit you to determine your bearing with respect to the radio beacon.
QTM.....	Send radio signals and submarine sound signals to enable me to determine my bearing and my distance.	I am sending radio signals and submarine sound signals to permit you to determine your bearing and your distance.
QTN......	Can you take the bearing of my station (or of ......) relative to you?	I cannot take the bearing of your station (or of ......) relative to my station.
QTP......	Are you going to enter the dock (or the port)?	I am going to enter the dock (or the port).
QTR......	What is the exact time?..............	The exact time is ......
QTS......	What is the true bearing of your station relative to me?	The true bearing of my station relative to you is ...... at ...... (o'clock).
QTU......	What are the hours during which your station is open?	My station is open from ...... to ......

II. *Abbreviations more especially used in the aircraft radio service.*

Abbreviation.	Question.	Answer.
QAA......	At what time do you expect to arrive at ......?	I expect to arrive at ...... at ...... (o'clock).
QAB......	Are you en route to ......?..........	I am en route to ...... or Go to ....
QAC......	Are you returning to ......?.........	I am returning to ...... or Return to ....
QAD......	At what time did you leave ......? (place of departure).	I left ...... (place of departure) at ...... (o'clock).
QAE......	Have you news of ...... (call signal of the aircraft station)?	I have no news of ...... (call signal of the aircraft station).
QAF......	At what time did you pass ......?.....	I passed ...... at ...... (o'clock).
QAH......	What is your height?...............	My height is ...... meters (or according to any other indication).
QAI.......	Has any aircraft signaled in my neighborhood?	No aircraft has signaled in your neighborhood.
QAJ......	Must I look for another aircraft in my neighborhood?	Look for another aircraft in your neighborhood (or) Look for ...... (call signal of the aircraft station) which was flying near ...... (or in the direction of ......) at ...... (o'clock).
QAK......	On what wave are you going to send the meteorological warning messages?	I am going to send the meteorological warning messages on wavelength of ...... meters (or ...... kilocycles).
QAL......	Are you going to land at ......?	I am going to land at ...... or Land ......
QAM.....	Can you give me the latest meteorological message concerning weather for ...... (place of observation)?	Here is the latest meteorological message concerning weather for ...... (place of observation).
QAN......	Can you give me the latest meteorological message concerning surface wind for ...... (place of observation)?	Here is the latest meteorological message concerning surface wind for ...... (place of observation).

II. *Abbreviations more expecially used in the aircraft radio service.*

Abbreviation.	Question.	Answer.
QAO......	Can you give me the latest meteorological message concerning upper wind for ...... (place of observation)?	Here is the latest meteorological message concerning upper wind for ...... (place of observation).
QAP......	Must I continue to listen for you (or for ......) on ...... meters (or ...... kilocycles)?	Continue to listen for me (or for ......) on ...... meters (or ...... kilocycles).
QAQ......	Will you hasten the reply to message No ...... (or in accordance with any other indication)?	I hasten the reply to message No. ...... (or in accordance with any other indication).
QAR......	Must I reply to ...... for you?	Reply to ...... for me.
QAS......	Must I send message No. ...... (or in accordance with any other indication) to ......?	Send message No. ...... (or in accordance with any other indication) to ......
QAT......	Must I continue to send?	Listen before sending; you are interfering; or Listen before sending; you are sending at the same time as ......
QAU......	What is the last message received by you from ......?	The last message received by me from ...... is ......
QAV......	Are you calling me? .... or Are you calling ...... (call signal of the aircraft station)?	I am calling you. or I am calling ...... (call signal of the aircraft station).
QAW......	Must I cease listening until ...... (o'clock)?	Cease listening until ...... (o'clock).
QAX......	Have you received the urgent signal sent by ...... (call signal of the aircraft station)?	I received the urgent signal sent by ...... (call signal of the aircraft station) at ...... (o'clock).
QAY......	Have you received the distress signal sent by ...... (call signal of the aircraft station)?	I received the distress signal sent by ...... (call signal of the aircraft station) at ...... (o'clock).
QAZ......	Can you receive in spite of the storm?...	I can no longer receive. I am going off watch because of the storm.

Scale Used to Express Strength of Signals:

1. Hardly perceptible; unreadable.
2. Weak; readable now and then.
3. Fairly good; readable, but with difficulty.
4. Good; readable.
5. Very good; perfectly readable.

ence traffic be transmitted on waves of type A1, rather than on waves of type A2 or B.

3 bis. All stations in the mobile service are bound to exchange traffic with the minimum of radiated energy necessary to insure good communication.

III. *Miscellaneous Abbreviations.*

Abbreviation.	Meaning.
C	Yes.
N	No.
P	Announcement of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	"All after ......" (to be used after a question mark to request a repetition).
AB	"All before ......" (to be used after a question mark to request a repetition).
AL	"All that has just been sent" (to be used after a question mark to request a repetition).
BN	"All between ......" (to be used after a question mark to request a repetition).
BQ	Announcement of reply to a request for rectification.
CL	"I am closing my station."
CS	Call signal (to be used to ask repetition of a call signal).
DB	"I cannot give you a bearing, you are not in the calibrated sector of this station."
DC	"The minimum of your signal is suitable for the bearing."
DF	Your bearing at ...... (o'clock) was ...... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DL	Your bearing at ...... (o'clock) was ...... degrees in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at ...... (o'clock).
DP	Beyond 50 miles, possible error of bearing can attain two degrees.
DS	Adjust your transmitter; the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is bilateral; what is your approximate direction in degrees relative to this station?
DZ	Your bearing is reciprocal. (To be used only by the central station of a group of radiocompass stations when it is addressed to other stations of the same group).
ER	"Here ......" (to be used before the name of the mobile station in the sending of route indications).
GA	"Resume sending" (to be used more especially in the fixed service).
JM	"If I may send, make a series of dashes. To stop my transmission, make a series of dots" (not to be used on 600 meters (500 kilocycles)).
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	"I resume transmission" (to be used more especially in the fixed service).
OK	"We are in agreement."
RQ	Announcement of a request for rectification.
SA	Announcement of the name of an aircraft station (to be used in the sending of indications of passage).
SF	Announcement of the name of an aeronautic station.
SN	Announcement of the name of a coast station.
SS	Announcement of the name of a ship station (to be used in the transmission of indications of passage).
TR	Announcement of the request or of the sending of indications concerning a mobile station.
UA	"Are we in agreement?"
WA	"Word after ......" (to be used after a question mark to request a repetition).
WB	"Word before ......" (to be used after a question mark to request a repetition).
XS	Atmospherics.
YS	"See your service advice."
ABV	"Shorten the traffic by using the International Abbreviations" or "Repeat (or I repeat) the figures in abbreviation form."
ADR	Address (to be used after a question mark to request a repetition).
CFM	"Confirm" or "I confirm."
COL	"Collate" or "I collate."
ITP	"The punctuation counts."
MSG	Announcement of telegram concerning ship service only (to be used as a prefix).
PBL	Preamble (to be used after a question to request a repetition).
REF	"Referring to ......" or "Refer to ......"
RPT	"Repeat" or "I repeat" only (to be used to ask or to give repetition of all or part of the traffic by making the corresponding indication after the abbreviation).
SIG	Signature (to be used after a question mark to request a repetition).
SVC	Announcement of a service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a question mark to request a repetition).

FREQUENCY ASSIGNMENTS FOR VARIOUS SERVICES.

Frequencies in Kilocycles per Second (kc/s).	Approximate Wavelengths in Meters.	Services.
10– 100	30,000–3,000	Fixed services.
100– 110	3,000–2,725	Fixed services and mobile services.
110– 125	2,725–2,400	Mobile services.
125– 150[1]	2,400–2,000[1]	Maritime mobile services *open to public correspondence exclusively.*
150– 160	2,000–1,875	Mobile services.
160– 194	1,875–1,550	(*a*) Broadcasting. (*b*) Fixed services. (*c*) Mobile services. The conditions for use of this band are subject to the following regional arrangements: All regions where broadcasting stations now exist working on frequencies below 300 kc/s (above 1000m). } broadcasting. Other regions { Fixed services. / Mobile services. Regional arrangements will respect the rights of other regions in this band.
194– 285	1,550–1,050	(*a*) Mobile services. (*b*) Fixed services. (*c*) Broadcasting. The conditions for use of this band are subject to the following regional arrangements: Europe { (*a*) *Air* mobile services *exclusively.* (*b*) *Air* fixed services *exclusively.* (*c*) Within the band 250–285 kc/s (1200–1050m). Fixed services *not open to public correspondence.* (*d*) Broadcasting within the band 194–224 kc/s (1550–1340m). Other regions { (*a*) Mobile services except commercial ship stations. (*b*) Fixed *air* services *exclusively.* (*c*) Fixed services *not open to public correspondence.*
285– 315	1,050– 950	Radio beacons.
315– 350[2]	950–850[2]	*Air* mobile services *exclusively.*
350– 360	850–830	Mobile services *not open to public correspondence.*
360– 390	830–770	(*a*) Radio compass service.

[1] The wave of 143 kc/s (2,100m) is the calling wave for mobile stations using long continuous waves.

[2] The wave of 333 kc/s (900m) is the international calling wave for air services.

FREQUENCY ASSIGNMENTS FOR VARIOUS SERVICES—*Continued.*

Frequencies in Kilocycles per Second (kc/s).	Approximate Wavelengths in Meters.	Services.
		(*b*) Mobile services, on condition that they do not interfere with radiocompass service.
390– 460	770–650	Mobile services.
460– 485	650–620	Mobile services (*except damped waves and radiotelephony*).
485– 515[3]	620–580[3]	Mobile services (distress, call, etc.).
515– 550	580–545	Mobile services *not open to public correspondence* (*except damped waves and radiotelephony*).
550– 1,300[4]	545–230[4]	Broadcasting.
1,300– 1,500	230–200	(*a*) Broadcasting. (*b*) Maritime mobile services, waves of 1365 kc/s (220m) exclusively.
1,500– 1,715	200–175	Mobile services.
1,715– 2,000	175–150	Mobile services. Fixed services. Amateurs.
2,000– 2,250	150–133	Mobile services and fixed services.
2,250– 2,750	133–109	Mobile services.
2,750– 2,850	109–105	Fixed services.
2,850– 3,500	105– 85	Mobile services and fixed services.
3,500– 4,000	85– 75	Mobile services. Fixed services. Amateurs.
4,000– 5,500	75– 54	Mobile services and fixed services.
5,500– 5,700	54– 52.7	Mobile services.
5,700– 6,000	52.7– 50	Fixed services.
6,000– 6,150	50– 48.8	Broadcasting.
6,150– 6,675	48.8– 45	Mobile services.
6,675– 7,000	45–42.8	Fixed services.
7,000– 7,300	42.8–41	Amateurs.
7,300– 8,200	41–36.6	Fixed services.
8,200– 8,550	36.6–35.1	Mobile services.
8,550– 8,900	35.1–33.7	Mobile services and fixed services.
8,900– 9,500	33.7–31.6	Fixed services.
9,500– 9,600	41.6–31.2	Broadcasting.
9,600–11,000	31.2–27.3	Fixed services.
11,000–11,400	27.3–26.3	Mobile services.
11,400–11,700	26.3–25.6	Fixed services.
11,700–11,900	25.6–25.2	Broadcasting.

[3] The wave of 500 kc/s (600m) is the international calling and distress wave. It may be used for other purposes on condition that it will not interfere with call signals and distress signals.

[4] Mobile services may use the band 550 to 1,300 kc/s (545–230m) on condition that this will not cause interference with the services of a country which uses this band exclusively for broadcasting.

FREQUENCY ASSIGNMENTS FOR VARIOUS SERVICES—*Continued.*

Frequencies in Kilocycles per Second (kc/s).	Approximate Wavelengths in Meters.	Services.
11,900–12,300	25.2–24.4	Fixed services.
12,300–12,825	24.4–23.4	Mobile services.
12,825–13,350	23.4–22.4	Mobile services and fixed services.
13,350–14,000	22.4–21.4	Fixed services.
14,000–14,400	21.4–20.8	Amateurs.
14,400–15,100	20.8–19.85	Fixed services.
15,100–15,350	19.85–19.55	Broadcasting.
15,350–16,400	19.55–18.3	Fixed services.
16,400–17,100	18.3–17.5	Mobile services.
17,100–17,750	17.5–16.9	Mobile services and fixed services.
17,750–17,800	16.9–16.85	Broadcasting.
17,800–21,450	16.85–14	Fixed services.
21,450–21,550	14 –13.9	Broadcasting.
21,550–22,300	13.9–13.45	Mobile services.
22,300–23,000	13.45–13.1	Mobile services and fixed services.
23,000–28,000	13.1–10.7	Not reserved.
28,000–30,000	10.7–10	Amateurs and experimental.
30,000–56,000	10 – 5.35	Not reserved.
56,000–60,000	5.35–5	Amateurs and experimental.
Above 60,000	Below 5	Not reserved.

NOTE.—It is recognized that short waves (frequencies from 6,000 to 23,000 kc/s approximately—wavelengths from 50 to 13m approximately) are very efficient for long distance communications. It is recommended that as a general rule this band of waves be reserved for this purpose, in services between fixed points.

CHAPTER 16

HANDLING AND ABSTRACTING TRAFFIC

1. **Introduction**—The operator in charge of the station is responsible for all money collected from the public as tolls or messages transmitted. He is required to account for the same at the end of each voyage, or, on ships making short voyages, at the end of each monthly period. When the money is turned in at the office of a service company controlling the radio service of the vessel he will be furnished with a receipt.

Usually the operator collects the money due for messages filed by the captain at the end of the voyage. Messages filed by the public or members of the crew should be collected at the time of filing the message.

By arrangement with the Radiomarine Corporation of America the author has been permitted to quote directly from their general orders relative to abstracting of traffic. The forms thus referred to in the text apply only to those forms used by this company although the methods employed by other companies are very much the same. By careful study of the following the student should secure an excellent idea of how to make up an abstract sheet at the end of a voyage.

2. **Acceptance of Radiograms**—(19) Radiograms and the money due thereon shall be accepted from passengers by the radio operators in accordance with the following instructions.

(20) Inquiries from the public should at all times be courteously and promptly answered, giving any particulars regarding stations, rates, etc., which may lead to the service being made use of. The number of messages handled on board ship is very largely dependent on the attention given by the operators to such matters, and to the proper advertising of the facilities offered. Operators should be on the alert to stimulate traffic, but should be careful not to resort to advertising methods which might not be approved by the steamship company or captain of the vessel.

(21) All messages accepted from the public or from the bridge must be written on the proper form provided by the corporation or attached thereto in such a manner as not to cover the space reserved for service entries. Messages accepted from the bridge

must be signed or initialed by the captain or his responsible officer before transmission.

(22) Care must be taken to obtain, for reference, the sender's full name, permanent postal address and cabin number on the back of the form; otherwise difficulty and delay may arise should it become necessary at any time to refer to the sender.

(23) The address of a message handed in for acceptance should be as clear and complete as possible to insure correct delivery.

(24) All radiograms accepted for transmission must be written legibly. Should the accepting operator be unable to read the message, he shall request the sender to rewrite or explain whatever is doubtful. If the sender refuses to comply with this request, the operator shall transmit the message as he understands it, and shall note on the back of the form that the sender has refused to rewrite or explain. Any correction, amendment or erasure made in a radiogram handed in for acceptance must be initialed by the sender.

3. **Censoring of Radiograms**—(25) Any message filed on board pertaining to the business of the steamship company (the ship's health, accidents at sea, service on board, etc.) must be submitted to the captain of the vessel for censoring before being transmitted, and the sender of the message concerned is to be advised of this procedure when the radiogram is handed in. Should the sender refuse to allow the message to be censored by the captain, the operator shall not accept it. All messages filed on board may be censored by the captain if he so desires.

(26) No message containing profane or obscene language may be accepted for transmission.

4. **Routing of Radiograms**—(27) Should the sender of the message specify the route by which it is required to be sent, the operator shall insert the necessary particulars in the preamble which shall not be counted or charged for. Messages not specifically routed otherwise by the sender shall in all cases be routed by the operator over the corporation's system when available.

5. **Receipt to be Given**—(28) An official receipt on the Corporation's form No. 10, showing the total amount paid must be given to the sender of each message on which cash is collected. These receipts shall be made out in duplicate, the carbon copy to be pasted on the back of the message concerned. This carbon copy must be an exact duplicate of the original held by the sender, and no change shall be made in the amounts as originally written. Should it be later found that an overcharge has inadvertently been made, the full amount collected must nevertheless be turned in to

the corporation with suitable explanation on the abstract in order that refund may be made to the sender.

(29) The charges collected on each message must be clearly shown in American money in the spaces provided for the purpose on the form on which the message is written. Ship charges, coast station charges and other charges must be entered separately.

6. **Numbering of Messages**—(30) All messages accepted shall be numbered progressively for the day of acceptance. This is the accepted number which is not to be transmitted. All messages transmitted shall be numbered progressively for the day of transmission and with regard to the station to which transmitted, a separate series of numbers being used for each station.

7. **Timing of Messages**—(31) The time and date of acceptance of all messages must be written on the message copy and transmitted in the preamble of the message, but shall not be counted or charged for.

8. **Language to be Used in Radiograms**—(32) Radiograms may be accepted when written in plain language, code, or cipher, except in the case of certain countries which do not admit code or cipher radiograms or only admit them under certain restrictions.

(*a*) *Plain Language*—Radiograms in plain language are those composed of words, figures, and letters which offer an intelligible meaning. They may be expressed in any of the European languages and certain others, such as Annamite, Arabic, Armenian, Japanese, Malay, Persian and Siamese. The words and letters must be written in Roman characters.

(*b*) *Code Language*—Radiograms in code language are composed of real words not forming intelligible phrases, or of artificial words consisting of pronounceable groups of letters. The real words may be drawn from any of the following languages: English, French, German, Italian, Spanish, Portuguese, Dutch and Latin. The artificial words must be formed of syllables which are pronounceable according to the current usage of one of these languages.

(*c*) *Cipher*—Radiograms in cipher are composed of Arabic figures or groups or series of Arabic figures having a secret meaning, or combinations of letters not fulfilling the conditions applicable to plain language or code.

9. **Counting and Charging**—(33) The number of words in a plain language message is computed on the basis of fifteen letters to each word. Where a word regularly used exceeds fifteen letters it will be charged for as two words. Subject to this limit ordinary compound words, names of towns, countries, provinces,

places, family names and names of ships are counted as single words, provided they are written without a break or hyphen. If joined by a hyphen or separated by an apostrophe, they are counted as so many separate words, and the hyphen or apostrophe, if transmitted, will be chargeable as an additional word. The same mode of counting applies to the names of streets, squares, etc., but the words "street," "square" or their equivalent in other languages cannot be combined contrary to the usage of the language with such names so as to form a single chargeable word. Compound numbers written in words and without a break are also counted as single words, subject to the same limit as to the number of letters.

(34) Words incorrectly spelled, so as to reduce the number of letters below the maximum, or incorrectly joined together contrary to the usage of the language, are inadmissible. Such words as "safternoon," "allright" or "alright," "midocean" and "good-bye" must in all cases be counted and charged for as two words.

(35) In all radiograms every isolated letter or figure is charged for as one word. Groups of figures are counted at the rate of five figures to a word, and at the same rate for any excess. The same method of counting is applicable to groups of letters forming a commercial expression, such as "cod," "fob," or commercial marks. Letters added to figures to form a number of an address or a commercial mark or quotation are considered as figures and charged for accordingly. Bars of division, decimal points and stops used in the formation of numbers are counted as figures. Otherwise signs of punctuation are not transmitted, except at the special request of the sender, and they are then charged for as separate words. The dollar mark ($) or pound mark (£) is always counted as a separate word.

(36) Code messages are counted at the rate of ten letters to a word. The presence of a code word in an otherwise plain language message converts the entire message into a code message and therefore subjects each word in the text of the message to a ten letter count.

(37) The combination "ch" which is counted as one letter in plain language, must always be counted as two letters when used in code.

(38) Cipher messages must be counted and charged for on the basis of five letters to a word. The letters or figures in each uninterrupted series shall be counted at the rate of five or a fraction of five as one word. The mixture in one group of figures and letters having a secret meaning is permitted, but such groups sub-

ject the count to one word for each letter or numeral, thus R2C counts as three words. This prohibition does not extend to trade terms, such as 106B which are not considered as having a secret meaning.

(39) Groups of letters and figures shall be transmitted in groups, as written by the sender of the message, and must not be divided in transmission, even when counted and charged for as more than one word.

(40) The cable system of counting is used for all radiograms, all words in the address, text and signature being counted and charged for. The message may contain any number of words and no text or signature is required. The address must consist of at least two words, the first indicating the name of the addressee and the second the destination. The name of the office of destination of a radiogram is counted and charged for as one word, without regard to the number of letters required to spell it. The name of the state, province or country in which the office of destination is located may be placed and transmitted in brackets without being counted or charged for. The number of a street written, for example, as 146th is counted as one word, provided the total number of characters, including figures and letters in the group does not exceed five. Telephone numbers appearing in the address must always be followed by the name of the office of destination. Letters following telephone numbers are counted in the same group subject to the limit of five characters.

(41) The following examples will serve to illustrate the rules to be followed in counting radiograms:

	Number of Words		
	In Address	In Text	
		Plain Language Message	Code Language Message
New York	1	2	2
Newyork	1	1	1
Frankfurt Main	1	2	2
Frankfurtmain	1	1	2
Newsouthwales	1	1	2
Dubois (name of a person)	1	1	1
Vandebrande (name of a person)	1	1	2
Saint James Street	3	3	3
Saintjames Street	2	2	2
Alright) contrary to the usage Allright) of the language		2	2
Times Square	2	2	2
Timessquare	2	2	2
Responsibility (14 characters)		1	2
Unconstitutionality (19 characters)		2	2
44 1/2 (5 characters)		1	1

		Number of Words	
	In Address	In Text	
		Plain Language Message	Code Language Message
444 1/2 (6 characters)		2	2
444.5 (5 characters)		1	1
444.55 (6 characters)		2	2
E	1	1	1
E M (isolated letters)	2	2	2
Ch23 (commercial sign or trade mark)		1	1
GHF456 (Commercial sign or trade mark)		2	2
Emythf (6 characters, unpronounceable, secret meaning)		2	2
Twohundredandthirtyfour (23 characters, numbers written out and joined)		2	3
The affair is urgent leave at once (two underlines)		9	9
Starokonstantinow (Town in Russia)	1	2	2
$100		2	2
Onehundred dollars		2	2
£100		2	2
10 fr. 50		3	3
11 h 30		3	3
44/2		1	1
City of Savannah (name of ship)	1	3	3
Cityofsavannah (name of ship)	1	1	2
USS	1	1	1
949893 (cipher)		2	2
106 A (number of house)	1	1	1
(no doubt)		3	3
Totally (underlined)		2	2
Incontrovertibly (underlined)		3	3

10. **Code Addresses**—(42) Radiograms bearing code addresses may be accepted but the operator should in such cases ascertain from the sender whether the address is registered with the telegraph service required to make delivery of the message at the office of destination. For example, a code address which is only registered with the Western Union Telegraph Company cannot be accepted in a message to be delivered in London by the British Post Office. The corporation will not be responsible for non-delivery of messages carrying code addresses not properly registered.

11. **Prefixes**—(43) The following prefixes shall be used with respect to the different classes of traffic, which must be transmitted in the proper order of priority. These prefixes are only to be used when communicating with RCA ships or coast stations and ships controlled by associated companies. The letter "X" should be dropped from the prefix of relayed messages by

the operator transmitting the message to the station of destination.

Priority	Prefix When for delivery	Prefix When for retransmission	Classification
First..........	S O S	S O S	Distress messages
Second........	S	X S	Government messages
Third.........	A	X A	Telegraphic service messages
Fourth........	M S G	M X G	"Masters Service" messages
Fifth..........	P	X	Ordinary paid messages
Sixth..........	P D H	X D H	Franked or dead head messages
Seventh.......	PRESSE	XPRESSE	Press messages
Eighth........	O L		Ocean letters

(44) Messages within the same class shall be transmitted in the order in which accepted.

12. **Government Messages**—(48) Messages may be accepted under this classification pertaining to official business of the United States Government. They may be filed by the captain of the ship or by an acccredited official or representative of the government on board. Such messages shall be forwarded through U. S. Government costal stations whenever possible.

(49) Government messages may further be of the nature of one or other of the following:

(*a*) *Govt. S. B.*—Official messages having relation to the navigation or operation of vessels owned or controlled by the U. S. Shipping Board, passing between the master or other accredited official aboard said vessels and officials of the U. S. Shipping Board or accredited agents of the person, firm or corporation assigned as manager, or operator of said vessels.

(*b*) *Govt. W. B.*—Weather Bureau messages addressed to "Observer." Such messages are not to be transmitted more than twelve hours after the time at which the observation was taken.

(*c*) *Govt. Hydro.*—Messages containing hydrographic information.

(50) The expression "Govt.," "Govt. S. B.," "Govt. W. B.," or "Govt. Hydro." whichever is applicable, must be transmitted in the preamble and "Govt." as the first item in the address of all government messages, and is counted and charged for as one word. Such messages shall contain no personal matter whatsoever.

13. **Telegraphic Service Messages**—(51) A service message shall only be sent when it pertains to traffic previously handled.

Every service message must be pasted on the back of the message to which it refers, in the order in which it was transmitted or received, but in such manner that all messages can be easily read.

(52) Whenever it is impossible to deliver a message that has been received, a service must be forwarded immediately to the office of origin of the message which cannot be delivered, stating the reason for non-delivery.

(53) Service message received pertaining to non-delivery due to improper address of a message previously transmitted should be compared with the original message, and if there is any discrepancy, the office reporting non-delivery shall be immediately notified by service of the correct address as appearing on the original message. In such cases it is not necessary to notify the sender.

(54) Should, however, the address as repeated in the service be found to correspond with the address on the original message, a copy of the service message shall be delivered to the sender and a receipt obtained. In such cases the sender can only rectify or complete the address by means of a paid service message.

(55) All service messages are addressed directly to the station or office concerned and signed by the office or origin, followed by the date filed. Such messages must contain the full address and signature of the message to which it refers, and must be transmitted with a number but no check or preamble.

14. **Masters Service Messages**—(59) Master service messages are those having relation to the navigation or other business in connection with the operation of a ship exchanged between the captain and his owners or duly accredited agents or between the respective captains of two or more ships. Such messages must always be signed or initialed by the captain or his responsible officer before transmission. They shall contain no personal matter whatsoever.

15. **Ordinary Paid Messages**—(60) These are messages fully prepaid accepted from the public for transmission or received for delivery to the public.

16. **Franked or Dead Head Messages**—(61) See section of this book pertaining to Franked or Dead Head Messages.

17. **Press Messages**—(62) These are messages accepted from duly accredited press representatives addressed to newspapers or press agencies for publication. News matter originating on board a vessel shall not be transmitted until the message has been censored and initialed by the captain. Press messages are subject to full tolls over the corporation's system, but will be handled at reduced rates on the landlines.

18. **Ocean Letters**—(63) This is a class of traffic at special rates accepted under certain conditions fully explained in the section of this book pertaining to Ocean Letters.

19. **Special Classes of Traffic**—(64) Certain classes of radiograms are indicated by conventional signs transmitted in the preamble and again as the first item of the address. Such signs are counted and charged for in the address as one word. These signs are as follows:

Radiograms with prepaid reply..	RP, and the amount prepaid
Collated Radiograms...........	TC.
Radiograms to be delivered by mail	The word "Post"
Radiograms to be posted as registered letters	PR.
Radiograms for special delivery when the cost of delivery is to be collected from the addressee	The word "EXPRESS"
Radiograms for special delivery in the country of the coast station through which the message is sent, when the cost of the special delivery is prepaid	XP.
Radiograms not to be delivered during the night time	The word "JOUR"
Radiograms to be delivered at night time if received then ...	The word "NUIT"
Radiograms to be called for at a Telegraph Office	TR.
Radiograms to be called for at a Post Office	GP.
Radiograms with multiple addresses	TM, and the figure representing the number of addresses.
Radiograms with acknowledgment of receipt:	
By Telegraph	PC.
By Post	PCP.
Radiograms to be given priority over the land telegraph system, i.e., urgent messages	D.
Paid service advices	ST.

20. Radiograms with Prepaid Reply—(65) Radiograms may be accepted with an answer prepaid. Full transmission charges for such messages must be collected and in addition the full charges for the reply based on the number of words the sender expects the reply to contain. "Reply Paid" messages are transmitted with the letters "RP" in the preamble and again as the first item in the address, followed by the amount prepaid, as for example "RP two dollars ten cents" or "RP francs 10.50," the entire expression "RP two dollars ten cents" or "RP francs 10.50" being counted and charged for as one word.

(66) When an "RP" message is received at its office of destination the receiving operator will deliver to the addressee with the message a Reply Paid Voucher (Form No. 11-A) covering the amount prepaid for a reply. Such a voucher will be accepted to the extent of its face value in lieu of cash in whole or part payment for any reply or other telegram which the holder may wish to send from the vessel on which the voucher was issued. Vouchers so accepted must be pasted on the back of the message for which it was taken in payment. A frank held by the sender of an "RP" message does not cover any of the charges due for the reply.

21. Collated Radiograms—(67) The sender of a radiogram may request that the message be repeated back to the sending station for the purpose of verification. Such messages may be accepted upon payment by the sender of an additional charge equal to one-half the regular tolls. The expression "TC" must be transmitted in the preamble and again as the first item of the address. A message carrying the expression "TC" must always be repeated back by each station immediately upon its being received.

22. Radiograms to be Delivered by Mail—(68) The address of this class of message must be drawn up in the following manner:

(*a*) The paid indication "Post" followed by the name of the port at which the radiogram is to be posted.

(*b*) Full name and address of the addressee.

(*c*) Name of the ship station from which the radiogram is to be posted. For example, the SS Philadelphia, wishing to send a radiogram to be posted from the SS Caracas at New York would address the message as follows:

Post New York John Smith
75 N. Charles St.,
Baltimore, Md.
Caracas.

(69) When a radiogram is handed in at an inland telegraph office for transmission through a land station to a ship station, to be posted from the latter at a port of call, the name of the land station must be included in the address. For example, a person wishing to transmit a message from Boston to be posted from the SS Huron on arrival at Buenos-Aires would address it as follows:

Post Buenos-Aires Jose Lopez
560 Calle Lavalle
Huron Cape May.

(70) Five cents for postage will be collected on such messages in addition to the radio charges. If message is to be forwarded by registered mail the expression "PR" is used instead of "Post" and fifteen cents collected for postage instead of five.

23. **Radiograms for Special Delivery**—(71) These are messages which involve delivery beyond the ordinary limits of the telegraph service. Such delivery is accomplished by special messenger or telephone. Charge for special delivery will be collected from the addressee so that only the usual rates are to be collected from the sender. Such messages are transmitted with the expression "Express" in the preamble and again as the first item of the address.

(72) Pre-payment of the special delivery charge may be allowed where the message is destined for the country in whose territory the receiving coast station is situated. Such messages are transmitted with the expression "XP" in the preamble and again as the first item of the address.

It should be noted, however, that in the United States the land-line rates for radio messages cover delivery to any point in a given state.

24. **Radiograms to be Called for at a Telegraph or Post Office**—(73) Radiograms from ships when intended to be left until called for at a telegraph office or post office should bear the words "Telegraphe Restante" or "Poste Restante" as required, as the first item of the address (counted as two words in each case), or the abbreviation "TR" and "GP" respectively may be used to represent these expressions, in which case the abbreviated sign will be counted and charged for as one word.

25. **Radiograms with Multiple Addresses**—(74) Radio-

grams may be accepted addressed either to several persons in the same town, or to the same person at several addresses in the same town; but to be transmitted by radio as a single message. In computing radio charges each word in all the addresses and the text is counted but once, but the landline tolls must be computed for so many different complete messages (cable count), as the landline telegraph companies in the United States do not recognize multiple messages. The expression "TM" followed by the number of addresses must be transmitted in the preamble and again as the first item of the address. Thus a multiple message with five addresses would carry the expression "TM5."

26. **Radiograms Calling for Acknowledgement of Receipt**—(75) Such messages must originate on shore and cannot be accepted on board ship. Acknowledgment of receipt is limited to notification to the office of origin of the date and hour at which the coastal station shall have transmitted to the station on shipboard a radiogram addressed to the latter. These messages are transmitted with the expression "PC" or "PCP" in the preamble and again as the first item of the address. "PC" calls for telegraphic acknowledgments and "PCP" for acknowledgment by mail. Mail acknowledgments are sent free. If telegraphic acknowledgment is requested the sender will be required to pay, in addition to the usual charges, the landline telegraph charges on a five word telegram by the same route.

27. **Urgent Radiograms**—(76) Certain foreign countries permit an urgent classification. Such messages are given no preference in the radio transmission but have priority on the inland telegraph systems of the countries permitting them. Extra landline charges must be collected, usually about double the ordinary rate. The letter "D" must be transmitted in the preamble, and again as the first item of the address.

28. **Paid Service Messages**—(77) Such messages may be accepted from the sender of and pertaining to a previous message for various reasons, as, to rectify or complete an address, rectify or complete the text, or to cancel a message. Paid service notices requesting a repetition or information are prohibited. The expression "ST" must be transmitted in the preamble and again as the first item of the address.

29. **Order of Transmission**—(78) All messages shall be transmitted in the following order:

Prefix
Number of message

Letter "M" (indicating vessel controlled by Radio Corp. of America).
Number of words (check)
The word "radio" (required by law)
Office of origin
Time filed
Date filed (only if different from date sent)
Service instructions (if any)
Address
Text
Signature

30. **Received Traffic**—(79) All messages received for delivery on board must be copied on Form No. 4 and Ocean Letters received for mailing on Form No. 275. Messages received for relay must be copied on Form No. 2, and service messages on Form No. 106A.

31. **Delivery**—(80) Messages delivered to the public (including the captain, passengers and crew) must be enclosed in a delivery envelope (Form No. 128) and handed to the addressee, from whom a delivery receipt must be obtained. This receipt is to be pasted on the back of the office copy of the message.

(81) Operators should bear in mind the importance of such receipt in the event that refund of tolls should be claimed for alleged non-delivery. In such cases, if the corporation is unable to prove delivery through negligence of an operator to obtain the signature of the addressee on a delivery receipt, the operator responsible will be held liable for the amount refunded by the corporation.

32. **Non-Delivery**—(82) In the event that for any reason delivery cannot be effected of any message received on board, a service message must be sent advising the office of origin of non-delivery. See paragraphs covering telegraphic service messages.

(83) Messages undelivered or not transmitted shall never be destroyed by the operator. A notation covering the circumstances should be made on such messages which must be abstracted and handed in with other traffic returns.

Franked or Dead Head Messages.

33. **Free Transmission**—(86) Franked messages are entitled to free transmission throughout the marine service of the corporation (with the exception of the ship tax of vessels operated under contract with the U. S. Shipping Board) but are sub-

ject to all "Other Line" charges, including charges of associated companies' ships and coast stations.

34. **Classification of Franked Messages**—(87) Franked or "Dead Head" messages may be of any one of the following classes:

(*a*) Messages filed by holders of the corporation's complimentary frank cards, properly countersigned, which must be exhibited at the time message is handed in.

(*b*) Messages pertaining to the corporation's business filed by duly authorized representatives of the corporation.

(*c*) Personal messages of the operators, limited to thirty words per ship per calendar month, which must be signed with the sender's full name. This privilege is not cumulative, only thirty free words per ship being allowed during each calendar month, regardless of the number of words used during the preceding months.

(88) Franked messages filed by the holders of the corporation's frank cards are only to be accepted when they are of a personal or social nature. Business or political messages cannot be franked.

(89) It must be particularly noted that the ship tax must be collected on all franked messages to or from U. S. Shipping Board vessels operated and controlled by the corporation.

(90) "Other Line" charges may also be franked upon presentation by the sender of a bonafide frank of the telegraph company concerned.

(91) Franked numbers must be inserted in the service instructions on the message copy and transmitted in the preamble of the message, except that an RCA frank number need not be transmitted if the message is sent to other than an RCA station. For example, if the holder of an RCA frank files a message on board an RCA ship to be forwarded through a naval coast station, the frank covers only the ship tax, and therefore is of no interest to the coast station and should not be transmitted.

Ocean Letters.

(92) The Ocean Letter is a class of radiogram which may be sent from one ship to another ship going in a different direction, for delivery by registered mail from the first suitable port of call of the latter vessel. Conditions covering the acceptance and transmission of Ocean Letters are as follows:

(*a*) The maximum length of such messages shall be 100 words, cable count.

(*b*) They shall only be exchanged between ships proceeding in different directions.

(*c*) Only one ship to ship transmission is permitted.

(*d*) They must be written in plain language only and the sender may not choose the ship via which the message is to be sent or the port from which it is to be mailed.

(*e*) No abbreviated addresses are allowed and the given name or the designation "Mr.," "Mrs.," "Miss," etc. should always be included in the address of this class of message. Ocean Letters may not contain multiple addresses.

(*f*) Under no condition whatever may such messages be sent to a coast station for delivery by mail.

(*g*) Transmission of Ocean Letters is not to interfere with the prompt despatch of ordinary traffic and such messages shall not be transmitted when either of the ships concerned is within the normal daylight working range of a shore station open for commercial traffic and no interference with the ordinary working of other stations in the neighborhood is to be caused by the transmission of Ocean Letters.

(*h*) Ocean Letters are to be transmitted only to ship stations of the corporation or associated companies, with the exception of the Italian Company, which company only admits this class of traffic when the handling is performed exclusively between ships of Italian registry. Ocean Letters can be handled between Shipping Board vessels, regardless of Radio Company control. Modification applies only to U. S. Shipping Board vessels and Ocean Letters handled must be in strict accordance with paragraphs 82 to 78, inclusive, of General Orders.

(93) As the sender of an Ocean Letter may not specify or select any particular route by which it is to be forwarded, and as this duty falls upon the operator, it is obvious that discretion should be exercised when clearing Ocean Letters. The receiving vessel shall be selected carefully from among such ships as are available. If the operator has a choice of several ships through which to forward Ocean Letters, preference should be given, if possible, to passenger ships bound for the country to which the message is destined. Speed of the vessel and her next port of call should also be taken into account. Operators should in all cases select from among ships within range the vessel which, in their opinion, is likely to effect the speediest delivery to office of destination.

(94) The prefix "O. L." and the service instruction "Ocean Letter" must be signalled to the receiving ship.

(95) When an operator is in receipt of Ocean Letters for mailing, he must exercise his best judgment as to the most suitable port from which to forward them and should always be guided by the nature of the postal facilities offered, with a view to there being as little delay as possible between the time of mailing and actual delivery to the addressee. For this reason Ocean Letters should be registered and mailed at the earliest possible moment after arrival at a suitable port. Registry receipts in respect to such messages will be accepted from the operator in lieu of cash when he turns in his traffic. In case registration cannot be effected, the message shall be forwarded by ordinary letter mail and a note of explanation made on the back of the office copy.

(96) Ocean Letters accepted on board shall be written on Form No. 274 and Ocean Letters received for mailing shall be written on Form No. 275. Form No. 128 with delivery receipt attached shall be used for mailing Ocean Letters.

(97) The rate for Ocean Letters is $1.20 for twenty words plus 4 cents per word for each word after twenty (maximum of one hundred words) inclusive of postage and registration.

Relay Traffic.

35. **Form to be Used**—(98) All messages received for relay shall be received on Form No. 2.

36. **Abstracting**—(99) All relayed messages must be entered on the abstract and copies handed in with the traffic returns. Under no circumstances, shall a message be relayed without a copy being kept by the relaying station. This is imperative.

37. **Free Relay Service**—(100) Ships operated and controlled by the corporation will relay free of retransmission charge messages for other ships operated by the corporation, or by one of the associated companies listed in this book; also for any ship of the United States Navy or other United States Government Department. Relay service performed by or for ships other than the above will be subject to a relay charge of 8 cents per word, except that traffic shall be relayed to or from any of the corporation's ship or shore stations free of charge regardless of the control of the ship for which such service is performed.

(101) Care should be taken to collect relay charges on messages accepted on board for relay via a ship not included in the reciprocal arrangements referred to above and to show on the

abstract relay charges due from the steamship company and from other wireless telegraph systems.

"This Line" Privileges.

38. **"This Line" Stations**—(102) All vessels on which the radio stations are operated and controlled by the corporation under rental or service contracts and all marine coastal stations operated by the corporation, together with vessels operated and controlled by associated companies, are known as "This Line" stations and are entitled to "This Line" privileges. All other vessels equipped with radio are known as "Other Line" stations and are not entitled to "This Line" privileges.

(103) "This Line" privileges comprise:

(*a*) Transmission of "Master's Service messages (MSG's) free of ship tax.
(*b*) Participation in "Ocean Letter" service.
(*c*) Free Re-transmission.

39. **"Other Line" Stations**—(104) Messages of class (a) transmitted to or received from any "Other Line" ship direct are subject to one receiving ship tax; for example, a "Master's Service" message transmitted from a "This Line" station to an "Other Line" ship station, should be charged as follows:

"This Line"—ship tax free.
"Other Line"—ship tax to be collected from sender.

Similarly, in cases of "Master's Service" messages received from an "Other Line" ship station, the "This Line" charge is to be entered on the abstract as due from the "Other Line" transmitting station.

40. **Free Relay Service**—(105) Free re-transmission or relay service will be performed for or by all "This Line" stations free of charge. However, all relayed messages must be abstracted by the relaying ship and under no circumstances should such messages be treated as having been handled direct.

(106) All relay service performed for and by "Other Line" stations shall be subject to the ship tax of the relaying ship and must be so abstracted. However, this will not apply to vessels of the United States Navy and other United States Government Departments with which the corporation has reciprocal relay arrangements.

(107) It must be particularly noted that Ocean Letters may not be forwarded to or received from "Other Line" stations.

(108) Operators may determine the names of "This Line" stations by reference to the International List of Radiotelegraph Stations and the list of associated companies given in this book.

Abstracts.

(118) Messages should be entered on abstract forms daily. Operators must take particular care to see to it that all messages handled, except telegraphic service messages, position reports to managers of RCA coast stations, free compass bearings and TR reports, are duly entered on the abstracts, and that the charges collected or due are entered in the proper columns. Failure to do this causes a large amount of unnecessary work when the abstracts are checked. Operators who have not properly prepared their abstracts will be required to rewrite them before they will be accepted.

(119) The abstract form (Form No. 7) and 7a Form for RCA traffic—7a for other than RCA is printed on both sides. Accepted messages are listed on the side printed in black and received messages on the side printed in red. Each message shall be entered on a separate line.

(120) The following is an explanation of the accepted side of the abstract form showing particulars to be entered in the various columns.

Column 1—The date of acceptance shall be entered here, regardless of whether the message is transmitted on a later date. A message accepted on the last day of the month, but not transmitted until the first day of the following month, shall be entered on the abstract for the month in which it was accepted.

Column 2—The name of the coast station through which the message was routed shall be entered here. Should the message be destined to another vessel this column is left blank, unless the message is relayed to the vessel of destination via a coastal station. In such cases the name of the coastal station shall be entered in this column.

Column 3—The name of the addressee and the office of destination shall be entered here.

Column 4—The prefix with which the message was transmitted shall be entered here.

Column 5—This column shall show the number of chargeable words in the message, which must agree with the check of the message as transmitted.

Column 6—The call letters of the ship or coast station to which message was transmitted shall be inserted here. In the case of messages relayed the call letters of the ship or station to which message was transmitted for relay are entered in this column, and not the call letters of the station of destination.

Column 7—This column must show the full amount of cash received by the operator for each message. If it is found that an overcollection has inadvertently been made the full amount collected must nevertheless be shown. The total of this column is the amount of cash that must be turned in with the abstract.

Column 8—The amount due on messages transmitted as prepaid but for which cash was not collected from the sender shall be entered here, with the exception that this column is not to be used for charges due from the steamship company. Notation shall be made in column 20, stating from whom the amount is due. For example, charges due on "Observer" messages are to be shown in this column, with notation in column 20 "Due from U. S. Weather Bureau." Also when an "RP" voucher is taken in lieu of cash, in payment for an accepted message, the amount of the voucher is to be entered here and not in column 7. In such cases the notation "Due from RP voucher" is made in column 20.

Column 9—All charges due from the steamship company for MSG's accepted on board are to be entered here, except when cash to cover the amount is collected from the captain as is the case on Shipping Board vessels. In such cases the amount collected on MSG's is entered in column 7. The amount entered in column 9 should never include the ship tax of the vessel of origin or any other vessel operated by the corporation, as ship tax is not charged on steamship business. If, however, the message was destined to another vessel, other than a vessel operated by the corporation, the amount entered in this column must include the ship tax of the ship of destination. In all cases the amount entered in this column shall include coast tax, if any, landline forwarding charges, if any, and war tax, if war tax is applicable. Also, if the message was forwarded for relay to a vessel controlled by another system having no reciprocal relaying arrangement with the corporation, the relay charges shall also be included in the amount entered in column 9. The corporation will invoice the steamship company for all charges entered in column 9. Whenever the charges on a particular message are entered in column 9, columns 7 and 8 are left blank, and vice versa.

Column 10—That proportion of the amount entered in columns 7 or 8 representing the ship tax of the vessel which the abstract covers is to be shown here. The amount entered here should be equal to the number of words in the message, as shown in column 5, multiplied by the vessel's rate of ship tax. If no ship tax is chargeable, this column is left blank. In the case of Ocean Letters, the amount to be entered in this column is arrived at by first charge on an Ocean Letter is $1.20, the amount to be entered in column 7 and dividing the remainder by two. Thus, if the total charge on an Ocean Letter is $1.20, the amount to be entered in column 10 is 54 cents, the remaining 54 cents plus 12 cents postage accruing to the ship to which the Ocean Letter was transmitted for mailing.

Column 11—The proportion of the tolls due another vessel controlled by the corporation is entered here. That is, if the message was destined to another vessel controlled by the corporation, the total ship tax due that vessel must be shown in this column. In the case of an Ocean Letter transmitted to another vessel controlled by the corporation, that vessel's proportion of the tolls plus the 12 cents postage shall be entered.

Column 12—This column is to be used only for messages routed through one of the corporation's coastal stations. The coastal station's charge plus the land line forwarding charge on each such message are to be added together and entered in this column as one amount.

Column 13.—This column is to be used only for messages sent through United States Naval coastal stations, or destined to a vessel of the United States Navy. If the message was sent through a United States Naval coastal station, the coastal station's charge plus the landline forwarding charge are to be added together and entered in this column as one amount. If the message was destined to a vessel of the United States Navy, the total ship tax due that vessel is shown here.

Columns 14, 15, 16, 17, 18 and 19—These columns are for listing amounts due other radio systems, except the United States Naval Communication Service. A separate column shall be used for each radio system to which money is due, and the name of such system must be plainly printed in the space at the top of the column. It should be noted that whenever a message is forwarded through a coastal station the coast tax and landline forwarding charge are to be added together and entered as one amount due to the radio system controlling the coastal station. However, should the coast tax or landline charge be covered by a frank, the amount so franked is not to be included in the amount entered. In such cases an explanatory notation must be made in column 20, as for example, "W. U. frank No. 75." All war tax collected must be entered in one of these columns, which shall be headed "War Tax." If an overcollection has been made on any particular message it is to be entered in one of these columns, which shall be headed "overcollections." If during the month covered by the abstract traffic has been sent to various stations controlled by a number of different radio systems so that there are not sufficient blank columns to provide a separate column for each system, then separate columns are to be used for as many systems as possible and the charges due all the remaining systems entered in column 19, which shall be used as a "general" column and so headed. Every entry in the "general" column must be supported by a notation in column 20, giving the name of the system to which the amount is due.

Column 20—This is the "Remarks" column, in which shall be entered the following:

A notation regarding all messages on which any part of the charges were franked, giving the frank number and name of the company by which it was issued.

A notation regarding elimination of any part of the charges on operator's personal messages sent with the prefix "PDH."

A notation supporting each item entered in column 8.

A notation in support of every entry in the "General" column.

A notation regarding all messages on which rates were obtained by "QSJ" showing the rates given.

Any other necessary explanatory notes pertaining to the traffic entered on the abstract.

(121) The following is an explanation of the received side of the abstract form showing particulars to be entered in the various columns.

Column 1—The date the message was received on board shall be entered here.

Column 2—The call letters of the coast station or ship from which the message was received shall be entered here. In the case of messages received by relay the call letters of the relaying ship or station are to be shown.

Column 3—The office of origin of the message is to be entered here, as for example, Albany, N. Y.; London, England; SS ZULIA, etc.

Column 4—This column shall show the name of the coastal station through which the message was routed.

Column 5—The name of the addressee and the office of destination are to be entered here.

Column 6—The prefix with which the message was received is to be entered here.

Column 7—This column shall show the number of chargeable words in the message which must agree with the check of the message as received.

Column 8—One of the following abbreviations are to be entered in this column: "Capt."—If message was delivered to the captain of the vessel. "Opr."—If message was delivered to one of the ship's staff of radio operators. "Pub."—If message was delivered to anyone other than the above. "Mail"—If message was mailed, as for example, an Ocean Letter.

Column 9—The total ship tax due the receiving vessel is entered here, provided the message originated on another ship controlled by the corporation.

Column 10—The total ship tax due the receiving vessel is entered here if the message was received via one of the corporation's coastal stations.

Column 11—The total ship tax due the receiving vessel is entered here if the message was received via one of the coast stations of the U. S. Navy, or from a U. S. Naval vessel.

Columns 12, 13, 14, 15 and 16—These columns are for listing amounts due from other radio systems, except the United States Naval Communication Service. A separate column shall be used for each radio system from which money is due, and the name of such system must be plainly printed in the space at the top of the column. Thus the total ship tax due the receiving vessel on a particular message is entered in the column which is headed with the name of the radio system controlling the station from which the message was received. In the case of an RP message received for delivery, the amount prepaid for a reply is added to and entered in the same column with the amount due for ship tax.

Column 17—The amount due the ship for ship tax or relay charges is to be entered in this column.

Column 18—The amount of ship tax due on MSG's originating on shore (except at New York and San Francisco) is to be entered in this column. This is for the reason that steamship companies filing MSG's ashore at Western Union or Postal Telegraph offices pay full tolls including ship tax. The ship tax on such messages is later refunded and therefore must be shown in this column as due to the steamship company. MSG's originating at New York and San Francisco, however, are filed at the corporation's offices, and on such messages no ship tax is charged. Therefore in abstracting MSG's originating at New York or San Francisco, this column is to be left blank.

Column 19—Miscellaneous amounts due are to be entered here, such as the amount of each RP voucher issued and money expended for postage on Ocean Letters and therefore due the operator.

Column 20—For all necessary remarks pertaining to the traffic received. For every received message abstracted, other than relays for which no entry is made in columns 17 or 18 or for which an entry is made in column 19, there should be a supporting notation in column 20.

(122) It should be noted that both the accepted and received sides of the abstract form are arranged for "debit" and "credit" entries. On the accepted side columns 7 to 9 inclusive are for debit entries and columns 10 to 19 inclusive for credit entries. The debit entries represent money received or chargeable and the credit entries must show the distribution to be made of such money. On the received side columns 9 to 16 inclusive are for debit entries and columns 17 to 19 inclusive for credit entries. The debit entries on the received side must show the amount of money due the ship and from what source. The credit entries must show how this money is to be credited.

(123) All columns, including columns containing the number of words, must be totaled. The grand total of all the columns in the debit section (exclusive of the column containing the number of words) must equal the grand total of all the columns in the credit section. If the debit and credit sections do not balance the abstract has not been properly compiled and must be checked and corrected so that it will balance. In order that grand totals may be readily checked at the time abstract is handed in the totals of the columns in the debit section are to be written in a circle on the debit section of the sheet and totaled, and the totals of the credit columns written in a circle and totaled on the credit section.

(124) All messages relayed for other ships or coast stations must be abstracted regardless of whether or not a charge is made for relaying. Cancelled messages which cannot be delivered shall nevertheless be abstracted and shall not be destroyed.

(125) A sample abstract showing the proper method of abstracting various classes of messages can be secured at any of the corporation's service stations, and all operators should obtain and preserve one of these sample forms for future reference.

41. **Form No. 15—Traffic Summary**—This form is to be used to summarize the traffic for the month as entered on the abstracts. Only one sheet of the Traffic Summary form is necessary even though the month's business may require several sheets of the abstract form.

42. **Form No. 47—Station Report**—This report is to be handed in at the office with the least possible delay after arrival at any port where the corporation maintains a service station. It must cover in detail the condition of the apparatus, stating repairs and parts required. It must also contain a list of all spare parts on hand.

Log Sheets.

(128) Form No. 6 is to be used for keeping a record of all important routine matters during the voyage, and of all communications with other stations.

(129) In compiling logs the following points shall be observed:

(*a*) On vessels where continuous watch is maintained an entry must be made at least every fifteen minutes of the voyage; on vessels having one operator similar entries shall be made during the times he is on duty.

(*b*) Each sheet of the log must be numbered and dated.

(130) The following shall be recorded:

(*a*) All communications established and reason.

(*b*) Call letters of other stations communicating and a few words of intercepted messages.

(*c*) Distress calls, unusual and special incidents. Such entries shall be the subject of a special report to be compiled by the operator-in-charge and handed in or forwarded promptly to the Division Superintendent.

(*d*) Delays in disposing of traffic or gaining attention of coastal or other stations and reason, break down of apparatus, failure of engine-room current supply, noises or disturbances tending to delay traffic.

(*e*) Arrival at and departure from ports.

(*f*) Position report of vessel in miles from some given point once each day. (Noon position preferred.)

(131) Logs must be signed as follows:

(*a*) On vessels carrying two or more operators, at change of each watch, both the relieved and relieving men shall sign. At end of voyage, senior operator shall sign completed log, as operator-in-charge.

(*b*) On vessels carrying one operator, completed log shall be signed at end of voyage.

(132) Upon completion of voyage the log sheets must be fastened together in numerical order and handed in with the trip's reports.

(133) All information entered on log must be regarded as strictly confidential.

(134) The time used for making entries in the log must be stated at the top of the sheet, i.e., Greenwich mean time, 75th meridian time, or whatever time is used, depending on the trade in which the vessel is engaged. It should be noted that for radio purposes 0000 G. M. T. represents midnight at the meridian of Greenwich which is equivalent to 7 p.m. 75th meridian time or 4 p.m., 120th meridian time, the time changing one hour for each fifteen degrees longitude.

(135) Below is given an extract from a well-kept log and operators should model their logs accordingly, paying particular attention to neatness, legibility of writing and accuracy of the time entries:

S. S. "HURON" January 1st, 1922.

Date	*Time*	*Remarks*
Jan. 1	9.00 a.m.	75th meridian time.
		Senior Operator J. Smith and Junior Operator E. Ward reported for duty.
	11.00	Left Pier 1, North River, New York, enroute Havana, Cuba. On watch, J. Smith
	.15	WNY de KUSD—Tr Huron left NY 11 a.m. enroute Havana, QRU—QTC?
		KUSD de WNY—R QRU
	.25	KUSD de KDOW—R No. 1 "MSG".
	.40	WNY de KUSD—S No. 1 "P"
		KUSD de WNY—R QRU
	.50	NQF de NAH—No answer.
	12.00 Noon	QST de NAA—Time tick and weather report. (Record weather report.)
	.30 p.m.	Off watch—J. Smith
		On watch—E. Ward.
	.35	Engine room advise dynamo temporarily out of commission. Power not available for short period.
	.50	Nil.—X's bad.
	1.00	Engine room advise power now O.K.
ETC.		....

Rates.

43. **Computing Rates**—(160) Tolls chargeable on a radiogram to or from a ship at sea are computed by adding together the charges of the various stations or systems handling the message during its transmission from the office of origin to the office of destination. The factors entering into the total rate consist of the charge of the ship station referred to as the ship tax; the charge of the relaying ship, if any, referred to as the relay charge; the charge of the coast station through which message was routed referred to as the coast tax; and landline, cable, or trans-oceanic radio charges referred to as forwarding charges.

(161) Therefore the total rate per word to be charged on a message originating on a ship at sea destined to some point on shore is arrived at by adding together the following separate rates:

Ship tax of ship of origin.
Relay charge (if any).
Coast tax of station through which message is routed.
Forwarding charges from coast station to destination.

(162) The total rate per word to be charged on a message originating on a ship destined to some other ship is arrived at by adding together the following separate rates:

Ship tax of ship of origin.
Relay charge (if any).
Ship tax of ship of destination.

(163) The total rate per word thus computed multiplied by the number of chargeable words in the message (to which must be added war tax on messages filed within the three mile limit) gives the total charge on the message.

44. **R. C. A. Rates**—(164) The ship tax of all vessels controlled by the Radio Corporation (except ships plying the Great Lakes) is 8 cents per word, no minimum. The coast tax of all coastal stations controlled by the Radiomarine Corporation is 10 cents per word, no minimum.

45. **Relay Charges**—(165) The same charge of 8 cents per word is made for relay service performed for vessels controlled by radio systems with which the corporation has no reciprocal relay arrangement. In general, the relay charge of all ships is the same as their rate of ship tax and the relay charge of coast stations is the same as their rate of coast tax.

46. **Rate Sheets**—(166) All ships controlled by the corporation will be furnished with a Berne List and rate sheets from which coast station and forwarding charges may be ascertained.

47. **Obtaining Rates by "QSJ"**—(167) Whenever there is

any doubt regarding the proper rate to be charged, the ship operator must obtain the rate by means of the abbreviation "QSJ" from the coast station or ship to which message was sent. Operators obtaining rates by "QSJ" must definitely ascertain the currency in which the rate is expressed and whether the amount given covers both coast tax and forwarding charges. An explanatory notation regarding rates so obtained must be made in the "Remarks" column of the abstract. In addition to this an exact copy of the information requested and also the reply obtained must be written on service blanks (Form 106-A) which shall be attached to the message to which they apply. This is required as a permanent record in the event of any question arising at a later date regarding the rates quoted.

48. **Ocean Letter Rates**—(168) The rate for Ocean Letters filed on board a vessel controlled by the corporation is $1.20 for twenty words, plus 4 cents per word for each word after twenty (maximum of 100 words) inclusive of postage and registration. It shall be noted, however, that Ocean Letters at this rate can only be accepted for forwarding via a ship controlled by the corporation or an associated company.

49. **Government Rates**—(169) Messages on United States Government business, carrying the abbreviation "Govt." as the first word of the address, are entitled to government rates on the landlines within the United States. The government landline rate is computed by deducting one cent from the regular landline rate per word for commercial messages, and dividing the remainder by two. For example, if the commercial rate is 6 cents per word the government rate will be 2½ cents per word.

(170) Government messages may be forwarded through United States Naval stations free of coast tax, but if sent through commercial coast stations, regular coast tax must be charged. No ship tax will be charged on such messages by United States Naval vessels or other United States Government vessels, including vessells operated by the United States Shipping Board.

(171) The rate for "Observer" (Govt. WB) messages, when forwarded through coastal stations other than those of the United States Navy, is 8 cents per word ship tax, plus the actual coastal station rate and landline charge. When forwarded through a U. S. Naval coastal station the only charge is 4 cents per word ship tax, no coast tax or landline charge being applied. If the message originates on a vessel of the United States Shipping Board, no ship tax is charged. Observer messages will be relayed by RCA

ships free of charge, regardless of the control of the ship on which they originate.

(172) No ship tax is charged on "Hydrographic" (Govt. Hydro) messages, and if sent to a U. S. Naval station no coast tax or landline forwarding charges are applied.

50. **Undercharges**—(173) Operators will be required to personally make good any undercharges due to the use of incorrect rates or other mistakes in the calculation of the charges due on a message.

Shipping Board Vessels.

51. **Special Instructions**—(195) The instructions in this section apply only to operators assigned to Shipping Board vessels. Should any part thereof conflict with other sections of this book, Shipping Board operators will comply with instructions given in this section.

52. **Contract with Shipping Board**—(196) The corporation operates and maintains under contract the radio service on a number of ships owned by the U. S. Shipping Board. Under the tems of this contract the Shipping Board has engaged the corporation to act as its radio service agent. The corporation inspects repairs and maintains the radio apparatus and storage batteries on board these ships in efficient working condition, assigns operators, attends to accounting for traffic and generally performs all service work in connection with the Shipping Board's radiotelegraph business.

53. **Status of Shipping Board Operators**—(197) The operators on these vessels are paid by the Shipping Board, through its agents, and are responsible to the Shipping Board and to the Master of the ship. However, the corporation is responsible for the proper care of the apparatus and conduct of the radio service, and under its contract has full jurisdiction over radio operators, and all operators will be expected to adhere strictly to instructions issued by the corporation. Our contract provides that radio operators on Shipping Board vessels shall be treated as officers but without executive authority, and shall be provided accommodations suitable for an officer.

54. **Official U. S. S. B. Messages**—(202) Official messages having relation to the navigation or operation of vessels owned or controlled by the Shipping Board, passing between Master or other accredited officials aboard said vessels, and officials of the Shipping Board, or accredited agents of the person, firm or corporation assigned as manager or operator shall be handled without ship charges. On these messages all other line charges and coast station charges must be collected by the radio operator from the

master or official of the Shipping Board sending said message when message is filed; however, until further notice, no coast station charge shall apply if the message is sent through a station of the United States Navy, provided message is transmitted with the special prefix "Govt. S. B." and carries the abbreviation "Govt." as the first word of the address. No message shall be deemed an official message if it contains any matter whatsoever of a personal nature; any such message must be prepaid at commercial rates by the sender. Operators will be held personally responsible for failure to collect proper charges.

(203) "Govt. S. B." messages should, whenever possible, be forwarded through U. S. Naval coastal stations. If sent through a commercial shore station full coast station tolls must be collected. Shipping Board vessels on bare-boat charter or sold on deferred payment plan are not entitled to "Govt. S. B." privileges.

55. **Government Rates**—(204) "Govt. S. B." messages are entitled to government rate on landlines (Western Union and Postal) within the United States regardless of whether they are forwarded through U. S. Naval or commercial stations. However, in both cases the prefix "Govt. S. B." and the abbreviation "Govt." as the first word of the address must be transmitted.

56. **Personal Messages**—(205) Full tolls at commercial rates including ship charge, must be collected from the captain or members of the crew on personal messages. Such messages shall be approved by the captain before transmission. This also applies to personal messages of the radio operator.

57. **U. S. S. B. Time and Date Code**—(209) When an official message is filed for transmission on a Shipping Board vessel the operator shall insert as the last word of the message immediately preceding the signature a five figure code which shall designate the time and date the message was filed. The first two figures shall designate the hour from 0 (midnight) to 23 (11 p.m.) the middle figure the nearest ten minute period and the last two the date (inserting 0 if less than 10). For example, a message filed at 2:40 a.m. on the 3d day of the month would be numbered 02403; a message filed at 4:27 p.m. on the 25th day of the month would be 16325; 8:08 p.m. on the 30th day of the month would be written 20130. The local standard time of the radio station through which message is transmitted shall be used.

Hours of Watch.

(189) On ships carrying two or more operators continuous watch must be maintained throughout the voyage. The operator

on watch must wear the head 'phones at all times and under no circumstances shall he leave the radio room, unless relieved.

(190) On vessels carrying but one operator, the hours of watch shall be arranged to conform to the wishes of the master, except on Shipping Board vessels, where the following schedule of watches must be maintained.

Zones.	Western Limit.	Eastern Limit.	Times of Watch for One Operator, Greenwich Mean Time.
A. Eastern Atlantic, Mediterranean, North Sea, Baltic, Western Arctic Sea.	Meridian of 30° W., Coast of Greenland.	Meridian of 30 E. to the South of the Coast of Africa. Eastern limit of Mediterranean, Black Sea, and of the Baltic, 30° E. to the North of Coast of Norway.	from 8 h. to 10 h. 12 h. to 14 h. 16 h. to 18 h. 20 h. to 22 h.
B. Indian Ocean, Eastern Arctic Sea.	Eastern Limit of Zone A.	Meridian of 90° E.	from 0 h. to 2 h. 12 h. to 14 h. 16 h. to 18 h. 20 h. to 22 h.
C. China Sea, Western Pacific Ocean.	Eastern Limit of Zone B.	Meridian of 160° E.	from 0 h. to 2 h. 4 h. to 6 h. 12 h. to 14 h. 20 h. to 22 h.
D. Central Pacific Ocean.	Eastern Limit of Zone C.	Meridian of 140° W.	from 0 h. to 2 h. 4 h. to 6 h. 8 h. to 10 h. 20 h. to 22 h.
E. Eastern Pacific Ocean.	Eastern Limit of Zone D.	Meridian of 70° W. South of the Coast of America, West Coast of America.	from 0 h. to 2 h. 4 h. to 6 h. 16 h. to 18 h. 20 h. to 22 h.
F. Western Atlantic Ocean and Gulf of Mexico.	Meridian of 70° W. South of the Coast of America, East Coast of of America.	Meridian of 30° W. Coast of Greenland.	from 0 h. to 2 h. 12 h. to 14 h. 16 h. to 18 h. 20 h. to 22 h.

APPENDIX 1

Schedules of Naval Stations Transmitting Time, Weather, Hydrographic, Ice, and Press Bulletins.

Time (Greenwich civil).	Station.	Call signal.	Frequency (kilocycles) and type of emission.	Wave-length (meters).	Material broadcast.
0000	Brownsville, Tex.	NAY	132 i. c. w.	2,273	Weather, hydrographic.
0045	San Juan, P. R.	NAU	48 c. w.	6,250	Weather (July 1 to Nov. 15).
0100	Norfolk, Va.	NAM	122 i. c. w.	2,459	Weather.
	Puget Sound, Wash.	NPC	118 c. w.	2,542	Do.
0115	Arlington, Va.	NAA	4,015 a. c. w.	74.72	Aviation weather and upper-air reports.
0130	Eureka, Calif.	NPW	104 i. c. w.	2,885	Weather, hydrographic.
	Norfolk, Va.	NAM	122 i. c. w.	2,459	Weather.
0200	Cavite, P. I.	NPO	56 c. w. 112 a. c. w.	5,357 2,679	Press (for naval vessels only).
	Guantanamo Bay, Cuba	NAW	113 c. w.	2,655	Weather (June 1 to Nov. 15).
	San Juan, P. R.	NAU	108 i. c. w.	2,778	Weather (July 1 to Nov. 15).
0215	San Francisco, Calif.	NPG	4,175 c. w. 8,350 c. w.	71.85 35.9	Aviation weather.
0255 to 0300	Arlington, Va.	NAA	112 a. c. w. 690 r. t. 4,015 a. c. w. 8,030 a. c. w. 12,045 a. c. w.	2,679 435 74.72 37.36 24.9	Time signals.
	Annapolis, Md.	NSS	17.6 c. w.	17,045	Do.
	Cavite, P. I.	NPO	56 c. w. 112 a. c. w.	5,357 2,679	Do.
0300	Arlington, Va.	NAA	68 c. w.[1] 112 a. c. w.	4,412 2,679	Marine weather, hydrographic, ice reports (in season).
	Cavite, P. I.	NPO	56 c. w. 112 a. c. w.	5,357 2,679	Weather, hydrographic.
	Key West, Fla.	NAR	102 i. c. w.	2,941	Do.
	Puget Sound, Wash.	NPC	118 c. w.	2,542	Hydrographic.
0305	Navy Yard, Wash., D. C.	NAA	690 r. t.	435	Weather.
0330	San Francisco, Calif.	NPG	42.8 c. w. 108 i. c. w. 8,350	7,009 2,778 35.9	Weather, hydrographic. Aviation weather.
	Tutuila, Samoa	NPU	66 c. w.	4,545	Hydrographic.
0355 to 0400	Balboa, Canal Zone.	NBA	46 c. w.	6,522	Time signals.
	Colon, Canal Zone.	NAX	132 i. c. w.	2,273	Do.
0400	Arlington, Va.	NAA	4,015 a. c. w.	74.72	Weather broadcast to Europe.
	Great Lakes, Ill.	NAJ	132 i. c. w.	2,273	Weather, hydrographic.
	Puget Sound, Wash.	NPC	118 c. w.	2,542	Weather.
	San Juan, P. R.	NAU	48 c. w.	6,250	Do.
0430	Astoria, Oreg.	NPE	112 a. c. w.	2,679	Hydrographic.
	San Diego, Calif.	NPL	102 a. c. w.	2,941	Weather.
0500	Brownsville, Tex.	NAY	132 i. c. w.	2,273	Weather, hydrographic.
0555 to 0600	San Francisco, Calif.	NPG	62 c. w. 108 i. c. w.	4,839 2,778	Time signals.
0600	....Do.	NPG	108 i. c. w.	2,778	Weather, hydrographic.
0630	Honolulu, Hawaii	NPM	54 a. c. w.	5,555	Do.

SCHEDULES OF NAVAL STATIONS TRANSMITTING TIME, WEATHER, HYDROGRAPHIC, ICE, AND PRESS BULLETINS—*Continued.*

Time (Greenwich civil).	Station.	Call signal.	Frequency (kilocycles) and type of emission.	Wave-length (meters).	Material broadcast.
0700	Annapolis, Md.	NSS	17.6 c. w.	17,045	Press (for naval vessels only).
	Arlington, Va.	NAA	112 a. c. w.	2,679	Do.
0730	Tutuila, Samoa	NPU	66 c. w.	4,545	Hydrographic.
1000	Balboa, Canal Zone.	NBA	46 c. w.	6,522	Hydrographic Press (for naval vessels only).
	....Do.	NBA	118 c. w.	2,542	Press (for naval vessels only).
	Colon, Canal Zone.	NAX	132 i. c. w.	2,273	Hydrographic.
	San Diego, Calif.	NPL	30.6 c. w.	9,804	Press (for naval vessels only).
1300	Puget Sound, Wash.	NPC	118 c. w.	2,542	Weather.
1315	Arlington, Va.	NAA	4,015 a. c. w. 8,030 a. c. w. 12,045 a. c. w.	74.72 37.36 24.9	Aviation weather and upper-air reports.
1330	Norfolk, Va.	NAM	122 i. c. w.	2,459	Weather.
1355 to 1400	Cavite, P. I	NPO	56 c. w. 112 a. c. w.	5,357 2,679	Time signals.
1400	....Do.	NPO	36 c. w. 112 a. c. w.	8,333 2,679	Weather, hydrographic.
1415	San Francisco, Calif.	NPG	4,175 c. w. 8,350 c. w.	71.85 35.9	Aviation weather.
1500	Arlington, Va.	NAA	112 a. c. w. 16,060 a. c. w.	2,679 18.68	Marine weather, ice reports (in season).
	New Orleans, La.	NAT	106 c. w.	2,830	Weather.
1505	Arlington, Va.	NAA	690 r. t.	435	Do.
1530	New York, N. Y.	NAH	108 i. c. w.	2,778	Weather, hydrographic, ice reports (in season).
	Charleston, S. C.	NAO	122 i. c. w.	2,459	Weather, hydrographic.
	San Francisco, Calif.	NPG	42.8 c. w. 108 c. w. 8,350 c. w.	7,000 2,778 35.9	Weather. Aviation weather.
1545	Philadelphia, Pa.	NAI	104 i. c. w.	2,885	Weather, hydrographic.
	Great Lakes, Ill.	NAJ	132 i. c. w.	2,273	Do.
	Norfolk, Va.	NAM	122 i. c. w.	2,459	Weather, hydrographic, ice reports (in season).
1600	Boston, Mass.	NAD	102 i. c. w.	2,941	Do.
	Newport, R. I.	NAF	118 i. c. w.	2,542	Do.
	Arlington, Va.	NAA	12,045 a. c. w.	24.9	Weather broadcast to Europe.
	New Orleans, La.	NAT	106 c. w.	2,830	Weather, hydrographic.
	San Juan, P. R.	NAU	48 c. w.	6,250	Weather.
	Savannah, Ga.	NEV	132 i. c. w.	2,273	Do.
1630	Jupiter, Fla.	NAQ	....Do.	2,273	Do.
	San Diego, Calif.	NPL	102 i. c. w.	2,941	Do.
	St. Augustine, Fla.	NAP	128 spark	2,344	Do.
1645	Pensacola, Fla.	NAS	112 i. c. w.	2,679	Do.

SCHEDULES OF NAVAL STATIONS TRANSMITTING TIME, WEATHER, HYDROGRAPHIC, ICE, AND PRESS BULLETINS—*Continued.*

Time (Greenwich civil).	Station.	Call signal.	Frequency (kilocycles) and type of emission.	Wave-length (meters).	Material broadcast.
1655 to 1700	Arlington, Va......	NAA	112 a. c. w......	2,679	Time signals.
			690 r. t........	435	
			4015 a. c. w.....	74.72	
			8030 a. c. w......	37.36	
			12,045 a. c. w....	24.9	
	Annapolis, Md.....	NSS	17.6 c. w........	17,045	Do.
	Great Lakes, Ill....	NAJ	132 i. c. w.......	2,273	Do.
	Key West, Fla.....	NAR	102 i. c. w.......	2,941	Do.
	New Orleans, La...	NAT	106 c. w.........	2,830	Do.
	San Diego, Calif...	NPL	30.6 c. w........	9,804	Do.
			102 a. c. w.......	2,941	
1700	Arlington, Va......	NAA	112 a. c. w.......	2,679	Hydrographic.
	Brownsville, Tex...	NAY	132 i. c. w.......	2,273	Weather, hydrographic.
	Eureka, Calif......	NPW	104 i. c. w.......	2,885	Do.
	Key West, Fla.....	NAR	102 i. c. w.......	2,941	Do.
	Puget Sound, Wash.	NPC	118 c. w.........	2,542	Do.
	San Francisco.....	NPG	42.8 c. w........	7,009	Do.
1755 to 1800	Balboa, Canal Zone.	NBA	46 c. w..........	6,522	Time signals.
	Colon, Canal Zone.	NAX	132 i. c. w.......	2,273	Do.
1800	Balboa, Canal Zone.	NBA	46 c. w..........	6,522	Hydrographic.
1830	Honolulu, T. H....	NPM	54 a. c. w.......	5,555	Weather, hydrographic.
1930	Tutuila, Samoa....	NPU	66 c. w..........	4,545	Hydrographic.
1955 to 2000	Astoria, Oreg......	NPE	112 a. c. w......	2,679	Time signals.
	Eureka, Calif.....	NPW	104 i. c. w.......	2,885	Do.
	San Francisco, Calif.	NPG	42.8 c. w........	7,009	Do.
			62 c. w..........	4,839	
			108 c. w.........	2,778	
2045	Arlington, Va......	NAA	690 r. t.........	435	Weather.
2100	Norfolk, Va.......	NAM	122 i. c. w.......	2,459	Weather, hydrographic.
	Puget Sound, Wash.	NPC	118 c. w.........	2,542	Do.
2130	Astoria, Oreg......	NPE	112 a. c. w......	2,679	Hydrographic.
2200	Boston, Mass......	NAD	102 i. c. w.......	2,941	Weather, hydrographic, ice reports (in season).
	Newport, R. I.....	NAF	118 i. c. w.......	2,542	Do.
	New York, N. Y...	NAH	108 i. c. w.......	2,778	Do.
	Philadelphia, Pa...	NAI	104 i. c. w.......	2,885	Weather, hydrographic.
	Eureka, Calif......	NPW	104 i. c. w.......	2,885	Do.
	Great Lakes, Ill....	NAJ	132 i. c. w.......	2,273	Hydrographic.
	New Orleans, La...	NAT	106 c. w.........	2,830	Weather, hydrographic.
	San Diego, Calif...	NPL	102 a. c. w......	2,941	Weather.
2230	Honolulu, T. H....	NPM	54 a. c. w.......	5,555	Weather, hydrographic.
2300	Charleston, S. C...	NAO	122 i. c. w.......	2,459	Do.
	Jupiter, Fla.......	NAQ	132 i. c. w.......	2,273	Weather.
	Pensacola, Fla.....	NAS	112 i. c. w.......	2,679	Do.
	Savannah, Ga.....	NEV	132 i. c. w.......	2,273	Do.
2330	Tutuila, Samoa....	NPU	66 c. w..........	4,545	Hydrographic.
2355 to 2400	Honolulu, T. H....	NPM	26.1 c. w........	11,494	Time signals.
			106 i. c. w.......	2,830	

[1] This frequency is discontinued at 0400 G. C. T.

38. Explanation of Bulletins—The bulletins which are broadcast from each radio station are of the same general character and are similarly translated. They are based upon observations taken in the United States at 8 a.m. (.0800) and 8 p.m. (2000), 75th meridian time, and one hour earlier at stations in the Gulf of Mexico and Caribbean Sea, of the date of distribution, as indicated.

The bulletins are divided into two parts. The first contains reports of barometric pressure, wind direction and velocity at certain stations, each of which is indicated by one or more "key letters," using a group of five figures to represent the data contained in the report. The second part consists of wind and weather forecasts and warnings of storms and hurricanes. If a weather report from any station can not be supplied, the key letters and data figures will be omitted altogether, but in case only a portion of a report is missing, the letter "x" will be substituted for the omitted data figure.

These weather reports contained in the first part of the bulletins and supplemented by others picked up from vessels, can be used in the production of weather maps, which will be of much value to navigating officers, and base charts prepared for this purpose, which show the reporting stations and their key letters, will be forwarded upon application.

39. Key to First Part and Examples—*Barometric pressure* (first three figures of group): Actual pressure in inches and hundredths used, except that first figure of full reading is omitted. Thus, if the actual corrected pressure is 29.98 inches, the figures 998 are sent; or, if the reading is 30.14 inches, the figures 014 are sent.

Direction of surface wind (fourth figure of group).

0 = calm, or no movement.
1 = north.
2 = northeast.
3 = east.
4 = southeast.
5 = south.
6 = southwest.
7 = west.
8 = northwest.

Force of wind (fifth figure of group): Sent according to Beaufort scale, values 0 to 9, inclusive.

Example of group as sent: 99852.

Translation: Barometric pressure, 29.98 inches, wind from south, wind force, 2 (4 to 7 statute miles per hour).

The second part of the bulletin consists of wind and weather forecasts and, whenever conditions warrant, information as to storm centers, storm and hurricane warnings and advices to shipping. Whenever a storm exists that is likely to affect a section, the location and expected direction of movement of the storm center will be given, followed by any storm or hurricane warnings and advices to shipping which have been issued.

BEAUFORT SCALE

Scale No.	Explanatory titles.	Miles per hour (statute).	Terms used in forecasts.
0	Calm	Less than 1	Light.
1	Light air	1 to 3	
2	Slight breeze	4 to 7	
3	Gentle breeze	8 to 12	Gentle.
4	Moderate breeze	13 to 18	Moderate.
5	Fresh breeze	19 to 24	Fresh.
6	Strong breeze	25 to 31	Strong.
7	High wind	32 to 38	
8	Gale	39 to 46	Gales.
9	Strong gale	47 to 54	
*10 (W)	Whole gale	55 to 63	Whole gale.
*11 (S)	Storm	64 to 75	
*12 (H)	Hurricane	Over 75	Hurricane.

* The numeral code does not admit of force in excess of 9 being sent. Therefore, the letters W, S, and H will be used for wind forces 10, 11, and 12, respectively.

Note.—The last column gives the terms applicable to the Beaufort scale which are used in the forecasts and warnings issued by the U. S. Weather Bureau.

40. Bulletins from Arlington—Bulletins (a) and (c) transmitted from NAA are separate weather forecasts for each of the states east of the Mississippi River, except Indiana, Wisconsin, and Illinois. A general forecast will also be included. On Wednesdays, from April to October 15, a summary of the previous week's meteorological conditions is included in messages (a) and (c).

Bulletins (b) and (d) contain the weather information.

Bulletin (e) consists of a special forecast which will include warnings of storms, cold waves, frosts, and heavy snows.

Explanation of bulletin at 0330 and 1530.

The bulletin is divided into two parts and invariably begins with the letters USWB (U. S. Weather Bureau). The first part consists of surface weather conditions based upon observations taken at 1300 G.C.T. (Greenwich Civil Time) and of upper air observations begun at 1200 of the date of distribution. The second part of the bulletin consists of a synopsis of general atmospheric pressure distribution, including the locations of high and of low areas, and the barometer readings at their centers; wind and weather forecasts for Atlantic and east Gulf offshore areas; storm and hurricane warnings for these areas; and flying weather forecasts for each of six aviation zones.

41. First Part—

KEY LETTERS AND STATIONS

J—St. John's, N. F.
S—Sydney, N. S.
CK—Cockrane, Ont.
FP—Father Point, Que.
ML—Montreal, Que.
E—Eastport, Me.
N—Northfield, Vt.
T—Nantucket, Mass.
NY—New York, N. Y. (Upper Air Rockaway). (1)
AC—Atlantic City, N. J. (Upper Air Lakehurst). (1)
WA—Washington, D. C. (Upper Air Wash.). (1)
NF—Norfolk, Va. (Upper Air Hampton Rds.). (1)
LB—Lynchburg, Va.
AV—Asheville, N. C.
H—Hatteras, N. C.
C—Charleston, S. C. (Upper Air Paris Island).
B—Bermuda
CO—Columbia, S. C. (Upper Air Due West). (1)
JA—Jacksonville, Fla.
K—Key West (Upper Air Key West). (1)
AT—Atlanta, Ga.

TA—Tampa, Fla.
P—Pensacola, Fla.
MG—Montgomery, Ala.
VK—Vicksburg, Miss.
NO—New Orleans, La.
LR—Little Rock, Ark.
GY—Galveston, Tex.
CN—Cincinnatti, Ohio.
PB—Pittsburgh, Pa.

F—Buffalo, N. Y.

D—Detroit, Mich.

L—Alpena, Md.

CH—Chicago, Ill.
DU—Duluth, Minn.
LC—La Crosse, Wis.
M—Marquette, Mich.

SL—St. Louis, Mo.
KC—Kansas City, Mo.

OK—Oklahoma City, Okla.
O—Omaha, Neb.

DA—Dallas, Tex.
EP—El Paso, Tex.

The stations are indicated by one or more key-letters which are followed by two or more 5-unit groups of figures. The first two groups are always surface observations often at the stations indicated by the key-letters. Additional groups containing upper air data are included only in the reports from stations marked thus (1), and invariably are represented in the third and succeeding 5-unit groups. When upper air observations are not possible because of dense fog, the word FOGGY will be sent instead of the third groups.

42. **Second Part**—The second part of the bulletin is in plain

language and consists of: A synopsis of general pressure distribution; wind and weather forecasts for ocean zones for a period of 24 hours beginning at 1700 day of issue; storm and hurricane warnings; and flying weather forecasts by zones for a period 1700 to 0500 of the day of issue.

43. **Ship Reports**—Ship reports are included in the first part of the bulletin immediately following the land stations. They are included in two groups, preceded by the call letters identifying the ship. The first group consists of five numerals, signifying the ship's position, and the second group of five numerals, expressing the barometric pressure, wind direction and force. In the group giving the ship's position (to the nearest degree), the first two numerals express the latitude (north) and the last three the longitude (west).

Example: KSY 33076 07475.

Translation: S.S. Broad Arrow; latitude, 33 degrees north; longitude, (0) 76 degrees west; barometric pressure, 30.74 inches; wind direction, west; wind force of 5 (19 to 24 miles per hour).

44. **Reporting Derelicts and Vessels in Distress**—Masters of vessels when sighting derelicts or vessels in distress are requested to make a report by radio to the U. S. Hydrographic Office, addressed "Govt Hydro," and to the U. S. Coast Guard, followed at the earliest opportunity by a written confirmation of the facts sent, with additional details. To be complete, information concerning a derelict should state:

(*a*) The position by latitude and longitude, confirmed by the approximate bearing and distance from a fixed point on land.

(*b*) The general condition of the vessel.

(*c*) Whether bottom up or awash.

(*d*) Height of hull above water and any abnormal conditions as to buoyancy.

(*e*) The trim of the vessel.

(*f*) As to whether masts are standing, sails set, or otherwise.

(*g*) Approximate heading of derelict.

(*h*) Force and direction of wind.

(*i*) Any observed current, its set and strength.

(*j*) The name of the vessel, if possible.

APPENDIX 2

45. **Installation of Automatic Alarm Apparatus (Auto Alarm) on Board British Vessels**—The British Government has authorized the use on British vessels of an automatic apparatus which will respond to a special signal called the alarm signal. This signal is used in addition to the distress signal SOS.

The alarm signal actuates the automatic receiving device installed on British ships, causing a bell to ring which attracts the attention of the radio operator if he is off duty. The radio operator immediately resumes his watch and listens for the distress message.

Vessels in distress of other nationalities may take advantage of the auto alarm installed on British ships by following the procedure adopted by British ships.

This procedure is as follows:

1. The distress call consists of the alarm signal followed by the distress signal SOS, followed by the call letters of the vessel in distress, followed by the distress message. Transmission must be made on 600 meters.

2. The alarm signal consists of a series of 12 dashes transmitted within one minute. The duration of each dash is 4 seconds and the duration of the interval between each is one second.

Since the alarm signal will attract the attention of vessels equipped with an auto alarm it must only be used in connection with the distress signal. To insure the accurate transmission of the alarm signal the operator must have at his disposal a clock or watch equipped with a second hand.

The alarm signal will actuate the auto alarm provided the dashes have a duration of not less than 3½ seconds or more than 4½ seconds and provided the intervals are not less than ⅕ of a second or more than one second and a half.

APPENDIX 3

Kilocycle–Meter Conversion Table

The provisions of the International Radiotelegraph Convention effective January 1, 1929, require that the assignment of waves to transmitting stations be designated in the first place by their frequency in kilocycles per second (kc/s). Following this designation there will be indicated, in parenthesis, the approximate length in meters. In the present Regulations, the approximate value of the wavelength in meters is the quotient of the number 300,000 divided by the frequency expressed in kilocycles per second. The Radio Division, Department of Commerce, has devised the following conversion table which gives values for every 10 kilocycles or meters between the limits of 10 and 30,000. The table is entirely reversible; that is, for example, 80 kilocycles equals 3,750 meters and also 3,750 meters equals 80 kilocycles. The range of the table is easily extended by shifting the decimal point; the shift is in opposite direction for each pair of values. For example, one cannot find 567 in the first column, but its equivalent is obtained by finding later in the table that 5,670 kilocycles or meters equals 52.91 meters or kilocycles, from which 567 kilocycles or meters equals 529.1 meters or kilocycles.

Kilocycles (kc) to Meters (m), or Meters to Kilocycles

Columns Are Interchangeable

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
10	30,000	560	536	1,110	270.3	1,660	180.7	2,210	135.7	2,760	108.7
20	15,000	570	526	1,120	267.9	1,670	179.6	2,220	135.1	2,770	108.3
30	10,000	580	517	1,130	265.5	1,680	178.6	2,230	134.5	2,780	107.9
40	7,500	590	509	1,140	263.2	1,690	177.5	2,240	133.9	2,790	107.5
50	6,000	600	500	1,150	260.9	1,700	176.5	2,250	133.3	2,800	107.1
60	5,000	610	492	1,160	258.6	1,710	175.4	2,260	132.7	2,810	106.7
70	4,286	620	484	1,170	256.4	1,720	174.4	2,270	132.2	2,820	106.4
80	3,750	630	476	1,180	254.2	1,730	173.4	2,280	131.6	2,830	106.0
90	3,333	640	469	1,190	252.1	1,740	172.4	2,290	131.0	2,840	105.6
100	3,000	650	462	1,200	250.0	1,750	171.4	2,300	130.4	2,850	105.3
110	2,727	660	455	1,210	247.9	1,760	170.5	2,310	129.9	2,860	104.9
120	2,500	670	448	1,220	245.9	1,770	169.5	2,320	129.3	2,870	104.5
130	2,308	680	441	1,230	243.9	1,780	168.5	2,330	128.8	2,880	104.2
140	2,143	690	435	1,240	241.9	1,790	167.6	2,340	128.2	2,890	103.8
150	2,000	700	429	1,250	240.0	1,800	166.7	2,350	127.7	2,900	103.4
160	1,875	710	423	1,260	238.1	1,810	165.7	2,360	127.1	2,910	103.1
170	1,765	720	417	1,270	236.2	1,820	164.8	2,370	126.6	2,920	102.7
180	1,667	730	411	1,280	234.4	1,830	163.9	2,380	126.1	2,930	102.4
190	1,579	740	405	1,290	232.6	1,840	163.0	2,390	125.5	2,940	102.0
200	1,500	750	400	1,300	230.8	1,850	162.2	2,400	125.0	2,950	101.7
210	1,429	760	395	1,310	229.0	1,860	161.3	2,410	124.5	2,960	101.4
220	1,364	770	390	1,320	227.3	1,870	160.4	2,420	124.0	2,970	101.0
230	1,304	780	385	1,330	225.6	1,880	159.6	2,430	123.5	2,980	100.7
240	1,250	790	380	1,340	223.9	1,890	158.7	2,440	123.0	2,990	100.3
250	1,200	800	375	1,350	222.2	1,900	157.9	2,450	122.4	3,000	100.0
260	1,154	810	370	1,360	220.6	1,910	157.1	2,460	122.0	3,010	99.7
270	1,111	820	366	1,370	219.0	1,920	156.3	2,470	121.5	3,020	99.3
280	1,071	830	361	1,380	217.4	1,930	155.4	2,480	121.0	3,030	99.0
290	1,034	840	357	1,390	215.8	1,940	154.6	2,490	120.5	3,040	98.7
300	1,000	850	353	1,400	214.3	1,950	153.8	2,500	120.0	3,050	98.4
310	968	860	349	1,410	212.8	1,960	153.1	2,510	119.5	3,060	98.0
320	938	870	345	1,420	211.3	1,970	152.3	2,520	119.0	3,070	97.7
330	909	880	341	1,430	209.8	1,980	151.5	2,530	118.6	3,080	97.4
340	882	890	337	1,440	208.3	1,990	150.8	2,540	118.1	3,090	97.1
350	857	900	333	1,450	206.9	2,000	150.0	2,550	117.6	3,100	96.8
360	833	910	330	1,460	205.5	2,010	149.3	2,560	117.2	3,110	96.5
370	811	920	326	1,470	204.1	2,020	148.5	2,570	116.7	3,120	96.2
380	789	930	323	1,480	202.7	2,030	147.8	2,580	116.3	3,130	95.8
390	769	940	319	1,490	201.3	2,040	147.1	2,590	115.8	3,140	95.5
400	750	950	316	1,500	200.0	2,050	146.3	2,600	115.4	3,150	95.2
410	732	960	313	1,510	198.7	2,060	145.6	2,610	114.9	3,160	94.9
420	714	970	309	1,520	197.4	2,070	144.9	2,620	114.5	3,170	94.6
430	698	980	306	1,530	196.1	2,080	144.2	2,630	114.1	3,180	94.3
440	682	990	303	1,540	194.8	2,090	143.5	2,640	113.6	3,190	94.0
450	667	1,000	300.0	1,550	193.5	2,100	142.9	2,650	113.2	3,200	93.8
460	652	1,010	297.0	1,560	192.3	2,110	142.2	2,660	112.8	3,210	93.5
470	638	1,020	294.1	1,570	191.1	2,120	141.5	2,670	112.4	3,220	93.2
480	625	1,030	291.3	1,580	189.9	2,130	140.8	2,680	111.9	3,230	92.9
490	612	1,040	288.5	1,590	188.7	2,140	140.2	2,690	111.5	3,240	92.6
500	600	1,050	285.7	1,600	187.5	2,150	139.5	2,700	111.1	3,250	92.3
510	588	1,060	283.0	1,610	186.3	2,160	138.9	2,710	110.7	3,260	92.0
520	577	1,070	280.4	1,620	185.2	2,170	138.2	2,720	110.3	3,270	91.7
530	566	1,080	277.8	1,630	184.0	2,180	137.6	2,730	109.9	3,280	91.5
540	556	1,090	275.2	1,640	182.9	2,190	137.0	2,740	109.5	3,290	91.2
550	545	1,100	272.7	1,650	181.8	2,200	136.4	2,750	109.1	3,300	90.9

KILOCYCLE-METER CONVERSION TABLE—*Continued*

c or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
3,310	90.6	3,860	77.7	4,410	68.03	4,960	60.48	5,510	54.45	6,060	49.50
3,320	90.4	3,870	77.5	4,420	67.87	4,970	60.36	5,520	54.35	6,070	49.42
3,330	90.1	3,880	77.3	4,430	67.72	4,980	60.24	5,530	54.25	6,080	49.34
3,340	89.8	3,890	77.1	4,440	67.57	4,990	60.12	5,540	54.15	6,090	49.26
3,350	89.6	3,900	76.9	4,450	67.42	5,000	60.00	5,550	54.05	6,100	49.18
3,360	89.3	3,910	76.7	4,460	67.26	5,010	59.88	5,560	53.96	6,110	49.10
3,370	89.0	3,920	76.5	4,470	67.11	5,020	59.76	5,570	53.86	6,120	49.02
3,380	88.8	3,930	76.3	4,480	66.96	5,030	59.64	5,580	53.76	6,130	48.94
3,390	88.5	3,940	76.1	4,490	66.82	5,040	59.52	5,590	53.67	6,140	48.86
3,400	88.2	3,950	75.9	4,500	66.67	5,050	59.41	5,600	53.57	6,150	48.78
3,410	88.0	3,960	75.8	4,510	66.52	5,060	59.29	5,610	53.48	6,160	48.70
3,420	87.7	3,970	75.6	4,520	66.37	5,070	59.17	5,620	53.38	6,170	48.62
3,430	87.5	3,980	75.4	4,530	66.23	5,080	59.06	5,630	53.29	6,180	48.54
3,440	87.2	3,990	75.2	4,540	66.08	5,090	58.94	5,640	53.19	6,190	48.47
3,450	87.0	4,000	75.00	4,550	65.93	5,100	58.82	5,650	53.10	6,200	48.39
3,460	86.7	4,010	74.81	4,560	65.79	5,110	58.71	5,660	53.00	6,210	48.31
3,470	86.5	4,020	74.63	4,570	65.65	5,120	58.59	5,670	52.91	6,220	48.23
3,480	86.2	4,030	74.44	4,580	65.50	5,130	58.48	5,680	52.82	6,230	48.15
3,490	86.0	4,040	74.26	4,590	65.36	5,140	58.37	5,690	52.72	6,240	48.08
3,500	85.7	4,050	74.07	4,600	65.22	5,150	58.25	5,700	52.63	6,250	48.00
3,510	85.5	4,060	73.89	4,610	65.08	5,160	58.14	5,710	52.54	6,260	47.92
3,520	85.2	4,070	73.71	4,620	64.94	5,170	58.03	5,720	52.45	6,270	47.85
3,530	85.0	4,080	73.53	4,630	64.79	5,180	57.92	5,730	52.36	6,280	47.77
3,540	84.7	4,090	73.35	4,640	64.66	5,190	57.80	5,740	52.26	6,290	47.69
3,550	84.5	4,100	73.17	4,650	64.52	5,200	57.69	5,750	52.17	6,300	47.62
3,560	84.3	4,110	72.99	4,660	64.38	5,210	57.58	5,760	52.08	6,310	47.54
3,570	84.0	4,120	72.82	4,670	64.24	5,220	57.47	5,770	51.99	6,320	47.47
3,580	83.8	4,130	72.64	4,680	64.10	5,230	57.36	5,780	51.90	6,330	47.39
3,590	83.6	4,140	72.46	4,690	63.97	5,240	57.25	5,790	51.81	6,340	47.32
3,600	83.3	4,150	72.29	4,700	63.83	5,250	57.14	5,800	51.72	6,350	47.24
3,610	83.1	4,160	72.12	4,710	63.69	5,260	57.03	5,810	51.64	6,360	47.17
3,620	82.9	4,170	71.94	4,720	63.56	5,270	56.93	5,820	51.55	6,370	47.10
3,630	82.6	4,180	71.77	4,730	63.42	5,280	56.82	5,830	51.46	6,380	47.02
3,640	82.4	4,190	71.60	4,740	63.29	5,290	56.71	5,840	51.37	6,390	46.95
3,650	82.2	4,200	71.43	4,750	63.16	5,300	56.60	5,850	51.28	6,400	46.88
3,660	82.0	4,210	71.26	4,760	63.03	5,310	56.50	5,860	51.19	6,410	46.80
3,670	81.7	4,220	71.09	4,770	62.89	5,320	56.39	5,870	51.11	6,420	46.73
3,680	81.5	4,230	70.92	4,780	62.76	5,330	56.29	5,880	51.02	6,430	46.66
3,690	81.3	4,240	70.75	4,790	62.63	5,340	56.18	5,890	50.93	6,440	46.58
3,700	81.1	4,250	70.59	4,800	62.50	5,350	56.07	5,900	50.85	6,450	46.51
3,710	80.9	4,260	70.42	4,810	62.37	5,360	55.97	5,910	50.76	6,460	46.44
3,720	80.6	4,270	70.26	4,820	62.24	5,370	55.87	5,920	50.68	6,470	46.37
3,730	80.4	4,280	70.09	4,830	62.11	5,380	55.76	5,930	50.59	6,480	46.30
3,740	80.2	4,290	69.93	4,840	61.98	5,390	55.66	5,940	50.51	6,490	46.22
3,750	80.0	4,300	69.77	4,850	61.86	5,400	55.56	5,950	50.42	6,500	46.15
3,760	79.8	4,310	69.61	4,860	61.73	5,410	55.45	5,960	50.34	6,510	46.08
3,770	79.6	4,320	69.44	4,870	61.60	5,420	55.35	5,970	50.25	6,520	46.01
3,780	79.4	4,330	69.28	4,880	61.48	5,430	55.25	5,980	50.17	6,530	45.94
3,790	79.2	4,340	69.12	4,890	61.35	5,440	55.15	5,990	50.08	6,540	45.87
3,800	78.9	4,350	68.97	4,900	61.22	5,450	55.05	6,000	50.00	6,550	45.80
3,810	78.7	4,360	68.81	4,910	61.10	5,460	54.95	6,010	49.92	6,560	45.73
3,820	78.5	4,370	68.65	4,920	60.98	5,470	54.84	6,020	49.83	6,570	45.66
3,830	78.3	4,380	68.49	4,930	60.85	5,480	54.74	6,030	49.75	6,580	45.59
3,840	78.1	4,390	68.34	4,940	60.73	5,490	54.64	6,040	49.67	6,590	45.52
3,850	77.9	4,400	68.18	4,950	60.61	5,500	54.55	6,050	49.59	6,600	45.45

KILOCYCLE-METER CONVERSION TABLE—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
6,610	45.39	7,160	41.90	7,710	38.91	8,260	36.32	8,810	34.05	9,360	32.05
6,620	45.32	7,170	41.84	7,720	38.86	8,270	36.28	8,820	34.01	9,370	32.02
6,630	45.25	7,180	41.78	7,730	38.81	8,280	36.23	8,830	33.98	9,380	31.98
6,640	45.18	7,190	41.72	7,740	38.76	8,290	36.19	8,840	33.94	9,390	31.95
6,650	45.11	7,200	41.67	7,750	38.71	8,300	36.14	8,850	33.90	9,400	31.91
6,660	45.05	7,210	41.61	7,760	38.66	8,310	36.10	8,860	33.86	9,410	31.88
6,670	44.98	7,220	41.55	7,770	38.61	8,320	36.06	8,870	33.82	9,420	31.85
6,680	44.91	7,230	41.49	7,780	38.56	8,330	36.01	8,880	33.78	9,430	31.81
6,690	44.84	7,240	41.44	7,790	38.51	8,340	35.97	8,890	33.75	9,440	31.78
6,700	44.78	7,250	41.38	7,800	38.46	8,350	35.93	8,900	33.71	9,450	31.75
6,710	44.71	7,260	41.32	7,810	38.41	8,360	35.89	8,910	33.67	9,460	31.71
6,720	44.64	7,270	41.27	7,820	38.36	8,370	35.84	8,920	33.63	9,470	31.68
6,730	44.58	7,280	41.21	7,830	38.31	8,380	35.80	8,930	33.59	9,480	31.65
6,740	44.51	7,290	41.15	7,840	38.27	8,390	35.76	8,940	33.56	9,490	31.61
6,750	44.44	7,300	41.10	7,850	38.22	8,400	35.71	8,950	33.52	9,500	31.58
6,760	44.38	7,310	41.04	7,860	38.17	8,410	35.67	8,960	33.48	9,510	31.55
6,770	44.31	7,320	40.98	7,870	38.12	8,420	35.63	8,970	33.44	9,520	31.51
6,780	44.25	7,330	40.93	7,880	38.07	8,430	35.59	8,980	33.41	9,530	31.48
6,790	44.18	7,340	40.87	7,890	38.02	8,440	35.55	8,990	33.37	9,540	31.45
6,800	44.12	7,350	40.82	7,900	37.97	8,450	35.50	9,000	33.33	9,550	31.41
6,810	44.05	7,360	40.76	7,910	37.93	8,460	35.46	9,010	33.30	9,560	31.38
6,820	43.99	7,370	40.71	7,920	37.88	8,470	35.42	9,020	33.26	9,570	31.35
6,830	43.92	7,380	40.65	7,930	37.83	8,480	35.38	9,030	33.22	9,580	31.32
6,840	43.86	7,390	40.60	7,940	37.78	8,490	35.34	9,040	33.19	9,590	31.28
6,850	43.80	7,400	40.54	7,950	37.74	8,500	35.29	9,050	33.15	9,600	31.25
6,860	43.73	7,410	40.49	7,960	37.69	8,510	35.25	9,060	33.11	9,610	31.22
6,870	43.67	7,420	40.43	7,970	37.64	8,520	35.21	9,070	33.08	9,620	31.19
6,880	43.60	7,430	40.38	7,980	37.59	8,530	35.17	9,080	33.04	9,630	31.15
6,890	43.54	7,440	40.32	7,990	37.55	8,540	35.13	9,090	33.00	9,640	31.12
6,900	43.48	7,450	40.27	8,000	37.50	8,550	35.09	9,100	32.97	9,650	31.09
6,910	43.42	7,460	40.21	8,010	37.45	8,560	35.05	9,110	32.93	9,660	31.06
6,920	43.35	7,470	40.16	8,020	37.41	8,570	35.01	9,120	32.89	9,670	31.02
6,930	43.29	7,480	40.11	8,030	37.36	8,580	34.97	9,130	32.86	9,680	30.99
6,940	43.23	7,490	40.05	8,040	37.31	8,590	34.92	9,140	32.82	9,690	30.96
6,950	43.17	7,500	40.00	8,050	37.27	8,600	34.88	9,150	32.79	9,700	30.93
6,960	43.10	7,510	39.95	8,060	37.22	8,610	34.84	9,160	32.75	9,710	30.90
6,970	43.04	7,520	39.89	8,070	37.17	8,620	34.80	9,170	32.72	9,720	30.86
6,980	42.98	7,530	39.84	8,080	37.13	8,630	34.76	9,180	32.68	9,730	30.83
6,990	42.92	7,540	39.79	8,090	37.08	8,640	34.72	9,190	32.64	9,740	30.80
7,000	42.86	7,550	39.74	8,100	37.04	8,650	34.68	9,200	32.61	9,750	30.77
7,010	42.80	7,560	39.68	8,110	36.99	8,660	34.64	9,210	32.57	9,760	30.74
7,020	42.74	7,570	39.63	8,120	36.95	8,670	34.60	9,220	32.54	9,770	30.71
7,030	42.67	7,580	39.58	8,130	36.90	8,680	34.56	9,230	32.50	9,780	30.67
7,040	42.61	7,590	39.53	8,140	36.86	8,690	34.52	9,240	32.47	9,790	30.64
7,050	42.55	7,600	39.47	8,150	36.81	8,700	34.48	9,250	32.43	9,800	30.61
7,060	42.49	7,610	39.42	8,160	36.76	8,710	34.44	9,260	32.40	9,810	30.58
7,070	42.43	7,620	39.37	8,170	36.72	8,720	34.40	9,270	32.36	9,820	30.55
7,080	42.37	7,630	39.32	8,180	36.67	8,730	34.36	9,280	32.33	9,830	30.52
7,090	42.31	7,640	39.27	8,190	36.63	8,740	34.32	9,290	32.29	9,840	30.49
7,100	42.25	7,650	39.22	8,200	36.59	8,750	34.29	9,300	32.26	9,850	30.46
7,110	42.19	7,660	39.16	8,210	36.54	8,760	34.25	9,310	32.22	9,860	30.43
7,120	42.13	7,670	39.11	8,220	36.50	8,770	34.21	9,320	32.19	9,870	30.40
7,130	42.08	7,680	39.06	8,230	36.45	8,780	34.17	9,330	32.15	9,880	30.36
7,140	42.02	7,690	39.01	8,240	36.41	8,790	34.13	9,340	32.12	9,890	30.33
7,150	41.96	7,700	38.96	8,250	36.36	8,800	34.09	9,350	32.09	9,900	30.30

KILOCYCLE-METER CONVERSION TABLE—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
9,910	30.27	10,460	28.68	11,010	27.25	11,560	25.95	12,110	24.77	12,660	23.70
9,920	30.24	10,470	28.65	11,020	27.22	11,570	25.93	12,120	24.75	12,670	23.68
9,930	30.21	10,480	28.63	11,030	27.20	11,580	25.91	12,130	24.73	12,680	23.66
9,940	30.18	10,490	28.60	11,040	27.17	11,590	25.88	12,140	24.71	12,690	23.64
9,950	30.15	10,500	28.57	11,050	27.15	11,600	25.86	12,150	24.69	12,700	23.62
9,960	30.12	10,510	28.54	11,060	27.12	11,610	25.84	12,160	24.67	12,710	23.60
9,970	30.09	10,520	28.52	11,070	27.10	11,620	25.82	12,170	24.65	12,720	23.58
9,980	30.06	10,530	28.49	11,080	27.08	11,630	25.80	12,180	24.63	12,730	23.57
9,990	30.03	10,540	28.46	11,090	27.05	11,640	25.77	12,190	24.61	12,740	23.55
10,000	30.00	10,550	28.44	11,100	27.03	11,650	25.75	12,200	24.59	12,750	23.53
10,010	29.97	10,560	28.41	11,110	27.00	11,660	25.73	12,210	24.57	12,760	23.51
10,020	29.94	10,570	28.38	11,120	26.98	11,670	25.71	12,220	24.55	12,770	23.49
10,030	29.91	10,580	28.36	11,130	26.95	11,680	25.68	12,230	24.53	12,780	23.47
10,040	29.88	10,590	28.33	11,140	26.93	11,690	25.66	12,240	24.51	12,790	23.46
10,050	29.85	10,600	28.30	11,150	26.91	11,700	25.64	12,250	24.49	12,800	23.44
10,060	29.82	10,610	28.28	11,160	26.88	11,710	25.62	12,260	24.47	12,810	23.42
10,070	29.79	10,620	28.25	11,170	26.86	11,720	25.60	12,270	24.45	12,820	23.40
10,080	29.76	10,630	28.22	11,180	26.83	11,730	25.58	12,280	24.43	12,830	23.38
10,090	29.73	10,640	28.20	11,190	26.81	11,740	25.55	12,290	24.41	12,840	23.36
10,100	29.70	10,650	28.17	11,200	26.79	11,750	25.53	12,300	24.39	12,850	23.35
10,110	29.67	10,660	28.14	11,210	26.76	11,760	25.51	12,310	24.37	12,860	23.33
10,120	29.64	10,670	28.12	11,220	26.74	11,770	25.49	12,320	24.35	12,870	23.31
10,130	29.62	10,680	28.09	11,230	26.71	11,780	25.47	12,330	24.33	12,880	23.29
10,140	29.59	10,690	28.06	11,240	26.69	11,790	25.45	12,340	24.31	12,890	23.27
10,150	29.56	10,700	28.04	11,250	26.67	11,800	25.42	12,350	24.29	12,900	23.26
10,160	29.53	10,710	28.01	11,260	26.64	11,810	25.40	12,360	24.27	12,910	23.24
10,170	29.50	10,720	27.99	11,270	26.62	11,820	25.38	12,370	24.25	12,920	23.22
10,180	29.47	10,730	27.96	11,280	26.60	11,830	25.36	12,380	24.23	12,930	23.20
10,190	29.44	10,740	27.93	11,290	26.57	11,840	25.34	12,390	24.21	12,940	23.18
10,200	29.41	10,750	27.91	11,300	26.55	11,850	25.32	12,400	24.19	12,950	23.17
10,210	29.38	10,760	27.88	11,310	26.53	11,860	25.30	12,410	24.17	12,960	23.15
10,220	29.35	10,770	27.86	11,320	26.50	11,870	25.27	12,420	24.15	12,970	23.13
10,230	29.33	10,780	27.83	11,330	26.48	11,880	25.25	12,430	24.14	12,980	23.11
10,240	29.30	10,790	27.80	11,340	26.46	11,890	25.23	12,440	24.12	12,990	23.09
10,250	29.27	10,800	27.78	11,350	26.43	11,900	25.21	12,450	24.10	13,000	23.08
10,260	29.24	10,810	27.75	11,360	26.41	11,910	25.19	12,460	24.08	13,010	23.06
10,270	29.21	10,820	27.73	11,370	26.39	11,920	25.17	12,470	24.06	13,020	23.04
10,280	29.18	10,830	27.70	11,380	26.36	11,930	25.15	12,480	24.04	13,030	23.02
10,290	29.15	10,840	27.68	11,390	26.34	11,940	25.13	12,490	24.02	13,040	23.01
10,300	29.13	10,850	27.65	11,400	26.32	11,950	25.10	12,500	24.00	13,050	22.99
10,310	29.10	10,860	27.62	11,410	26.29	11,960	25.08	12,510	23.98	13,060	22.97
10,320	29.07	10,870	27.60	11,420	26.27	11,970	25.06	12,520	23.96	13,070	22.95
10,330	29.04	10,880	27.57	11,430	26.25	11,980	25.04	12,530	23.94	13,080	22.94
10,340	29.01	10,890	27.55	11,440	26.22	11,990	25.02	12,540	23.92	13,090	22.92
10,350	28.99	10,900	27.52	11,450	26.20	12,000	25.00	12,550	23.90	13,100	22.90
10,360	28.96	10,910	27.50	11,460	26.18	12,010	24.98	12,560	23.89	13,110	22.88
10,370	28.93	10,920	27.47	11,470	26.16	12,020	24.96	12,570	23.87	13,120	22.87
10,380	28.90	10,930	27.45	11,480	26.13	12,030	24.94	12,580	23.85	13,130	22.85
10,390	28.87	10,940	27.42	11,490	26.11	12,040	24.92	12,590	23.83	13,140	22.83
10,400	28.85	10,950	27.40	11,500	26.09	12,050	24.90	12,600	23.81	13,150	22.81
10,410	28.82	10,960	27.37	11,510	26.06	12,060	24.88	12,610	23.79	13,160	22.80
10,420	28.79	10,970	27.35	11,520	2 .04	12,070	24.86	12,620	23.77	13,170	22.78
10,430	28.76	10,980	27.32	11,530	26.02	12,080	24.83	12,630	23.75	13,180	22.76
10,440	28.74	10,990	27.30	11,540	26.00	12,090	24.81	12,640	23.73	13,190	22.74
10,450	28.71	11,000	27.27	11,550	25.97	12,100	24.79	12,650	23.72	13,200	22.73

Kilocycle-Meter Conversion Table—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
13,210	22.71	13,760	21.80	14,310	20.96	14,860	20.19	15,410	19.468	15,960	18.797
13,220	22.69	13,770	21.79	14,320	20.95	14,870	20.17	15,420	19.455	15,970	18.785
13,230	22.68	13,780	21.77	14,330	20.94	14,880	20.16	15,430	19.443	15,980	18.773
13,240	22.66	13,790	21.75	14,340	20.92	14,890	20.15	15,440	19.430	15,990	18.762
13,250	22.64	13,800	21.74	14,350	20.91	14,900	20.13	15,450	19.417	16,000	18.750
13,260	22.62	13,810	21.72	14,360	20.89	14,910	20.12	15,460	19.405	16,010	18.738
13,270	22.61	13,820	21.71	14,370	20.88	14,920	20.11	15,470	19.392	16,020	18.727
13,280	22.59	13,830	21.69	14,380	20.86	14,930	20.09	15,480	19.380	16,030	18.715
13,290	22.57	13,840	21.68	14,390	20.85	14,940	20.08	15,490	19.367	16,040	18.703
13,300	22.56	13,850	21.66	14,400	20.83	14,950	20.07	15,500	19.355	16,050	18.692
13,310	22.54	13,860	21.65	14,410	20.82	14,960	20.05	15,510	19.342	16,060	18.680
13,320	22.52	13,870	21.63	14,420	20.80	14,970	20.04	15,520	19.330	16,070	18.668
13,330	22.51	13,880	21.61	14,430	20.79	14,980	20.03	15,530	19.317	16,080	18.657
13,340	22.49	13,890	21.60	14,440	20.78	14,990	20.01	15,540	19.305	16,090	18.645
13,350	22.47	13,900	21.58	14,450	20.76	15,000	20.000	15,550	19.293	16,100	18.634
13,360	22.46	13,910	21.57	14,460	20.75	15,010	19.987	15,560	19.280	16,110	18.622
13,370	22.44	13,920	21.55	14,470	20.73	15,020	19.973	15,570	19.268	16,120	18.610
13,380	22.42	13,930	21.54	14,480	20.72	15,030	19.960	15,580	19.255	16,130	18.599
13,390	22.40	13,940	21.52	14,490	20.70	15,040	19.947	15,590	19.243	16,140	18.587
13,400	22.39	13,950	21.51	14,500	20.69	15,050	19.934	15,600	19.231	16,150	18.576
13,410	22.37	13,960	21.49	14,510	20.68	15,060	19.919	15,610	19.218	16,160	18.564
13,420	22.35	13,970	21.47	14,520	20.66	15,070	19.907	15,620	19.206	16,170	18.553
13,430	22.34	13,980	21.46	14,530	20.65	15,080	19.894	15,630	19.194	16,180	18.541
13,440	22.32	13,990	21.44	14,540	20.63	15,090	19.881	15,640	19.182	16,190	18.530
13,450	22.30	14,000	21.43	14,550	20.62	15,100	19.868	15,650	19.169	16,200	18.519
13,460	22.29	14,010	21.41	14,560	20.60	15,110	19.854	15,660	19.157	16,210	18.507
13,470	22.27	14,020	21.40	14,570	20.59	15,120	19.841	15,670	19.145	16,220	18.496
13,480	22.26	14,030	21.38	14,580	20.58	15,130	19.828	15,680	19.133	16,230	18.484
13,490	22.24	14,040	21.37	14,590	20.56	15,140	19.815	15,690	19.120	16,240	18.473
13,500	22.22	14,050	21.35	14,600	20.55	15,150	19.802	15,700	19.108	16,250	18.462
13,510	22.21	14,060	21.34	14,610	20.53	15,160	19.789	15,710	19.096	16,260	18.450
13,520	22.19	14,070	21.32	14,620	20.52	15,170	19.776	15,720	19.084	16,270	18.439
13,530	22.17	14,080	21.31	14,630	20.51	15,180	19.763	15,730	19.072	16,280	18.428
13,540	22.16	14,090	21.29	14,640	20.49	15,190	19.750	15,740	19.060	16,290	18.416
13,550	22.14	14,100	21.28	14,650	20.48	15,200	19.737	15,750	19.048	16,300	18.405
13,560	22.12	14,110	21.26	14,660	20.46	15,210	19.724	15,760	19.036	16,310	18.394
13,570	22.11	14,120	21.25	14,670	20.45	15,220	19.711	15,770	19.023	16,320	18.382
13,580	22.09	14,130	21.23	14,680	20.44	15,230	19.698	15,780	19.011	16,330	18.371
13,590	22.08	14,140	21.22	14,690	20.42	15,240	19.685	15,790	18.999	16,340	18.360
13,600	22.06	14,150	21.20	14,700	20.41	15,250	19.672	15,800	18.987	16,350	18.349
13,610	22.04	14,160	21.19	14,710	20.39	15,260	19.659	15,810	18.975	16,360	18.337
13,620	22.03	14,170	21.17	14,720	20.38	15,270	19.646	15,820	18.963	16,370	18.326
13,630	22.01	14,180	21.16	14,730	20.37	15,280	19.634	15,830	18.951	16,380	18.315
13,640	21.99	14,190	21.14	14,740	20.35	15,290	19.621	15,840	18.939	16,390	18.304
13,650	21.98	14,200	21.13	14,750	20.34	15,300	19.608	15,850	18.927	16,400	18.293
13,660	21.96	14,210	21.11	14,760	20.33	15,310	19.595	15,860	18.912	16,410	18.282
13,670	21.95	14,220	21.10	14,770	20.31	15,320	19.582	15,870	18.904	16,420	18.270
13,680	21.93	14,230	21.08	14,780	20.30	15,330	19.569	15,880	18.892	16,430	18.259
13,690	21.91	14,240	21.07	14,790	20.28	15,340	19.557	15,890	18.880	16,440	18.248
13,700	21.90	14,250	21.05	14,800	20.27	15,350	19.544	15,900	18.868	16,450	18.237
13,710	21.88	14,260	21.04	14,810	20.26	15,360	19.531	15,910	18.856	16,460	18.226
13,720	21.87	14,270	21.02	14,820	20.24	15,370	19.519	15,920	18.844	16,470	18.215
13,730	21.85	14,280	21.01	14,830	20.23	15,380	19.506	15,930	18.832	16,480	18.204
13,740	21.83	14,290	20.99	14,840	20.22	15,390	19.493	15,940	18.821	16,490	18.193
13,750	21.82	14,300	20.98	14,850	20.20	15,400	19.481	15,950	18.809	16,500	18.182

Kilocycle-Meter Conversion Table—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or k
16,510	18.171	17,060	17.585	17,610	17.036	18,160	16.520	18,710	16.034	19,260	15.57
16,520	18.160	17,070	17.575	17,620	17.026	18,170	16.511	18,720	16.026	19,270	15.56
16,530	18.149	17,080	17.564	17,630	17.016	18,180	16.502	18,730	16.017	19,280	15.56
16,540	18.138	17,090	17.554	17,640	17.007	18,190	16.493	18,740	16.009	19,290	15.55
16,550	18.127	17,100	17.544	17,650	16.997	18,200	16.484	18,750	16.000	19,300	15.54
16,560	18.116	17,110	17.534	17,660	16.988	18,210	16.474	18,760	15.991	19,310	15.53
16,570	18.105	17,120	17.523	17,670	16.978	18,220	16.465	18,770	15.983	19,320	15.52
16,580	18.094	17,130	17.513	17,680	16.968	18,230	16.456	18,780	15.974	19,330	15.52
16,590	18.083	17,140	17.503	17,690	16.959	18,240	16.447	18,790	15.966	19,340	15.51
16,600	18.072	17,150	17.493	17,700	16.949	18,250	16.438	18,800	15.957	19,350	15.50
16,610	18.061	17,160	17.483	17,710	16.940	18,260	16.429	18,810	15.949	19,360	15.49
16,620	18.051	17,170	17.472	17,720	16.930	18,270	16.420	18,820	15.940	19,370	15.48
16,630	18.040	17,180	17.462	17,730	16.920	18,280	16.411	18,830	15.932	19,380	15.48
16,640	18.029	17,190	17.452	17,740	16.911	18,290	16.402	18,840	15.924	19,390	15.47
16,650	18.018	17,200	17.443	17,750	16.901	18,300	16.393	18,850	15.915	19,400	15.46
16,660	18.007	17,210	17.432	17,760	16.892	18,310	16.384	18,860	15.907	19,410	15.45
16,670	17.996	17,220	17.422	17,770	16.882	18,320	16.376	18,870	15.898	19,420	15.44
16,680	17.986	17,230	17.411	17,780	16.873	18,330	16.367	18,880	15.890	19,430	15.44
16,690	17.975	17,240	17.401	17,790	16.863	18,340	16.358	18,890	15.881	19,440	15.43
16,700	17.964	17,250	17.391	17,800	16.854	18,350	16.349	18,900	15.873	19,450	15.42
16,710	17.953	17,260	17.381	17,810	16.844	18,360	16.340	18,910	15.865	19,460	15.41
16,720	17.943	17,270	17.371	17,820	16.835	18,370	16.331	18,920	15.856	19,470	15.40
16,730	17.932	17,280	17.361	17,830	16.826	18,380	16.322	18,930	15.848	19,480	15.40
16,740	17.921	17,290	17.351	17,840	16.816	18,390	16.313	18,940	15.839	19,490	15.39
16,750	17.910	17,300	17.341	17,850	16.807	18,400	16.304	18,950	15.831	19,500	15.38
16,760	17.899	17,310	17.331	17,860	16.797	18,410	16.295	18,960	15.823	19,510	15.37
16,770	17.889	17,320	17.321	17,870	16.788	18,420	16.287	18,970	15.814	19,520	15.36
16,780	17.878	17,330	17.311	17,880	16.779	18,430	16.278	18,980	15.806	19,530	15.36
16,790	17.868	17,340	17.301	17,890	16.769	18,440	16.269	18,990	15.798	19,540	15.35
16,800	17.857	17,350	17.291	17,900	16.760	18,450	16.260	19,000	15.789	19,550	15.34
16,810	17.847	17,360	17.281	17,910	16.750	18,460	16.251	19,010	15.781	19,560	15.33
16,820	17.836	17,370	17.271	17,920	16.741	18,470	16.243	19,020	15.773	19,570	15.33
16,830	17.825	17,380	17.261	17,930	16.732	18,480	16.234	19,030	15.765	19,580	15.32
16,840	17.815	17,390	17.251	17,940	16.722	18,490	16.225	19,040	15.756	19,590	15.31
16,850	17.804	17,400	17.241	17,950	16.713	18,500	16.216	19,050	15.748	19,600	15.30
16,860	17.794	17,410	17.231	17,960	16.704	18,510	16.207	19,060	15.740	19,610	15.29
16,870	17.783	17,420	17.222	17,970	16.694	18,520	16.199	19,070	15.732	19,620	15.29
16,880	17.773	17,430	17.212	17,980	16.685	18,530	16.190	19,080	15.723	19,630	15.28
16,890	17.762	17,440	17.202	17,990	16.676	18,540	16.181	19,090	15.715	19,640	15.27
16,900	17.751	17,450	17.192	18,000	16.667	18,550	16.173	19,100	15.707	19,650	15.26
16,910	17.741	17,460	17.182	18,010	16.657	18,560	16.164	19,110	15.699	19,660	15.25
16,920	17.730	17,470	17.172	18,020	16.648	18,570	16.155	19,120	15.690	19,670	15.25
16,930	17.720	17,480	17.162	18,030	16.639	18,580	16.146	19,130	15.682	19,680	15.24
16,940	17.710	17,490	17.153	18,040	16.630	18,590	16.138	19,140	15.674	19,690	15.23
16,950	17.700	17,500	17.143	18,050	16.620	18,600	16.129	19,150	15.666	19,700	15.22
16,960	17.689	17,510	17.133	18,060	16.611	18,610	16.120	19,160	15.658	19,710	15.221
16,970	17.678	17,520	17.123	18,070	16.602	18,620	16.112	19,170	15.649	19,720	15.21
16,980	17.668	17,530	17.114	18,080	16.593	18,630	16.103	19,180	15.641	19,730	15.205
16,990	17.657	17,540	17.104	18,090	16.584	18,640	16.094	19,190	15.633	19,740	15.19
17,000	17.647	17,550	17.094	18,100	16.575	18,650	16.086	19,200	15.625	19,750	15.19
17,010	17.637	17,560	17.084	18,110	16.565	18,660	16.077	19,210	15.617	19,760	15.182
17,020	17.626	17,570	17.075	18,120	16.556	18,670	16.069	19,220	15.609	19,770	15.175
17,030	17.616	17,580	17.065	18,130	16.547	18,680	16.060	19,230	15.601	19,780	15.167
17,040	17.606	17,590	17.055	18,140	16.538	18,690	16.051	19,240	15.593	19,790	15.159
17,050	17.595	17,600	17.045	18,150	16.529	18,700	16.043	19,250	15.584	19,800	15.151

Kilocycle-Meter Conversion Table—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
19,810	15.144	20,360	14.735	20,910	14.347	21,460	13.979	22,010	13.630	22,560	13.298
19,820	15.136	20,370	14.728	20,920	14.340	21,470	13.973	22,020	13.624	22,570	13.292
19,830	15.129	20,380	14.720	20,930	14.333	21,480	13.966	22,030	13.618	22,580	13.286
19,840	15.121	20,390	14.713	20,940	14.327	21,490	13.960	22,040	13.612	22,590	13.280
19,850	15.113	20,400	14.706	20,950	14.320	21,500	13.953	22,050	13.605	22,600	13.274
19,860	15.106	20,410	14.699	20,960	14.313	21,510	13.947	22,060	13.599	22,610	13.268
19,870	15.098	20,420	14.691	20,970	14.306	21,520	13.941	22,070	13.593	22,620	13.263
19,880	15.091	20,430	14.684	20,980	14.299	21,530	13.934	22,080	13.587	22,630	13.257
19,890	15.083	20,440	14.677	20,990	14.293	21,540	13.928	22,090	13.581	22,640	13.251
19,900	15.075	20,450	14.670	21,000	14.286	21,550	13.921	22,100	13.575	22,650	13.245
19,910	15.068	20,460	14.663	21,010	14.279	21,560	13.915	22,110	13.569	22,660	13.239
19,920	15.060	20,470	14.656	21,020	14.272	21,570	13.908	22,120	13.562	22,670	13.233
19,930	15.053	20,480	14.648	21,030	14.265	21,580	13.902	22,130	13.556	22,680	13.228
19,940	15.045	20,490	14.641	21,040	14.259	21,590	13.895	22,140	13.550	22,690	13.222
19,950	15.038	20,500	14.634	21,050	14.252	21,600	13.889	22,150	13.544	22,700	13.216
19,960	15.030	20,510	14.627	21,060	14.245	21,610	13.882	22,160	13.538	22,710	13.210
19,970	15.023	20,520	14.620	21,070	14.238	21,620	13.876	22,170	13.532	22,720	13.204
19,980	15.015	20,530	14.613	21,080	14.231	21,630	13.870	22,180	13.526	22,730	13.198
19,990	15.008	20,540	14.606	21,090	14.225	21,640	13.863	22,190	13.520	22,740	13.193
20,000	15.000	20,550	14.599	21,100	14.218	21,650	13.857	22,200	13.514	22,750	13.187
20,010	14.993	20,560	14.591	21,110	14.211	21,660	13.850	22,210	13.507	22,760	13.181
20,020	14.985	20,570	14.584	21,120	14.205	21,670	13.844	22,220	13.501	22,770	13.175
20,030	14.978	20,580	14.577	21,130	14.198	21,680	13.838	22,230	13.495	22,780	13.169
20,040	14.970	20,590	14.570	21,140	14.191	21,690	13.831	22,240	13.489	22,790	13.164
20,050	14.963	20,600	14.563	21,150	14.184	21,700	13.825	22,250	13.483	22,800	13.158
20,060	14.955	20,610	14.556	21,160	14.178	21,710	13.819	22,260	13.477	22,810	13.152
20,070	14.948	20,620	14.549	21,170	14.171	21,720	13.812	22,270	13.471	22,820	13.146
20,080	14.940	20,630	14.542	21,180	14.164	21,730	13.806	22,280	13.465	22,830	13.141
20,090	14.933	20,640	14.535	21,190	14.158	21,740	13.799	22,290	13.459	22,840	13.135
20,100	14.925	20,650	14.528	21,200	14.151	21,750	13.793	22,300	13.453	22,850	13.129
20,110	14.918	20,660	14.521	21,210	14.144	21,760	13.787	22,310	13.447	22,860	13.123
20,120	14.911	20,670	14.514	21,220	14.138	21,770	13.780	22,320	13.441	22,870	13.118
20,130	14.903	20,680	14.507	21,230	14.131	21,780	13.774	22,330	13.435	22,880	13.112
20,140	14.896	20,690	14.500	21,240	14.124	21,790	13.768	22,340	13.429	22,890	13.106
20,150	14.888	20,700	14.493	21,250	14.118	21,800	13.761	22,350	13.423	22,900	13.100
20,160	14.881	20,710	14.486	21,260	14.111	21,810	13.755	22,360	13.417	22,910	13.095
20,170	14.874	20,720	14.479	21,270	14.104	21,820	13.749	22,370	13.411	22,920	13.089
20,180	14.866	20,730	14.472	21,280	14.098	21,830	13.743	22,380	13.405	22,930	13.083
20,190	14.859	20,740	14.465	21,290	14.091	21,840	13.736	22,390	13.399	22,940	13.078
20,200	14.851	20,750	14.458	21,300	14.085	21,850	13.730	22,400	13.393	22,950	13.072
20,210	14.844	20,760	14.451	21,310	14.078	21,860	13.724	22,410	13.387	22,960	13.066
20,220	14.837	20,770	14.444	21,320	14.071	21,870	13.717	22,420	13.381	22,970	13.060
20,230	14.829	20,780	14.437	21,330	14.065	21,880	13.711	22,430	13.375	22,980	13.055
20,240	14.822	20,790	14.430	21,340	14.058	21,890	13.705	22,440	13.369	22,990	13.049
20,250	14.815	20,800	14.423	21,350	14.052	21,900	13.699	22,450	13.363	23,000	13.043
20,260	14.808	20,810	14.416	21,360	14.045	21,910	13.692	22,460	13.357	23,010	13.038
20,270	14.800	20,820	14.409	21,370	14.038	21,920	13.686	22,470	13.351	23,020	13.032
20,280	14.793	20,830	14.402	21,380	14.032	21,930	13.680	22,480	13.345	23,030	13.026
20,290	14.786	20,840	14.395	21,390	14.025	21,940	13.674	22,490	13.339	23,040	13.020
20,300	14.778	20,850	14.388	21,400	14.019	21,950	13.667	22,500	13.333	23,050	13.015
20,310	14.771	20,860	14.382	21,410	14.012	21,960	13.661	22,510	13.327	23,060	13.010
20,320	14.764	20,870	14.375	21,420	14.006	21,970	13.655	22,520	13.321	23,070	13.004
20,330	14.757	20,880	14.368	21,430	13.999	21,980	13.649	22,530	13.316	23,080	12.998
20,340	14.749	20,890	14.361	21,440	13.993	21,990	13.643	22,540	13.310	23,090	12.993
20,350	14.742	20,900	14.354	21,450	13.986	22,000	13.636	22,550	13.304	23,100	12.987

KILOCYCLE-METER CONVERSION TABLE—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
23,110	12.981	23,660	12.680	24,210	12.392	24,760	12.116	25,310	11.853	25,860	11.601
23,120	12.976	23,670	12.674	24,220	12.387	24,770	12.111	25,320	11.848	25,870	11.596
23,130	12.970	23,680	12.669	24,230	12.381	24,780	12.107	25,330	11.844	25,880	11.592
23,140	12.965	23,690	12.664	24,240	12.376	24,790	12.102	25,340	11.839	25,890	11.587
23,150	12.959	23,700	12.658	24,250	12.371	24,800	12.097	25,350	11.834	25,900	11.583
23,160	12.953	23,710	12.653	24,260	12.366	24,810	12.092	25,360	11.830	25,910	11.579
23,170	12.948	23,720	12.648	24,270	12.361	24,820	12.087	25,370	11.825	25,920	11.574
23,180	12.942	23,730	12.642.	24,280	12.356	24,830	12.082	25,380	11.820	25,930	11.570
23,190	12.937	23,740	12.637	24,290	12.351	24,840	12.077	25,390	11.816	25,940	11.565
23,200	12.931	23,750	12.632	24,300	12.346	24,850	12.072	25,400	11.811	25,950	11.561
23,210	12.925	23,760	12.626	24,310	12.341	24,860	12.068	25,410	11.806	25,960	11.556
23,220	12.920	23,770	12.621	24,320	12.336	24,870	12.063	25,420	11.802	25,970	11.552
23,230	12.914	23,780	12.616	24,330	12.330	24,880	12.058	25,430	11.797	25,980	11.547
23,240	12.909	23,790	12.610	24,340	12.325	24,890	12.053	25,440	11.792	25,990	11.543
23,250	12.903	23,800	12.605	24,350	12.320	24,900	12.048	25,450	11.788	26,000	11.538
23,260	12.898	23,810	12.600	24,360	12.315	24,910	12.043	25,460	11.783	26,010	11.534
23,270	12.892	23,820	12.594	24,370	12.310	24,920	12.039	25,470	11.779	26,020	11.530
23,280	12.887	23,830	12.589	24,380	12.305	24,930	12.034	25,480	11.774	26,030	11.525
23,290	12.881	23,840	12.584	24,390	12.300	24,940	12.029	25,490	11.769	26,040	11.521
23,300	12.876	23,850	12.579	24,400	12.295	24,950	12.024	25,500	11.765	26,050	11.516
23,310	12.870	23,860	12.573	24,410	12.290	24,960	12.019	25,510	11.760	26,060	11.512
23,320	12.864	23,870	12.568	24,420	12.285	24,970	12.014	25,520	11.755	26,070	11.507
23,330	12.859	23,880	12.563	24,430	12.280	24,980	12.010	25,530	11.751	26,080	11.503
23,340	12.853	23,890	12.558	24,440	12.275	24,990	12.005	25,540	11.746	26,090	11.499
23,350	12.848	23,900	12.552	24,450	12.270	25,000	12.000	25,550	11.742	26,100	11.494
23,360	12.842	23,910	12.547	24,460	12.265	25,010	11.995	25,560	11.737	26,110	11.490
23,370	12.837	23,920	12.542	24,470	12.260	25,020	11.990	25,570	11.732	26,120	11.485
23,380	12.831	23,930	12.537	24,480	12.255	25,030	11.986	25,580	11.728	26,130	11.481
23,390	12.826	23,940	12.531	24,490	12.250	25,040	11.981	25,590	11.723	26,140	11.477
23,400	12.821	23,950	12.526	24,500	12.245	25,050	11.976	25,600	11.719	26,150	11.472
23,410	12.815	23,960	12.521	24,510	12.240	25,060	11.971	25,610	11.714	26,160	11.468
23,420	12.810	23,970	12.516	24,520	12.235	25,070	11.966	25,620	11.710	26,170	11.464
23,430	12.804	23,980	12.510	24,530	12.230	25,080	11.962	25,630	11.705	26,180	11.459
23,440	12.799	23,990	12.505	24,540	12.225	25,090	11.957	25,640	11.700	26,190	11.455
23,450	12.793	24,000	12.500	24,550	12.220	25,100	11.952	25,650	11.696	26,200	11.450
23,460	12.788	24,010	12.495	24,560	12.215	25,110	11.947	25,660	11.691	26,210	11.446
23,470	12.782	24,020	12.490	24,570	12.210	25,120	11.943	25,670	11.687	26,220	11.442
23,480	12.777	24,030	12.484	24,580	12.205	25,130	11.938	25,680	11.682	26,230	11.437
23,490	12.771	24,040	12.479	24,590	12.200	25,140	11.933	25,690	11.678	26,240	11.433
23,500	12.766	24,050	12.474	24,600	12.195	25,150	11.928	25,700	11.673	26,250	11.429
23,510	12.761	24,060	12.469	24,610	12.190	25,160	11.924	25,710	11.669	26,260	11.424
23,520	12.755	24,070	12.464	24,620	12.185	25,170	11.919	25,720	11.664	26,270	11.420
23,530	12.750	24,080	12.458	24,630	12.180	25,180	11.914	25,730	11 660	26,280	11.416
23,540	12.744	24,090	12.453	24,640	12.175	25,190	11.909	25,740	11.655	26,290	11.411
23,550	12.739	24,100	12.448	24,650	12.170	25,200	11.905	25,750	11.650	26,300	11.407
23,560	12.733	24,110	12.443	24,660	12.165	25,210	11.900	25,760	11.646	26,310	11.403
23,570	12.728	24,120	12.438	24,670	12.161	25,220	11.895	25,770	11.641	26,320	11.398
23,580	12.723	24,130	12.433	24,680	12.156	25,230	11.891	25,780	11.637	26,330	11.394
23,590	12.717	24,140	12.428	24,690	12.151	25,240	11.886	25,790	11.632	26,340	11.390
23,600	12.712	24,150	12.422	24,700	12.146	25,250	11.881	25,800	11.628	26,350	11.385
23,610	12.706	24,160	12.417	24,710	12.141	25,260	11.876	25,810	11.623	26,360	11.381
23,620	12.701	24,170	12.412	24,720	12.136	25,270	11.872	25,820	11.619	26,370	11.377
23,630	12.696	24,180	12.407	24,730	12.131	25.280	11.867	25,830	11.614	26,380	11.372
23,640	12.690	24,190	12.402	24,740	12.126	25,290	11.862	25,840	11.610	26,390	11.368
23,650	12.685	24,200	12.397	24,750	12.121	25,300	11.858	25,850	11.605	26,400	11.364

KILOCYCLE-METER CONVERSION TABLE—*Continued*

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
26,410	11.359	27,010	11.107	27,610	10.866	28,210	10.635	28,810	10.413	29,410	10.201
26,420	11.355	27,020	11.103	27,620	10.862	28,220	10.631	28,820	10.409	29,420	10.197
26,430	11.351	27,030	11.099	27,630	10.858	28,230	10.627	28,830	10.406	29,430	10.194
26,440	11.346	27,040	11.095	27,640	10.854	28,240	10.623	28,840	10.402	29,440	10.190
26,450	11.342	27,050	11.091	27,650	10.850	28,250	10.619	28,850	10.399	29,450	10.187
26,460	11.338	27,060	11.086	27,660	10.846	28,260	10.616	28,860	10.395	29,460	10.183
26,470	11.334	27,070	11.082	27,670	10.842	28,270	10.612	28,870	10.391	29,470	10.180
26,480	11.329	27,080	11.078	27,680	10.838	28,280	10.608	28,880	10.388	29,480	10.176
26,490	11.325	27,090	11.074	27,690	10.834	28,290	10.604	28,890	10.384	29,490	10.173
26,500	11.321	27,100	11.070	27,700	10.830	28,300	10.601	28,900	10.381	29,500	10.169
26,510	11.316	27,110	11.066	27,710	10.826	28,310	10.597	28,910	10.377	29,510	10.166
26,520	11.312	27,120	11.062	27,720	10.823	28,320	10.593	28,920	10.373	29,520	10.163
26,530	11.308	27,130	11.058	27,730	10.819	28,330	10.589	28,930	10.370	29,530	10.159
26,540	11.304	27,140	11.054	27,740	10.815	28,340	10.586	28,940	10.366	29,540	10.156
26,550	11.299	27,150	11.050	27,750	10.811	28,350	10.582	28,950	10.363	29,550	10.152
26,560	11.295	27,160	11.046	27,760	10.807	28,360	10.578	28,960	10.359	29,560	10.149
26,570	11.291	27,170	11.042	27,770	10.803	28,370	10.575	28,970	10.356	29,570	10.145
26,580	11.287	27,180	11.038	27,780	10.799	28,380	10.571	28,980	10.352	29,580	10.141
26,590	11.282	27,190	11.033	27,790	10.795	28,390	10.567	28,990	10.348	29,590	10.139
26,600	11.278	27,200	11.029	27,800	10.791	28,400	10.563	29,000	10.345	29,600	10.135
26,610	11.274	27,210	11.025	27,810	10.787	28,410	10.560	29,010	10.341	29,610	10.132
26,620	11.270	27,220	11.021	27,820	10.784	28,420	10.556	29,020	10.338	29,620	10.128
26,630	11.265	27,230	11.017	27,830	10.780	28,430	10.552	29,030	10.334	29,630	10.125
26,640	11.261	27,240	11.013	27,840	10.776	28,440	10.549	29,040	10.331	29,640	10.121
26,650	11.257	27,250	11.009	27,850	10.772	28,450	10.545	29,050	10.327	29,650	10.118
26,660	11.253	27,260	11.005	27,860	10.768	28,460	10.541	29,060	10.323	29,660	10.115
26,670	11.249	27,270	11.001	27,870	10.764	28,470	10.537	29,070	10.320	29,670	10.111
26,680	11.244	27,280	10.997	27,880	10.760	28,480	10.534	29,080	10.316	29,680	10.108
26,690	11.240	27,290	10.993	27,890	10.757	28,490	10.530	29,090	10.313	29,690	10.104
26,700	11.236	27,300	10.989	27,900	10.753	28,500	10.526	29,100	10.309	29,700	10.101
26,710	11.232	27,310	10.985	27,910	10.749	28,510	10.523	29,110	10.306	29,710	10.098
26,720	11.228	27,320	10.981	27,920	10.745	28,520	10.519	29,120	10.302	29,720	10.094
26,730	11.223	27,330	10.977	27,930	10.741	28,530	10.515	29,130	10.299	29,730	10.091
26,740	11.219	27,340	10.973	27,940	10.737	28,540	10.512	29,140	10.295	29,740	10.087
26,750	11.215	27,350	10.969	27,950	10.733	28,550	10.508	29,150	10.292	29,750	10.084
26,760	11.211	27,360	10.965	27,960	10.730	28,560	10.504	29,160	10.288	29,760	10.081
26,770	11.207	27,370	10.961	27,970	10.726	28,570	10.501	29,170	10.285	29,770	10.077
26,780	11.203	27,380	10.957	27,980	10.722	28,580	10.497	29,180	10.281	29,780	10.074
26,790	11.198	27,390	10.953	27,990	10.718	28,590	10.493	29,190	10.277	29,790	10.070
26,800	11.194	27,400	10.949	28,000	10.714	28,600	10.490	29,200	10.274	29,800	10.067
26,810	11.190	27,410	10.945	28,010	10.710	28,610	10.486	29,210	10.270	29,810	10.064
26,820	11.186	27,420	10.941	28,020	10.707	28,620	10.482	29,220	10.267	29,820	10.060
26,830	11.182	27,430	10.937	28,030	10.703	28,630	10.479	29,230	10.263	29,830	10.057
26,840	11.177	27,440	10.933	28,040	10.699	28,640	10.475	29,240	10.260	29,840	10.054
26,850	11.173	27,450	10.929	28,050	10.695	28,650	10.471	29,250	10.256	29,850	10.050
26,860	11.169	27,460	10.925	28,060	10.691	28,660	10.468	29,260	10.253	29,860	10.047
26,870	11.165	27,470	10.921	28,070	10.688	28,670	10.464	29,270	10.249	29,870	10.044
26,880	11.161	27,480	10.917	28,080	10.684	28,680	10.460	29,280	10.246	29,880	10.040
26,890	11.157	27,490	10.913	28,090	10.680	28,690	10.457	29,290	10.242	29,890	10.037
26,900	11.152	27,500	10.909	28,100	10.676	28,700	10.453	29,300	10.239	29,900	10.033
26,910	11.148	27,510	10.905	28,110	10.672	28,710	10.449	29,310	10.235	29,910	10.030
26,920	11.144	27,520	10.901	28,120	10.669	28,720	10.446	29,320	10.232	29,920	10.027
26,930	11.140	27,530	10.897	28,130	10.665	28,730	10.442	29,330	10.228	29,930	10.023
26,940	11.136	27,540	10.893	28,140	10.661	28,740	10.438	29,340	10.225	29,940	10.020
26,950	11.132	27,550	10.889	28,150	10.657	28,750	10.435	29,350	10.221	29,950	10.017
26,960	11.128	27,560	10.885	28,160	10.653	28,760	10.431	29,360	10.218	29,960	10.013
26,970	11.123	27,570	10.881	28,170	10.650	28,770	10.428	29,370	10.215	29,970	10.010
26,980	11.119	27,580	10.877	28,180	10.646	28,780	10.424	29,380	10.211	29,980	10.007
26,990	11.115	27,590	10.874	28,190	10.642	28,790	10.420	29,390	10.208	29,990	10.003
27,000	11.111	27,600	10.870	28,200	10.638	28,800	10.417	29,400	10.204		

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	·—
B	—···
C	—·—·
D	—··
E	·
F	··—·
G	——·
H	····
I	··
J	·———
K	—·—
L	·—··
M	——
N	—·
O	———
P	·——·
Q	——·—
R	·—·
S	···
T	—
U	··—
V	···—
W	·——
X	—··—
Y	—·——
Z	——··
Ä (German)	·—·—
Á or À (Spanish-Scandinavian)	·——·—
CH (German-Spanish)	————
É (French)	··—··
Ñ (Spanish)	——·——
Ö (German)	———·
Ü (German)	··——
1	·————
2	··———
3	···——
4	····—
5	·····
6	—····
7	——···
8	———··
9	————·
0	—————

Period	······
Semicolon	—·—·—·
Comma	·—·—·—
Colon	———···
Interrogation	··——··
Exclamation point	——··——
Apostrophe	·————·
Hyphen	—····—
Bar indicating fraction	—··—·
Parenthesis	—·——·—
Inverted commas	·—··—·
Underline	··——·—
Double dash	—···—
Distress call	···———···
Attention call to precede every transmission	—·—·—
General inquiry call	—·—· ——·—
From (de)	—··
Invitation to transmit (go ahead)	—·—
Warning—high power	——··——
Question (please repeat after ....)—interrupting long messages	··——··
Wait	·—···
Break (Bk.) (double dash)	—···—
Understand	···—·
Error	········
Received (O. K.)	·—·
Position report (to precede all position messages)	—·—·
End of each message (cross)	·—·—·
Transmission finished (end of work) (conclusion of correspondence)	···—·—

INDEX

B

C

D

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W