The Radio Educator

by Sidney Gernsback

A Reading Course in Five Books

Book No. I

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PART I

THE PRINCIPLES OF ELECTRICITY

IN the study of radio, many electrical terms and instruments are encountered, making it necessary for the beginners to obtain a reasonable working knowledge of electricity before invading the subject of present-day radio. We have therefore devoted the first, second and part of the third books of this series to a concise and practical course in elementary electricity and wireless telegraphy. We do not claim that it is complete, but if the simple lessons here taught are learned, the student will find it rather easy to assimilate radio terms and technicalities. For a better knowledge of electricity, we recommend the reader to the many excellent text books which cover the subject in a more thorough manner.

Electricity in its simplest form was known to the ancients many centuries before the Christian era. Thales, of Miletus, a city of Asia Minor, in the seventh century B. C., described the remarkable property of attraction and repulsion which amber possesses when rubbed. When being thus rubbed he found that it would attract particles of dust, dry leaves, straws, etc. This phenomenon was noted from time to time in the centuries succeeding, but it was not until 1600 A. D., that Dr. Gilbert of Colchester, England, took up the study of this subject. Because of the thoroughness with which he delved into the study of electricity, he is considered the founder of the science of electricity. He gave the name of electricity, which he derived from the Greek name "Elektron," (meaning Amber), to this peculiar force.

Electricity is found in two forms, in one it exists as a charge upon a body, and is known as **static electricity,** while in the other form it consists of a moving current through a wire, known as **dynamic electricity.** We therefore have:

Static (otherwise known as electro-static) **electricity** is that branch of the science which treats with electricity at rest.

Dynamic (also known as electro-dynamic) **electricity** is that branch of the science which treats with electricity in motion.

If a glass rod is rubbed with a silk handkerchief and brought near a small pith ball, (made of the soft central portion in the stalks of dried plants or flowers), which has been suspended by a silk thread, there will be an attraction of the pith ball towards the rod. However, as soon as the pith ball touches the rod, another action takes place: the ball being repelled from the rod. The explanation is that the ball originally held a charge opposite to that held by the rod, the charge being neutralized on touching the rod, and some of the charge of the rod being stored on the pith ball. Inasmuch as the same charges then existed on the ball and the rod, both repelled each other.

Two kinds of charges are produced by friction. the kind of charge being dependent on the substances rubbed together. Thus if glass is rubbed with silk it becomes charged with **positive electricity.** On the other hand, sealing wax receives a **negative** charge if rubbed with flannel. Positive electricity is represented by a plus sign (+), and negative electricity by the minus sign (—). Where the current has been perfectly neutralized so that no polarity exists, a combination of both signs is used (±).

While a charge may be given to a body by contact, it is also possible to charge a body at a distance by what is known as **induction.** If an electrified rod is brought near a glass cylinder, the latter will receive a temporary charge which disappears again when the charged rod is removed from the vicinity of the cylinder. However, if a permanent charge is desired, the glass cylinder is touched by the hand while the rod is held in the other hand near the end opposite to that being touched. A body touched or grounded while near a charged body is electrified oppositely. A body brought near a charge of electricity is electrified oppositely on the near end and similarly on the far end.

The following table represents **electrical conductors** and **non-conductors** in their respective value:

Conductors.	**Insulators (or non-conductors)**	
Silver	Dry air	
Copper	Shellac	
Other metals	Paraffin	Ebonite
Charcoal	Amber	India Rubber
Plumbago	Rosin	Silk
Damp Earth	Sulphur	Paper
Water containing solids	Glass	Oils
Moist air	Mica	

It must be noted carefully that the conductors do not hold static charges on them, and are therefore known as "**non-electrics.**" The insulators, which do not carry current, do hold static charges and are known as "**electrics.**"

The amount of electricity a body may be able to retain in the form of a charge is spoken of as its **capacity.** The total quantity that can be held depends directly on the surface area over which the charge is spread and upon the material separating two oppositely charged bodies. The thickness of this material is also of importance. If we employ a definite amount of electricity to charge a body of small capacity, it will be to a higher degree than one of a larger capacity, because the charge can spread out more on the surface of the larger than on the smaller.

One of the most familiar types of capacity is in the form of a glass jar or bottle, coated on its inside and outside with tinfoil, secured to the glass by shellac or other adhesive. This is known as

Fig. 1

Fig. 2

the **Leyden jar,** Fig. 1, the first one having been produced at Leyden, Holland. A brass rod with a ball at its end is passed through a wooden cover and makes contact either by a chain or a spring clip to the inner sides of the tin foil. The outer foil may be connected by other means. To charge the Leyden jar, the outside coating is grounded (held in the hand by the operator) and the inside contact ball on rod is touched by a charged body. To discharge the jar, the inner and outer coatings are connected together by means of a **discharger,** Fig. 2, which consists of two brass balls connected together by a metallic rod or wire and mounted on an ebonite handle.

By means of a Leyden jar having brass inner and outer cups as substitutes to the tin foil, it may be noticed that after the jar has been charged and these carefully removed, the charge will not be found in either brass cup, proving that the charge really resides in the glass surface. It will also be noticed that in any Leyden jar, when it is discharged, there is one large spark, and an instant after a weak spark, proving that the electric charge seemingly soaks into the glass dielectric, and does not release itself upon the first discharge.

If a heavy charge of current is to be stored, a number of Leyden jars are employed, all the inner coatings being connected together, and all the outside coatings connected to each other as shown in the illustration, Fig. 3. The entire groups may then be charged or discharged together.

The capacity of a condenser depends on the size and shape of the plates and the distance between them, as well as the insulating medium (dielectric). The larger the plates, the greater the amount of current required to fully charge them, hence the greater the capacity. By

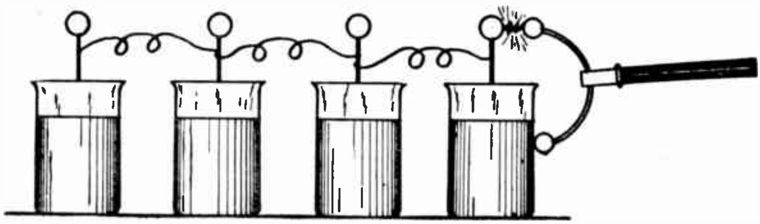


Fig. 3

decreasing the distance between the plates, the capacity is also increased, since the nearer a body is brought under the influence of a charged body, the more electricity it will retain.

Specific Inductive Capacity, is the name given to the ratio of the capacity of any condenser, for a given insulating material, to its capacity with air as a dielectric. The table below illustrates the relative dielectric value of various materials. As an example of its use, if a condenser has a certain capacity with air as a dielectric, it will have 2.05 times that capacity if Petroleum is substituted for the air as the dielectric.

Relative Value of Inductive Capacities.

Glass	6.5 to 10	Paraffin	1.9
Shellac	2.9 to 3.7	Carbonic Acid	1.000
Sulphur	2.8 to 3.2	Air	1.000
Ebonite	2.7	Hydrogen	.999
India Rubber	2.34	Vacuum	.94
Petroleum	2.05		

To produce **static electricity** in large amounts, a machine employing the principle of friction is often used for experimental purposes. There are various types of these frictional machines, the most popular type being a glass cylinder upon which a silk flap rubs as it is turned. The charge is gathered by appropriate collectors.

The most successful machine of the type illustrated herewith, Fig. 4 is the **influence static machine**, which consists of a number of plates upon which tin foil sectors have been placed. Each pair revolve in opposite directions, and the current is gathered by suitable collectors. These machines operate best on cold, dry days, but some of the larger of these influence machines are capable of developing a spark several feet long in even unfavorable conditions while it is not unusual to find miniatures only fifteen inches high giving a five inch spark.

CURRENT GALVANIC ELECTRICITY.

In the foregoing pages we have only considered static electricity, which is not used extensively in commercial activities, inasmuch as it does not possess such useful characteristics as current electricity.

There are three kinds of current electricity, as follows:

Continuous or direct current, is current which flows in one direction only.

Alternating current, is current which flows in opposite directions changing its direction periodically.

Pulsating current, is current which flows in one direction, but is interrupted periodically.

In explaining the properties of current electricity and the meaning of its terms, a striking similarity between water and electric current will serve as an effective example.

We will therefore consider a tank of water several feet above the surrounding ground, likening it, let us say, to reservoirs of municipal water supplies. If a pipe be connected to this tank, and the pipe be brought to a lower level, there will be considerable pressure exerted in the water coming through the pipe. This pressure may be gauged in pounds per square inch. In electricity, we find a current similar to water, the pressure varying likewise according to

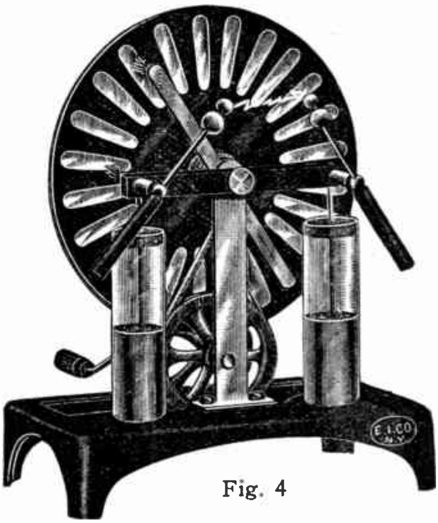


Fig. 4

the source of supply. This pressure is gauged in **volts**, and is also referred to as potential. Volts therefore are the units used to denote the pressure of an electrical current. Coming back to the water pipe, we note that if the end of the pipe is left open, the water will flow out of it at a certain rate of speed. This may be measured in gallons per minute if necessary, or a smaller unit, if the rate of flow is very slight. The rate of flow of the water will be in proportion to the pressure of the water, and also in ratio with the size of the pipe. If the pipe is larger, and the pressure greater, the rate of flow is likewise higher. In electricity, we measure the flow of current through wires in the term of **Amperes**, and analogous to the pipe with the water, the greater the voltage (pressure), and the larger the conductor (pipe), the greater the amount of current passing.

For the **resistance** the conductors offer to the flow of electric current (the water pipe itself, in our example) the term **Ohm** is used. The ohm is a unit used in denoting the resistance offered to the passage of electric current in a conductor. We therefore note that the lower the number of ohms resistance in a conductor, the greater the number of amperes which are forced through the conductor by a certain pressure (voltage). Also, the greater the voltage, the more amperage is passed through a given resistance.

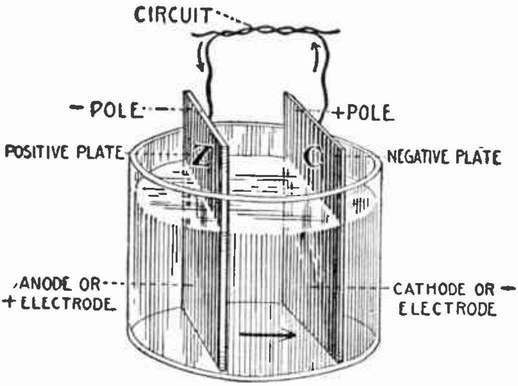


Fig. 5

Fig. 6

As every part of the conductor offers resistance to the flow of electricity, a certain amount of pressure or force is necessary to overcome this resistance.

This force is called the **ELECTROMOTIVE FORCE**, or abbreviated **E.M.F.**

The unit in which the **E.M.F.** is measured is the **Volt.**

The **E.M.F.** is the whole electrical pressure existing in a circuit. This force may not be the same at every point in the circuit, and it may vary in pressure between one point and another. This difference is called the **POTENTIAL DIFFERENCE** or abbreviated **P. D.**, and is measured in the same unit as the Electromotive Force, the **Volt.**

In the early part of this lesson, we learned that electricity of the static form can be produced by friction and influence, but now as we are considering current electricity, we will consider the **chemical** means of producing electric current.

If a piece of sheet copper and another piece of sheet zinc are placed in a weak solution of sulphuric acid and water, an electric current will be generated, which may suffice to ring a bell. The electric current is formed through the decomposition of the zinc by the powerful action of the acid. The copper sheet is not attacked by the acid, but is used merely to form the complete circuit, which starts at the copper sheet, passes through the conductor, back to the zinc, after which it goes through the solution and again reaches the starting point, the copper sheet. The two exposed plates are named **poles** or **electrodes**, and sometimes **elements**, Fig. 5. The solution is termed the **electrolyte**, the entire apparatus being known as a **galvanic cell**, or **galvanic battery**. When a number of cells are combined together in order to obtain a heavy current, this group is called a **battery**, though battery is often used incorrectly to denote a single cell. The flow of current is always from the inactive element to the active, the latter being zinc in the majority of cells. The path through which the current is obliged to pass in its journey, from one element to the other is termed the **circuit**.

There are many forms of cells and a description of each type would require more space than we can give to the subject. However, the type most used is the dry cell, see Fig. 6 and Fig. 6a, which though named a "**dry**" **cell**, is not, strictly speaking, dry. If such a cell is opened, we find a carbon rod passing through the center surrounded by absorbent material, saturated with the active chemical. The containing case is made of zinc so that the chemical can attack it from the inside and thus generate the current.

Another type which is rather successful by virtue of its excellent constant service is the Lalande Primary Cell. The electrolyte is a solution of caustic soda, while the plates are of zinc and cupric oxide. The electrolyte is usually covered with a layer of paraffin oil to prevent evaporation. While the cell furnishes only but seven-tenths of a volt, it develops a relatively high amperage.

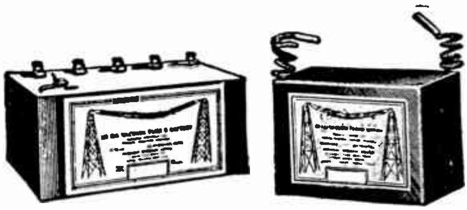
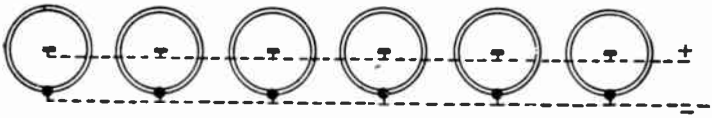


Fig. 6a

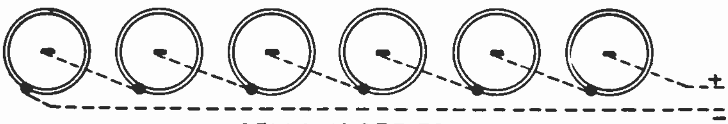
After a cell such as the first cell we described made with the copper and zinc plates has been used for a short time, the voltage is noticed to decrease to such a point that the cell cannot be used further. On investigation one finds that a fine film of gas composed of innumerable bubbles has formed on the copper plate. This is known as the **polarization** of the cell. This gas being a non-conductor of electricity for such low potentials as are generated in a single cell, causes the voltage to be considerably reduced. But, fortunately, there are means of overcoming the formation of the gas, namely **Depolarizers** as for instance manganese oxide. This compound having a great attraction **for free hydrogen**, combines with the hydrogen surrounding the copper plate to form other compounds which do not interfere with the formation of electric current. In dry cells, manganese dioxide is used, while in the Lalande Primary Cell the copper oxide plate serves the purpose. Other types of cells employ countless different substances as depolarizers. In some wet cells we find nitric acid used, this acid also possessing the characteristic of combining with free hydrogen. In the common wet cell used in bell work we find manganese oxide mixed in with the carbon cylinder, which is here used as a depolarizer.

Electrical circuits are of many varieties. In instances where the current passes through a number of separate paths on its way back to the starting point, the circuit is known as a **multiple circuit**, and the individual circuits are said to be connected in multiple, or parallel, Fig. 7. Each small branch is known as a shunt or branch. If all



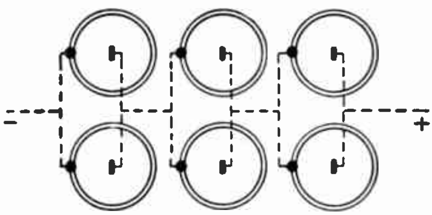
CELLS IN PARALLEL OR MULTIPLE.

Fig. 7



CELLS IN SERIES.

Fig. 8



CELLS IN MULTIPLE SERIES.

Fig. 9

the circuits are connected together in such fashion that the current must travel through each in perfect succession, then the circuit is known as a **series circuit**. Fig. 8.

In connecting cells into batteries, it is important to pay particular attention to the manner of connecting the cells. If all the cells are connected so that the zinc of one cell is connected to the copper or carbon of the next cell, the mode of correction is called **series**. The voltage in this instance will be equal to the sum of all the voltages of the individual cells, but the amperage will be equal to that of one average cell. On the other hand, if we connect all the cells in parallel, connecting the zinc elements together, and the carbon or copper elements together, then the potential will be the same as the voltage of one average individual cell; but the current will be equal to the sum of all the individual amperages. Combinations can be made so that any desired amperage and voltage is obtained as shown in Fig. 9.

Fig. 10

Electricity, like water, may also be stored away for future use. The device for doing this is known as the storage battery. Briefly the operation consists of passing electric current to lead or composition plates suspended in dilute sulphuric acid. This causes a chemical change in the plates and when the supply of current is subsequently removed a reverse chemical action takes place and the cell gives up the current it has accumulated. See Fig. 10.

Coming back to our problem of water and electricity, we find that in water, the resistance, pressure, and quantity of flow in a pipe, bear a mathematical relation to each other. In electricity, an eminent scientist, George Simon Ohm of Germany, (1827) founded a law showing the definite relations of resistance, voltage, and amperage, this law being known as Ohm's Law, which is the all important factor in electrical calculations.

Ohm's Law states:—

$$\text{Current} = \frac{\text{Electromotive Force}}{\text{Resistance.}}$$

or expressed in an algebraical equation:

$$C = \frac{E}{R}$$

Let us illustrate the application of this rule in a practical example. Assume that we have a coil of wire with a resistance of 100 ohms, this having been determined by measuring instruments. We want to find the amount of current at 25 volts pressure which will flow through this winding. Referring again to Ohm's Law, we have

$$C = \frac{E}{R}$$

substituting the voltage (25) for the E, and the ohmage (100) for the R, we have the equation:

$$C = \frac{25}{100} = \frac{1}{4}$$

$$C = \frac{1}{4}$$

Therefore the winding will permit ¼ ampere to pass through it. Ohm's Law may be written in other ways, to allow all factors included in it to be figured. Hence we have:

First:

$C = \frac{E}{R}$ for determining the current consumed or passed by an apparatus or conductor.

Second:

$E = C \times R$ for determining the voltage required to pass a definite current through a given resistance.

Third:

$R = \frac{E}{C}$ used in determining the resistance required for a given current and voltage.

From these three formulas most any simple electrical problem may be figured. The reader will undoubtedly be able to use these without further instructions. They are of sufficient importance to warrant their introduction here. The formulas are easy enough to remember and memorizing them is of considerable value in assisting the reader to work out many seemingly perplexing problems.

The most important electrical units as we have just learned are the ampere, volt, and ohm. These units were originally determined by electrochemical methods, in which the decomposition of water was taken as the means of figuring the exact unit, but today both ammeters and voltmeters are used. A coil of very fine wire mounted so as to act upon an iron piece connected to a pointer or the coil itself directly connected to the pointer is used in voltmeters. In ammeters the wire is much heavier. A permanent magnet acting on the iron piece or a spring acting on the movable coil tends to hold the pointer at zero. Current to the coil upsets the relation and causes the instrument to register. Ammeters (Fig. 11) are usually connected in series with circuits in which the amperage is to be indicated, and voltmeters (Fig. 12) are connected across the two wires of the circuit. In measuring resistance, a comparison between a known value, and an unknown resistance is generally made.

A galvanometer or very sensitive current meter indicates when both circuits are evenly balanced, and then, reading the amount of resistance in the known circuit, the ohmage of the unknown circuit is also found. This instrument is called a Wheatstone Bridge.

Other terms have been derived from the three units we have discussed in the preceding paragraphs. **Watt** is a term which combines volts and amperes; one watt being equal to a current of one ampere at a pressure of one volt. If we have a current of 10 amperes and 50 volts potential, we have 500 watts. If we have a pressure of 2 volts, and a current of 3 amperes, we have a wattage of 6. All statements of current made in watts are more definite than merely in either volts or amperes, since individually these units are not complete without the other. If we have a current of one watt for one hour, it is known

Fig. 11

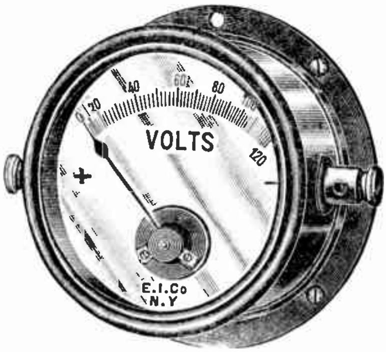


Fig. 12

as a **watt-hour.** If we have a current of 1,000 watts, it is called a **kilowatt,** this unit being the standard for the calculation of heavy currents. Transformers, as well as dynamos, motors and other appliances, are usually rated in kilowatts. Electric current is sold by the **kilowatt-hour,** which is the equivalent of 1,000 watts for one continuous hour. It requires 746 watts to equal one mechanical **horse-power** when comparing mechanical and electrical energy. It will thus be noted that a one kilowatt motor should develop about 1 1/3 H. P. One mechanical horse-power is the force required to raise 33,000 lbs. to a height of one foot in one minute.

PART II

THE PRINCIPLES OF MAGNETISM

THE name "Magnet" originated from the name of a town, Magnesia, in Asia Minor, where the loadstones, which could attract small particles of iron, were first found. The first discovery is recorded as having been made by the philosopher Plato, who was born 480 years before the dawn of the Christian Era.

Magnetism is found in nature in the form of ore, commonly known as loadstone, or magnetite by the mineralogists. This ore is found in many parts of the world, including the United States where there is a fair supply. The **compass**, Fig. 1, a magnetic device, is an invention which rendered navigation over seas possible, and is attributed to the Chinese, who it is said, used the device long before it became known in Europe.

Dr. Gilbert, who will be recalled by the reader as the first active worker in static electricity, published in England his famous work "De Magnete" in the year 1600, which comprised a complete account of the remarkable characteristics of magnetism.

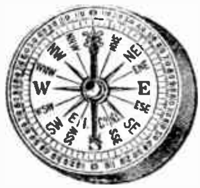


Fig. 1

Fig. 1a

If a bar of steel is rubbed with a loadstone, the rubbing commencing at one end and continuing to the other end of the steel bar, the steel becomes magnetized, viz., it possesses magnetism. Another method of magnetizing a steel bar is to be given later in this lesson. If the steel bar be now suspended on a thread, Fig. 1a, it will point north and south, otherwise act as a compass. The end pointing north is the south pole of the compass, while the end pointing south is the north pole. If a needle or other steel object be brought near the bar magnet, it will be attracted at either end, but in the center of the bar comparatively no magnetism will be found. This illustrates that the magnetism at the center is neutral, increasing in strength toward the ends and in opposite polarity of magnetism at these ends.

Now, if the bar magnet be laid under a piece of white paper and coarse iron filings be scattered over the paper, the filings will arrange themselves in wave-like formation, the lines extending from the magnetic poles, and in faint lines circling to the opposite poles, Fig. 2. These lines represent the magnetic lines of force, which extend from one pole to the other in all magnets, the strength being less as the distance from the poles increases. These lines of force in passing from one pole to the other are known as the magnetic circuit. Fig. 3. A closed magnetic circuit is one where the magnetism is limited to a continuous iron mass, the magnetism having no gaps to cross in order to complete its magnetic circuit from one pole to the other. A closed magnetic circuit is usually employed in watchcase telephone receivers or in closed core transformers and possesses many ad-

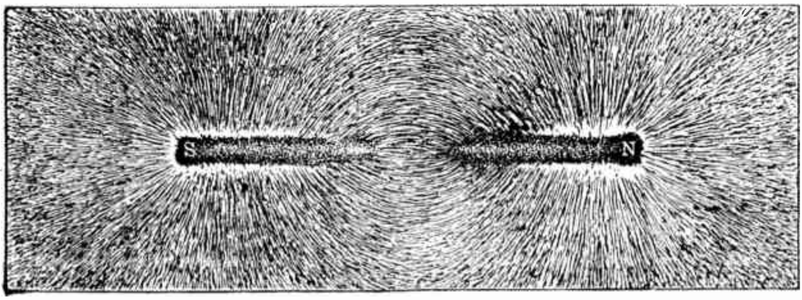


Fig. 2

vantages over the open magnetic type. The **open magnetic** circuit is one in which there are air gaps for the lines of force to bridge in their travel from one pole to the other. This form of magnetic circuit is largely employed in spark coils, etc.

We have learned that a magnet always possesses two poles, the north and the south, represented by N and S respectively.

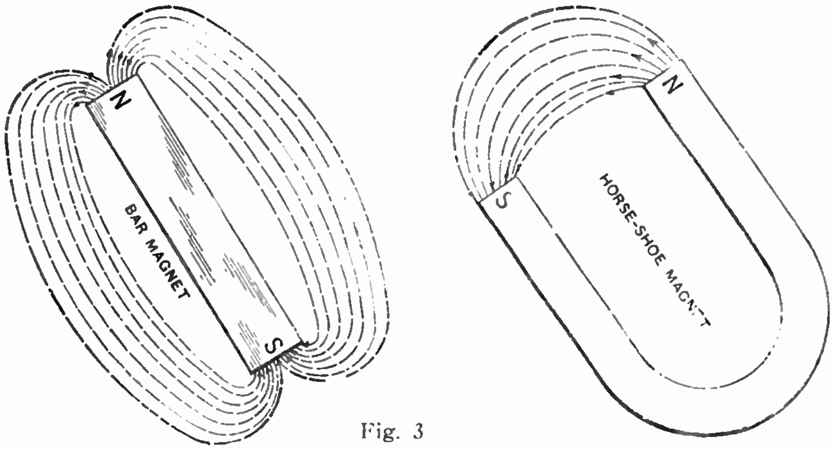


Fig. 3

If we consider the earth as the fundamental magnet, then in comparison with it, we ought to call that pole of any magnet which tends to point north, a south pole, and vice versa. The so-called north pole or end of a compass needle, is thus really a south pole, and its south pole or end, is a north pole. The reason for this inaccuracy is probably due to the mariner's compass being the first general practical application of magnetism. That end of the needle which points always to the north would naturally be called its north end. According to the modern theory of magnetism this is an inaccurate name for it. A more correct designation would be the north-seeking end or pole.

If we take a magnet and suspend it on a thread, it will point north and south, so that we can mark the ends with the polarity they possess. The end pointing north being marked with an "S" and the ending pointing south with an "N." If we treat another bar magnet in the same manner, we can then bring the last mentioned magnet near to the suspended magnet so that both "S" poles are near together. The suspended magnet will immediately begin to turn away from the other magnet, showing that there is a repulsion between the two "S" ends. Now, if the "N" poles are treated in the same way the same results will be obtained. This teaches us that like magnetic poles repel each other, identically as with similar charges of static electricity. Then if the "S" pole of one magnet is brought near to the "N" pole of the other magnet, there will be an attraction; the suspended magnet turning and following the one held by the hand. Unlike poles attract each other. It will be noticed that if it were possible to reverse the polarity of the magnets at a critical moment, so that opposite poles would attract each other while the like poles would repel each other, the suspended magnet would assume a rapid rotary motion, depending on the frequency in the reversal of polarity. This is the principle of the electric motor, the magnetism being changed at the critical moment. The magnetism in this instance is produced by electrical current passing through wire coils, the direction of the current being changed rapidly either mechanically or rapidly changing current being applied to the wire coils directly.

Magnetic bodies are those which can acquire and retain magnetism.

Paramagnetic bodies are those which are attracted by magnetism.

Diamagnetic bodies are those which are repelled or on which magnetism has no effect. The following table illustrates common metals and substances in their relative magnetic order.

Paramagnetic.		**Diamagnetic.**	
Steel	Cerium	Bismuth	Copper
Iron	Titanium	Phosphorus	Gold
Nickel	Palladium	Antimony	Water
Cobalt	Platinum	Zinc	Alcohol
Manganese	Oxygen	Mercury	Tellurium
Chromium	Ozone	Lead	Selenium
		Silver	Sulphur
			Thallium

The best method of forming a bar magnet cheaply is to magnetize each end individually. One end is first rubbed from the center to the end by a permanent bar magnet or loadstone and then the opposite end is rubbed with the opposite pole from the center to its respective end, as shown in the sketch, Fig. 4.

A horse-shoe type of magnet as generally sold by electrical houses, see Fig. 5, is nothing more than a bar magnet with its two ends brought close to each other by a bending process. When this magnet is not in use, a small piece of steel is placed across both poles. This piece is known as the "keeper." Its purpose is to form a closed magnetic circuit and thus help to retain the magnetism.

If a magnet be placed in acid so that the outside surface be attacked and dissolved, it will be found that the magnetism is greatly lessened, if not entirely destroyed. This proves that the magnetism is largely confined to the surface. For this reason, it has been found advisable to use a greater number of smaller magnets, in order to obtain a large magnetic surface, instead of making one magnet for the same area out of a single piece of iron or steel. In practice this method is employed, a number of permanent magnets with all the "N" poles together and all the "S" poles together, are attached to

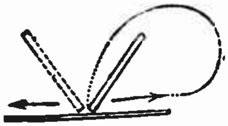


Fig. 4

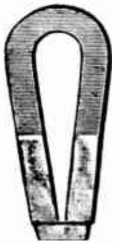


Fig. 5

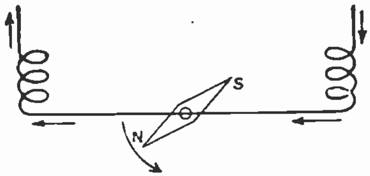
one common iron pole for each polarity with screws or otherwise fixed. The magnets so made are known as laminated, built-up, or compound magnets.

Heat has a temporary effect of removing magnetism from bodies, but only while the body is heated, the magnetism again being present when the metal cools, but not to the same extent. Jarring a magnet will permanently weaken it, the degree of loss being in proportion to the conditions. Inasmuch as many conditions effect permanent magnets, in the electrical industry where magnets are manufactured for accurate purposes; as in measuring instruments, the process is thorough, and the magnets are subjected to boiling, jarring, and other tests so that the surplus magnetism may be removed and absolute permanency assured.

A magnetic circuit is similar to an electric circuit, in that the lines of force start at one pole and travel to the other pole. Magnetism may be produced inductively, by bringing a permanent magnet in the vicinity of a piece of iron or steel, when this object will be found to possess magnetism, but it loses this power as soon as the permanent magnet is removed to a greater distance where the magnetic lines of force become too weak to induce magnetism. It is also possible to locate magnetism in a piece of steel rod, so that various sections in the same rod will have north and south poles. This is accomplished by magnetizing the independent sections with a powerful magnet. It is also possible for steel or iron to carry magnetism through it, yet only be magnetized as long as in actual contact with the magnetizing source. The best grades of steel retain magnetism the longest time, and display great permanency. The softer the steel, the less efficient it is for use as a permanent magnet. Iron is still less efficient, the softer grades are worthless for making permanent magnets. For this reason soft iron is used in electro-magnets where they must be completely demagnetized after the passage of the electric current.

ELECTRO-MAGNETISM.

Early experimenters suspected that some relation existed between magnetism and electricity, but it was not until 1819 that this was



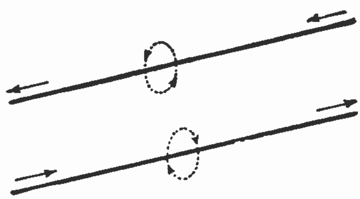
ELECTRIC CURRENTS EFFECT ON COMPASS NEEDLE

Fig. 6

proven by Oersted of Copenhagen, Denmark. He demonstrated that a wire carrying a current would deflect a compass needle. The needle tends to turn at right angles to the direction of the current in the conductor, the degree of the angle being in proportion to the strength of the current. The arrows in illustration, Fig. 6, represent the direction of flow of the current and the N and S poles of a compass needle.

Around a wire carrying an electrical current, a magnetic field of force is also formed. This field extends in concentric lines further and further away from the conductor. Only current electricity produces marked magnetic effects in conductors, static electricity developing but a slight effect.

In the next cut, Fig. 7, are represented the lines of force in dotted lines produced by two currents flowing in opposite directions in two wires.



MAGNETIC FLUX OF CURRENTS

Fig. 7

If we take a heavy piece of wire and bend it so as to pass over and under a pivoted compass needle as shown in the cut, Fig. 8, it will be found that by connecting both binding posts to a source of current, the flow of this current may be detected by the reflection of the compass needle as well as its relative strength. This instrument is a simple type of galvanometer, and in its more complicated and perfected forms is used for detecting feeble electric currents.

If a wire carrying an electric current is wound into a spiral form, it will exert a powerful magnetic field in the direction of its axis, the

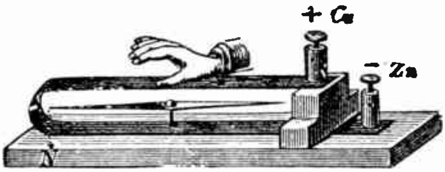


Fig. 8

polarity being controlled by the flow of current as illustrated by the accompanying cut, Fig. 9. This wire coil is called a solenoid.

If a number of turns of wire be wound on a wooden spool and current passed through the winding, a small iron rod will be pulled into the spool. If a spring balance is connected to the rod, the strength of the pull may be gauged. A form of commercial meter formerly used and known as the "plunger" voltmeter employed this principle, the spring being in this case fitted with a pointer which indicated on a scale marked in volts, and if desired the scale could be graduated in amperes instead. If iron is used, it will be pulled into the spool, no matter in what direction the current is flowing, inasmuch as soft iron does not possess permanent magnetism and is therefore attracted by magnetism of either polarity.

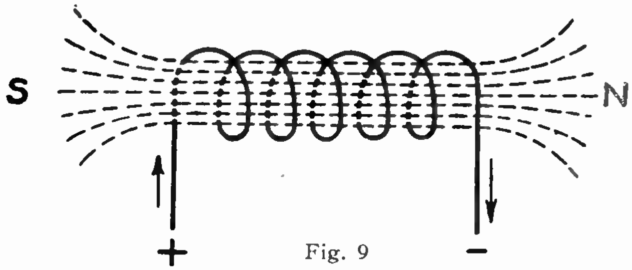
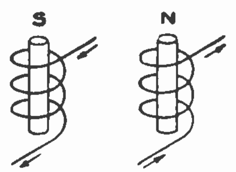


Fig. 9

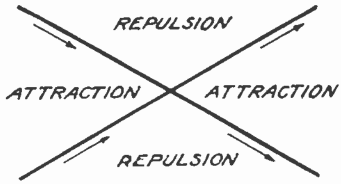
To construct an electromagnet, a piece of soft iron is first covered with a thin sheet of paper, in order that the current flowing through the wire will not form a by-path through the iron accidentally, which by-path would be called a ground. Over the paper, the layers of wire are wound, there being two end pieces (coil or spool heads) in order to secure the winding in place, these being either of fiber or hard rubber. The iron rod around which the windings is placed is known as the core. The accompanying diagram, Fig. 10, represents the polarity imparted in the core with the direction of current given. In order to obtain the maximum efficiency in such electromagnets, two are usually mounted on one steel or iron bar, the N and S poles being connected together. This greatly increases the magnetic force for a given current strength, the gain being derived through the reduction of the magnetic leakage. The electromagnet when subjected to alternating magnetizing currents, produces a heating effect in the iron core which is known as hysteresis.

Hysteresis is that magnetic inertia or resistance to change in polarity of the molecules evidenced whenever the magnetizing power is reversed or changed. The molecules of the iron resist this change in polarity, and this results in molecular friction, (as it is often called),



POLARITY OF ELECTRO MAGNETS

Fig. 10



OBLIQUELY CROSSED CONDUCTORS

Fig. 11

whenever the reversal of magnetism is raised to a certain frequency or number of times per second, the hysteresis effect or friction is soon made evident by the heating of the iron mass.

This phenomenon of electromagnetic induction will be treated upon again in a later chapter, dealing with detectors.

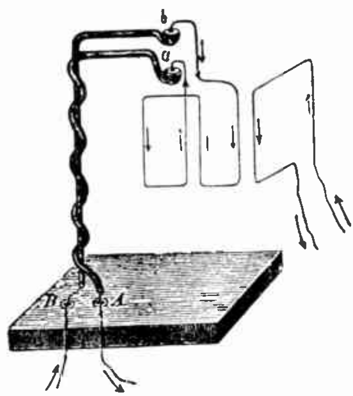


Fig. 12

ELECTRODYNAMICS.

Electrodynamics is that branch of electrical study which deals with the action of one current carrying conductor upon another one.

One of the laws relative to electrodynamics is:

Two parallel conductors attract each other when the currents therein flow in the same direction, and repel each other when the currents flow in opposite directions.

This rule is applicable whether the wires are of the same or different circuits, and whether the wires are straight or curved.

Another rule applying to the action of conductors states:

Conductors crossing each other obliquely tend to take up a position in which they are parallel and the currents in them are flowing in opposite directions. This is illustrated in the accompanying Fig. 11.

There is no tendency for the wires to be attracted or repulsed lengthwise, the action being entirely sideways. For illustrating the attraction and repulsion of electrical conductors, an apparatus known as "Ampere's Stand" is employed. In the cut, Fig. 12, the principle is briefly shown, the instrument consisting of two heavy loops of wire, one being pivoted so as to freely revolve, while the other is fixed. Currents from different circuits may be used on both coils.

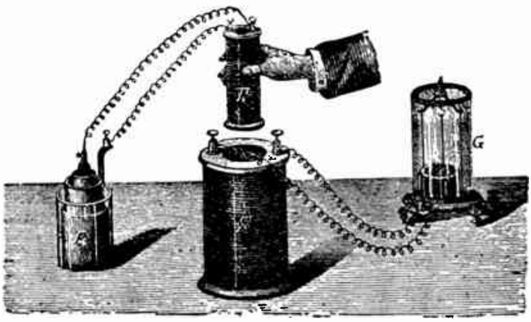


Fig. 13

ELECTROMAGNETIC INDUCTION.

Electromagnetic induction is the production of electric current in a wire, through the action of a magnetic field.

In 1831, Faraday of England, demonstrated that the motion of a magnet near a closed circuit produced an electric current in that circuit. Moving the circuit and keeping the magnet still produces the same result, the essential element being to cut the magnetic lines of force by the moving of the wire or magnet. An apparatus producing this effect consists of a spool of wire connected to a galvanometer. When a permanent bar magnet is plunged into the center of the spool, there is a deflection of the needle, proving that a current has been produced. But, as soon as the bar comes to rest against the bottom of the spool there is no further deflection of the galvanometer needle, and it returns to its normal position. However, as soon as the bar is pulled out of the spool, the galvanometer needle swings in the opposite direction demonstrating that a current has been produced, which flows in the opposite direction to that produced when the bar was being plunged into the spool. It is therefore noted that the current induced in the circuit is governed by the movement of the magnet. While either the spool or magnet remains stationary there is no current produced, but upon altering the position of either factor, a current is generated.

If in place of a bar magnet we substitute a small coil of wire which can fit into the larger spool, and the two terminal ends of the wire are connected to a suitable source of current supply, a battery, for instance, we find that upon plunging this spool into the larger spool, a current is again produced. As soon as this spool is removed, a current in the opposite direction is induced, exactly as in the instance of the bar magnet, Fig. 13.

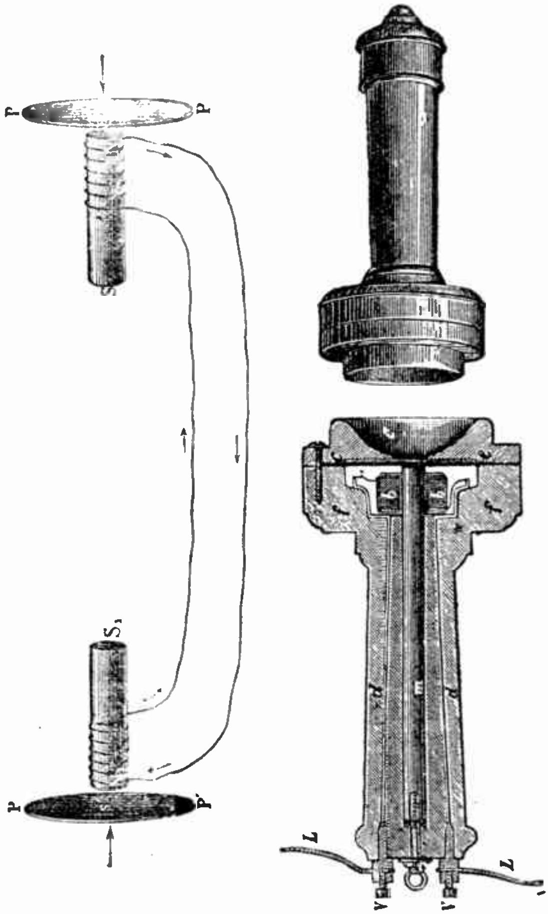


Fig. 14

In the two preceding methods, the position of the two elements has been altered in order to create the induced current. Now, if we place the smaller coil within the larger one and break the electric current in the exciting spool, a current will be detected in the other circuit. When the current is turned on in the exciting circuit, the galvanometer again detects a current, but in the opposite direction. Thus by making and breaking the circuit of the smaller coil, it is possible to induce a periodic current in the other circuit. The smaller coil may be termed the **primary**, inasmuch as it contains the current which produces the magnetic flux, and the other coil which receives the induced current may be termed the **secondary**. It is by applying this principle that the **induction coils** and **transformers** for wireless telegraphy and telephony as well as all other types of transformers render it possible to raise a low potential.to a high potential, in virtue of the ratio existing between the number of turns in the two coils. Nevertheless, even though the voltage may be raised the amperage or current is decreased in like proportion or if the voltage is lowered the amperage is raised. In all cases watts on primary = watts in secondary minus transformer losses.

The lines of force of a magnetic field are termed "magnetic flux," and measured by the number of lines per unit area of the field. Whenever the amount of flux that passes within a closed electrical circuit is changed for any cause, there is set up an induced current in this circuit. The circuit must always cut the lines of force at right angles, in order to obtain the maximum effect. There is no current induced if the circuit moves in parallel direction to that of the lines of force.

The principle of electro-magnetic induction as applied to telephones and telephone receivers is shown in Fig. 14. The permanent bar magnets have two coils of wire placed at their ends and any change in the current strength traversing them, results in a change of the magnetic flux. increasing or decreasing the effect on the iron diaphram. The current in this case is set up and varied by the sound waves impinging upon one diaphram, thereby causing a change in the lines of force, and resulting in the production of the current.

The direction of the induced current will be opposite to that in the exciting circuit when the current is turned on.

If a disc of copper or other metal rotated in a magnetic field, currents will be induced in the metal mass, these currents being known as **Eddy currents.** If the rotation of the disc is continued for a certain length of time, the disc will become heated through the action of these Eddy currents. These currents flow in round circles, and oppose the rotation of the mass through the magnetic field. If the disc be rapidly spun and the driving power removed, it will come to an abrupt stop owing to the drag existing between the Eddy currents and the magnetic field. For this reason, metal discs or masses are employed extensively in electrical instruments where it is desired to secure a damping effect, as well as in electric brakes which have been used for street cars with some success. In motors and dynamos, the rotating portion known as the armature is laminated, the entire mass consisting of a great number of thin iron punchings which have been individually coated with insulating paint. Thus each punching is insulated from its neighbor, and the Eddy currents thus reduced to a minimum.

When a wire is moved through a magnetic field, a mechanical drag is encountered, due to the opposition of the current generated in the wire. If the ends of the wire be connected, the mechanical resistance becomes more pronounced. In all instances of electro-magnetic induction, the induced currents have such a direction that their reaction tends to stop the motion producing them.

From the foregoing it has been learned that circuits have inductive effects upon each other, but these circuits also have inductive effects upon themselves, this being termed **self-induction** or **inductance.**

The unit of inductance is the **Henry**, and inductance is represented by the symbol-letter L. The effect of inductance is not as noticeable in short lengths of wire as in long lengths, and the action is considerably augmented by winding the wire in coils. If an iron rod is introduced in the center of the coil, the effects will be greatly increased. By constructing a small coil with an iron core and connecting it to a powerful battery, it will be noticed that upon opening the circuit a heavy spark is caused at the break. If the terminals of the battery alone be connected for an instant and disconnected, the spark will be entirely different and much smaller than the spark caused when the circuit with the coil is broken. This illustrates that there is an extra current produced by the action of the coil upon the circuit. If the hands be placed across the two wires which are disconnected to open the current, a shock will be experienced. If the hands are placed across the battery, no shock will be felt. This proves that the current produced by self-induction is of a higher voltage than that of the battery supplying the current to the coil. This principle of self-induction is used in gas-lighting coils, where many turns of wire are wound upon an iron core. These coils give a heavy spark upon the opening of the circuit. Primary coils for ignition of gas and gasoline engines are made in the same manner.

INDUCTION COILS AND TRANSFORMERS.

It has been learned that if a small coil of wire is placed within a larger coil and interrupted current passed through the smaller coil, there will be a current induced in the larger coil. If an iron core is placed within the smaller coil, the action will be more pronounced. Based upon these facts, an apparatus known as the **Induction coil**, also called **Spark coil**, for the conversion of low voltage currents to high voltage currents has been produced. The induction coil, Fig. 15, consists essentially of a core, usually made of straight lengths of soft iron wire, in order that the magnetism be only present when the current is passing through the surrounding winding. Over this iron core, insulating tape is carefully wound, in order to insulate the currents from the core, and on the tape a number of layers of heavy wire are placed. This is termed the **primary winding**, the core and the winding mentioned, together form the **primary.** Over the primary is placed a hard rubber or fibre tube as a precaution against the sparking of the secondary into the primary. Surrounding this tube are the many turns of fine copper wire known as the **secondary winding.** In order to facilitate the construction and future repairing of these secondaries, the windings are made in the form of small spools or sections, simultaneously increasing the insulating value. These sections are known as "pies." The entire secondary winding when completed is subjected to a thorough soaking in an insulating compound which has been heated to a liquid state. As it cools, it forms a solid mass of the winding which is thus thoroughly insulated. The end wires lead to a pair of binding posts usually located at the top

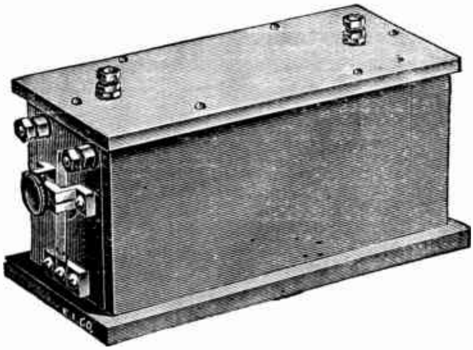


Fig. 15

of the coil, and to these binding posts may be connected a pair of spark balls with the rods and insulated handles. On one end of the induction coil is a spring carrying a heavy iron disc at its uppermost portion. The spring is fitted with a platinum point which strikes against a similar point located at the end of a brass adjustment screw. This is known as the vibrator or interrupter, the screw being known as the **adjustable contact screw.** The interrupter serves the purpose of automatically making and breaking the primary current with which

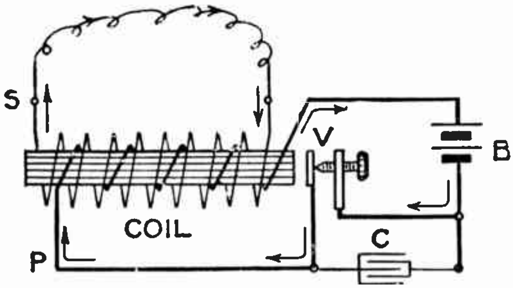
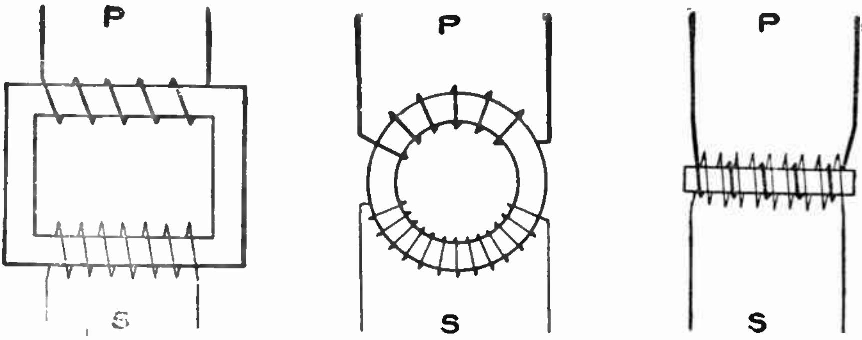


Diagram of Induction Coil.

it is connected in series. The magnetism of the core attracts the iron disc which is drawn to it. In so doing it moves the spring, separating the contact points and thus opening the circuit. The current being disconnected, leaves the core without magnetism which allows the disc to return to its former position and again make contact with the adjustment screw, and thus the action is repeated over and over again. A large **condenser** made of paraffined paper and tin foil is bridged across the interrupter contacts to reduce the sparking caused by the self-induction of the primary, this condenser being known as the **primary condenser.**

A **transformer** is an apparatus consisting of two windings placed on the same core for the purpose of transferring the current from the one coil to the other by means of electromagnetic induction. There are two main divisions of transformers, the **open core** and the **closed core.** The open core is one in which the iron magnetic circuit is open, the core consisting of but a single straight rod with both ends pointing in opposite directions. The closed core transformer is one in which the iron magnetic circuit is continuous, the core being continuously joined, Fig. 16, left and center illustrations. The most common form of closed core transformer is that in which the core consists of four square cores joined together to form a perfect rec-



CLOSED AND OPEN CORE TRANSFORMERS.

Fig. 16

tangle. Closed core transformers are preferred to open core types for the reason that the percentage of loss is much less than in the open core type, due to the more efficient magnetic circuit which has the minimum loss of flux. In the open core, there is a certain loss of magnetic flux at both ends. Transformers may be operated by alternating current, and are rated in kilowatts. Open core transformers may also be used on direct currents, as in the instance of the induction coil, but a means of interrupting the current must be provided. A small electric motor carrying a contact which makes and breaks the circuit may be employed. For all open core transformers and induction coils, a type known as the **electrolytic interrupter** may be used, which is described in a future lesson. This, however, cannot be used on closed core transformers.

PART III

DYNAMOS, MOTORS, GENERATORS AND WIRING.

HAVING studied the principles of magnetism the student will remember that the attraction and repulsion was caused by the action of like and unlike magnetic polarities. This principle has been applied in the electric dynamo, which is in reality an electromagnetic engine, since the electricity must be converted into magnetism before the dynamo can operate.

As we have seen in a previous lesson, it was Faraday, who in 1831 discovered this principle. The electromagnetic engines are the following:

The Generator. If an electromagnetic engine is used to transform mechanical energy into electrical energy, it is called a generator

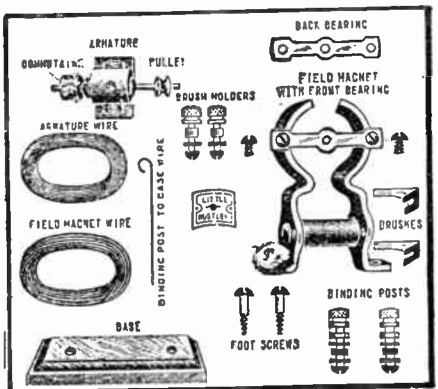


Fig. 1.

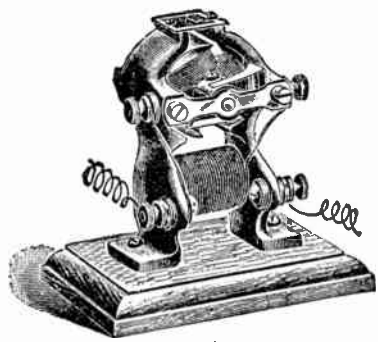


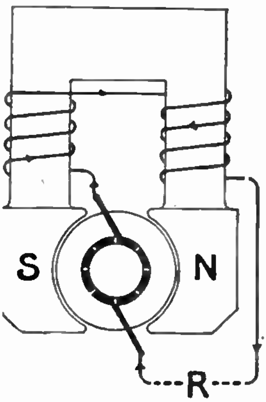
Fig. 2

The Motor. If an electromagnetic engine is used to transform electrical energy into mechanical energy it is called a motor.

An alternator is a machine converting mechanical energy into electrical alternating current. Various combinations also occur frequently such as dynamotor, a combination dynamo and motor in one unit; motor generator, a combination of a motor and a generator, etc.

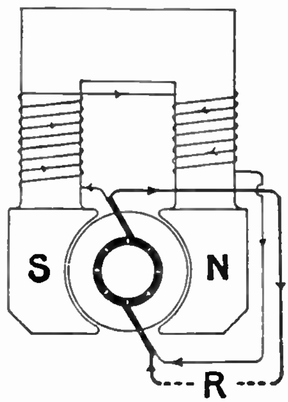
In the accompanying illustration, Fig. 1, will be noticed the parts of a small battery motor, while the complete assembled motor is seen in Fig. 2. The armature is the rotating member of the motor, and in this instance contains three iron pole pieces upon which are placed the windings. These windings are connected to three brass or copper segments shown to the left of the armature and mounted on the same shaft which also holds the pulley. These segments are known as the **commutator,** and its purpose is that of changing the polarity of the magnetism in the three pole-pieces of the armature at the critical instant, so that like and unlike poles will be approaching each other at the correct moment so as to impart a rotary motion to the armature. On this commutator, two copper strips press at opposite sides, and are known as **brushes**, being held in suitable clamps which are termed **brush-holders.** These brushes convey the current to the rotating commutator. The **field** contains a winding and thus produces a powerful magnetic flux in the space in which the armature revolves.

Larger motors employ the same principles and similar parts, though naturally these must be of larger construction and improved in details to perform the heavier work. Instead of three pole-pieces on the armature, a large number are used, which are very small in size, the windings being placed between these small poles or teeth. The field contains perhaps four or more pole-pieces with windings on each. Alternating current motors differ from the direct current type which we have mentioned, and more about their operation will be stated later.



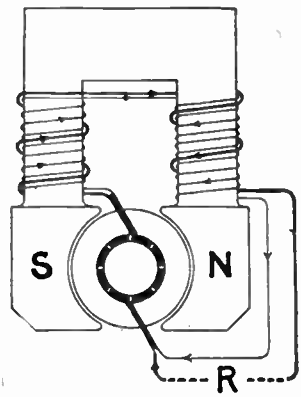
Series Wound Generator.

Fig. 3



Shunt Wound Generator.

Fig. 4



Compound Wound Generator.

Fig. 5

Motors of the direct current type are classified in accordance with the connections of the field winding and its relation to the armature:

A **series motor** is one in which the field winding is connected in series with the armature as shown in the illustration. This type of connection is usually used in small motors, as well as motors for railroad work. A series motor can be started with full load, and will easily gain its full speed under such conditions, though the speed varies considerably with the load, and is never dependable for work requiring constant speed. Fig. 3.

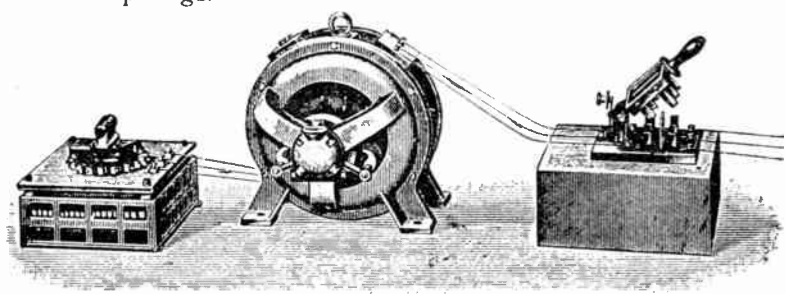
A **shunt motor** is one in which the field winding is connected across the armature, which, in turn, is placed across the power supply wires. This type is the one in general use. It must be slowly started but when it has gained its maximum speed, it maintains this speed fairly constant for varying loads. Fig. 4.

The **compound motor** is a combination of the two foregoing types, the disadvantages of each being largely overcome, and the advantages retained. There is a double winding on the field. The current first passes through the series field, and then to the armature which is connected in series with this field, and has the shunt field connected across its terminals as shown in the diagram. Fig. 5.

In starting motors on high voltage circuits a form of rheostat must be used, Fig. 6. This is termed a "**starting box**" in the case of a shunt or compound motor, and consists of a number of contacts mounted on a slate base with a handle to touch the contact. Resistance wire is mounted on the back of the slate base and connected with the contacts. As the handle is moved over the contacts, the motor gains more and more speed, until the arm has reached the last contact where a stop prevents its further movement. An electromagnet immediately attracts an iron bar on the arm, and holds this at the last contact. This electromagnet is connected across the line and holds the arm while current is passing through the motor. Should the current fail or be shut off, the motor will continue to revolve for a few moments, the current generated in its armature being sufficient to hold the arm to the electromagnet. However, as the motor slows down, the electromagnet releases the arm which is forced by a spring to return to the first contact and thus cuts off the line from the motor. Now should the current be again turned on, the motor will be safe as it has been automatically disconnected. Otherwise if such a device did not release the arm, the motor would come to a stop when the source of current supply failed, and when the power was again turned on, the armature would probably be ruined or badly damaged by the rush of current, due to the fact the motor would not be producing any counter E. M. F. This counter E. M. F. is a current produced by the motor which is induced oppositely to the driving current. In other words it opposes the current from the supply lines. This fact prevents motors from running away with themselves when the current supply is increased. This electromagnet is termed "no-voltage release" and starting boxes equipped with them are styled "automatic." To start a motor equipped with a starting box, the switch controlling the current is first turned on, and then the arm is moved slowly, waiting till the armature has attained the maximum speed on each contact before the arm is moved to the next contact. When the motor is to be stopped, the switch is opened and the motor will come to a stop. Care should be taken to see that the arm has been released before starting a motor, for the failure of the arm to return may cause damage to the motor. By covering the pole pieces of the electromagnet with thin paper its failure to operate can often be prevented.

To increase the speed of a motor, the field is weakened by inserting resistance. A special form of variable resistance consisting of an iron frame containing many turns of german silver or other resistance wire and having a handle which makes contact with contact buttons connected to different points on the wire is used, and is termed a "**rheostat.**" By turning the handle, more or less resistance is introduced into the shunt field winding, and the speed thus varied, the more resistance inserted, the higher the speed.

A dynamo is built upon the same principles as the motor, and the student will remember that a wire cutting the lines of a powerful magnetic field causes an electromotive force to be generated in that wire and if the wire forms a part of a closed circuit a current will flow through it. This is the action of the dynamo. The dynamo also has the armature and commutator, the windings in the armature cutting the magnetic lines of force and generating current. This current is actually alternating current, but is rectified to direct current through the action of the commutator. Most dynamos may be used as motors, and likewise some motors may be used as dynamos, so that the student may readily see that the details are practically the same. An alternating current dynamo embodies the same principles, but has two brass rings on the end of the armature shaft in place of the commutator. Two brushes press on same. These brass rings are termed collector or slip rings.



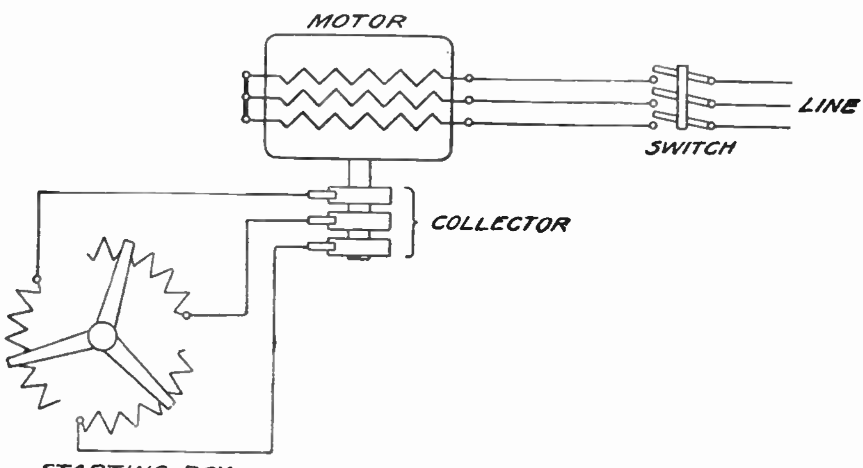


Fig 6

The voltage of a direct current dynamo at a given speed may be varied by changing the current in the field winding. This is accomplished by means of a rheostat usually mounted on the switchboard. The speed may also be raised with a corresponding increase in the voltage. Dynamos, as in the instance of motors, are made in three types, series, shunt, and compound. A fourth type sometimes employed, is separately excited, which consists in having the current for the field supplied by some external power supplying device, such as a battery, or generator. A small direct current generator is often mounted on the same shaft as the armature of an alternating current dynamo, and serves the purpose of furnishing the field winding with direct current. Of the various types, the shunt is the most common for charging storage batteries, etc., or where the load is constant, while the compound type is used where the voltage must be kept constant with a varying load. In alternating current installations, the generators must be separately excited with direct current inasmuch as the alternating current is not suitable for this purpose.

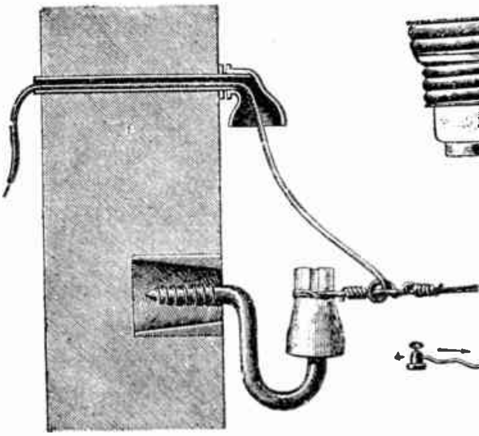


Fig. 7

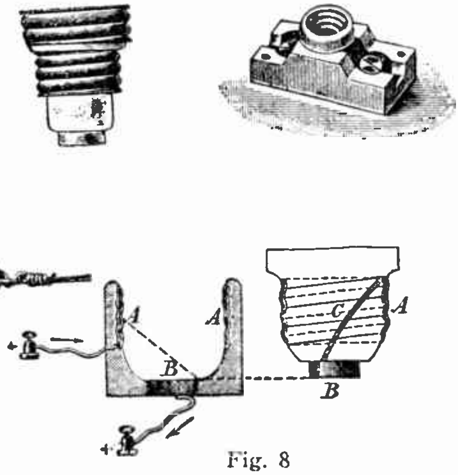


Fig. 8

In changing alternating current to direct current, or direct current to alternating current, a motor directly coupled to a generator on a common base is used and is known as a motor-generator set. The motor is operated on the current which is to be converted. In wireless telegraphy where a transformer is used and only direct current is available, the direct current operates the motor of a motor-generator set, while the generator supplies the alternating current.

A simpler form of this combination is the rotary converter, which consists of a single machine having slip rings at one end of its armature, and the usual commutator at the other end.

POWER TRANSMISSION AND WIRING.

From the generator in the power station, the leads are brought to a switchboard, which contains the voltmeters, and ammeters, as well as all the rheostats and other controlling devices. The switchboard is the "brain" of the entire power station, for it is the controlling center for all the machinery and distribution of current. From the switchboard the wires pass out through tubes in the walls of the station and thence to the consumers of the current.

In the country, overhead construction is employed, as it is comparatively inexpensive when the underground distributing systems employed in large cities is considered. The overhead system, however, possesses a number of disadvantages, the damage from storms, and the objectionable appearance being among the most important.

From the porcelain or composition tubes through the walls of the power station, Fig. 7, the wires pass to the insulators on the cross arms of the poles. If the current is direct current and of a suitable voltage for power and lighting purposes, the leads to the various buildings are taken off the nearest wires, these leads passing through porcelain tubes or iron pipes and into the house. The leads are then connected to a fuse block, which usually consists of a porcelain base with suitable screw parts mounted on same, Fig. 8. Into these screw parts are placed porcelain plugs which have a metal screw portion to

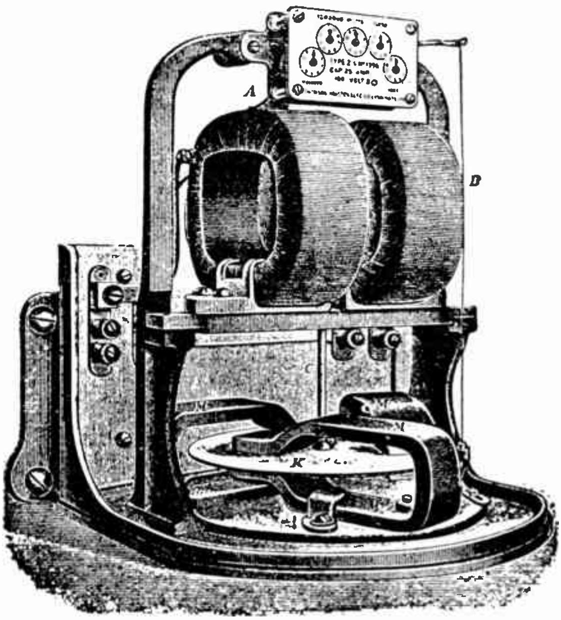


Fig. 9

fit the thread of the parts in the porcelain base. Each plug contains a fine wire which connects the screw portion with a contact button on the bottom, the wire being protected by a mica window. The porcelain base is known as a fuse cut-out, and the plugs as fuse-plugs.

The purpose of the fuse wire is to protect the circuit beyond the fuse block from heavy accidental currents. Fuse wire is composed of an alloy, of tin, lead and other metals, which melts at a low temperature. Fuses and fuse wire are rated at the current which will cause the wire to melt. On plug fuses the number of amperes is stamped on the bottom contact button, or on the rim, while in fuse wire, the rated ampere capacity is marked on the containing spool. Another type of fuse usually employed for power purposes is the cartridge fuse. This consists of a fibre tube, with metal parts for the connections at both ends and containing fuse wire which connects both metal parts within the tube and is surrounded by asbestos powder which quickly extinguishes the arc formed and protects the fibre tube from being blown to pieces. In the plug fuses the mica window permits an examination of the fuse wire, so as to determine whether it has been melted or "blown out," while in cartridge fuses the label contains a device to indicate when the fuse has been melted. Fuses should be used in all instances where apparatus is operated on 10 volts or more, or on storage batteries to protect the apparatus and wiring against sudden heavy currents which might cause damage.

From the fuse block the leads are usually brought to the recording watt-hour meter. which records the amount of power used by the consumer. In certain localities, where electric power is cheap (water supply being used to drive turbine generators). the current is charged to customers by the month, based on a fixed number of lamps. An accurate switch automatically shuts off the current or flashes the lights when even one lamp more is used in excess of the contracted number. This controls the current, and protects the company from fraud. However, to return to the watt-hour meter more generally used, we find that it operates on the same principles as the motor, the inside construction, Fig. 9, consists of a small armature turning on jewelled bearings fitted with a small silver commutator and brushes. A field winding exerts a magnetic field in which the armature rotates the field flux being in proportion to the current used; the field coils being connected in series with the circuit. The armature, being supplied with current in shunt with the power circuit, rotates in proportion to the voltage used, and is connected through a series of gears to pointers which indicate on dials the number of watt-hours of energy consumed. On the bottom of the armature shaft a copper or aluminum disc is fixed which rotates with the armature and passes between the poles of three powerful permanent magnets. The Eddy currents in the disc retard the rotation of the armature, so that by moving the magnets nearer to the edge of the disc more drag and more retardation can be secured. Thus the speed can be accurately regulated so as to coincide with the readings of a standard watt-hour meter.

There are five dials on the common watt-hour meter, these dials being respectively marked from left to right, 10,000,000, 1,000,000, 100,000, 10,000, and 1,000. These figures represent the number of watt-hours represented by one complete revolution of the individual pointer on each dial. Each dial is marked from 1 to 0 which represent tenth parts of a complete revolution. One complete revolution of the dial on the extreme right marked 1,000, will cause the neighboring dial to the left to indicate 1 on its dial, and so on. The reading is therefore taken by noting the readings from the first dial at the left to the last dial at the right. In order to determine the current consumed during a definite period of time, it is necessary to know the reading of the meter at the beginning of the period, and this figure is subtracted from the last reading at the expiration of the period, thus giving the number of watt-hours for the period between both readings.

From the meter the current is conveyed by wires to various fixtures and appliances. In dry locations this wiring is often placed in wooden moulding which has suitable grooves to hold the wire. After the wiring is in the grooves, a covering commonly named "capping" is nailed over the moulding. In places where there is considerable moisture such as in cellars or porches of houses, cleat wiring is employed, which consists of running the wires between porcelain blocks spaced four feet from each other. Two screws pass through the two cleats and the wire is secured between the jaws of both blocks. Knob wiring is also employed, which consists of using porcelain knobs in place of cleats, the both wires being individually supported on a separate row of knobs. In houses where the wiring is concealed iron piping is passed between the floors and walls, this piping being known as **conduit.** At regular intervals where fixtures are to be placed, an iron box is inserted between the lengths of the piping, these boxes being named **outlet boxes.** The wires pass through the outlet box and again into the next length of piping, so that the wires must be scraped and the connections for the fixtures soldered to each wire which is carefully covered with tape afterwards. For short

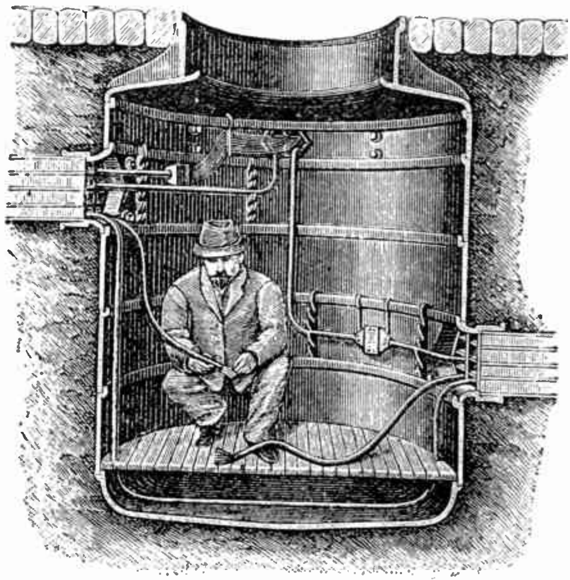
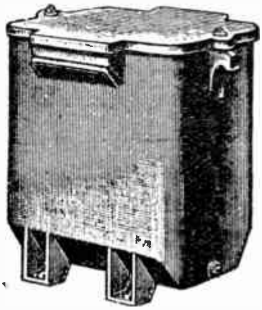


Fig. 10

stretches or where it is desired to run a line for heavy current, steel armored but flexible tubing containing the wires firmly imbedded, is employed, this being known to the electrical trade as "BX." It is especially recommended for carrying the current from the cellar where the meter and fuse cutout are located, to the upper floors where a wireless station is to be operated. The BX is fastened to the walls by means of iron strips which firmly clamp it. These are usually known as "straps."

In the cities, the electric feeders are placed underground in conduits. At convenient intervals small rooms are placed under the street and can be reached through a hole in the street which is normally covered with an iron lid, the entire structure is termed a "man hole," Fig. 10. On the walls of these rooms are the many cables, supported on iron racks, which pass from one section of the conduit to the next section, and thereby allowing a workman to ex-



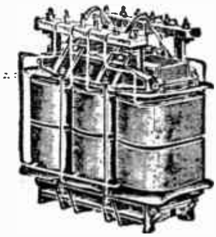


Fig. 11

amine and test the different cables as well as to allow new cables to be passed through the conduit or old cables removed. From the conduits the leads are brought into the houses through the cellars where connections are made to the cutout and the meter. From the meter the same wiring as previously described is used.

In alternating current transmission, the voltage is often far above that which may be used for lighting and power purposes, the reason being that the lower the amperage and the higher the voltage, the less copper is needed in the conductors and thus a large saving in the construction of the line is accomplished. This is analogous to an instance where water represents electricity and a pipe represents the wire, and a certain quantity of water measured by gallons must be passed through the pipe to be delivered at the other end. Now, if we employ a powerful pressure to force the water through, a small pipe may be used, but if we employ a large quantity of water with little pressure behind it, a large pipe must be employed to obtain a suitable amount of water at the other end. The pressure illustrates the voltage which is applied to force a greater current through a smaller wire. Therefore, in alternating current the voltage is usually as high as possible in order to gain the advantage of using smaller copper conductors. In overhead construction the student has probably noticed iron boxes on the poles at intervals and did not know the purpose of these boxes. These boxes are **transformers,** Fig. 11, and contain two windings, the primary being connected to the power supply while the secondary is connected to the consumer's wiring. The transformer is of the closed core type, and has very high efficiency, usually ranging between 92 and 98 per cent. It is termed a step-down transformer, since the voltage is stepped down in this instance. The current of the line is thus lowered to a suitable voltage which the consumer can employ, so that the advantage gained in employing high voltage does not cause any inconvenience to the consumer. The transformer can also be used to step up the current.

For instance, if for reasons of safety a low voltage can only be sent through the wire, the tension can be increased or stepped up by the use of a transformer to any voltage desired at the place where it is to be used.

If the transformer is to be used to step up a current, the secondary winding has more turns of wire than the primary, and vice versa, if the current has to be stepped down, the primary has more

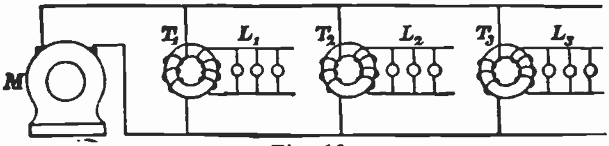


Fig. 12

turns of wire than the secondary. Figs. 12 and 13 are hook-ups of transformers connected in series and in parallel. M represents the generators, T_1, T_2 and T_3 the transformers. and L_1, L_2 and L_3 the lines leading therefrom.

Alternating current is gaining in favor over direct current for power transmission, and it is probably a matter of only a few years before it will be extensively used and will supersede direct current in all transmissions of any reasonable distance.

Alternating current motors are of so many types that they would occupy more space to describe than this course permits, but it is important to know that the most common type in small sizes is the induction motor. This type consists of a number of iron poles with field windings, mounted on the motor frame, the windings being connected to the power supply. The moving member is not named an "armature" but is known as the rotor. The stationary winding is called the stator. It consists of many punched discs which are insulated with varnish and mounted together on a steel shaft. In suitable grooves in these discs are heavy copper wires which are connected together, though they have no connection with the current supply. The action of the motor is therefore based on induction

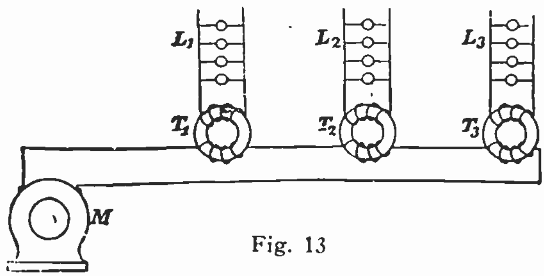


Fig. 13

effects in these windings and in the iron discs, causing the rotary movement. There are other types besides the induction, notably the slip ring type which is also extensively used.

Alternating current differs from direct current as already stated, by the fact that it changes its polarity at regular intervals. At one instant a wire carrying an alternating current will be the positive pole while at the next instant it will be the negative pole. The current beings at O voltage and rises to the maximum positive voltage and then descends to O, but immediately begins to arise to the maximum negative voltage and then descends to O, which may be noticed in the diagram. Fig. 14, where the straight center line represents time elapsed, and also O potential. One complete period in which the maximum potentials in both polarities have been reached is termed **a cycle.** Alternating current is always specified in cycles, as this constitutes an important item which is needed in the furnishing of proper apparatus and machinery to operate on this current. Standard power circuits employ either 25 or 60 cycles and lighting circuits 60, 125 and, in some instances, 133 cycles, per second. An alternation is half a cycle, and represents the rise and fall of one potential cycle. The **frequency** is the number of cycles per second, and usually is employed in connection with the number of cycles, thus, if a motor is said to operate on a frequency of 60 cycles, it means that the motor will

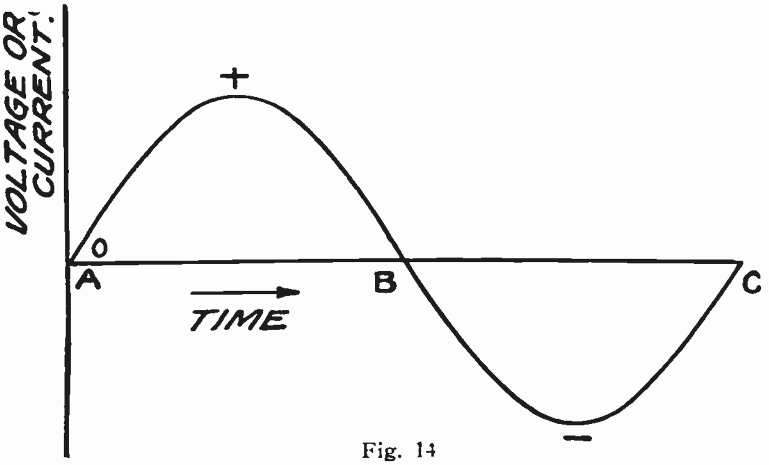
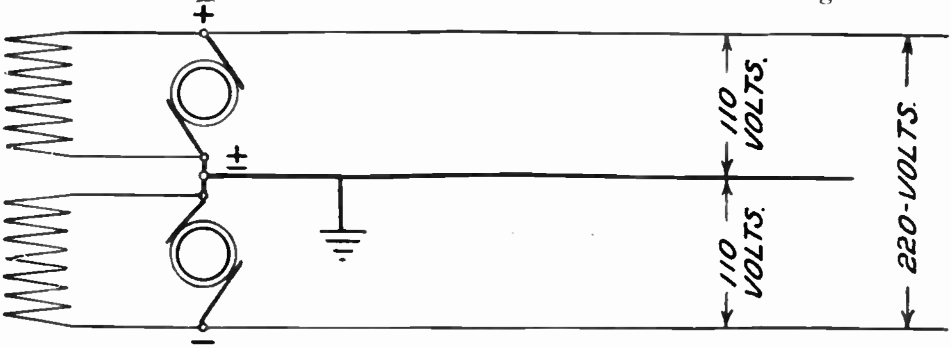


Fig. 14

operate on an alternating current having 60 cycles per second. If frequency is not mentioned in connection with cycles, the meaning is lost. In the diagram the relation of the terms may be clearly seen, the alternation being from A to B or from B to C, and the cycle from A to C.

In some power transmissions, a number of cycles may be employed at the same time, and thus when one cycle is rising towards its maximum positive voltage, the next cycle is just beginning, while a third cycle may just have passed through half of its period. Each one of these separate cycles are termed **phases,** a **single phase** line being one in which only one definite cycle exists, while in a **two phase** line there are two cycles at the same instant, and in a **three phase** line there are three cycles at the same instant. The study of these complicated forms of current transmission may be thoroughly covered by referring to text books which cover the electrical engineering field. These cycles do not start simultaneously at the same fraction of a second but follow each other.

In direct current transmission, a method of great convenience and representing a 62½% saving in copper is largely used, and known as the Edison three wire system, Fig. 15. Two 110 volt generators are connected in series across two wires so that the voltage on these leads will be 220 volts. From the connection between the two generators, another lead is taken so that by connecting to this lead and one of the other leads a voltage of 110 volts is obtained since the current of only one generator is being used. Thus the consumer may use either 110 or 220 volts in accordance with his requirements. By using 220 volts a considerable saving is effected in the two outside leads and the common return is used for both circuits delivering 110 volts, saving the cost of a fourth independent wire. The center wire is termed the neutral wire, and usually is grounded so as to give greater protection to consumers. Great care must therefore be taken against accidental contact of either outside wire with the ground



THE EDISON THREE WIRE SYSTEM.

Fig. 15

connection or with objects which are connected to the ground, such as gas, water, or steam pipes, for there will be a rush of current and a blowing of the fuses. For this reason it will be noticed that all lighting fixtures are connected to the gas pipe, or the fixture hanger, through a small insulating joint which thoroughly insulates the fixture from accidental contact with the ground should one of the wires touch the metal. All motors under ¼ H. P. may be used on 110 volts, but those of a higher power must be used on 220 volts. For this reason the student must bear in mind that it is important to examine a motor closely when it is larger than ¼ H. P. and is to be used on a three wire transmission system, since a 110 volt motor would be useless in this instance, in obeyance with the Underwriter's rules.

After these few chapters, in which the subject of electricity has been but roughly covered, the explanations being only to identify certain facts and points as are necessary to understand the complicated apparatus and operations of wireless telegraphy and radio, the next part begins with the principles of wireless telegraphy with the succeeding parts leading through a complete and thorough study of the subject to which these books are devoted.

PART IV

THE PRINCIPLES OF WIRELESS TELEGRAPHY.

THE explanation of the principles of wireless telegraphy to the layman would be a difficult problem if a comparison with the waves of a body of water were not possible. Fortunately, however, we can make an interesting analogy between water and wireless waves as in the previous study of elementary electricity.

We will take for instance, a body of water 30 feet in length. At the two opposite banks, small platforms have been built as illustrated in Fig. 1. On one of these platforms, a large paddle has been arranged so that a person may operate its handle. Now, if the paddle is moved back and forth, a series of waves extending in all directions from this source of creation, will be formed. The waves spread further and further away from the paddle in concentrical rings until their strength is completely expended. In this instance, the pond is small and the waves are sufficiently powerful to reach the opposite bank whereon the other platform is built.

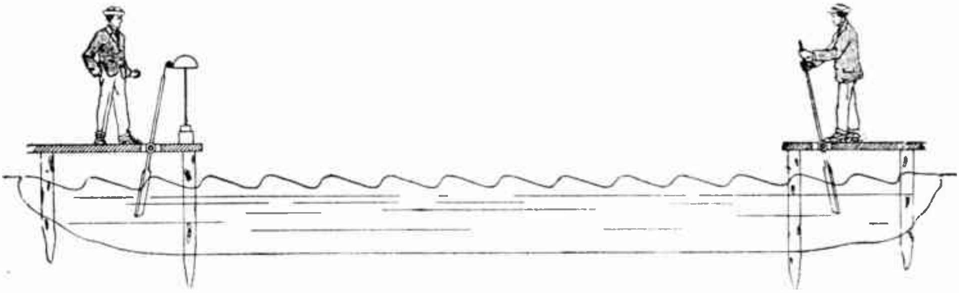


Fig. 1

On the other platform, located on the opposite shore, we have a smaller paddle, on the handle of which a hammer hitting against a gong, has been arranged. It is obvious that the waves moving the paddle will cause the gong to ring, informing the operator on that platform that the operator on the other platform is moving the paddle and creating waves on the surface of the water. By skillful manipulations of the larger paddle, it is possible to cause the smaller paddle to ring the bell periodically as desired, and if a series of signals have been prearranged, the operator with the larger paddle may communicate certain information by properly operating its handle. This represents both the transmitting and receiving stations of the wireless telegraph, the larger paddle being the transmitter, and the conducting medium being the water, while the smaller paddle is the receiver.

In the actual wireless telegraph system, we find the same essentials. The **ether** is the conducting medium, the **Hertzian waves** are the means of communication, and the codes are the prearranged signals. The paddles correspond to the "aerials" in the actual wireless system, since aerials both impart and intercept the waves travelling through the theoretical ether.

The ether or conducting medium in wireless telegraphy, is little understood at the present time. It is a substance which fills all spaces not already occupied by other substances. It exists everywhere; between planets, suns, in nature, and even in the pores of metals, wood, and other substances.

Although **Senatore Marconi** is credited with being the inventor of wireless telegraphy, there were many investigators who preceded him. Columbus was not the first one to lay claim to the fact that the earth was round and to all probabilities was not the first one to journey across the ocean, nevertheless his accomplishment was great and he deserves due credit. So with Marconi. Aided by the discoveries of **Hertz, Calzecchi-Onesti, Branly,** and a score or more other investigators and apparatus improvements, Marconi succeeded in transmitting a message across the ocean in 1901.

As early as 1871, seventeen years before the famous discovery of Hertz, **Prof. E. J. Houston** showed that electrical energy could be induced through space without the aid of wires. In December, 1875, continuing this work in conjunction with **Prof. Elihu Thomson,**

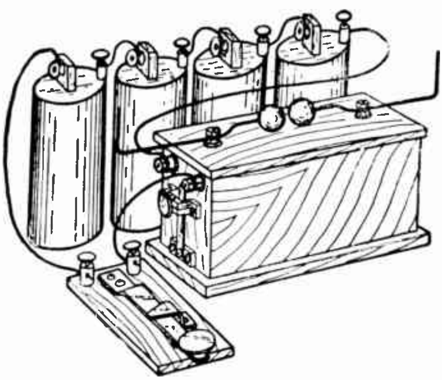


Fig. 2

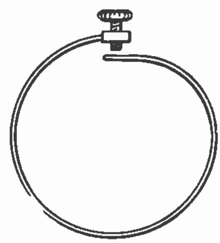


Fig. 3

signals were actually transmitted from the sending station to the receiving installation, a distance of 90 feet with five brick walls intervening. This work was not pursued however, and was not recalled until twelve years later when Hertz made his announcement.

In 1888, a young German scientist, **Heinrich Rudolf Hertz,** set forth in a written statement, a series of interesting experiments in which remarkable characteristics of electro-magnetic waves were discussed. These waves have since been named Hertzian waves, in honor of the researches performed by Hertz. The waves were produced by connecting to the terminals of a spark coil two brass balls mounted on rods, these rods having little metal squares at the extremities, or if desired, the ends of the rods may be bent, serving the same purpose. This arrangement is known as the Hertz **radiator** or **oscillator,** and is illustrated in Fig. 2. When the current was supplied to the spark coil, a discharge passed between the brass balls. When a loop of heavy wire with a small gap left between the ends of the spiral was brought in the neighborhood of the oscillator, small sparks were noticed to jump across the gap of this spiral, proving that the electro-magnetic waves had been generated and propagated through the intervening space or ether. This loop is known as the Hertz **resonator or receiver** and is shown in Fig. 3. Those electro-magnetic waves, caused by the discharge of a high tension electric current, are similar to light rays in certain characteristics, and they may be reflected, deflected, gathered, and dispersed by metal screens. Differing from light rays in other respects, they will penetrate without difficulty stone, wood, earth, and other non-metallic material, which are impenetrable by light rays.

Thus the principle of wireless telegraphy is based on the fact that an electrical discharge may be employed for generating electro-magnetic waves which travel through space in all directions from the source of production. It is also known that these electro-magnetic waves can produce effects in conductors placed within the range of the waves. The problem therefore consisted in perfecting means of detecting these waves, and to increase the efficiency and distance possible to create these results with a reasonable amount of electrical energy in the spark coil.

In 1894, **Professor A. Rhigi** of Italy, made interesting experiments along the same lines as his predecessor Hertz, but used perfected apparatus of his own. His resonator consisted of a glass sheet upon which copper had been deposited in a strip. This strip was scratched with a sharp razor blade, so that a minute spark gap was formed between the two separated halves of the copper strip. By placing the gap under a powerful microscope, the almost invisible sparks could be seen. This resonator, of course, proved to be far more practical than the Hertz resonator, and much greater distances were covered.

The early experimenters perceived the possibility of using these waves for transmitting energy across space without connecting wires, and steady progress was made towards perfecting the apparatus. In 1886, **S. A. Varley** had discovered that the high electrical resistance of metal filings might be greatly decreased by the passing of an electrical discharge through them, and on being shaken, the original high resistance was regained. In 1887, **Calzecchi-Onesti** also discovered that the high electrical resistance of filings could be thus effected, and wrote on his experiments and discoveries.

In 1890, **Professor E. Branly** of the University of Paris, rediscovered the interesting action of filings, but places these in a glass tube with metal plugs fitting in on both sides, thereby making electrical connections with the filings. He discovered that, even discharges at a distance from the filings created the same effect though the actual discharge did not pass through the filings. To the tube he gave the name of "radio-conductor."

The following information describes the principle upon which the Branly coherer operates. As the resistance between the filings in such a coherer is extraordinarily high, amounting to several hundred ohms, the current from a battery cannot possibly flow through the filings. But, upon the receipt of a high frequency current wave, minute sparks jump between the filings and cause the neighboring filings to be slightly fused together. The electrical contact between the filings is immediately improved, and the resistance decreases to

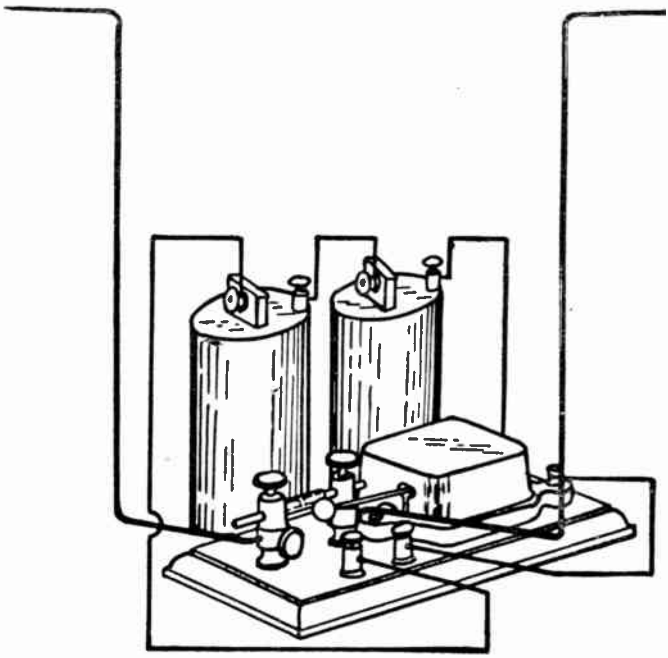


Fig. 4

about 5 to 10 ohms. The same battery as previously mentioned which was unable to pass a suitable current strength through the coherer, can now send a very powerful current through the cohered filings and operate a relay placed into the circuits.

In 1893 and 1894, **Sir Oliver Lodge** applied the Branly tube in place of a micrometer spark gap on the Hertz resonator and gave the name of "**coherer**" to the filings tube. The terminals of the coherer were connected to a galvanometer and powerful battery, and the tube could be shaken or tapped by means of a clockwork mechanism or an electrical bell. With the reception of the Hertzian waves the coherer operated and allowed the battery current to deflect the galvanometer. The clockwork or electrical bell was then employed to decohere the filings and to return them to the original high resistance state. The maximum distance obtained with this apparatus was 55 yards from the transmitter.

In 1895, Professor Popoff employed the nearest approach to the present day receiving outfit. To each terminal of a coherer, he connected respectively a wire leading to the ground, and a wire supported on a high pole outside the building, corresponding to the aerials of the present day systems. Shunted across the coherer was a relay and

Fig. 5

battery, while the relay contacts operated an electric bell which tapped against the coherer tube. The apparatus was used with success to register the discharges of lightning at great distances.

In 1896, G. Marconi began his early experiments which finally led to the perfection of the present day commercial systems. At the transmitting end a spark coil with the Hertz oscillator as shown in Fig. 2 was employed, while the receiving end contained a coherer and decoherer similar to that shown in Fig. 4. At each discharge of the transmitter the coherer causes the bell to ring, which decoheres the filings the instant the transmitter stops. The adjustment of the coherer has to be very delicate, since the metal plugs have to be arranged until the filings are correctly packed. If they are tightly

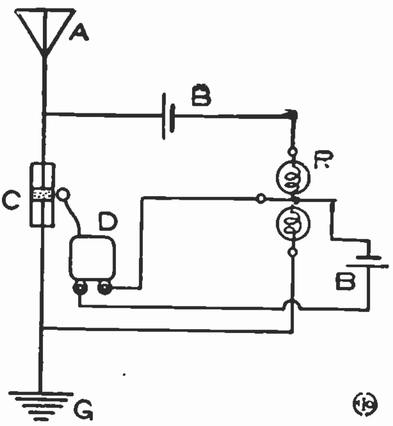


Fig. 6

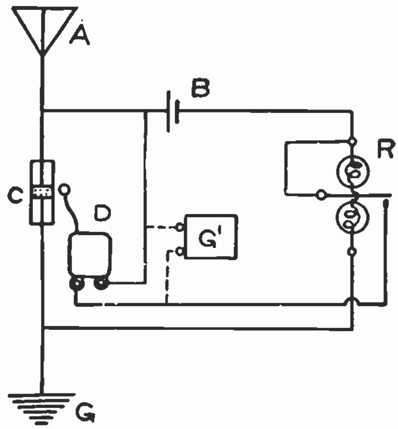


Fig. 7

packed, the coherer will not operate, and if the filings are too loose, the action is again spoiled. While the results obtained with the ordinary bell are satisfactory, much greater distances can be obtained by using a sensitive relay in place of the bell. Marconi soon adopted a high resistant and sensitive relay which was connected across the coherer in series with the battery. The bell was then substituted with a delicate electromagnetic hammer which could be accurately adjusted in order to strike the tube properly, insuring a perfect shaking. The

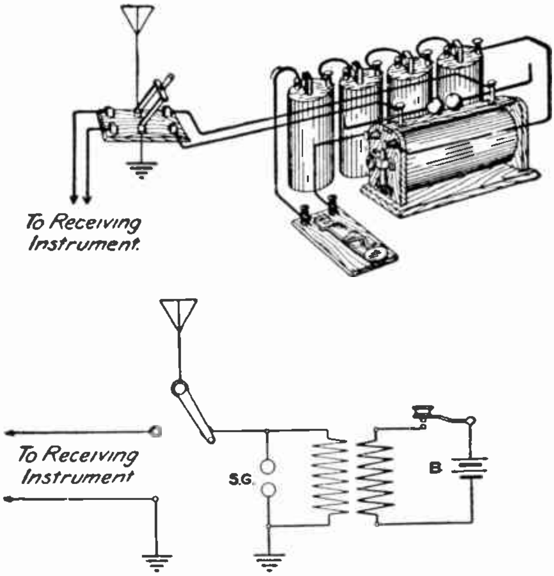


Fig. 8

coherer was then changed to another type (Fig. 5) where the whole tube was sealed with the wires coming through both ends, the interior of the tube having been exhausted of its air. The metal plugs were bevelled across the entire surfaces, so that by tilting the tube the filings would be either tighter or looser, depending upon the arc through which the tube was turned. Fig. 6 illustrates the wiring of the earlier receiving sets.

Marconi soon discovered that by using elevated wires or surfaces, and grounded connections on both the receiver and the transmitter, it was possible to increase the range considerably, and consequently adopted these connections in his later experiments. By connecting a Morse tape register across the point marked G in Fig. 7, a permanent record of the signals could be kept. By means of a plain knife switch it was possible to throw on either the sending or receiving apparatus to the aerial in order to transmit or receive, as shown in Fig. 8.

However, all the systems thus far have been simply discussed in view of the fact that they will receive and send when operated, but the subject of wave-length has not been mentioned. Electro-magnetic waves are similar to those of sound and we will therefore make the following analogy. If two instrument strings are stretched at opposite ends of a table, and one of these strings is caused to vibrate, the other string will remain motionless. However, if the silent string be carefully tuned until it is in harmony with the first string, it will begin to vibrate, this action being due to the sound waves in the air caused by the vibrating string. In wireless telegraphy the electro-magnetic waves emitted by a transmitter also have a definite pitch or "tune" as it is named. It is also referred to as **"wave-length."** This wave-length is caused by the capacity and inductance in the circuit of either the transmitter or the receiver. In the instance of the Hertz oscillator and resonator, the small metal squares or rods at each of the spark gap are adjusted so as to be in tune with the resonator, or the little squares or wire ends of the resonator may be adjusted

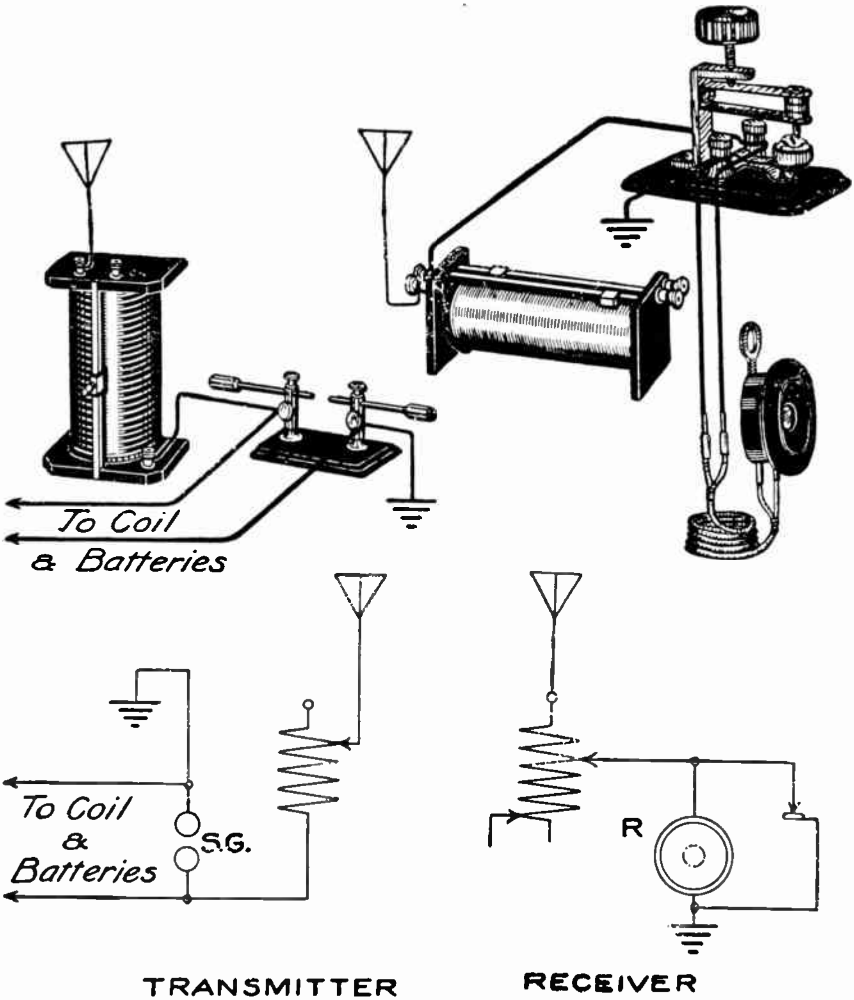


Fig. 9

so as to be in tune with the oscillator waves. Thus, in all instances, two methods for tuning the both stations may be employed, either tuning the transmitter to the receiver, or the receiver to the transmitter The latter is, in commercial practice, generally used, as it is more practical than the tuning of the transmitter.

The fact that electro-magnetic waves have a definite wave value, has rendered syntonic or selective wireless telegraphy possible. The simplest method employed and applied to the early Marconi sets, is illustrated in Fig. 9, where there are two sets with aerial and ground connections. At the transmitting station, a coil containing a number of turns of heavy wire and with an adjustable contact to make connection for any number of turns, is employed in the aerial circuit. This coil is known as the "**helix**" and will be described in detail in a later lesson. By adding more or less turns, the inductance of the aerial is varied and the wave-length altered. The more inductance placed in the circuit, the greater the resultant wave-length.

At the receiving end, inductance is likewise added in the aerial circuit, thus giving the receiving circuit a greater wave-length in order to be in tune with the transmitter. In this instance, unlike the coil in the transmitter, many turns of fine wire are used, with a sliding contact to make connections with any turn desired. This coil is known as the "tuner" or "tuning coil," and will be described at length in a future lesson also.

Wave-length is quoted in meters, which is determined by means of a calibrated instrument known as the "wave-meter." In the instance just described, it has been learned that wave-length may be increased by adding more inductance in the aerial circuit. It has also been stated that capacity likewise determines wave-length. In some instances, it so happens that the wave-length of the transmitter is shorter than that of the receiver, even with no inductance turns in the receiving aerial. In this instance, the following method is employed in the receiving circuit. A condenser is placed in the ground circuit as illustrated in the diagram of Fig. 10, which thereby reduces the wave-length of the circuit, through the fact that capacity in series decreases the total capacity of a circuit. With the circuit illustrated in Fig. 10, it will be possible to tune in long wave-lengths, and also short wave-lengths, by varying the inductance, or varying the capacity in the ground circuit. In the transmitting circuit, the same procedure is employed, the condenser being of the leyden jar type. Only in rare instances, however, is such a method employed, since the transmitting energy is greatly reduced through the introduction of the ground capacity in series.

The various circuits outlined thus far are known as the open circuit type; but not possessing the high degree of selectivity and efficiency as is possible to obtain with closed circuits, Marconi abandoned the open types and began the study of closed types for both receivers and transmitters. These are used to-day for all commercial work. The main objection of the open type of circuit is due to the fact that it contains but slight capacity, and hence the resultant waves are highly damped. By damped is meant that the individual sparks of the transmitter produces but a single train of waves, which rapidly diminishes in value, while an undamped wave is one in which the individual sparks produce a train of waves where the fluctuations are more persistent and deteriorate very slowly in value. This may be illustrated by a simple mechanical experiment. If a string of sufficient length is attached to a heavy weight at its lower end, and allowed to swing back and forth, it will swing slowly but for a long period.

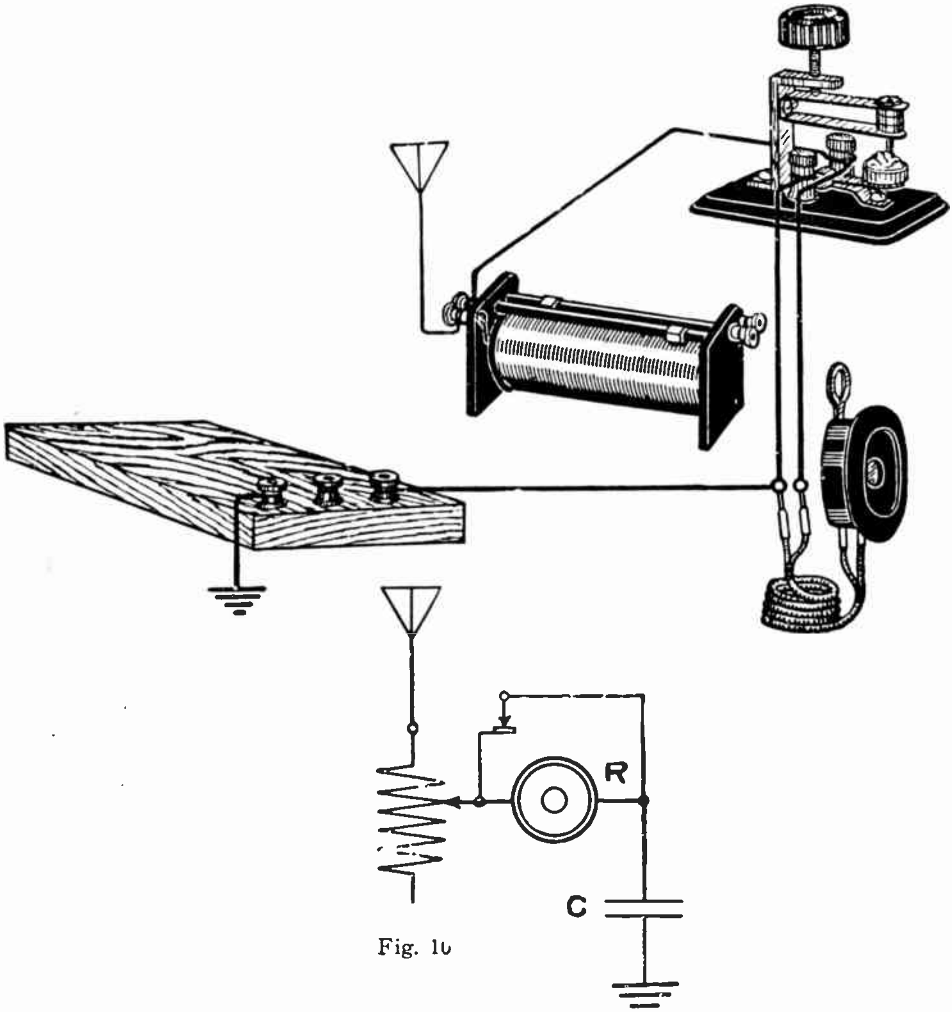


Fig. 16

The length of the string represents the capacity in the wireless circuit. Now, if this same string be suddenly shortened, the weight will swing much faster, but the swings will rapidly subside and the swinging cease. This illustrates a wireless circuit with slight capacity as encountered in the open circuits. The former instance with the long string is known as a slightly damped circuit in the corresponding electrical action, and the latter is known as a highly damped circuit in the electrical equivalent. Thus it will be seen that a great advantage exists in employing a closed circuit so as to obtain the longer and slightly damped waves, which create greater effects on distant receivers. The comparative efficiency of tuned closed circuits over open circuits, may be noticed by the experiments of Marconi, in which it was experienced that a tuned transmitter operated a tuned receiver 30 miles away, while the same transmitter did not effect a non-tuned receiver only 160 feet away.

A great improvement in the transmitting apparatus was secured through the use of the closed circuit and using condensers, which heretofore had not been used with the open circuit transmitters. This permitted the full capacity effect to add to the lengthening of the waves, so that they would be damped to a minimum. Fig. 11 illustrates a tuned transmitter in which it will be noted that a condenser has been placed across the induction coil, while the spark gap has been arranged in series with the inductance which is interposed between the ground and the aerial. The spark gap may also be arranged across the induction coil, and the condenser in series with the inductance; either method of connection being satisfactory. The action of this circuit, is the charging of the condenser to its utmost capacity, which then discharges across the gap, and the gap being connected in series with the inductance coil, causes the energy to surge through the closed circuit and to be radiated into the aerial and the ground. It will be noted that the connections of the aerial may be altered on the inductance, so that the proper relation of wave-length may be obtained. The closed circuit, which is termed the "**closed oscillating circuit,**" is also variable, the maximum results being obtained when both the aerial and closed oscillating circuits are in perfect tune, which is accomplished by adding or lessening the number of turns of either circuit.

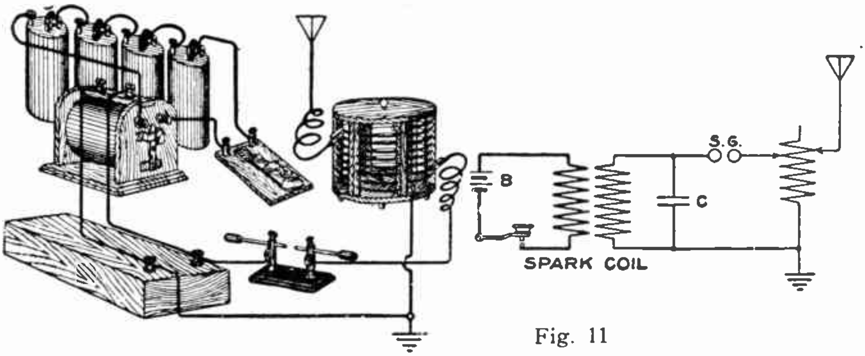


Fig. 11

The closed circuit receiving apparatus likewise consists of a condenser and an inductance. This method enables the apparatus to receive the full advantage of the intercepted waves, and operates by the difference of potential across the inductance coil, the connections being illustrated in Fig. 12. It will be noted, that as in the transmitter, the two circuits are separately tuned, so that perfect tune or resonance may exist between the aerial and closed circuit.

Both the transmitting and receiving circuits above described are known as closed direct coupled circuits. Another form of closed circuit, is known as the inductive coupled type, in which the aerial

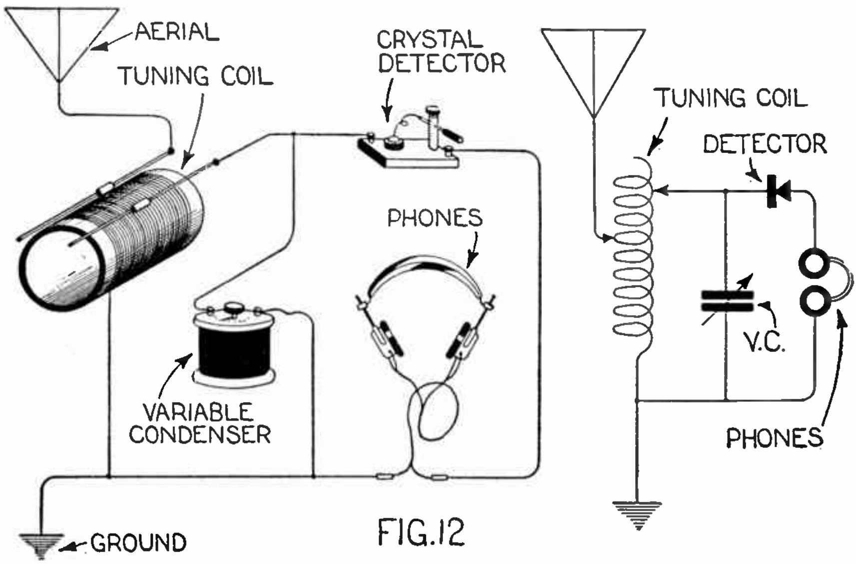


FIG. 12

circuit is connected to the ground through a coil, while another coil placed near the first coil, is connected to the transmitter or receiver, the principle being that of a transformer. By the adoption of these

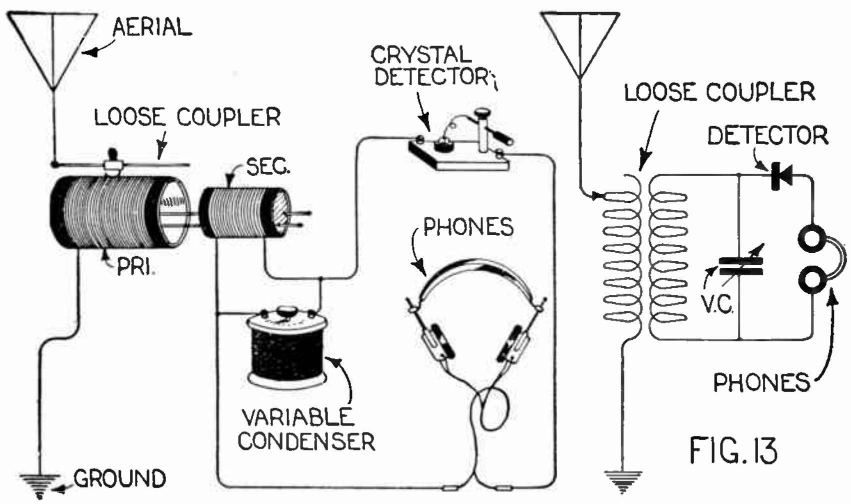


FIG. 13

inductive circuits (Fig. 13), a considerable advancement over the preceding systems, as regarding selectivity and efficiency, has been made possible. However, in receiving, the inductive coupled method is much superior to the direct coupled; the two spools being suitably mounted so that one coil may be drawn away from the other coil, and a greater or less degree of coupling attained. Such an instrument containing these two coils is known as a "loose-coupler" or "inductive-tuner." In audion or vacuum tube receiving and transmitting sets different types of apparatus are employed with greater degrees of efficiency. These will be treated with in another book.

In the receiving circuits, the loose-coupler not only performs the mission of tuning the apparatus, but also converts the intercepted high frequency waves which flow down the aerial wire, into high frequency currents of any desired potential, which act upon the receiving apparatus. In a later book different types of wave detecting devices will be described and which are known as "detectors" or cymoscopes. Different detectors operate better on different current.

Short wave-lengths are more readily absorbed by obstacles than longer wave-lengths. For most commercial work, the standard wave-length of 600 to 1800 meters has been adopted. For long distance transmission, longer wave-lengths are used, sometimes as high as 25,000 meters. For the average station of limited power, it is impossible to use long wave-lengths, for the transmitter is incapable of giving fair results with this huge wave-length. At the present time all amateurs must be licensed in order to operate a sending station and may use any wave-length up to 200 meters. Amateurs in the United States have been heard in England on this wave-length.

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PART I

AMATEUR TRANSMITTING SETS AND APPARATUS

FOR years past while broadcasting was becoming popular, another force was building up. This was amateur radio. Since the time when a few curious men and boys built crude coils wound on rolling pins and used crystals of carborundum, galena, silicon, etc., to receive the mysterious dots and dashes, amateur radio has been growing steadily and surely until today it is one of the most powerful and universal organizations in the field. Crudely adapted apparatus has been gradually displaced with fine, highly specialized equipment and at present the results obtained by amateurs with their low power transmitters is better than that obtained by high powered commercial stations. From the time when a few intense and eager listeners

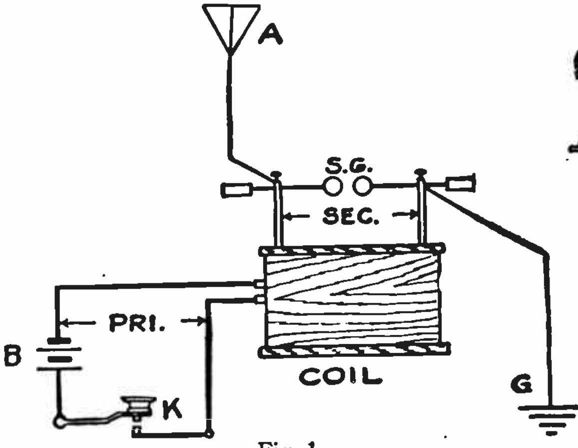


Fig. 1

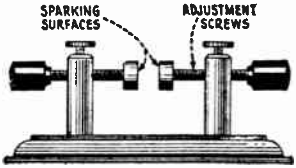


Fig. 2

An adjustable Spark-Gap, in which the brass balls are replaced by two zinc discs, forming the sparking surfaces.

heard faint and almost imagined signals from a few miles away, amateur radio has grown so that now, communications between the eastern coast of the United States and Australia are not unusual.

Before operating a station, the amateur must secure operator's and station licenses. The operator's license is obtained by passing a test at designated points of the United States. The amateur must be able to read the International Morse Code at ten words per minute (five letters to the word) or better, and be able to explain how simple radio apparatus works. The station license is a record for the government of the power and the type of apparatus used in each station and is obtained by filling a form supplied by the government.

Besides these requirements for transmitting, the amateur must construct his transmitter without breaking any of the rules of the

National Fire Underwriters' code. A copy of this code may be obtained from any local fire or insurance house.

Now we will explain the technical side of the amateur transmitting sets.

The reader has learned that the simplest set for producing electromagnetic waves, consists of a spark coil with a Hertz oscillator, and connections made to an aerial and ground wire. This is the type of

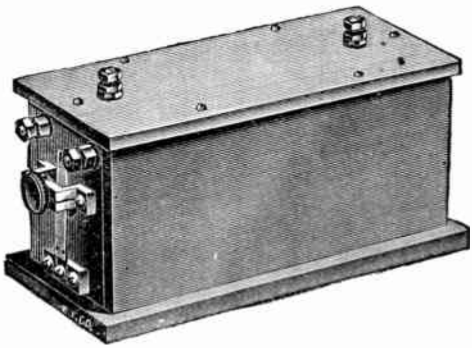


Fig. 3

Spark-Coil as used in the earlier Amateur Transmitter sets.

transmitter originally used by Marconi in his early commercial apparatus. In consequence the simplest apparatus at the command of the amateur wireless student will be based on this principle and is illustrated in Fig. 1. Here, the coil is shown with two large binding posts into which two rods can slide so as to vary the gap between the brass

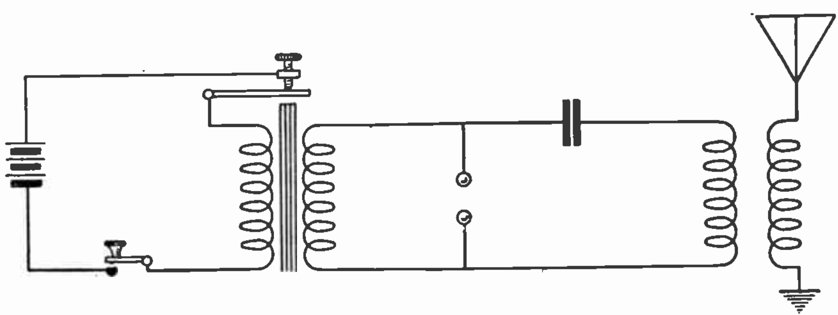


Fig. 4

balls. A telegraph key has been interposed at K, so that the circuit may be made and broken to form the dots and dashes for the forming of the code signals.

Since the present Radio Laws require a transmitter to be inductively coupled, the set shown in Fig. 1 could not be used and is shown only as a matter of record. The simplest form of spark set that could be used is shown in Fig. 4.

This type of transmitter, however, is almost obsolete. The low efficiency and the broad wave obtained with the damped wave transmitters has forced them out of the show in these days of progress and the use of the tube type of transmitter has become almost universal.

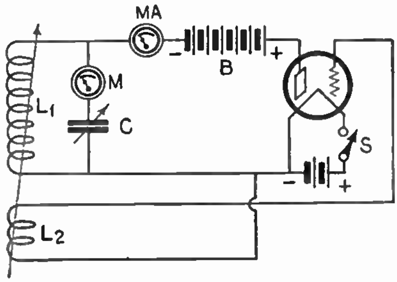


Fig. 5

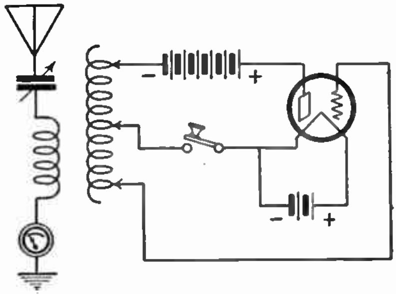


Fig. 6

The vacuum tube, which may be used as a detector and an amplifier through its relay action as previously explained may also be used, to generate high frequency currents, and the use of this action has brought about the remarkable improvement in radio communication which has taken place in the last few years.

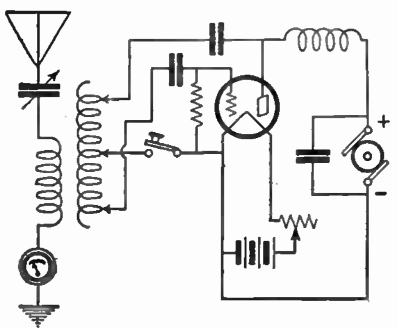


Fig. 7

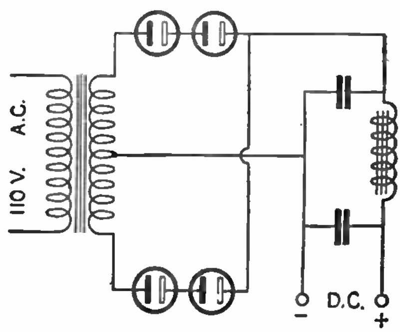


Fig. 8

In Fig. 5 when we close the battery switch S we allow a current to flow in the filament. This starts a current to flow in the plate circuit. This current induces a current in the grid coil and charges the condenser. A positive grid helps the plate, so that the current in the plate circuit builds up to the greatest possible value and the tube is said to be saturated. Then the current stops increasing. The condenser discharges, sending electrons through the grid coil and making the grid less positive until finally it is at zero potential, that is, neither positive nor negative. While the condenser is discharging, the electrons in the grid coil get a habit of flowing from the grid to the filament. If it was not for this habit the electron stream in this coil would stop as soon as the grid had reduced to zero voltage. Because of this peculiar habit, however, the grid becomes negative and opposes the plate current. The plate current then starts to reduce

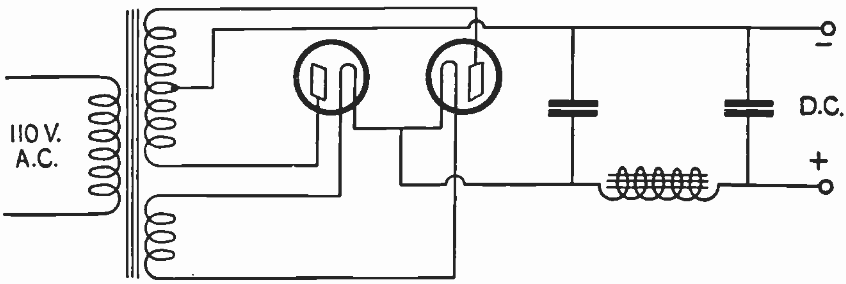


Fig. 9

and finally reduces to zero. The condenser then discharges and makes the grid less negative. The plate current begins to increase again. This completes the "cycle" or revolution and the action is repeated. Thus an alternating current is produced in the grid and amplified in the plate.

Figure 5 shows a simple circuit, which may be used in conjunction with a vacuum tube for the production of continuous waves, which are generated as follows:

When the switch S is closed, lighting the filament, the current from the "B" battery flowing through L1 charges the condenser C, which, when discharging through the circuit CL1 induces into the other coil L2, closely coupled to it, some oscillations. If a meter is connected in the oscillating circuits as shown at M, it registers a current which is alternating, since direct current cannot pass through a condenser.

It will be noticed for a given value of plate current, which may be measured by the milliameter MA, a certain intensity of alternating current flows in the circuit L1C.

This type of oscillator constitutes an efficient continuous wave transmitter and may be used as such by connecting an antenna and ground inductively to the oscillating circuit as shown by the dotted line. A key should be introduced in the circuit, so as to form the dots and dashes composing the Continental Code. One of the simplest types of vacuum tube transmitters is shown in Fig. 6; it is the Hartley circuit, in which only one inductance is used for both the plate and grid circuits, this being tapped in the center so as to divide into two sections.

A hot wire ammeter is connected in the aerial circuit to show the intensity of a current flowing and to indicate the point of resonance when the set is tuned for a certain wavelength.

The key may be connected in the lead from the filament to the rest of the circuit. This circuit is suitable for a low power transmitter, using "B" batteries to supply the energy to the plate circuit. When more power is needed, a high voltage dynamo is employed and connected as shown in Fig. 7.

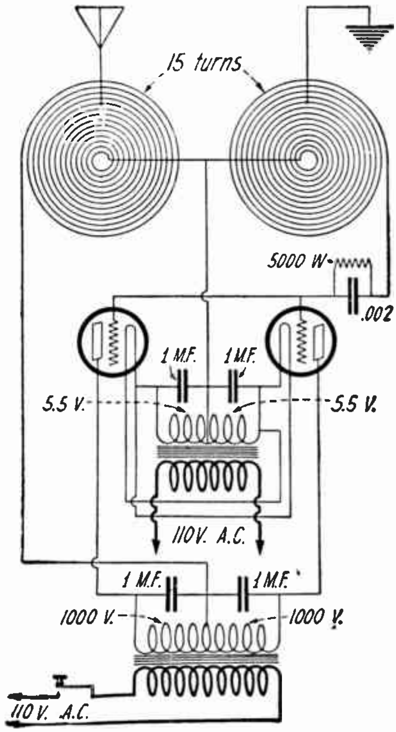


Fig. 10

Here the high tension supply is out of the oscillating circuit and a choke coil prevents the high frequency current from flowing back through the supply circuit; also, a condenser is inserted between the plates and the antenna circuit, so that only the oscillating current flows in it, since the direct current supply is stopped by the condenser.

Another improvement is the use of a grid condenser and grid leak, whereby the grid potential may be kept negative, in order to reduce the plate current, which would be excessive if the grid were allowed to be at a high positive potential. Instead of using batteries or other sources of direct current, alternating current may be employed to supply both the filament and plate current of a continuous wave or radio phone transmitter.

Since it is necessary to apply the direct current to the plate, two rectifier tubes or an electrolytic rectifier are generally used to change the high tension alternating current obtained from a step-up transformer into the required direct current. Figs. 8 and 9 show the high tension supply from an alternating line, with these types of rectifiers. In order to smooth out the rectified current, a filter circuit composed of large capacities and iron core choke coils is inserted between the rectifier and the vacuum tube set. The current obtained through this combination is practically constant.

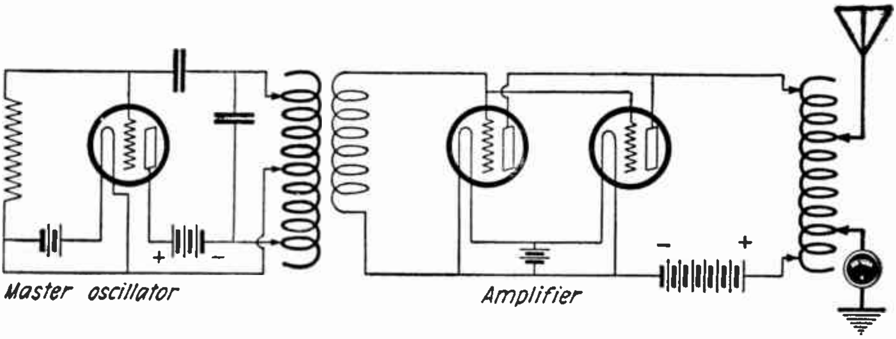


Fig. 11

Electrolytic rectifier shown in Fig. 8, the transformer supplies alternating current to the rectifier jars which contain aluminum and lead plates immersed in a saturated solution of borax and distilled water. These cells have the peculiar quality of only passing a current in one direction. Two of the cells are working on each half of the cycle. The tube type of rectifier is shown in Fig. 9. This is also a full wave rectifier, that is one tube works on each half of the cycle. These tubes work on the principle of the vacuum tube as previously described.

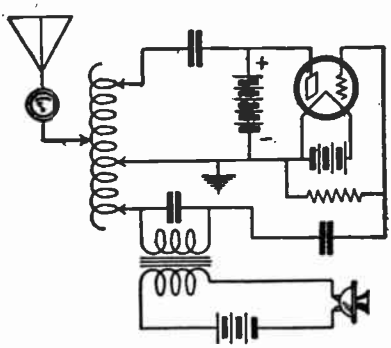


Fig. 12

In order to simplify some transmitters and to avoid the use of Kenotron rectifier tubes, the vacuum tubes themselves may be used to act at the same time as rectifiers and oscillation tubes. In this case, which is illustrated in Fig. 10, each of the two tubes work only during one half of a cycle, when the plate is made positive. The total efficiency of this kind of transmitter is about equal to that of a one tube set supplied with direct current.

In order to increase the power of a transmitter, several tubes may be used in parallel, all the grids and the plates being connected together. However, a better system to obtain increased power is to

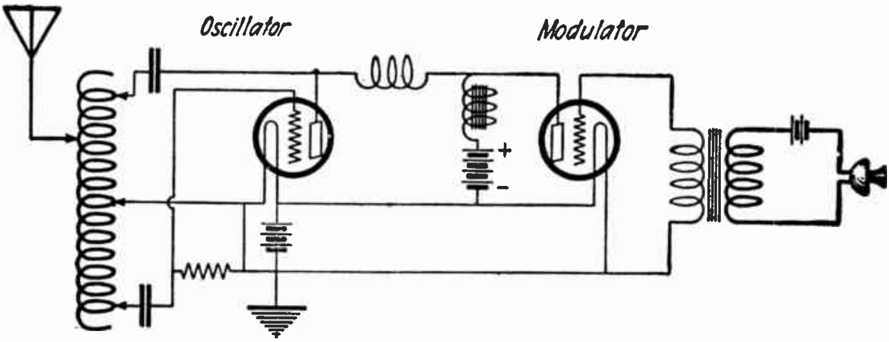


Fig. 13

use the system known as the master oscillator amplifier system. The circuit of such a transmitter is shown in Fig. 11. As may be seen, one tube, which may be of any power, produces the oscillations, which are applied by induction upon the grids of power tubes which amplify the original oscillation produced by the master tube. Not only is this system more efficient, but it also has the advantage of keeping

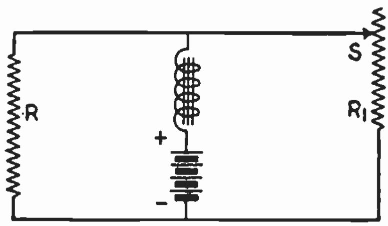


Fig. 13-A

the frequency of the emitted wave constant, since variation in the antenna capacity caused by its swinging in the wind or other causes do not affect the oscillating circuit which is entirely separate. This is a marked advantage since at short wavelengths a very small variation of capacity in the transmitting antenna is sufficient to cause the signals to fade out entirely at the receiving station, when the receiving set is tuned sharply.

It is necessary to use a vacuum tube oscillator or to cause a detector itself to oscillate, for the reception of continuous waves; if it is desired to make the signals of a continuous wave transmitter audible at a station only equipped with a crystal or other type of non-oscillating detector, the wave must be cut into portions equivalent to the wave trains of a spark transmitter. This is easily accomplished by means of an interrupter called a "chopper" and connected in a series with the key or at other convenient points in the circuit. This chopper is usually made by revolving a disk with many contacts between two electrodes, alternately making and breaking the circuit. A buzzer may also be used in small transmitters.

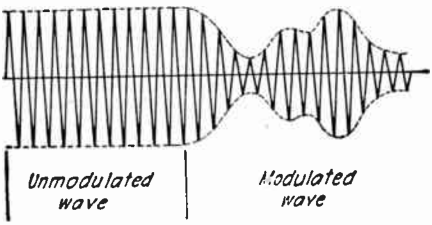


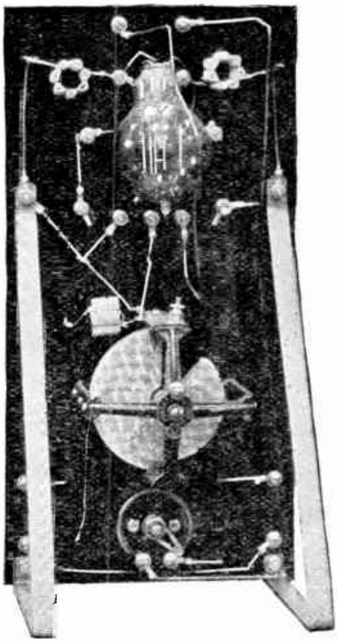
Fig. 14

A radio telephone transmitter, such as used in broadcasting stations, consists primarily of a continuous wave transmitter to which has been added the proper system for modulating the emitted wave which in this case is called the carrier wave, since it carries the variation caused by the musical voice impressed upon the wave. The modulations may be accomplished by two methods which are used in practice, namely the absorption and the constant current systems. The former consists of inserting in the grid circuit a microphone the resistance of which varies under the influence of the speech alternating the amplitude of the wave as shown in Fig. 12. This method of modulation gives fairly good results but is surpassed in efficiency by the constant current method.

The constant method of modulation was originated by the Frenchman Latour and the well-known American engineer R. Heising, and is now extensively used in modern radio phone transmitters. Fig. 13 shows the hook-up of such a set together with the diagram explaining its functioning. One of the tubes in the transmitter produces the continuous wave, while the other two are used exclusively to modulate it, but in such a way that the amplitude of the wave can reach a value double to that of the normal amplitude, therefore increasing the efficiency of the system.

As may be seen. an iron core choke coil is connected in the supply to the plate; this is used to keep the current constant and prevent the variation caused by the modulated tube from passing through the high tension supply.

If we refer to diagram 13A this may easily be understood. Supposing that the two resistances R and R1 represent the internal resistance of the tubes. The same current will flow through each resistance, since they have the same value. However, if the resistance R1 is varied suddenly, the current through R will be greater or smaller according to the position of the slider S, since the current from the battery B is kept at a constant value by means of the choke coil C. In the radio phone set of Fig. 13 the same thing happens. The resistance of the modulator tube being varied by the variation of the voice



Rear view of a short wave amateur transmitter showing methods of construction, keeping the leads short and straight in the vital parts.

applied to the grid, through a transformer. For instance if a high voltage of the source is 300 it may vary from zero to 600 on the plate of the oscillator tube when the resistance of the modulator tube is varied from minimum to maximum. The shape of the wave emitted by this type of radio transmitter is shown in Fig. 14.

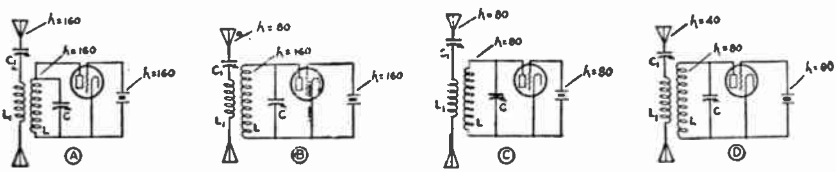


Fig. 15

A few years ago when amateur transmitting became very congested on the 200 meter wavelength, some venturesome amateurs decided to see what would happen if they used the lower wavelengths. They constructed temporary transmitters to work on 180 meters.

The results obtained, because of the lack of congestion caused a sudden rush for the lower wavelengths and with the help of governmental ratification, the hitherto unknown wavelengths were explored.

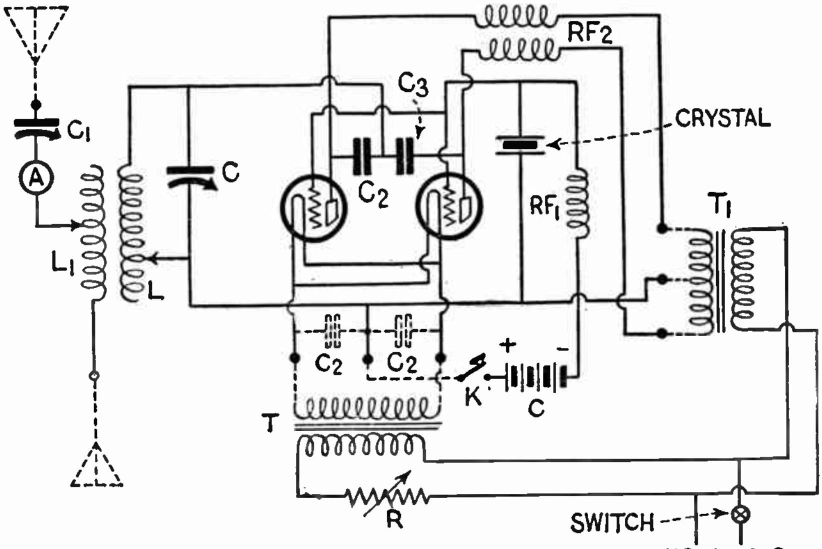
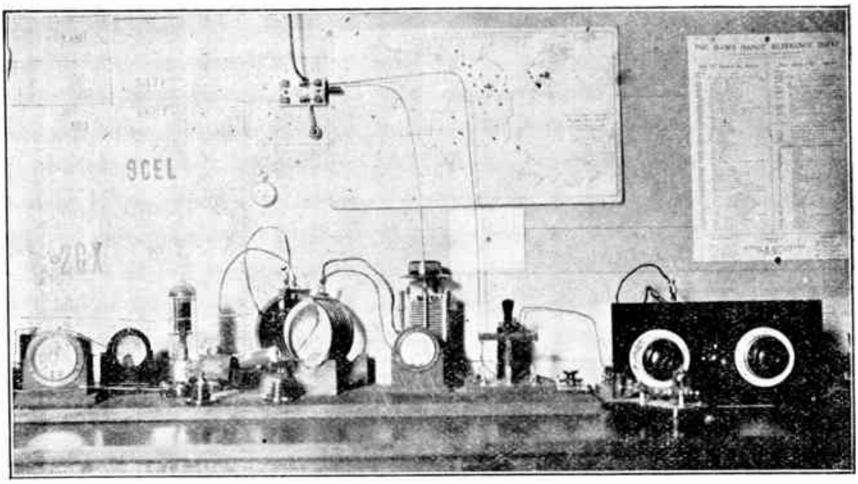
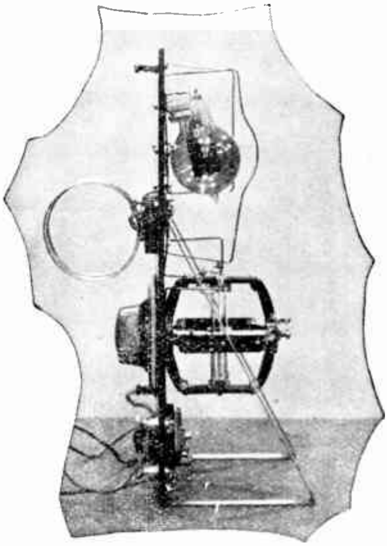


Fig. 16



Typical short wave amateur installation working on a wavelength of 42.6 meters.

The American Relay League and other national and local radio clubs assisted in the natural continuation of experiments. They installed experimental research laboratories and compiled data for use in constructing short wave transmitters. The amateurs themselves contributed all the information they could gather and the monthly publications of these organizations began to show signs of results. The popularity of the short wave increased and regular schedules of communication were arranged between amateur stations.



Side view of a short wave 5 meter transmitter showing the method of mounting the tube to keep down internal capacity.

The distances obtained with short wave apparatus were startling and it is no unusual feat for a small receiving tube to be used as a transmitter. Distances of 5,000 miles and more have been obtained with transmitters using only a few watts of power.

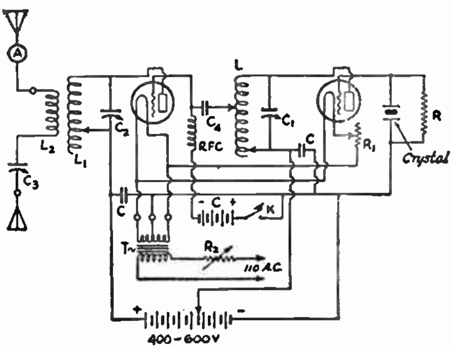
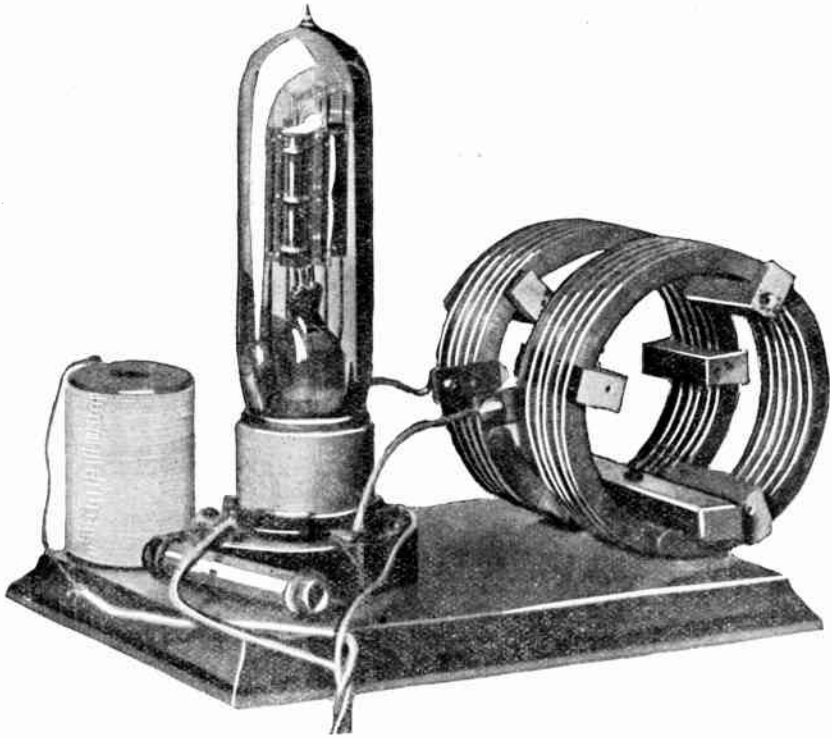


Fig. 17

At present, while many amateurs or "hams" as they prefer to be called are operating on 200 meters, a great majority are using wavelengths between 150 and ½ meter. The use of these high frequencies required many ingenious contrivances, among which were the designing of new tubes which would oscillate on high frequencies and the oscillating quartz crystal to maintain a constant frequency in the transmitter. It was found that by grinding a crystal of quartz to a certain thickness and inserting it in the grid circuit of a transmitter that it would subdue all frequencies except the one to which it was tuned. This phenomenon was a great help in low wave sets and many amateurs are now using these crystals.



A twenty-meter transmitter used in a modern amateur station.

At first many difficulties were encountered. The tubes on the market had such a high internal capacity that they would not oscillate on the low wave lengths. The type of antenna formerly used was utterly hopeless. The rectifiers and filters used with great satisfaction for rectifying alternating current for supplying the plates of the tubes were atrocious on these high frequencies. A million other obstacles were placed in the way, but gradually they were overcome and today amateur transmission on the low waves, while still comparatively new, is a reality.

The construction of low wave (high frequency) transmitting apparatus needs much thought and consideration before plunging blindly ahead.

A few general considerations before dropping into specific details are necessary. In the type of transmitter we are going to describe, there are several different ways in which the desired wavelength can be secured. A tube oscillator is found to have several different frequencies besides the main frequency. These other frequencies are called harmonics and are found to be at one-half, one-third, one-fourth, twice and three times the wave, etc. They are called the second harmonic for twice the wave, etc. The theory of this will be found in various text books on radio transmitters. The use of this theory is very helpful in building short wave transmitters as will be shown.

In Fig. 15 at A the whole system is tuned to 160 meters to get a 160-meter signal in the antenna from a tube controlled by a 160-meter crystal. At B an 80 meter signal gets out into the air. Note

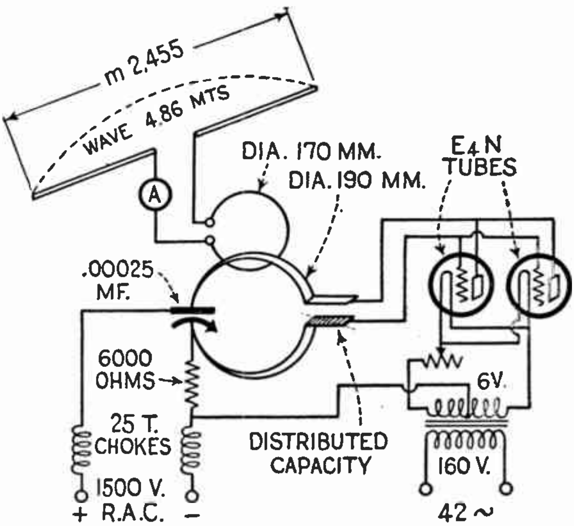


Fig. 18

that LC in the crystal plate circuit is tuned to 160 meters, the second harmonic (half wavelength) being picked off by tuning the antenna to 80 meters. At C, an 80-meter crystal gives an 80-meter signal from the antenna, while at D the antenna is tuned to 40 meters and uses the second harmonic from the crystal. Note that the plate circuit is always tuned to the wavelength of the crystal.

The antenna itself does not have to be tuned to 160, 80, or 40 meters in the above cases but may be used at some of its harmonics (preferably the odd ones). For instance the antenna in D, Fig. 15, may actually have a fundamental wavelength of 120 meters and a third harmonic of the antenna will be picked up on the second harmonic in the plate circuit, resulting in a 40 meter signal in the air.

The diagram for a crystal controlled transmitter which uses the self-rectifying principle previously described is shown in Fig. 16.

The transformer T1 is a step-up transformer with a primary winding for 110 volts and two secondary windings of 500 volts each. The transformer T has a primary winding for 110 volts and two secondary windings of 8 volts each. The radio frequency chokes are made by winding No. 30 to No. 34 D.C.C. wire on a form ½ inch by 2½ inches until the form is full. The plate coil L should have 18 turns tapped every turn on a 3-inch form for a 160-meter crystal or 10 turns tapped every third turn after the fourth for the 80-meter crystal. The antenna coil L1 has 8 turns of No. 16 D.C.C. wire on a 2½-inch form. The choke coil RF1 is wound on a ¾-inch form and consists of about 60 turns for the 80-meter crystal. The condensers C and C1 are .00025 microfarad variable condensers and the fixed condensers in the plate circuits are of .001 microfarad capacity. When wiring the set care should be taken to make the lead from the crystal to the two grids come mid-way between them.

Another type of short wave crystal controlled transmitter is shown in Fig. 17. This circuit uses direct current on the plates in the master oscillator circuit previously described.

A transmitter for use on the 5-meter wave would be of interest to many, and the circuit diagram is shown in Fig. 18. Two power tubes are used in parallel. The inductances consist of flat copper strips bent into shape. The tuning condenser is .00025 microfarads.

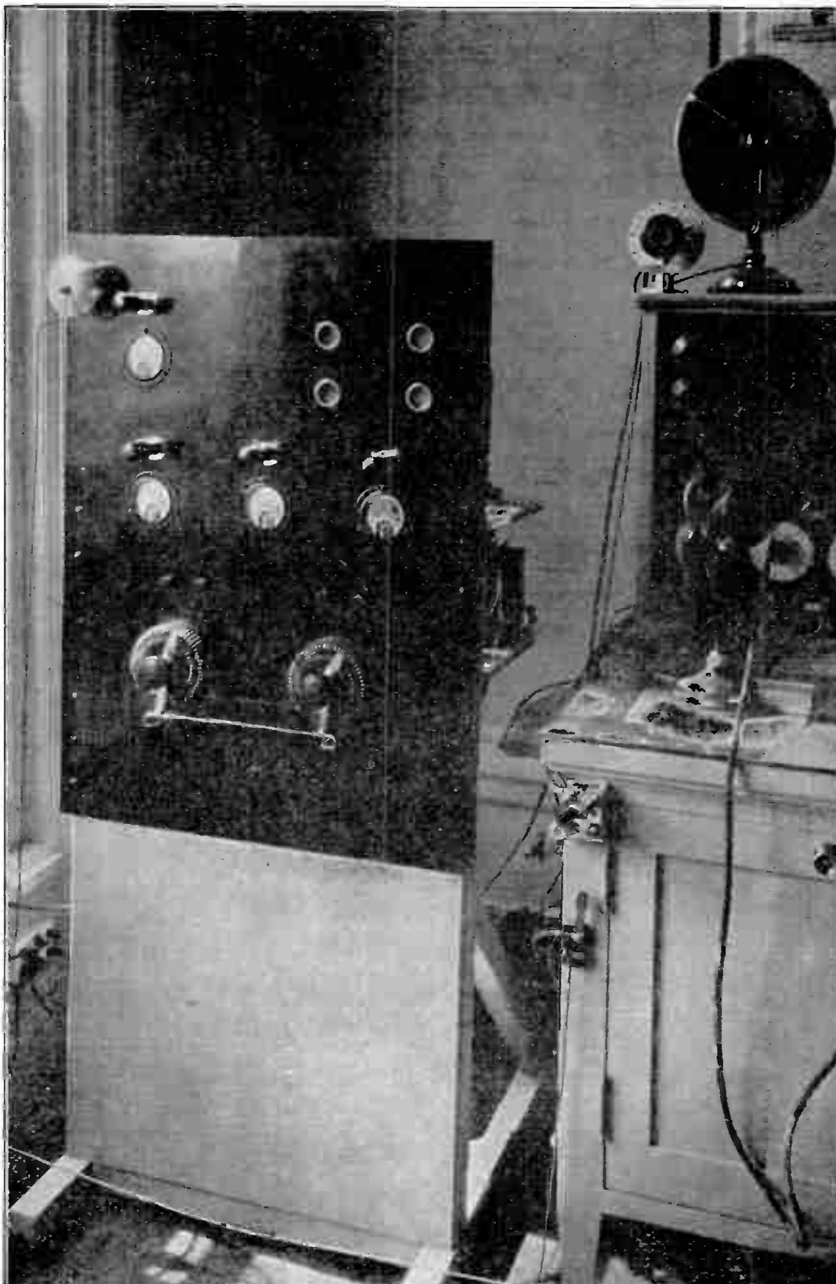
The choke coils are wound on ½-inch tubing, and consist of 25 turns each. The filaments are operated from a transformer with a center tap and the plate current is supplied by a high voltage generator.

With the results achieved by amateurs since the beginning of radio, when they were alloted wavelengths considered worthless by the governments of the world, it is hard to forecast any future from amateur radio. The amateurs were given the wavelengths up to 200 meters, because these were considered of little use to commercial transmission and out of this left over, they have discovered a veritable gold mine for research and achievement. With successful operation on ½ meter who can tell how far down it is possible to go?

The results of television offer another very interesting field for experiment and in a few years with the combined results of amateurs and commercial inventors we may have unimaginable victories.

Before attempting to build and operate a transmitter, the amateur should thoroughly master the code. A few rules and instructions will be of service to the beginner on the use of the key. This seemingly simple piece of apparatus is in reality the hardest for most amateurs to master and the following methods of learning the code will be of great help in overcoming the difficulty.

There are two general codes used today in telegraph and radio but in amateur radio, only one of these is used. However, it will be of interest to many to compare the two methods, so explanations of both are included. The code used universally in amateur radio is the International Morse Code or Continental Code. This code is much simpler than the other since it has only one length for the dots and dashes while the Morse Code has several lengths of dashes.



The 100 Watt Transmitter shown on the left is a good example of the workmanship found in the modern "shack" of an amateur.

There are several different ways of learning the codes so as to operate properly by them, and in general, two classes of beginners in wireless undertake the work, namely, former wire operators, who are used to sounder Morse, with its back-kick; and the novice who cannot send a dot.

It seems to be the common experience, that a wire operator taking up wireless, has but little difficulty in grasping the rudiments of the newer art and quickly becoming an expert at the wireless key; on the other hand, many otherwise well grounded students of wireless, who think they can operate, succeed in charging the ether with a nondescript series of spasmodic signals intended for the code, which are enough to make good old S. F. B. Morse himself turn over in anguish.

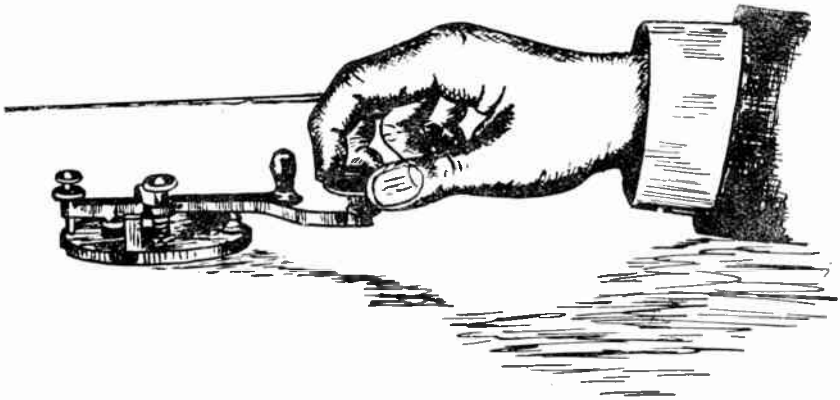


Fig. 19

The first thing an operator must or should learn, is the correct manner of holding the key in transmitting, this being very important, when any long messages or a batch of them are to be sent in succession.

A form of grasping the key adopted by the majority of fast commercial operators, is to rest the first and second fingers on the top of the key button and close to the edge of it, with the thumb placed against the edge of the button see Fig. 19. Then the first and second fingers are curved to form a quadrant of a circle avoiding any undue straightness or rigidity of these fingers and the thumb. The third and fourth fingers are partly closed and the elbow allowed to rest easily upon the table, permitting the wrist to be perfectly limber. A moderately firm grasp should be taken on the key, but not a rigid one. If the key button is grasped too tightly, the hand will soon become tired or fatigued, resulting in what is known as "telegrapher's cramp." A little practice, on the key, with careful attention to the codes, will soon break in the amateur operator, and do more for him than a dozen pages of reading on the subject.

In this connection it might be mentioned that there are on the market, several automatic instruments which send dots and dashes of regular length, irrespective of the operator's characteristics, two of them being the "Mecograph" and the "Vibroplex." These instruments are satisfactory for wireless work, but generally have to be utilized in connection with a relay, as they are not capable of handling heavy currents, such as occur in a wireless station of any size. These patent keys are operated by a sidewise motion, and are claimed to prevent "telegrapher's cramp," but they nevertheless require as many movements of the hand as a common Morse key, in sending, excepting dot letters. Sending machines or keys must also be kept in the very best condition, and carefully watched, or they become irregular in the closing of the contacting parts, owing to collections of oil and dirt or burnt surfaces.

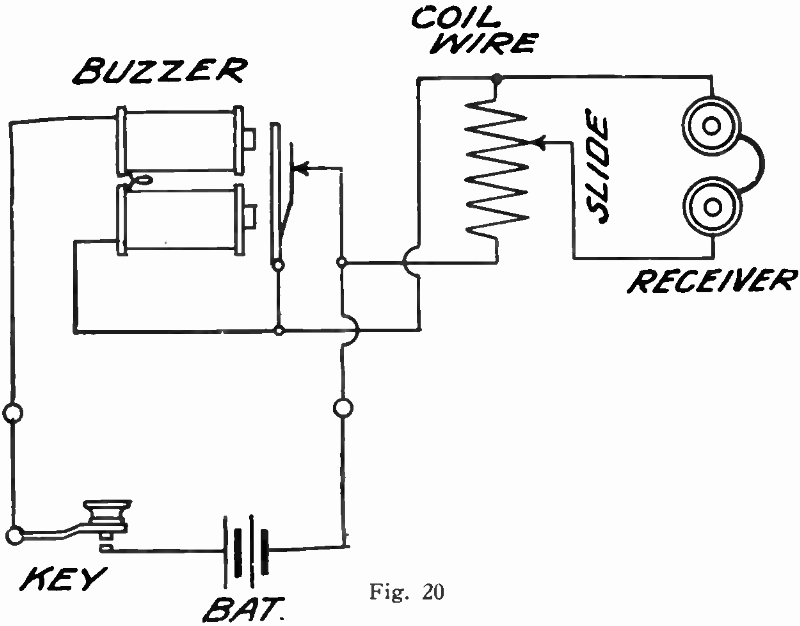


Fig. 20

The Morse code in its present form was arranged by Mr. Alfred Vail, of Morristown, N. J., and due respect has been given to the most frequently occurring letters, so that they may be the shortest.

The great fundamental building block of a good code sender, is the correct time spacing of the various signals employed, and composing the alphabet. To begin with, the time unit upon which the code is built, is the dot, the shortest signal used, and whatever its time duration, the spaces and dashes must be made of proportionate length. This is quite clearly remembered, if it is known that the ordinary space is of the same time duration as a dot, and the ordinary dash twice the length of a dot. In the Morse code, the letter L, is a dash of four times the duration of a dot, while for the figure 0, the signal is an extra long dash, equivalent to the duration of five dots.

Between words, the space interval should be two ordinary spaces, and between sentences, the equivalent of three spaces.

If the operator aspirant desires to be thoroughly proficient in his chosen profession, he must pay the strictest attention to the proper time spacing of the various letters and figures of the code. A good plan for the beginner, is to have a friend a short distance from his place, who will send arbitrary signals to him, and he will undoubtedly learn to receive quicker in this manner than in any other, unless he can attend a school for the purpose.

A "skeeter" spark, as it is often termed in the profession, meaning a "singing" or high pitched spark note, may be closely imitated by altering the buzzer construction somewhat, as shown at Fig. 3, and placing a thin iron strip across the magnet poles, slightly above them, varying its tension by a thumb nut attached to one end of it. This arrangement gives an exceedingly high note in the receivers.

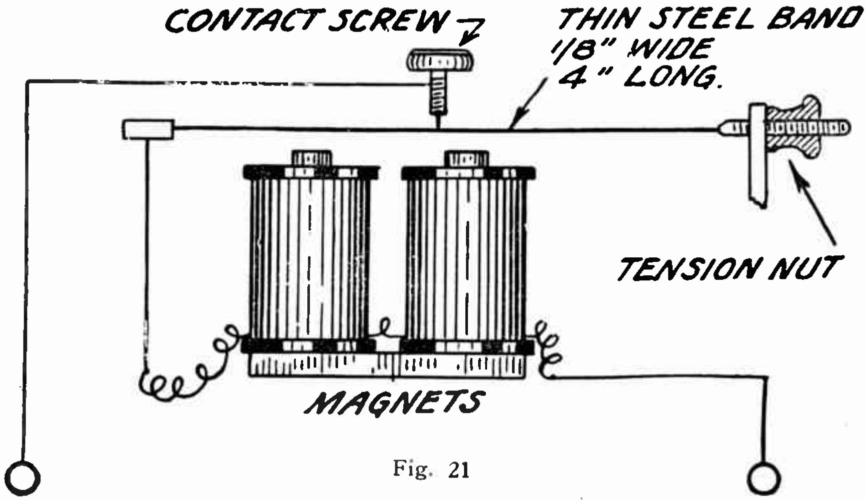


Fig. 21

The buzzer set described above can be operated manually by hand, but for beginners who find it hard to properly space the signals, it is better to control it from some sort of automatic sending device, such as the "Omnigraph," which costs from $2.00 up, according to how elaborate an instrument is desired. It works on the principle, that a circular metal disc with projecting teeth around its periphery, and rotating by means of a spring mechanism, opens and closes an electrical circuit, at definite intervals, by means of a spring contact pressing against certain teeth while rotating. Different discs, for various combinations of words and phrases can be obtained for it, and where the learner has access to no other teacher, this automatic sender, capable of transmitting at any speed, should be a boon.

On regular wire telegraph land systems, a speed of 40 to 50 words per minute is usual in sending, except in bad weather it may be reduced to 25 or 30 or less. The speed of transmission for wireless work, is often as high as 40 or more words per minute under good conditions, but the United States Examiners, before whom all commercial ship operators must appear, require a sending and receiving speed of not less than 15 words a minute, American Morse, or twelve words in the Continental code, as the operator may elect.

The Continental code, although recognized at the Berlin convention for International wireless arrangements, has not been used to any great extent commercially, although the United States Navy employs it. The advantage of the Continental code over the regular Morse code, is that there are no spaced letters, as the letters O and R, in Morse; the Continental signals being composed of straight combinations of dots and dashes.

The disadvantage of the Continental code, when compared to the Morse, is that the figure symbols in the former, are unduly long and require too much time to send. In the letter section of the codes, there are but few differences.

It is advisable for the beginner to practice certain exercises involving the repetition of letters of the same make-up, as dot letters and dash letters, etc.

An exercise in dot letters for the Morse code is:—Ship, she, his, hips, sips, pies, sheep, pipe.

Some practice words, containing dot and dash letters are:—Spanish, spite, ship-shape, dishevel, dapple, hissing.

Some dash letters for practice are:—Met, till, time, metal, pell-mell, mammal, tittle, timid, skilled, multiple, multitude, mallet, emit.

Dot before dash letters:—Awe, awful, law, valve, Eva, vault, lava, pawl, squaw.

Dash before dot letters:—Bend, bidden, ban, dunned, dabble, nab, dined.

Combination of the last two:—Julep, jungle, quaff, quake, exit, exquisite, exhaust.

An exercise in spaced letters is:—Err, errant, corner, eczema, corollary, co-operate, coon, circus, buzzard, correlate, corrupt, cohesion, road, dory, there is no royal road to learning.

In learning the beginner should try to send at an even regular speed, going slow at first and gradually increasing the speed to the necessary degree. One of the most common defects in a beginner is his choppy or irregular speed in transmitting, which makes it very difficult for even a good operator to receive.

A large amount of sending is easily and readily taken care of by the steady sender, who makes few mistakes, with consequent few repeats, although in long dispatches the question sign should be given after every 20 words, which will save repeating a whole message. A steady, well trained sender, can operate for 10 hours at a stretch, if need be, but a poor sender, who has not learned to handle the key properly, would succumb to a cramp in a few hours.

A beginner, or "ham" operator as they are termed in popular parlance, is generally known by his style of sending, a very frequent fault of his being, the string of 8 or 10 dots he sends out like so many shots from a gatling gun, and intended for the poor little letter P. It is interesting to note in this connection, that there are professional operators, who cannot for the life of them, send those five dots representing the letter P, correctly at high speed. It seems to be a freak of human nature. Another string of rapid-fire dots often come hurtling through space intended for the six dots, representing the figure 6. The only remedy for these freaks, is to thoroughly practice over and over again, those particular balky symbols, slowly at first, then faster until normal speed is attained.

In the Morse code, a common mistake is that of prolonging the T dash, and shortening the L dash. Another tendency is to lengthen the first and last dots of a letter; running the spaced dots together; dropping dots out of some letters; running letters of different words together; making unintelligible combinations of different half-words and a multitude of others.

When the student has learned how to handle the key properly, so that dots and dashes of the proper length are sent out, his duties will concern the proper handling of dispatches and messages as sent in regular commercial work.

Before a message can be sent, it is necessary to send out the call of the station desired to communicate with, and at the proper wave-length, as the call might be sent out all day, at the wrong wave-length, and never be acknowledged. A book published by the U. S. Government Printing office, at Washington, D. C., gives all the calls for registered ships and shore stations, exclusive of private stations, which are listed in a special book published each year.

For instance, suppose the station wanted, is rated in the book as, call B N G, wave-length 428 meters. In this case, the call should be repeated at intervals of about fifteen seconds, followed by the call letters of the station calling, allowing time for acknowledgment of call. It is not always possible to send out the call at the wave-length of the called station, in which event it is necessary to send it out at the regular transmitting wave-length and take a chance on the operator of the desired station stumbling over it, while "listening in," at various wave-lengths or tunes.

After the called station acknowledges the call, and gives the "go ahead sign," abbreviated to G A, the following arrangement is a standard one for sending the message: Send the sign "H R" or "M S G," meaning message; then give the number of message; the station's call; operator's sign; number of words, excluding address and signature; date; route of message; address; body of message; and signature.

Regarding the charges on board ship, land wire charges, or both, they can be given after the "number of words." For messages to be forwarded by a certain land, the directions can be indicated after "Route of message," by the letter "W. U." for Western Union, "P. T." for Postal Telegraph, etc.

All messages are not transmitted in regular form or as they are written, the services of a cipher code, special codes, and various abbreviations being widely used to increase the speed of transmission, decrease the cost of transmitting, and thirdly, to preserve secrecy in some cases.

In wireless work at present a fair list of standard abbreviations have been generally adapted, some of them being given here.

International Morse Code and Conventional Signals—Table

[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 Å (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)	...—.—

List of Abbreviations to be Used in Radio Communications

Abbreviation.	Question.	Answer or notice.
CQ	—.—. ——.—	Signal of inquiry made by a station desiring to communicate.
T R	— .—.	Signal announcing the sending of particulars concerning a station on shipboard (Art. XXII).
(i)	——..——	Signal indicating that a station is about to send at high power.
PRB	Do you wish to communicate by means of the International Signal Code	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?....	This is ......
QRB	What is your distance?................	My distance is ......
QRC	What is your true bearing?...........	My true bearing is ...... degrees.
QRD	Where are you bound for?............	I am bound for ......
QRF	Where are you bound from?...........	I am bound from ......
QRG	What line do you belong to?..........	I belong to the ...... Line.
QRH	What is your wave length in meters?..	My wave length is ...... meters.
QRJ	How many words have you to send?...	I have ...... words to send.
QRK	How do you receive me?..............	I am receiving well.
QRL	Are you receiving badly? Shall I send 20 ....—. for adjustment?	I am receiving badly. Please send 20. ...—. for adjustment.
QRM	Are you being interfered with?........	I am being interfered with.
QRN	Are the atmospherics strong?..........	Atmospherics are very strong.
QRO	Shall I increase power?...............	Increase power.
QRP	Shall I decrease power?...............	Decrease power.
QRQ	Shall I send faster?..................	Send faster.
QRS	Shall I send slower?..................	Send slower.
QRT	Shall I stop sending?.................	Stop sending.
QRU	....	I have nothing to transmit. I have nothing for you.
QRV	Are you ready?........................	I am ready. All right now.
QRW	Are you busy?.........................	I am busy (or, I am busy with ...... Please do not interfere).
QRX	Shall I stand by?.....................	Stand by. I will call you when required.
QRY	When will be my turn?...............	Your turn will be No. ......
QRZ	Are my signals weak?.................	Your signals are weak.
QSA	Are my signals strong?...............	Your signals are strong.
QSB	Is my tone bad?...................... Is my spark bad?.....................	The tone is bad. The spark is bad.
QSC	Is my spacing bad?...................	Your spacing is bad.
QSD	What is your time?....................	My time is ......
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG	....	Transmission will be in series of 5 messages.
QSH	....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for?.........	Collect ......
QSK	Is the last radiogram canceled?.......	The last radiogram is canceled.
QSL	Did you get my receipt?..............	Please acknowledge.

[1] When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

Abbreviation.	Question.	Answer or notice.
QSM	What is your true course?............	My true course is ...... degrees.
QSN	Are you in communication with land?..	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with ......)?	I am in communication with ...... (through ......).
QSP	Shall I inform ...... that you are calling him?	Inform ...... that I am calling him.
QSQ	Is ...... calling me?..................	You are being called by ......
QSR	Will you forward the radiogram?.....	I will forward the radiogram.
QST	Have you received the general call?..	General call to all stations.
QSU	Please call me when you have finished (or: at .. o'clock).	Will call when I have finished.
QSV[1]	Is public correspondence being handled?	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency?..	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?.	Decrease your spark frequency.
QSY	Shall I send on a wave length of ...... meters?	Let us change to the wave length of ...... meters.
QSZ	....	Send each word twice. I have difficulty in receiving you.
QTA	....	Repeat the last radiogram.
QTC	Have you anything to transmit?.......	I have something to transmit. I have one or more radiograms for ......
QTE	What is my true bearing?.............	Your true bearing is ...... degrees from ......
QTF	What is my position?.................	Your position is ...... latitude ...... longitude.

[1] Public correspondence is any radio work, official or private, handled on commercial wave lengths.

PART II

COMMERCIAL TRANSMITTING SYSTEMS.

WITHIN the last few years new systems have been introduced for producing electrical oscillations for wireless transmission. These systems have proven superior to the older spark system but even these installations are giving way to the influences of the vacuum tubes which are making inroads to their supremacy. The tube sets will not be treated with in this chapter.

Aside from the regular spark system, there are other methods of producing oscillations for wireless purposes used at present in commercial work. The **Quenched spark** system, the **Arc**, the **High frequency Alternator**, and the **Vacuum tube.**

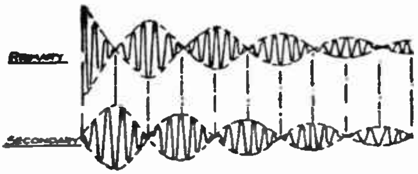


Fig. 1

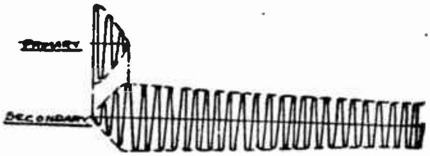


Fig. 2

With this quenched spark system it is possible to send wireless messages at three times the range procurable with an equal amount of power using the older systems. The spark produced is of a perfect musical pitch, and can be distinguished above the rumbling of static electricity in the air, and above the interference of other stations.

The novel feature in the Telefunken quenched spark system is in the spark gap, which is entirely original in design. This gap causes the oscillating circuit and the aerial circuit to react upon each other in such a manner as to produce the greatest effect, the action being as follows:

Most operators have, no doubt, noticed that stations using the ordinary spark gap can be heard in two places on their tuners, in other words, these stations each seem to have two different wave lengths at the same time. In reality there are two wave lengths present, even when the aerial and condenser circuits are tuned to the same wave length, and neither wave is that to which the two circuits are tuned. This double wave results from an interchange of energy between the condenser and aerial circuits. Following the initial discharge of the condenser, the primary (condenser) circuit starts oscillating, the oscillations increasing to a maximum value, at which point the secondary (aerial) circuit begins to oscillate and gradually increases to a maximum. Meanwhile the primary oscillations are decreasing in value and become zero at the time the secondary oscillations reach their maximum. The primary then begins oscillating again, as before, but the energy necessary is not supplied by the power transformer but is taken from the aerial circuit, which causes the secondary oscillations to die down to zero at the time the primary oscillations reach their second maximum, which, however, is lower than the first. This is illustrated in Fig. 1.

This interchange of energy continues until the oscillations of both circuits decrease to a point where the current in the primary circuit is no longer able to jump the spark gap. Then the oscillations in the secondary circuit slowly die out but are too feeble to radiate much energy from the aerial. The result of this is that the aerial circuit, instead of radiating a strong train of waves for each discharge of the condenser, radiates a number of short wave trains whose aggregate value is much below that of a single peaked long, slightly damped wave train that would result if the oscillations in the primary circuit be stopped just as soon as the secondary oscillations reach their maximum value, as shown in Fig. 2.

In order to radiate the most energy from the aerial, it is essential that the primary remain active long enough to build up the secondary oscillations to a maximum. If, at this point, the spark gap can be made to lose its conductivity, the energy in the secondary will not be lost in setting the primary circuit oscillating again, but will be radiated from the aerial.

There are several forms of spark gap which possess this desirable property of promptly damping out the primary oscillations. The most widely known is probably the rotary gap (which has been explained in the previous lesson), and which was introduced originally by Marconi, and then there are the quenched gaps of Von Lepel, Peukert, the Telefunken Company, and others, which operate on the principles first made known by Professor Max Wein in 1906, and the Mercury Vapor discharger of Cooper-Hewitt.

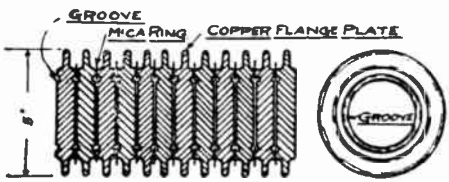


Fig. 3

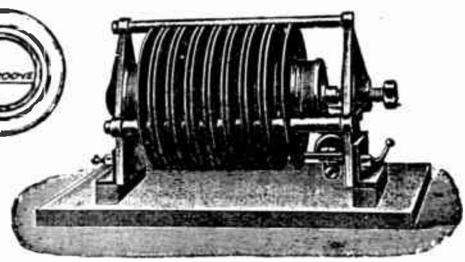


Fig. 4

The student will be given a thorough explanation of the quenched spark system used at present by the Telefunken Company in such manner as the limited space allows.

The Telefunken quenched spark gap consists of a series of copper plates which are so arranged that their center faces are raised, as shown in Fig. 3. This is accomplished by having the ridges turned out near the edges of the plates, and by placing mica rings of slight thickness between the two ridges of adjacent plates, a very small gap, (0.01 inch), is introduced. In Fig. 3 one may note the mica rings and the very slight gap which is formed between the plates. Usually 1,200 volts are allowed to each gap, and as many are placed in series as necessary. In the standard Telefunken sets, the gap is composed of a number of copper discs clamped together in a special framework, and each gap is provided with a metal spring piece which is inserted between the gaps which are to be short-circuited. If a nearby station is to be called, the operator lowers the voltage of his generator, and short-circuits all but one or two of the gaps. In this manner the signals are reduced to such a point as to reach the neighboring station without disturbing the other stations within the usual range. The center raised portion of the Telefunken copper discs is made of silver which has been welded on the copper.

In all of the larger sets, the copper plates are single faced, the raised portion being on only one side, while the other side of the plate is perfectly flat. The plate is then placed into the countersunk portion of a large bronze plate which serves the purpose of adding more cooling surface to the plate. These extra cooling plates are necessary, since the sparks can be quenched with better efficiency while the gap remains reasonably cool. The gap is shown in Fig. 4.

While the gap is in operation the sound of the sparks does not resemble the loud crashing sound of the regular spark sets, but instead a faint sound like escaping steam may be barely heard at a distance of more than 10 feet from the gap. On shipboard this system is particularly desirable, since the signals cannot be read from sound by an unauthorized person located near the wireless room.

After describing the gap which forms the vital feature of the Telefunken system, a description of the other parts of this system is naturally of interest. The power is supplied to the gap at a voltage of about 6,000 volts, and is furnished by a closed core transformer of very small dimensions. The efficiency of this transformer is extremely high, and but a very slight percentage of power is lost in the transformation of the voltage. A 500 cycle generator supplies current at 110 or 220 volts to this transformer through a simple telegraph key. This generator is another feature of the set which is extremely novel, for the obtaining of such high frequency current from a small size generator is a problem requiring much experimenting and designing. This generator has the two windings, both field and armature, mounted on pole pieces which are attached to the iron frame. Between the poles on which these windings are placed, a mass of laminated iron with many teeth, revolves, driven by either a directly coupled electric motor or an engine. In instances where a motor is used, the motor is supplied with a field rheostat of a special type so that the speed of the motor may be carefully varied. This rheostat is similar to a tuning coil, being wound on a cylinder about 10 inches long, and fitted with a sliding contact mounted on a rod. By moving the slider a slight distance, one turn or more can be interposed into the field circuit, with the resulting slight difference in speed of the motor. By moving this rheostat handle, the pitch of the spark is changed, and likewise the emitted signal. This is a very valuable characteristic, especially so in war operations, inasmuch as a station can change its spark and disguise its identity. A coil of wire mounted on a handle and connected across a pair of telephone receivers and detector is used by the operator for determining the pitch of the signals being transmitted by the station.

The condenser used in connection with the transformer and spark gap is also a novelty, since it uses heavy paraffined paper for the dielectric, in place of the glass plates usually employed. The voltage being only 6,000 volts as against the 25,000 volts used in the regular spark systems, enables heavy paraffined paper to be sufficiently strong electrically, to withstand the voltage. The condenser made of these paraffined paper sheets is mounted in a neat wooden case and placed in the framework holding the spark gap and tuning instruments.

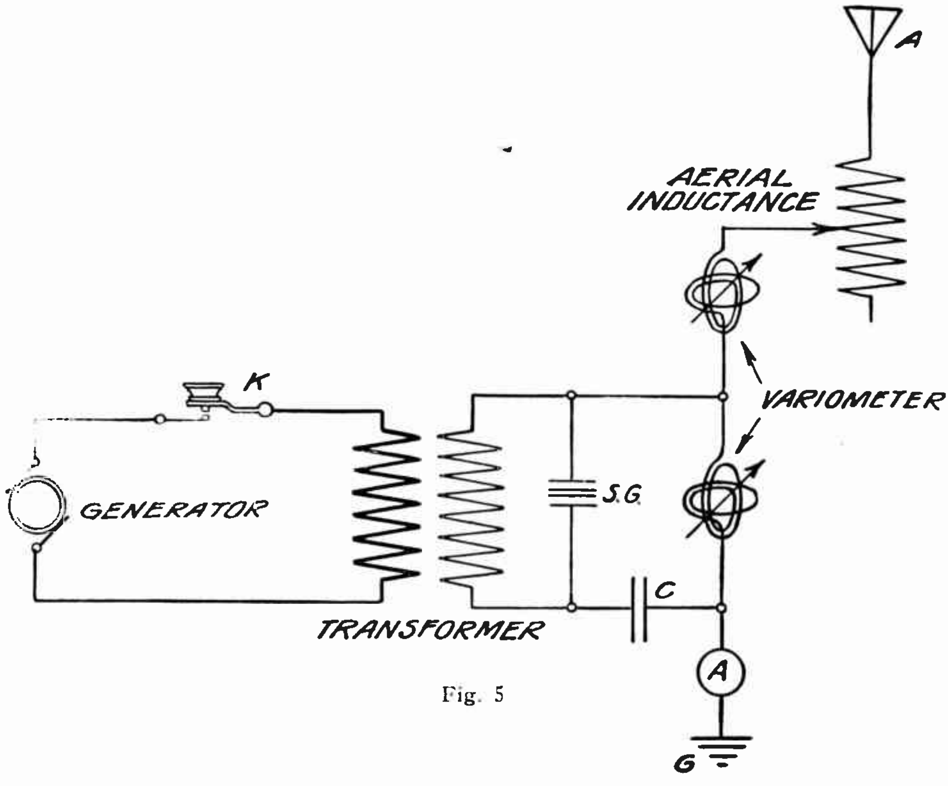


Fig. 5

In Fig. 5 will be seen a wiring diagram of the Telefunken system, and it will be immediately noticed that no helix arrangement is used for the connecting of the oscillation and aerial circuits. Instead, the aerial and oscillation circuits are separately tuned by independent inductance producers known as "Variometers." See photograph of Variometer, Fig. 6.

In the ground connection, a hot wire ammeter is mounted, so that the two variometers may be turned until the hot wire ammeter indicates the greatest deflection. In a 2 K. W. set this deflection will be about 18 amperes.

The transmitter may be tuned with a wave-meter, by moving the variometer in the oscillation circuit until the circuit is tuned to a desired wave-length. The variometer in the aerial circuit is then turned until the hot-wire ammeter indicates the greatest deflection, the set then emitting the wave-length desired. The flexibility of the set is without equal, for any wave-length may be obtained in an instant with the adjusting of the variometers.

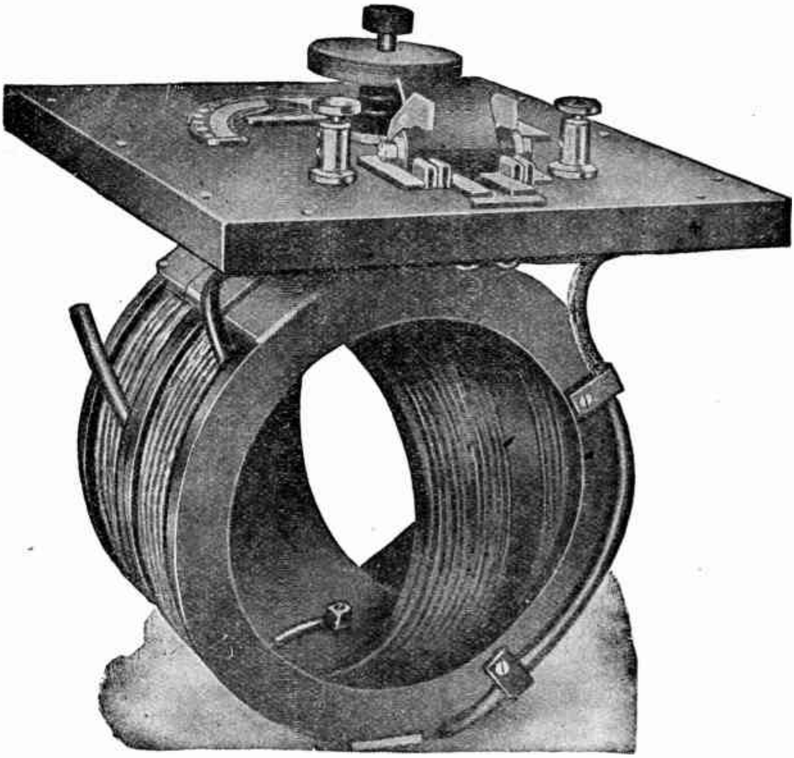


Fig. 6

The Von Lepel system varies but little from the Telefunken system, the principle of operation being the same, though the execution of the idea is slightly different.

In 1907, the Von Lepel system of producing wireless waves was introduced by Baron Von Lepel of Germany, and during 1908 and 1909, a continuous controversy was engaged in between the Von Lepel interests and the Telefunken Company as to the originality of the rival systems. These debates were printed in the English "Electrician" and were followed by all those interested in wireless telegraphy, though the final results as to which system had the priority in the quenched spark application to wireless telegraphy apparatus, could not be definitely decided. Both the Telefunken Company and the Von Lepel interests have many patents in Germany on presumably similar inventions.

The new and important feature of the Von Lepel system consists of its quenched spark gap. This gap is made of two copper discs which are separated by a piece of ordinary paper, or perhaps two sheets may be used if desired. A small hole has been made in the center of the paper. The copper discs are then tightly clamped together so that no air can enter. An arc or spark forms between the two copper discs where the paper is removed, but when the arc operates for two or three hours, the paper finally becomes entirely consumed and must be replaced. The burning of the paper furnishes additional advantages for the arc. The space between the copper discs is said to be .002 inch, while the plates are 3 inches in diameter. In the larger forms of the Von Lepel spark gap, the copper discs are water cooled. The arc or spark gap may operate on very low direct current voltages, since the gap is separated by such a small distance. Whether the discharge takes place in the form of an arc or in the form of sparks is a question which is still discussed with uncertainty. It is probably safe to presume that the discharge is an arc, and that the burning paper furnishes a gas to this arc, thus steadying it in constancy of operation.

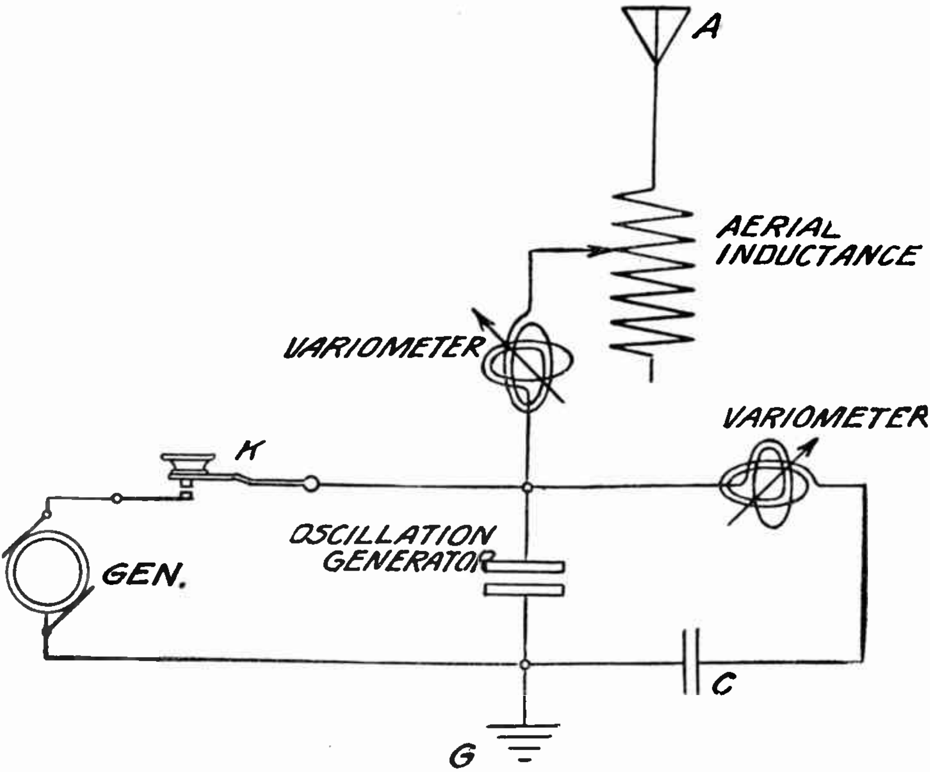


Fig. 7

The arc operates on currents as low as 300 to 500 volts, a transformer being unnecessary if a motor-generator set is employed to raise the current. Direct current is employed at a consumption of

1 to 2 amperes. Owing to the extreme simplicity of the Von Lepel instruments, it is admirably adapted for portable purposes. As in the Telefunken system, the condenser is made of mica but is only 4 cubic inches in dimensions.

The wiring diagram of the Von Lepel system shown in Fig. 7 illustrates the connections. It will be noted that as in the Telefunken system, the oscillation circuit is separately tuned by its own inductance while the aerial also is separately tuned and has an additional aerial inductance for long wave-lengths.

The Poulsen system introduced by **Valdemar Poulsen,** a Dane, in 1903, is based on the arc principle of producing electrical oscillations, and is used today with much success.

The Poulsen system is based on the experiments performed by Duddell in 1900, in which an arc was made to produce electrical oscillations and give out a musical note when shunted with an inductance and condenser. It has since been called the singing arc. Fig. 8 illus-

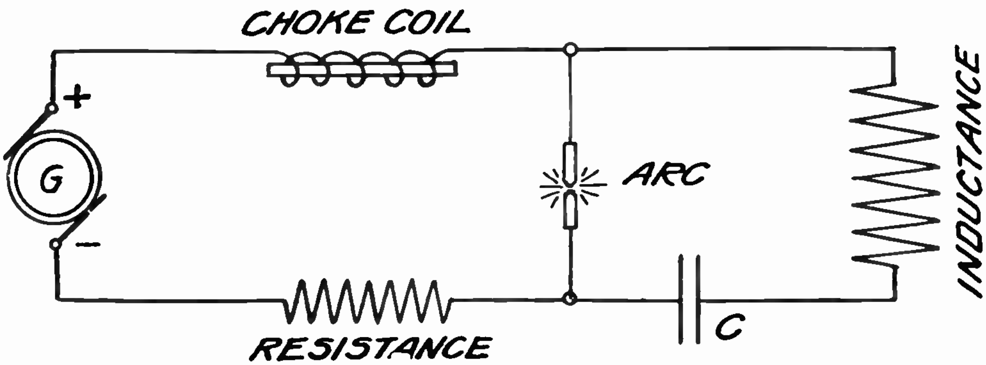


Fig. 8

trates the Duddell singing arc hook-up, in which it will be noted that a choke coil is used to prevent the oscillations from backing through the generator, and instead are made to charge the condenser and then discharge through the inductance and arc. The following explanation illustrates the reason why electrical oscillations are formed when an arc is shunted by a capacity and inductance.

It is known that with an increase in current through an arc the voltage between the arc terminals decreases. For this reason, when the arc is connected in series with a source of voltage and the current turned on into the arc, this current tends to increase to a very large value, and for this reason resistances are usually interposed in the power leads of arc lamps. If the capacity and inductance are now shunted around the arc, the condenser begins to charge. This takes current from the arc and in consequence the voltage between the arc terminals increases, and causes more current to flow into the condenser, since it is barred by the increasing voltage difference between the terminals of the arc. Finally the condenser becomes charged to an equal potential to that of the arc, but owing to the inductance in the circuit, the charging of the condenser continues for a time after this period. The result is that the condenser has a higher potential difference than the arc, which causes the current to cease flowing into the condenser. The condenser then begins to discharge through the arc, causing a drop in the arc voltage, and a further discharge of the condenser. While the condenser is discharging, the inductance in series with the condenser tends to preserve the discharging current, so that the condenser potential finally falls below that of the arc.

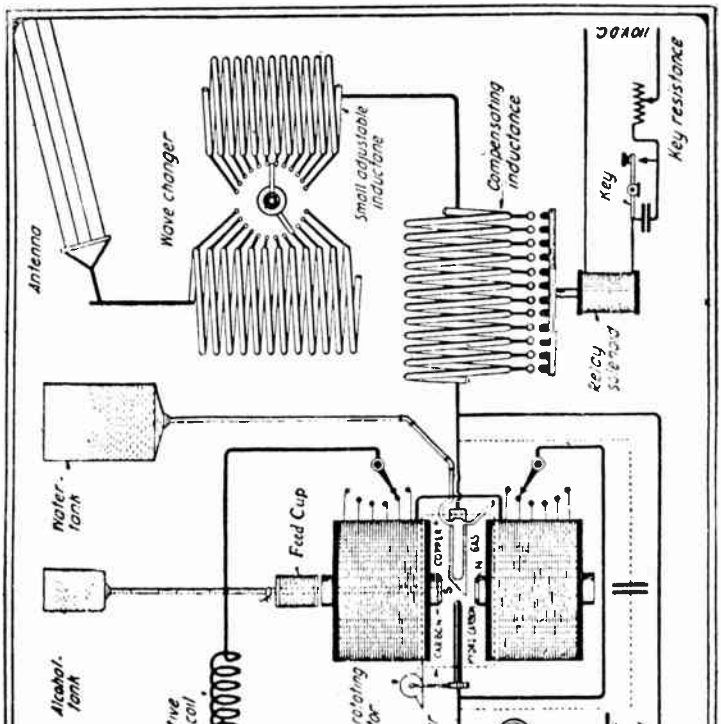


Fig. 9

After a minimum potential in the condenser has been reached by this discharging, the process is reversed and the action begins anew. The arc and the condenser circuit are thus in an unstable condition and the condenser continues to charge and discharge, thus impoverishing and replenishing the arc as to current. Whatever energy is expended in this oscillation circuit is drawn from the direct current source. It is well to mention here that alternating current cannot be used on the arc for wireless purposes.

In the Duddell arc the period of the oscillations was not sufficiently rapid to enable their use in wireless telegraphy. The improvements of Poulsen made the application possible, and today this system ranks among the foremost for efficiency and advantages.

The main difference between the Poulsen and the plain Duddell arc, is that the former is so arranged that the arc takes place between a solid carbon electrode, and a hollow copper vessel in which a continuous current of cold water is caused to flow. This keeps the arc cooled, and the arc is steadied by being enclosed in a chamber to which hydrogen gas is supplied. In some types the carbon electrode is slowly rotated by a motor, and two powerful electro-magnetic poles cause the arc to be steady.

THE ARC.

There are several ways of creating undamped waves of radio frequencies, namely:

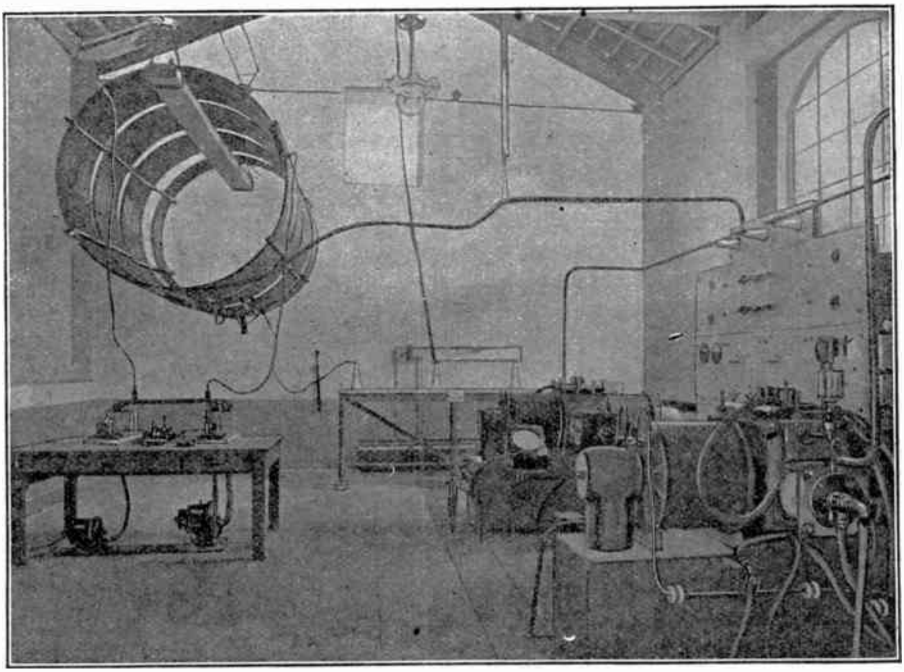
1. The Federal arc transmitter.
2. The Goldschmidt.
3. Alexanderson and Bethenod alternators.
4. The Marconi "Timed Spark" discharger.
5. The vacuum tube transmitter.

For the present, however, we shall concern ourselves with a general explanation and description of the Poulsen arc. Figure 9 shows a schematic diagram of a standard Poulsen arc transmitting system. This diagram and the following descriptions and explanations, unless otherwise specified, do not refer to any specific type of the Poulsen arc, but it may be said that in general the principles involved in the standard 15, 20, 60, 100 and 500 K.W. sets are the same except that the higher power transmitters are so constructed as to overcome the greater mechanical and electrical difficulties encountered in dealing with the necessary current for the ignition and regulation of the arc, the radio frequency tuned oscillatory circuit connected to antenna and ground, and the compensating relay key circuit. The direct current may be delivered by a motor-generator set or a steam turbine driven 500-volt generator; a suitable switchboard fitted with switches, fuses, circuit-breaker, volt and ammeter; a variable resistance to control the starting of the arc; two sets of choke coils, one on the positive and one on the negative side of the circuit; two large "blow-out" magnets mounted on the arc pedestal above and below the arc electrodes, with means of regulating the magnetic strength of each coil separately; a copper anode for the positive electrode and a carbon cathode for the negative electrode with a spring device to enable the operator to strike the electrodes together when starting the arc; a small motor to slowly rotate the carbon tip; a feed cup filled with alcohol so arranged as to drip slowly into the arc chamber, and a water circulating system to cool, primarily, the copper tip as well as the walls and door of the air-tight arc chamber are usually found. Concerning the "blow-out" magnets it may be well to mention that with some types of arcs there is but one large electro-magnet mounted below the arc electrodes, its yoke or core being constructed to form the opposite pole directly above the arc.

The oscillatory or antenna circuit may consist of a main antenna inductance, a small adjustable inductance in the form of a variometer, a wave changing device, a compensating inductance, a hot-wire ammeter placed either in the ground or aerial circuit, and in some cases a high potential condenser shunted across the arc electrodes.

The Alexanderson High Frequency Alternator

Frequencies as high as 100,000 cycles per second have been accomplished by means of a special form of alternator of the inductor type, as for instance, the one developed by Dr. E. F. W. Alexanderson. In this case 100,000 inductor teeth must pass a given point every second. This extraordinary number can be obtained only by having



The high power station at Rome, Italy. Two powerful arcs are used to supply the energy to the aerial.

a great many teeth on the rotor and driving it at an unusually high velocity. In a 2 K.W. generator, the rotor has 300 inductors and makes 20,000 R.P.M. which gives the required 6,000,000 inductors per minute. The armature conductors are laid in a zigzag manner in little slots in the flat face of the core, this face being perpendicular to the shaft.

The rotor consists of a steel disk with a thin rim and much thicker hub, shaped for maximum strength. Instead of having teeth on the edge it is slotted with little windows, the inductors being in the form of spokes, leaving a solid rim of steel. To cut down the air friction, the slots are filled with non-magnetic material such as phosphor-bronze, which are finished off smoothly with the face of the disk. These machines embody a number of novel features made necessary by the small space per inductor and the exceptional speed. Their construction became possible only through engineering skill of a very high order and by the finest workmanship. The only undesirable feature of these exceptional machines, however, is that they are not suitable for field work, but are mainly designed and used at high power long-distance land stations.

At the gigantic transmitting station located at Radio Central, Long Island, near Port Jefferson, and about seventy miles east of New York City, we find one of the most powerful stations in the world. This station communicates regularly with Wales, France, Germany, and Norway. Some distance away we find the receiving station, at Riverhead, Long Island, which picks up the messages transmitted by the foreign stations entailing no interference from the very

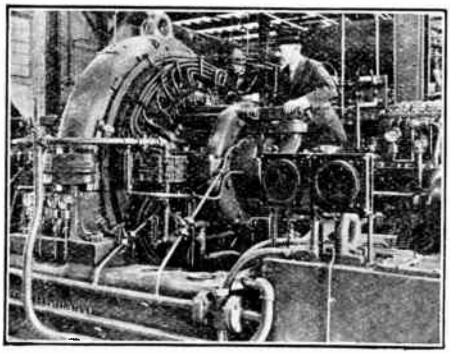


Fig. 10

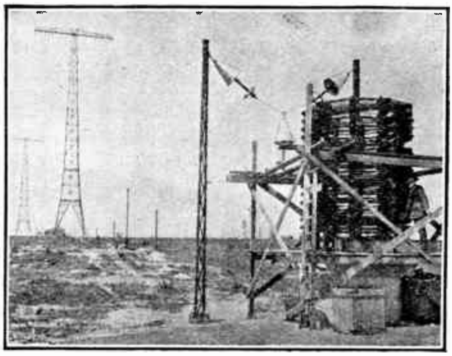


Fig. 11

powerful transmitter at Radio Central or the other powerful stations located at New Brunswick, Marion, or Tuckerton.

The transmitting station at Radio Central, with its 200 K.W. alternators, Fig. 10; its tuning inductances, shown here erected in the open, Fig. 11; its magnificent towers of structural steel mounted on insulating bases, Fig. 12, which radiate in all directions of the compass, as shown in the illustration, Fig. 13; and its condenser racks as shown in Fig. 14 constitute the last word in radio transmitting stations of the commercial type. This is the station through which the Radio Corporation of America transmits to the various foreign stations previously mentioned.

Several years ago, each transmitting station had its own receiving station. This system is changed now, however, for at Riverhead all of the receiving is done. Radio Central, Tuckerton, Marion, and New Brunswick can all carry on an uninterrupted conversation with the foreign stations while Riverhead patiently listens and completely handles all of the incoming signals of the European centers. This station automatically transfers the signals over trunk line wires to the Broad Street office in New York City, where all of the incoming and outgoing messages are handled.

The antenna is of a new type, very directional in effect. It is so orientated that it will receive signals from the transmitting stations

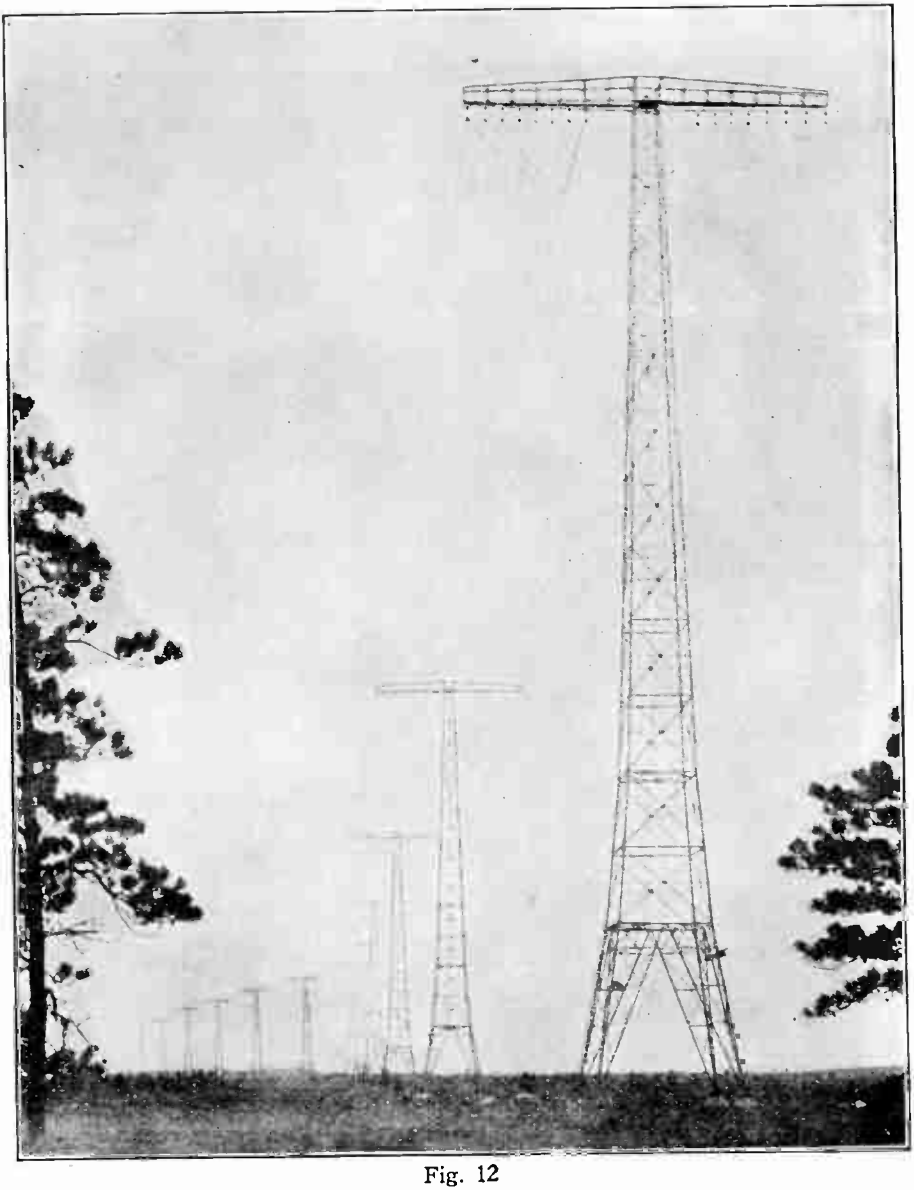


Fig. 12

across the ocean, while almost entirely ignoring those signals from powerful stations close by. The antenna is nine miles long, supported on telegraph poles and stretches out only in one direction. A special receiving circuit is fed by it, which reduces interference almost entirely. Atmospheric disturbances known as static are greatly suppressed, at least to the extent of about 90 per cent.

In Fig. 15 Dr. E. F. W. Alexanderson, the inventor of the alternator and other radio and electrical devices can be seen at the Riverhead receiver. The tape recorder at this station is shown in Fig. 16 and in Fig. 17 a portion of the nine-mile antenna suspended from thirty foot telegraph poles, may be seen.

Fig. 13

The station at Riverhead continuously receives signals from Carnarvon, Wales; Bordeaux, France; Stavanger, Norway, and Nauen and Eilveese, Germany. All of these stations transmit on wave lengths of over 12,000 meters, one of them on a wave as high as 23,400 meters.

The Goldschmidt Alternator

A certain desirable principle not previously mentioned in connection with our study of electrical machinery is utilized in the high frequency generators of several high power German stations, such as the well known Nauen station, which has the familiar call letters of "POZ."

In this case, advantage is taken of the building up of large currents by electrical resonance in the rotor and stator circuits of the machine itself, as well as the multiplication of frequency by the effect of rotor currents on the stator windings.

When a rotor is revolved, and at the same time alternating currents are made to flow at a frequency corresponding to the speed of rotation and to the number of poles, then, due to these currents, pulsations take place in the strength of the magnetic field of the machine at double the frequency of the alternating currents.

By providing suitable circuits, it is possible to obtain a frequency four times as great as that corresponding to the actual speed and number of poles of the machine.

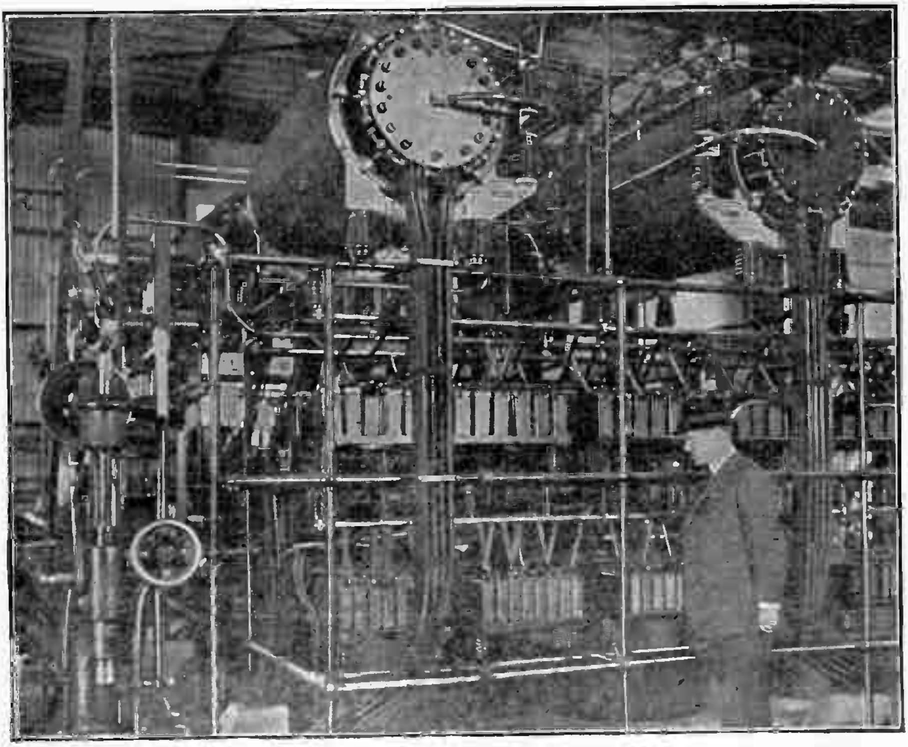


Fig. 14

Fig. 15

Fig. 16

The above brief explanation has been given as though the machines were bi-polar. This would naturally necessitate extraordinary

Fig. 17

speeds. Instead, however, the large machines used in trans-oceanic work have **360 poles** and are driven at 4000 r.p.m. by 250 h.p. motors. The fundamental frequency is therefore 12,000, which is quadrupled as has been explained, thereby giving 48,000 cycles at the antenna. To secure efficient operation of these machines is no easy matter, and the finest sort of workmanship is necessary in building them. They are being used to great advantage at the present day in commercial transoceanic telegraphy.

The Bethenod High Frequency Alternator

Mr. Bethenod, chief engineer of the Radio Electric Society of France, has invented a very efficient type of high frequency alternator, which is very compact and at the same time does not present the disadvantages found in some other similar types of machines. In this type of alternator, there is no rotating winding, nor any brush. The speed is not excessive and makes the machine safer and more steady in operation, and since the space between the rotor and the stator is comparatively large, there is no danger of the rotor rubbing against the stator. The efficiency of this machine at maximum output is 63 per cent for the 200 K.W. machine and 67 per cent for the 500 K.W. type. The signalling is made by short-circuiting the machine on itself which reduces the consumption of current, since it does not absorb any power during the interval of the signals. Therefore, it is possible to obtain, for a given amount of energy, much stronger signals in the antenna than obtained for a continuous dash. The efficiency of this system is almost double that of an arc. A further advantage of this alternator is that when increased output is desired, several machines may be coupled together. Fig. 18 shows a view of the 250 K.W. Bethenod high frequency alternator and in Fig. 19 is seen the stator of this alternator. Note the fine slots containing the winding and the water pipes for cooling.

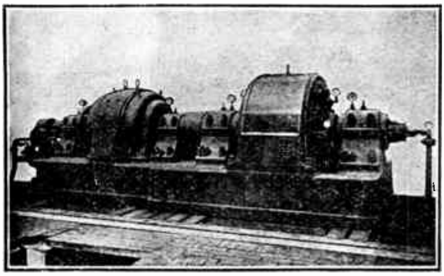


Fig. 18

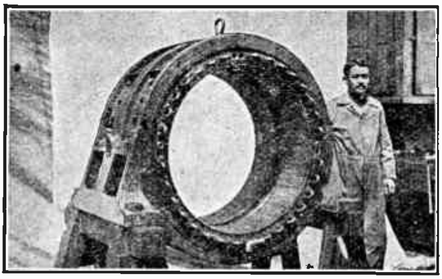


Fig. 19

The Bethenod alternators are made in several sizes, varying from 25 to 500 K.W. output. The speed varies from 6,000 to 2,330 r.p.m. and the frequency from 30,000 cycles for the smaller machines, to 14,000 or 15,000 cycles for the larger types. These machines are in use at Y.N., Lyon, France, F.L. and other high power stations.

PART III

AERIALS AND HOW THEY ARE INSTALLED

IN this part we deal more particularly with the antenna. Although the word antenna means to reach out and feel, it cannot be very correctly applied to sending aerials. Nevertheless, it has come to general use among radio enthusiasts, and is employed synonymously with the word aerial. These two terms represent the wires erected either within or outside of the building, upon which a minute quantity of the energy transmitted by the sending station, is intercepted.

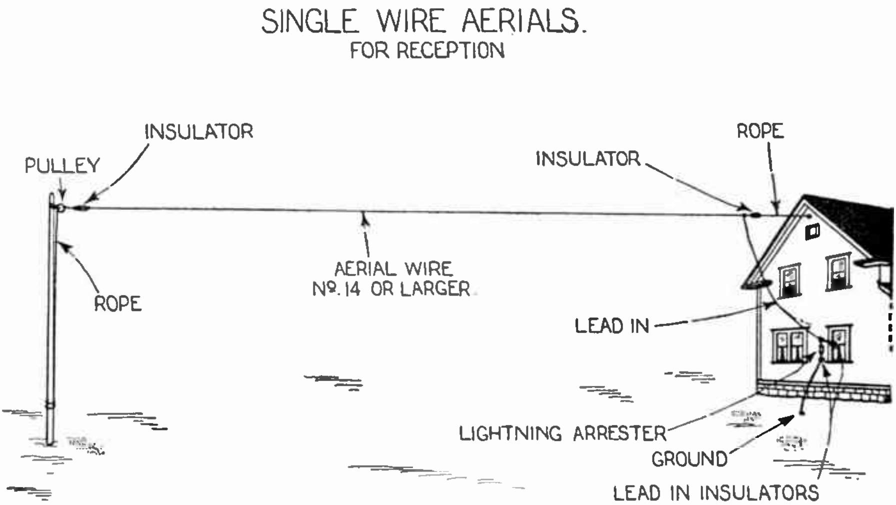


Fig. 1

At the present day with audions or vacuum tubes so prevalent in receiving circuits, the antenna presents no real difficulty. An umbrella, a small coil of wire, a bed spring, a fire escape, wet clothes line or a clothes line with wire wound around the same, a nail in a tree, wires sunk underground, in fact any conceivable object made of metal having considerable bulk, or wire either straight or coiled, has been impressed into service. For receiving messages from the broadcasting stations, a wire stretched between two insulators, preferably one hundred to one hundred and fifty feet apart, and thirty-five or more feet above the ground, with a lead-in anywhere along its length, but preferably at one end, constitutes a very efficient form of aerial. The wire may be of copper or aluminum or copper covered steel. Phosphor bronze braids or tinsel tubing as well as woven copper wire is of course more effective, but the cost would not warrant its installation, except where it is desired to use the same antenna for both transmitting and receiving purposes. For the amateur's antenna steel wire with a thin coating of copper welded to it, the wire size No. 14 B. & S. gauge or larger, is recommended because it is cheap and a greater stretch of wire can be put up without much sag. The copper coating welded to the steel is sufficiently thick to permit the high frequency currents to pass along the wire freely. The currents of this nature travel only a short depth below the surface of the conductors, producing a pure skin effect. For this reason tubing is very efficient but highly expensive.

As aforementioned, many elaborate types of aerials have been advocated, and on travelling through the country or city one can see everywhere antennaes of every description decorating the roofs of houses, or strung from a rafter or an adjoining tree. In the city it is against the rule to string an aerial across the street, no attempt should be made to string an aerial above or below telephone wires or power lines, as a wire may break either in the power line or the aerial itself, causing the energy from those power circuits to travel through the set to the ground, destroying either the set itself or placing those individuals handling the same in a dangerous position.

The simplest way to erect an aerial is to procure two insulators, one of these is fastened rigidly about three feet from the end of a chimney, rafter, or from a pole erected upon the roof of a building. The other is secured to a rope passing over a pulley mounted on an-

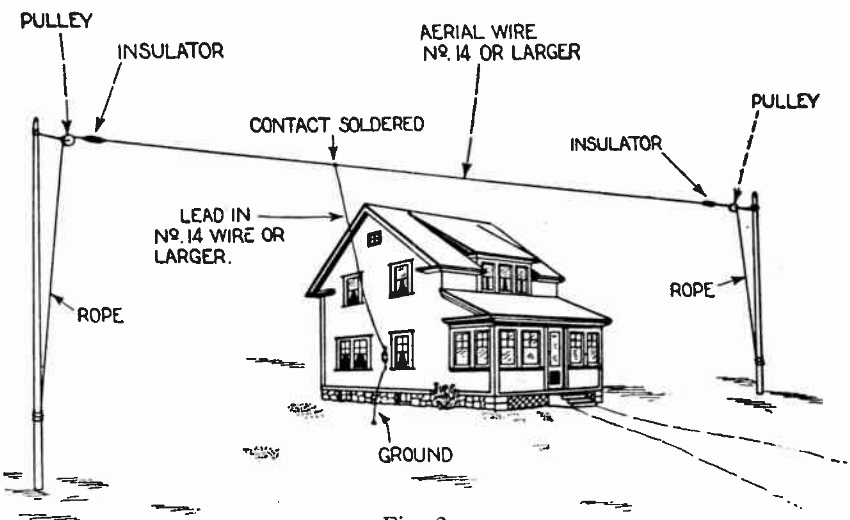


Fig. 2

other pole or else is fastened to another piece of wire which will be secured to a second suitable location. If the roof of a house is of metal and there is a metal pipe leading to the ground, it is advisable to string the aerial considerably above the metallic roof, or between two or more adjoining buildings. A lead-in wire which goes to the apparatus is then twisted to the antenna, and brought down to the apparatus. If the attachment of the antenna to the house causes the antenna to come very close to the roof, because of lack of other suitable location, it is advisable to place the insulator in such a position that the end of the aerial will be at least two feet from the building. See Figs. 1 and 2. The lead-in should be constructed as shown in Fig. 3, which also shows the method of making a good ground.

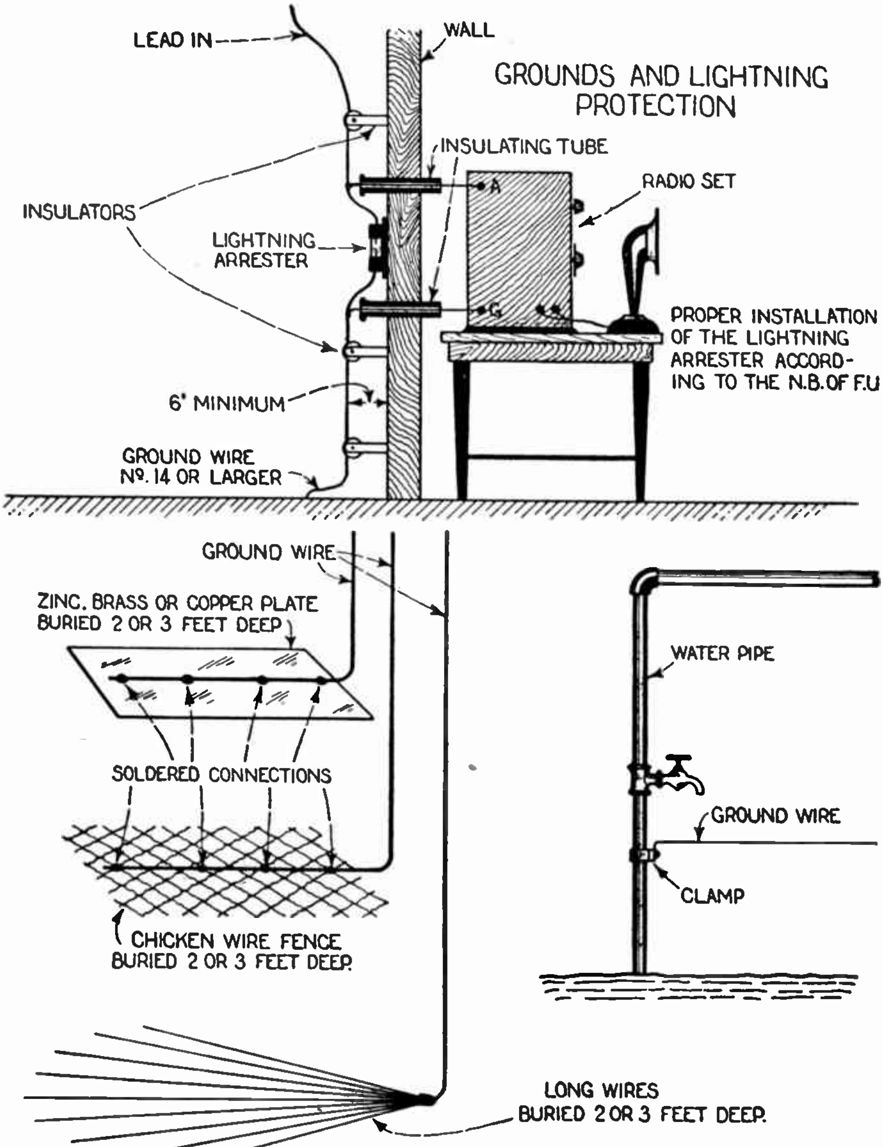


Fig. 3

One fact should remain in mind and that is an antenna of this nature is fairly directional. It will receive messages in one direction better than in another.

Assuming that the portion of the aerial stretched between the insulators is the thigh of the leg, and the lead-in the remainder of the leg, then the knee of the aerial should point toward the broadcasting station, or in the direction from which the greater amount of messages and the greater distance is to be obtained.

Of course, many amateurs prefer more elaborate antennae, which will, of course, differ in dimensions according to the available locations, but with transmitting sets an aerial stretched between two poles 50 or 75 feet apart, and about 50 feet high, answers the purpose admirably. Two spars or spreaders, 6 feet long and sufficiently stout, are secured to the top of each pole by a rope passing over a pulley. These permit for the lowering of the aerial for repairs. Bamboo is

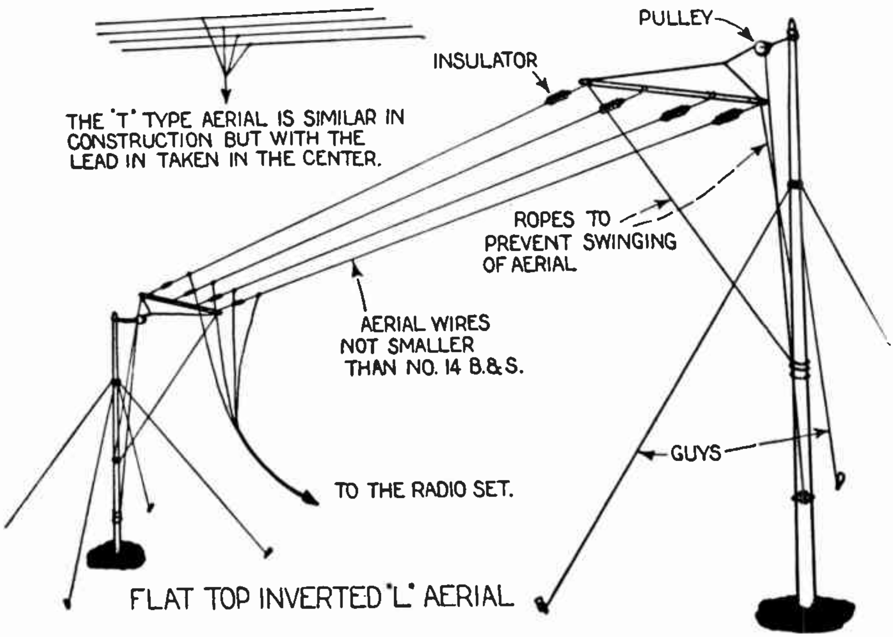


Fig. 4

excellent wood to use for the spreaders, because it is both light and strong. The wires are then strung upon the spreaders each insulated from the spreader itself by the standard insulator made of either glazed porcelain, electrose, or hard rubber, as shown in Fig. 4. It is not absolutely necessary to insulate the wires from the wooden spreaders in ordinary receiving sets, one insulator on the guy rope being amply sufficient to prevent leakage of currents to the ground. The wooden aerial masts which have been used for a great many years are now being supplanted by iron masts or poles. These are usually made up of sections of iron pipe, connected together by reducing couplings, so that a pipe about 1 inch in diameter connected to a flange at its base reduces in size until at the top it is but ½ inch, through the interposition of a ¾ inch pipe, between the two extremes. These iron masts must be well guyed and for this purpose iron guy wires are employed, and if the guy wires are 20 feet or more long they are broken up by means of strain insulators into 20 foot sections. This is to prevent any undue absorption or dissipations of currents being induced in them unnecessarily, and thus causing a loss of the aerial's efficiency. To reduce the loss to a minimum when employing iron or steel poles, the base of the poles is also insulated, even such large towers as that of Fessenden's Brant Rock which is 420 feet high, sets upon a pillar of glass. In attaching an iron mast to a roof, permission is not often granted to bolt this mast directly to the cross-beams below the surface of the roof, and for this reason two 4 x 8 pieces of wood are lapped at right angles to each other. Each piece is at least 8 feet long. The flange for the pipe is then bolted to the wood at the crossing.

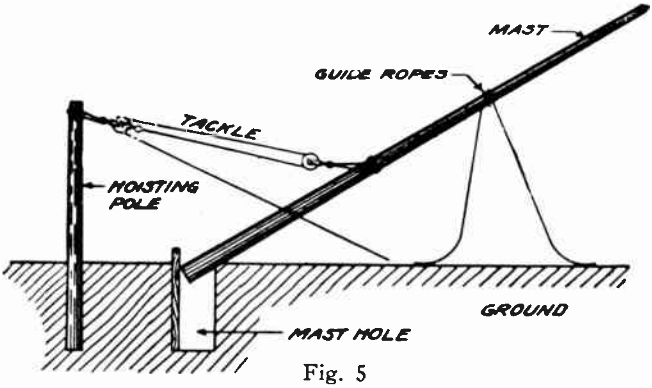


Fig. 5

In erecting aerials of the wooden or steel kinds of any desired height it will be found that if another mast is planted alongside of the hole into which the mast is to sink, which mast should be about 1/3 the length of the mast to be erected, raising it becomes an easy proposition. Pulleys are fastened to the hoisting pole and to the mast as shown in the illustration herewith, and using the guy wires or guide ropes to steady the pole it is hoisted into position. See Fig. 5.

In putting two or more wires into the antenna, it is advisable to place the adjacent wires two or more feet apart, inasmuch as nothing is gained in the closer spacings. In very large aerials the space between the wire may be increased to four or six feet.

Many landlords do not allow radio enthusiasts to erect aerials on their premises because they are either afraid that the building would be in greater danger of lightning during severe thunderstorms or because many aerials on top of a large apartment house disfigure the house.

Let us repeat here that an aerial placed upon a building does not present any hazard whatever if the same is properly grounded. True it does act as a lightning arrester but that is an asset, not a detriment. It thus prevents the house from being struck by lightning rather than "drawing' the current to the home. When properly grounded by means of a lightning arrester or a lightning switch of a design approved by the underwriters, it prevents the accumulation of electrical charges in the air, permitting them to pass into the ground as quickly

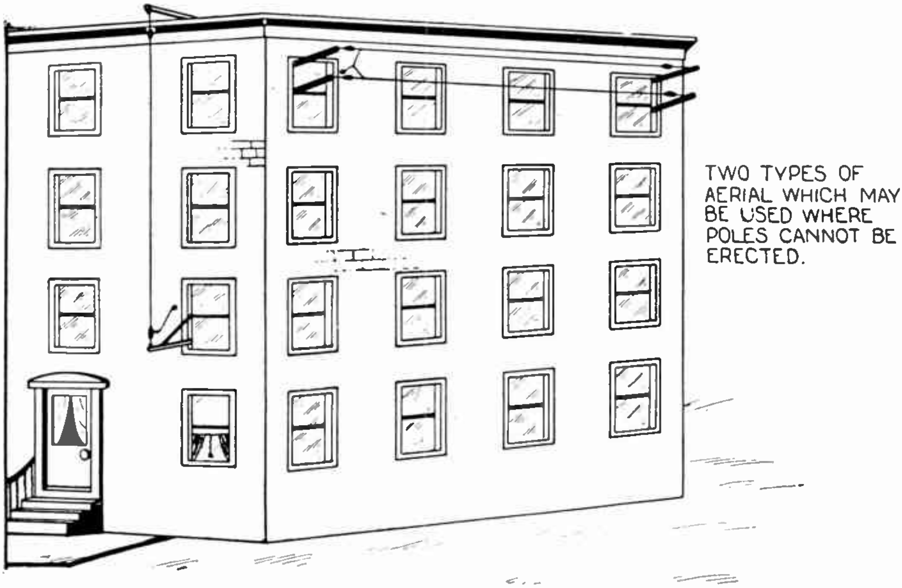


Fig. 6

as they are formed; and inasmuch as the negative charge must leap to an area charged positively and in view of the fact that one of these charges has been constantly dispersed by the action of the antenna, a bolt of lightning will not strike the house in the vicinity of the aerial.

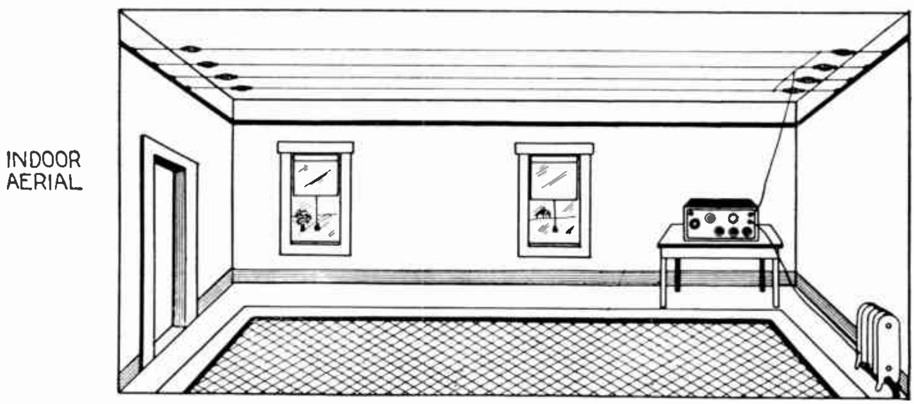


Fig. 7

No amount of argument will convince some owners, however, so the amateur must devise other forms of aerials. Fig. 6 may solve the difficulty.

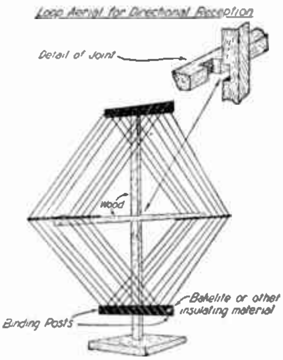


Fig. 8

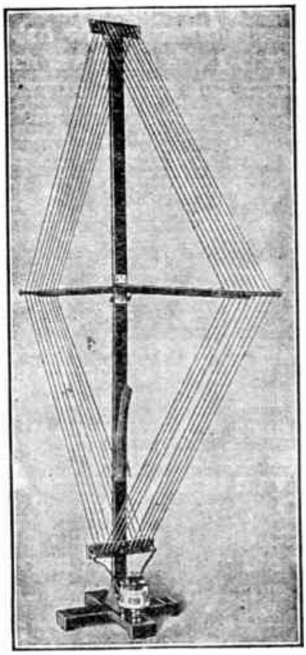


Fig. 10

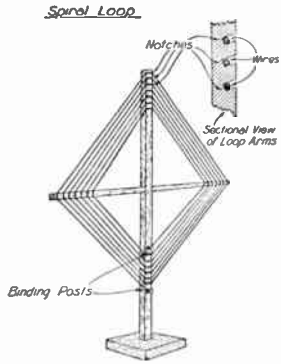


Fig. 9

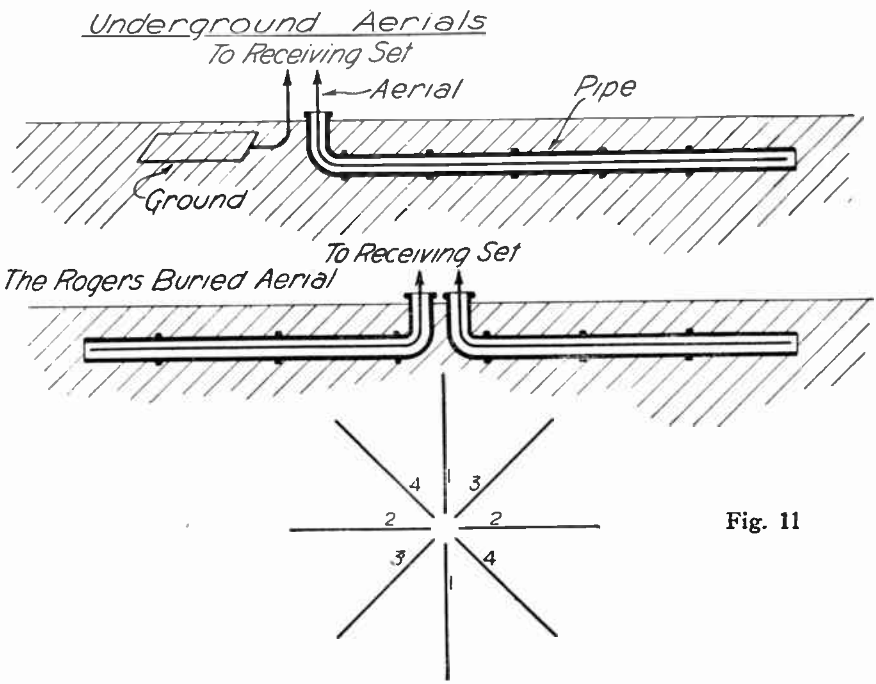


Fig. 11

By tying an insulator to the washline and attaching a flexible wire to this insulator the aerial may be drawn out through a window and pulled back whenever desired. The landlord will not object to this form of antenna.

The aerial may be erected indoors but presents an objectionable appearance, Fig. 7, for this reason a single wire running around the room above the picture molding is barely visible and with a suitable ground fulfills its duty admirably.

A loop aerial built up as shown in Figs. 8 and 9 or the collapsible loop, Fig. 10, with sides three feet long and the wires separated from each other by a three-quarters of an inch space, eight turns in all being required, not only serves as a very efficient type of antenna, but is very directive as well. For audion circuits this form of aerial is practically unsurpassed. In the summer time when static is very prevalent, this aerial is practically unaffected by atmospheric surges.

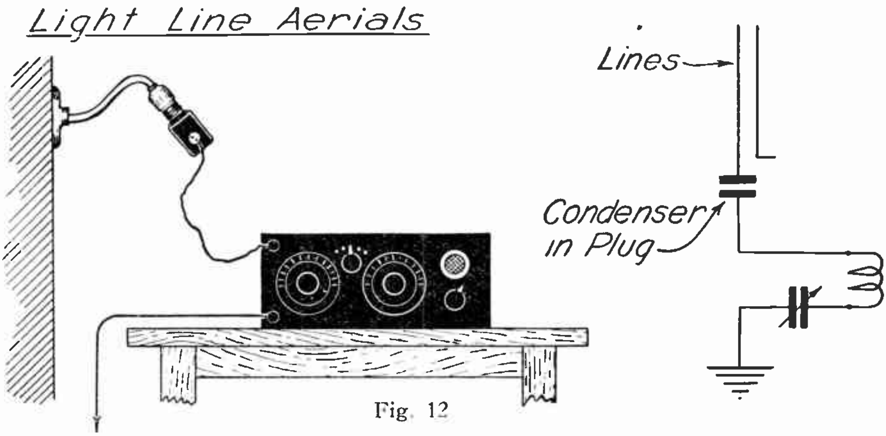


Fig. 12

The underground aerials as designed by Dr. Rogers, are likewise unaffected by static. They are impractical for the ordinary amateur but a diagram of the installation is given here. Fig. 11.

A buried loop is both directive and static proof.

Attachments to the regular lighting circuits, which may be screwed into the lamp sockets in a manner similar to the attachment plugs of electric irons or lamps may now be found upon the market. For those whose homes are supplied with electricity this kind of an attachment converts the wire network running through the house into a worthy antenna. It consists of a plug which screws into the socket of a lamp. To one side of the house circuit the lead of a condenser is attached. The lead from the other side of the condenser is attached to the aerial side of the receiving outfit. The second lead is left open. In another form two condensers, one in series with each side of the lightning circuit is employed. This antenna is not subject to lightning, it uses no current whatever and may be used with crystal receiving sets. Fig. 12.

For transmitting purposes the cage style of aerial is most efficient. Attached to an insulator is a brass hoop five or more inches in diameter. About half a dozen wires are then equally spaced around the hoop. See Fig. 13. These extending the distance of the aerial terminate at a similar hoop at the opposite end of the aerial. Here and

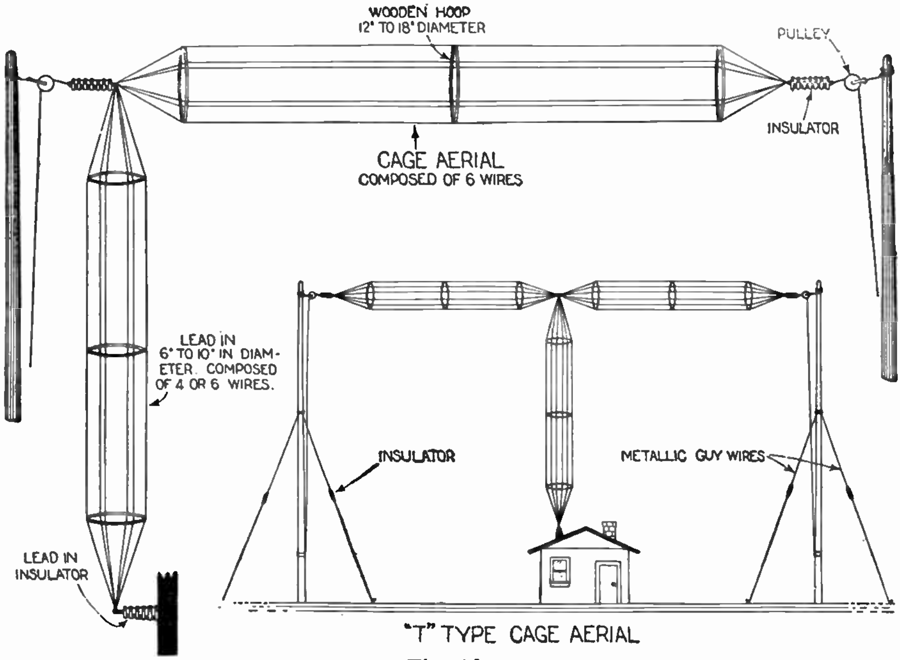


Fig. 13

there along the length of the aerial, similar, but insulating, hoops are found. These serve the purpose of spacing the wires properly. This aerial does not change its wavelength appreciably when it sways in the breeze.

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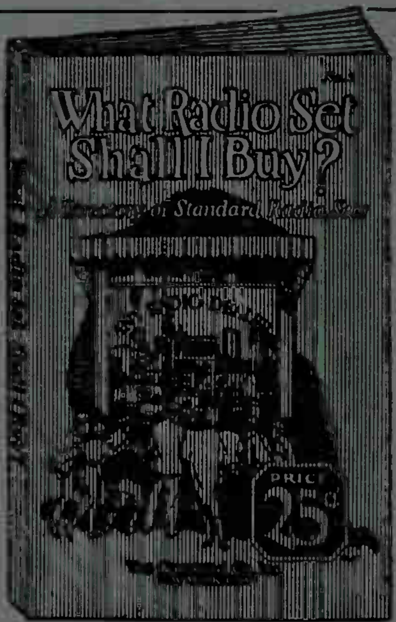

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BOOK NUMBER THREE

PART I

RADIO RECEIVING APPARATUS

THE various instruments brought into play, in the receiving of Radio messages, have been much improved upon since the then **Commendatore William Marconi** sent his immortal three dots, representing the Morse code letter "S," across the broad Atlantic in 1901.

It will probably be the best plan, to first explain the function and actions of a simple receiving outfit. In Fig. 1, is shown such a layout, including the aerial, a detector D, telephone receiver R, and ground connection G. This forms the very simplest receptor for wireless signals possible.

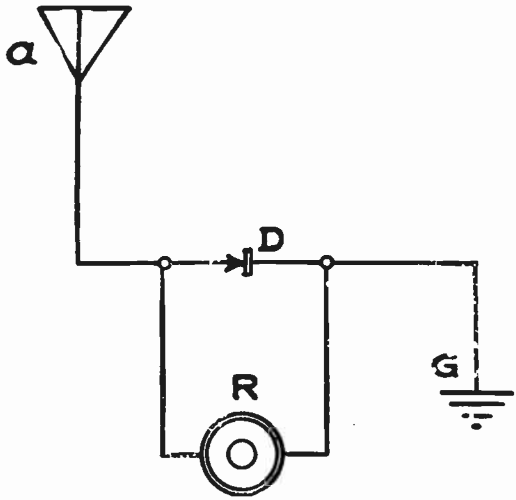

Fig. 1

The incoming oscillations induced in the aerial wire pass through the **detector** and on down to earth. The detector, which in these discussions will be considered one of the crystal rectifying type, such as the galena, tends to act as an electrolytic valve, and permits the currents coming in one direction to traverse it many times better than currents from the opposite direction, or polarity*, and the clipping off of the half waves or oscillations due to this phenomena. causes the telephone receiver to have a pulsating rectified or direct current (practically) impressed upon its windings, and consequently a varying or constantly changing magnetic pull is exerted upon the iron diaphram, giving rise to the buzzes heard by the ear, whenever a wave train impinges upon the aerial circuit. The high self-inductance of the receiver coils prevent the oscillations from passing through it, instead of the detector.

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* See Part II on "Detectors" in this book.

Such a receiving set as just described, is not capable of being tuned to any desired wave-length, and consequently, except for certain wave-lengths or short distance work, its sphere of usefulness is limited.

The first method applied to tune the receiving apparatus to any desired wave-length, employed a simple cylindrical coil of insulated wire, made up of several hundred turns or convolutions, each turn being insulated from its neighbor, and a sliding contact arranged to make connection with any desired number of turns. The connection of such a tuning coil is depicted in Fig. 2. By means of the slider more or less of the wire can thus be readily inserted in series with the aerial, thereby changing its wave-length to a high or low value.

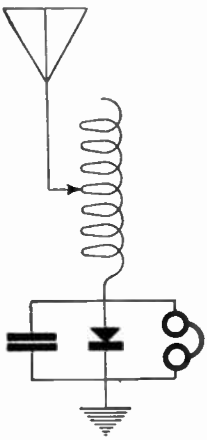


Fig. 2

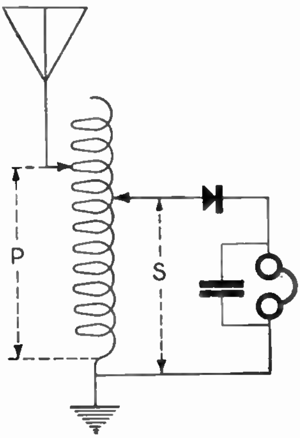


Fig. 3

This method is not, however, very efficient for reasons to be subsequently explained, and is not used any more, except for the purpose of an extra tuning inductance, or "loading coil" in the aerial lead, where long wave-lengths beyond the range of the regular instruments are to be received.

The next method utilized for tuning the receiving apparatus was that where the free end of the tuning coil is grounded or connected to earth, as shown in Fig. 3. This scheme at once rendered the tuning coil something more than a mere dead resistance coil in the aerial lead, or in other words, it now became a transformer of the type commercially used and known as an "auto-transformer" or mono-coil transformer, meaning one whose primary and secondary coils were combined into one coil, instead of the two separate windings employed in most transformers. A two-slide tuner is shown in Fig. 4.

This tuning coil transformer action is a very important one now, in receiving sets, and is made good use of in administering the proper voltage and current to certain classes of detectors, some of which require a stronger voltage than others for their proper operation. These are usually referred to as current actuated and voltage actuated detectors, respectively.

The manner of varying this impressed detector voltage, in virtue of the transforming action occurring in the three-lead tuning coil, is due to the following reasons:

When the oscillations set up on the aerial wire pass through the tuning inductance coil, they cause this coil to become surrounded by an electro-magnetic field of force, which embraces all the turns of wire thereon. Now, if the section of the coil represented by P in Fig 3 is taken as the primary winding of the auto-transformer, and the turns or section at S, as the secondary winding, then the voltage of the secondary leads to the detector will be, as the ratio existing between the number of primary and secondary turns, i. e., if the primary were connected across 100 turns of the coil, and the secondary leads across only 70 turns, then supposing that one volt passed through the primary section, only seven-tenths of a volt would be taken off through the secondary leads.

Here the transforming action is step-down, but it can also be made step-up by simply reversing the ratios and connections of the primary and secondary sections, as depicted in Fig. 5, in which case it is at once perceived that the aerial slider is below the detector slider, and consequently there are more turns of the coil embraced in the secondary section S, than in the primary section P. Hence the secondary voltage impressed upon the detector, would be greater than the primary voltage, or if the primary potential were one volt passing through fifty turns of wire, and the secondary section took in one hundred turns of the same coil, then the latter voltage would be stepped up in the same proportion, or two to one, or the secondary potential would be twice one volt or two volts. Of course, in wireless work, the potentials obtaining in the tuning coil circuits are usually very small, except when a high power station is in close proximity to the station receiving.

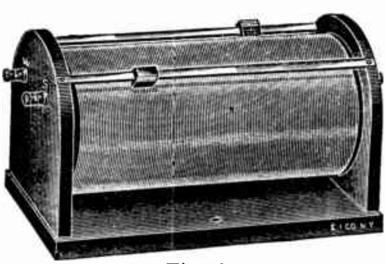


Fig. 4

The receiving station employing any form of a single coil tuning inductance is called a "**close-coupled**" set. In the past few years, due to certain peculiarities occurring in radio-communication, such as static and interference currents, the two-coil or regular type of transformer has been widely adopted, which seems to give the greatest clearness and sharpness in tuning, as it is possible to place the secondary coil in any relative position to the primary or aerial coil.

This type of receiving set, involving the use of a two-coil transformer, is termed professionally a "**loose-coupled**" set, as there is no metallic electrical connection existing between the primary and secondary circuits, in other words, the coupling is therefore loose. A standard form of a receiving "loose-coupler" or transformer is illustrated in Fig. 6.

Receiving transformers are generally made with a primary or outer winding of a comparatively few turns of large copper wire,

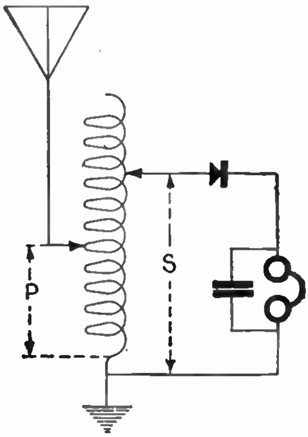


Fig. 5

about No. 18 to 20 B. & S. gauge, and an inner sliding secondary coil having many turns of fine copper wire, about No. 26 gauge, the idea of this arrangement being to give a good step-up ratio between the primary and secondary windings, and consequently in their voltages, although this ratio can be varied considerably by the position of the primary or secondary sliders and of the secondary coil itself.

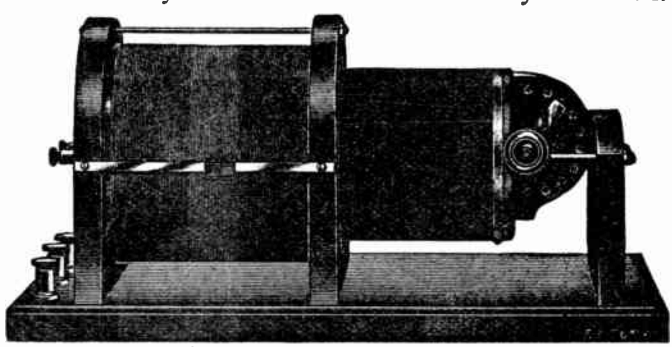


Fig. 6

It has been found, that to be the most efficient for wireless work, which involves the use of high frequency current, the copper wire used on tuning coils or tuning transformers should have the lowest possible inherent capacity. Enameled wire, which has a very high inherent capacity, is thus unsuited for these purposes, and the best wire is bare copper, with the individual convolutions or turns spaced a slight distance apart, so that they do not touch and short-circuit themselves. Double cotton covered wire is also excellent.

The action of the loose-coupler or transformer is as follows:—Referring to Fig. 7, the incoming oscillations or currents surge along the aerial, into the primary P winding of the transformer, and cause an electro-magnetic field of force to be set up around it, whose lines of force naturally embrace the adjacent secondary coil of many turns of fine wire, and induce in it an electro-motive force which passes out into the detector circuit.

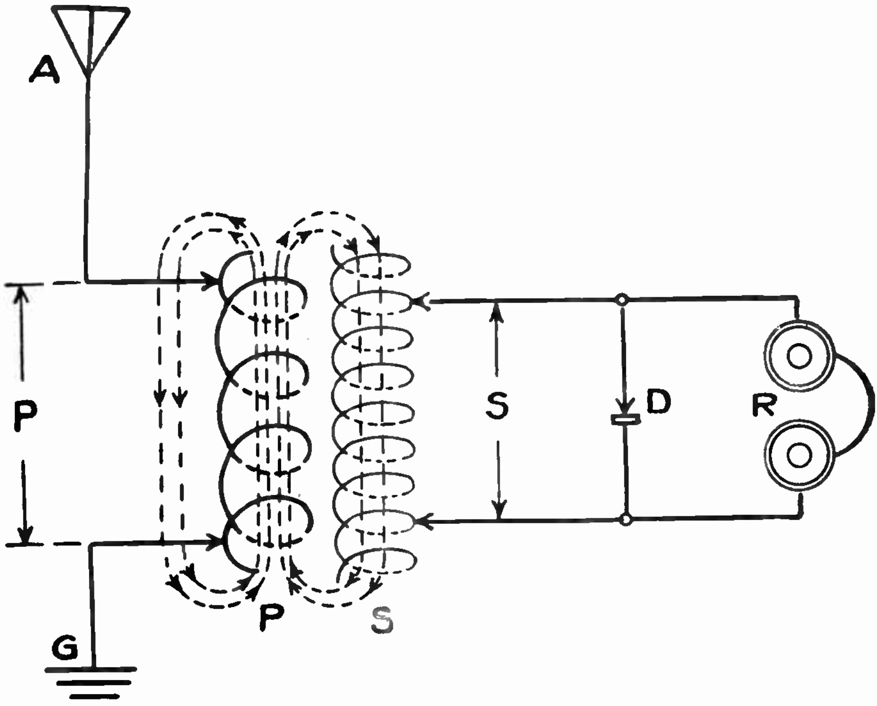


Fig. 7

The electro-motive force induced in the secondary winding of the loose-coupler is dependent upon the ratio existing between the number of primary turns and number of secondary turns, i. e., if the sliders of the primary coil are set to include 20 turns of wire, and the secondary turns in use amount to 100, then the **"ratio of transformation,"** existing between the two coils is as 100:20 or 5 to 1, and the secondary voltage would be equivalent to five times the primary voltage, the current, however, being decreased accordingly, as the total energy cannot be increased, only changed in its form. So if one-tenth of an ampere at one volt pressure was the primary energy passing, and the ratio of transformation existing is 5 to 1, then the secondary energy would be in the form of 5 volts, and but one-fifth of the current or one-fifth of one-tenth ampere, which is one-fiftieth of an ampere. This supposes that the efficiency of transformation is 100 per cent, but for an air-core transformer of this type, the efficiency would be very much below this figure, probably not above 5 per cent. Thus the secondary voltage is equal to the calculated value as stated above, but due to the losses in transformation the current strength is about 5 per cent of the computed value, or 5 per cent of 1-50 ampere, which is 1-1,000 ampere. These figures are taken merely to help explain the action taking place, and are of course much smaller in actual radio work.

Fig. 8

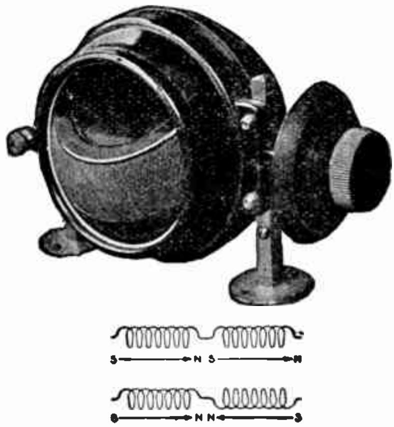


Fig. 9

The reason why this class of apparatus, whether one or two-coil type, realizes such a poor efficiency is because the electro-magnetic lines of force must be carried through the air, instead of iron, which has an electro-magnetic conducting power varying from 100 or more, times that of air. Naturally only a fraction of the magnetic flux of the primary coil reaches the secondary coil.

Instead of having one coil sliding in and out of the other, it may be turned at right angle so that the lines of force no longer can pass through the center of the coil. Any degree of coupling may be obtained by turning the coil more or less. This type of loose coupler is generally called vario coupler and is shown in Fig. 8.

Besides the familiar tuning coil and loose-coupler for receiving purposes, there is another instrument known as a **"variometer,"** which is employed extensively in modern radio sets. This instrument is nothing more than two helices of wire, one within the other, the inner helix being adjustable as regards its position in relation to the other helix.

In Fig. 9 is shown the idea of the variometer. Change in wavelength is accomplished in this instrument by rotating the movable inner coil or helix, to a certain position in respect to the stationary helix, this position determining the value of the self-inductance and mutual inductance of the two coils. When the two windings run in the same direction, the magnetic field of each coil adds to the other, providing maximum inductance, while, when one of the coils is turned at 180 degrees, the fields oppose each other and the resulting inductance is minimum. In any intermediate position, the value of inductance in the circuit varies according to the angle at which the movable coil is placed. The ratio of, inductance from the maximum to the minimum position should be about 4 to 1 in a well designed variometer.

The most important instrument, aside from the detector itself, is the telephone receiver, serving to make intelligible to the human ear, the various changes going on in the detector circuit, whenever an incoming oscillation representing a signal impinges upon it. The changes occurring in the detector circuit, due to the action of the detector under the influence of an oscillatory high frequency current, are infinitesimally small and minute, and naturally an instrument which is capable of detecting and interpreting them, must of necessity be extremely sensitive.

Fig. 10

For the purpose of receiving signals over very short distances, it is possible to use a low resistance telephone receiver, having a small number of turns of wire upon its bobbins, but for serious work over greater distances, it is necessary to employ special wireless receivers, wound with many hundred turns of fine copper wire, and equipped with good strong permanent magnets of the best grade of steel, such as Tungsten or Swedish steel, coupled with a thin soft iron diaphram of proper thickness, the air gap left between the magnet pole-faces and it, being very short and correctly adjusted.

A cut of a pair of head receivers widely adopted by commercial and experimental stations, is shown at Fig. 10. For crystal circuits a very sensitive head-set is desirable. For audion circuits and in receivers for loud talkers sensitivity is neither looked for or desired. A powerful tug on the diaphram without rattler is looked for.

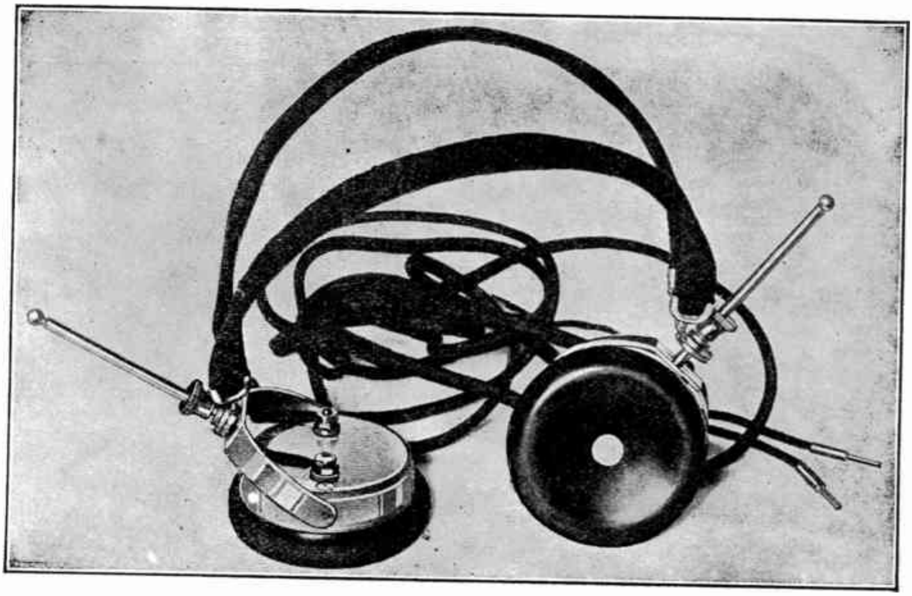


Fig. 11

The sensitiveness of a wireless receiver depends upon the correct proportioning of its various parts; the proper strength of its permanent magnets, and the number of turns of copper wire wound upon its magnet spools, not upon how many ohms of resistance that can be crowded into it. If this were the case, German silver or other high resistance wire might as well be used on the bobbins.

The idea is to get the greatest possible number of ampere turns active on the receiver magnet spools, which determines the effect of a certain current strength upon the diaphram. By ampere-turns is inferred the product of the amperes passing through a coil and the number of turns of wire thereon, this determining directly the amount of magnetic flux, in lines of force per square unit of cross-section, which will be set up to react upon the diaphram.

The best receivers now are wound with No. 36 to 42 B. & S. gauge silk covered copper wire. The resistance in ohms of the various types differ greatly, the commercial styles being wound to a resistance of 1,600 to 3,200 ohms per pair. There were some receivers made having a resistance per set of 10,000 ohms and more, but this very high resistance has no material advantage over other receivers.

The telephone receivers used in radio work are known as the watch case type. Essentially they consist of permanent magnets, curved in shape to fit the metal, hard rubber, fibre, bakelite or composition case. To the north and south ends of these magnets soft iron pole pieces are secured. Upon these pole pieces many turns of fine wire are wound. A diaphram is placed adjacent to the pole pieces. Audio frequency currents passing through the coils of wire, if passing in the proper direction increase the pull of the pole pieces on the diaphram.

Thus if no signal is being received, a constant pull is being exerted on the diaphram by the pole pieces and their relative permanent magnets. In order to make the diaphram of the receiver vibrate as much as possible the strength of the permanent magnets is made much greater than that produced by the current flowing through the windings of the coils. In this way, distortional effects are minimized and the maximum amplitude of vibration of the diaphram for a given amount of signal current is secured.

In Fig. 11 we see a typical radio head-set, similar to the one just described.

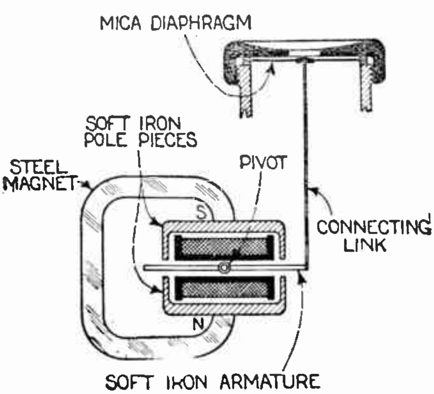


Fig. 12

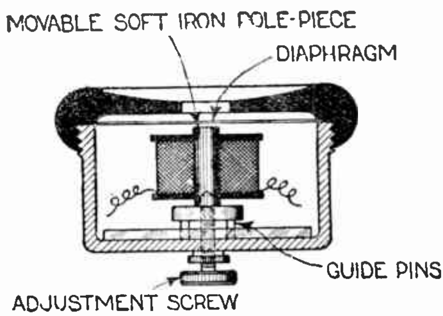


Fig. 13

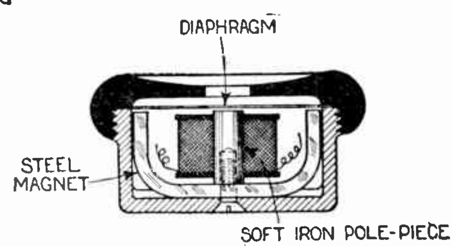


Fig. 14

Another type of receiver, developed during recent years is known as the Baldwin receiver. In this, the diaphram is not initially maintained under tension as in the case of the receivers described above. It is thus more sensitive and more responsive to the pull exerted upon it by the flux caused by the signal current. An entire absence of pull is found only when the receiver is being used with crystal detectors, but the pull, when used in circuits employing vacuum tubes or detectors equipped with a polarizing battery is very slight and may be practically disregarded. In this receiver, when no signal is being received, the armature is balanced in a neutral position (both sides of the armature being acted on in the same direction, by the flux from the permanent magnets, no pull is consequently exerted on the mica diaphram, with which this receiver is equipped. When current passes through the receiver winding, the flux produced combines with the permanent flux and the subsequent asymmetrical distribution of flux, causes a pull to be exerted on the armature and thence via a thin wire, to the diaphram.

Due to the low reluctances of the magnetic circuit the receiver responds powerfully to very weak currents. The armature acts similarly to a lever, a force being exerted at either end and is then transmitted to the diaphram. The diagram of this type of receiver is shown in Fig. 12.

Another style of receiver is the one in which the distance of the pole pieces are varied with relation to the diaphram by means of a thumb screw passing out through the shell of the receiver. This adjustable pole piece receiver is shown in Fig. 13. It possesses the advantage of permitting the pole pieces to be drawn away from the diaphram when strong signals are being received, eliminating, in this manner rattling or buzzing diaphrams due to their striking the pole pieces while vibrating. At the same time the pole pieces can be brought quite close to the diaphram, making weaker signals more audible.

Still another form of receiver is the Tripole Receiver. In this, the permanent magnet is U shaped and so magnetized that the two arms of the U have the same polarity and the center pole of the magnet, coming as it does from the lowermost portion of the U is magnetized oppositely. The wire is wound around this center pole. The receiver cords of the instrument are marked (+) and (—), indicating which of the leads is to go to the positive side of the battery and which to the negative. This is good practice. If the receivers are connected into the circuit so that current passing through them tends to increase the strength of the permanent magnets, the life of the receivers is materially increased. For this reason the jack and plug serves a distinct purpose in that once the phones are connected to the jack, errors in connecting them to the vacuum tube receiving set after they have been disconnected are not likely to occur. The arrangement of the receiver is shown in Fig. 14.

We could name countless types of telephone receivers differing in some respect or other, but the reader is for the present left with this brief description so that the other important phases of radio communication may be considered.*

We will now study the functions of other instruments used to receive radio waves.

To begin with, the diagram, Fig. 15, shows the use of a variable condenser, in connection with a loose-coupler, a detector and a pair of receivers.

**For collateral reading the student is referred to a book such as the "How and Why of Radio Apparatus," by H. Winfield Secor. This contains information regarding other types of receivers.*

There are more different types and designs of **condensers** than one can easily keep in mind; but they are all the same elementally, irrespective of their outward appearance. Likewise, in a sense they all serve the same purpose: namely, to accumulate ("condense") and release electrical energy, but the ends to which they serve differ greatly. In any standard receiving set there are **fixed** and **variable** condensers. Some are used for **tuning,** some to **by-pass** electrical energy and others to **block** electrical energy. There are many other purposes which they can service in a receiving set and its attendant devices.

The importance of condensers is not fully appreciated by the average radio student. Without them, radio would be a hopeless affair. Many of the successful radio circuits and many of the new radio devices, such as "B" eliminators, are reliant more on condensers than on any other part.

In order to gain a satisfactory conception of the value of condensers and the ways in which they can be used, one must have some understanding as to how they function.

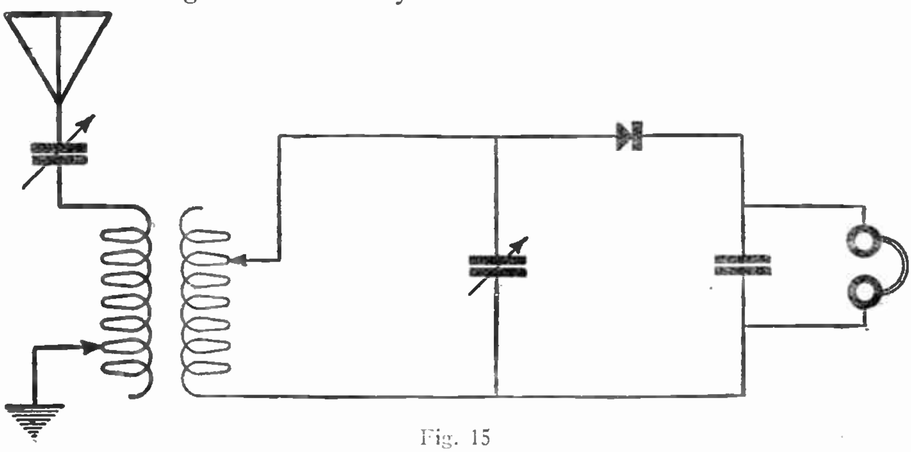


Fig. 15

Basically, a condenser consists of nothing more than two electrical conductors insulated from each other. If we take two metal plates and bring them close to each other, we have formed an electrical condenser. If we move the two plates towards or away from each other the capacity of the unit is altered. The nearer the plates are to each other, the greater is the capacity, and vice versa.

The unit of capacity is the farad. Since this value is too large for practical purposes we employ the more convenient terms microfarad (abbreviated as mf. or mfd.) and micro-microfarad (abbreviated as mmf. or mmfd.). The first is one thousandth of a farad, and the second the thousandth part of a microfarad. All condensers employed in radio have capacities which can be stated conveniently in one or the other of the above units.

The capacity of a condenser is determined by a number of factors. These factors are: the total surface area of the two conductors, the distance between the two conductors, and the nature of the insulation between the conductors, which is called the dielectric. Let us take an example: assume a condenser of two plates, each three square inches in area, with an air space between them of ¼ in. If we increase the area of both plates to six square inches, the capacity of the condenser is doubled. If we decrease the air space between the plates to ⅛ in. the capacity takes a big jump—four times; for the capacity of any condenser varies inversely with the square of the distance between the two conductors.

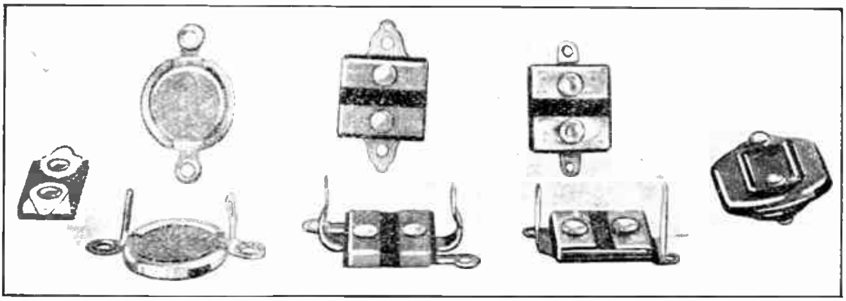


Fig. 16

The capacity can be further increased if the nature of the dielectric or insulation is changed. If instead of air as the dielectric, we use, say, castor oil so that it fills up all the space between the two conductors, the capacity of the condenser will have increased nearly five times. The amount of increase in capacity in this instance is dependent on the dielectric constant of the medium employed, which is expressed on a comparative basis. Air is the standard, and is considered to have a dielectric constant of 1. The constant of castor oil is 4.7, of good mica 5.7 and of paraffin, 2. If paraffin was used in place of air the capacity would be exactly doubled.

In order to produce the necessary capacities for radio work, series of small metal plates or sheets, spaced one above the other, are used so that the size of the condenser will not be too large. In other words,

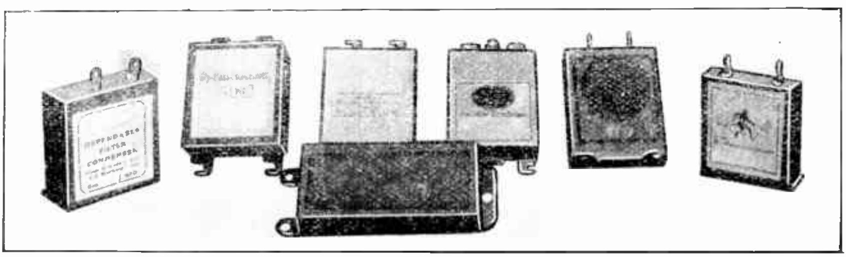


Fig. 17

instead of using two very large plates to get the required surface we pile up a batch of small ones, the alternate plates being connected together. Thus, a fixed condenser must consist of six small sheets of foil with mica between sheets. The first, third and fifth sheets, connected together, would constitute one conductor; and the second, fourth and sixth sheets, also connected together, the other, the five sections of mica being the dielectric.

Dry air is the most satisfactory dielectric, as it introduces no serious losses. Other forms of dielectric, such as hard-rubber, mica, paraffin, paper, etc., present higher leakage paths than air, and also

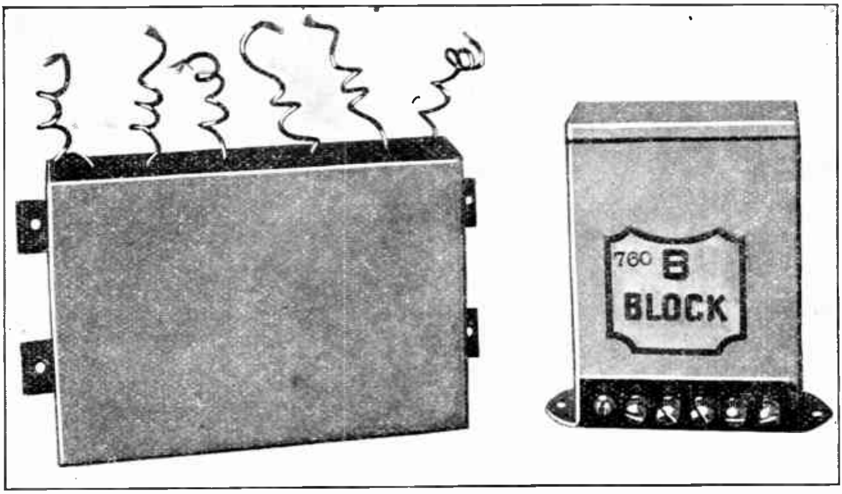


Fig. 18

introduce "hysteresis" losses. It is for this reason that air is employed as the dielectric in most variable condensers designed for use in receiving circuits. Fixed condensers employ either mica or paraffin paper, as the losses brought about by their use are not very high, comparatively. The main point, however, is the reduction in size made

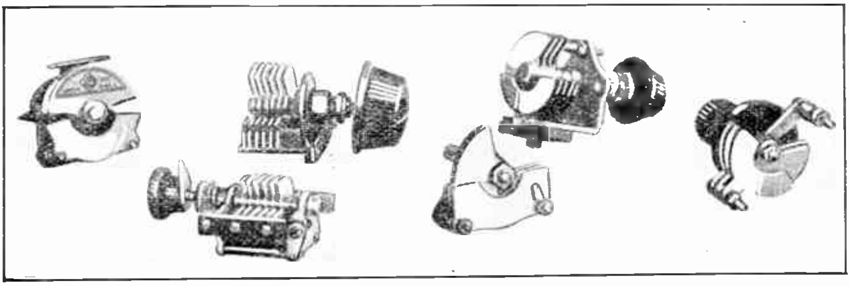


Fig. 19

possible by the use of a dielectric with a high constant, which allows extremely small spacing between conductors. Furthermore, it is not so important to keep down the losses in fixed condensers as it is in variable condensers. In most cases fixed condensers are not connected in the "vital points" of a receiving circuit.

A condenser can be likened to a water tank. We can charge a condenser with electricity, just as we can pour water into a tank. The

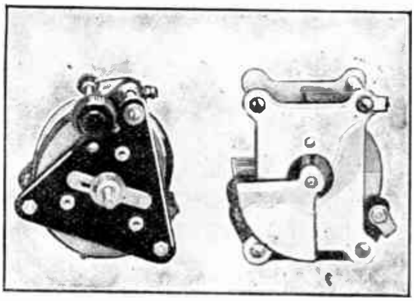


Fig. 20

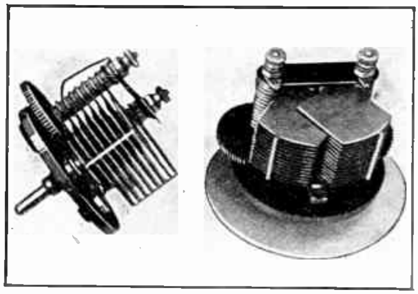


Fig. 21

amount of electricity a condenser can hold is dependent on its capacity. The amount of water a tank can hold depends on its size. When a condenser is connected in a working circuit and becomes fully charged, that is, filled to capacity, it will automatically discharge its entire contents through an attached circuit. When it is empty it will start

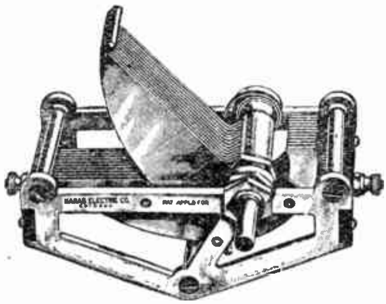


Fig. 22

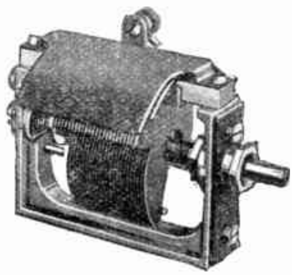


Fig. 23

charging again. The number of times a condenser will charge and discharge each second depends on its capacity and on the frequency of the current flowing in the circuit containing it. It is obvious that it takes a condenser of large capacity longer to charge than one of small capacity. Consequently, it will discharge at a slower rate than a small one. The capacity of a condenser has a great deal to do with its reactance, or resistance to currents. A condenser of small capacity offers high resistance or reactance to alternating currents of low frequency, but as the frequency of the current increases the reactance of the condenser decreases.

Right here is supplied the missing link in the explanation. It will be noted that the reactance of any condenser increases as the frequency of the alternating current is lowered. If we continue to lower the frequency, until it alternates only once every minute or so, the reactance of the condenser to it is practically infinite. When the current ceases to alternate, or becomes direct current, the reactance of the condenser is infinite and no current can flow through it. It becomes a blocking device. The answer is, then, that a direct current cannot pass through a condenser, but an alternating current can. The

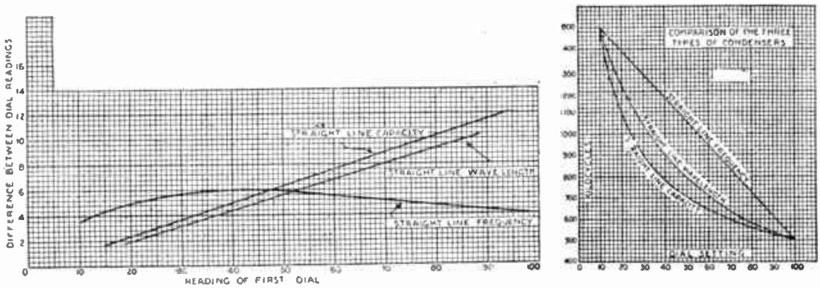
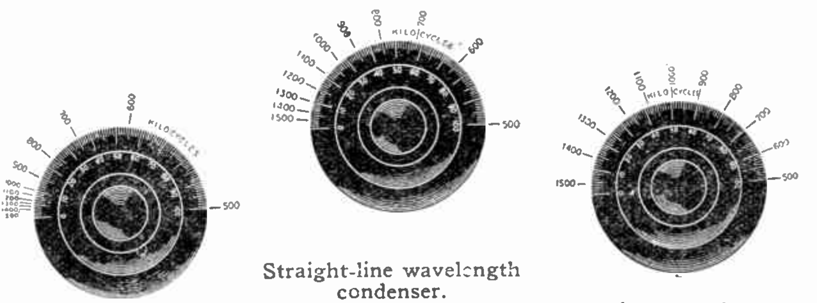


Fig. 24

amount of alternating current that can pass depends on its own frequency and the capacity of the condenser. These characteristics of a condenser are important.

It might be well to explain here just how important variable condensers are in a radio circuit. The chief property of a coil used in a receiver is inductance, and it is this property, together with the capacity of the condenser, that makes it possible for us to vary the frequency of our receiving circuits and so "tune-in" one station after another.



Circular plate condenser.

Straight-line wavelength condenser.

Straight-line frequency condenser.

Fig. 25

In order to change the point of resonance of a circuit (at which it responds to a station's carrier wave) from one frequency to another, if the inductance is fixed, then the capacity must be capable of being varied. It is thus that turning the dials of the tuning condensers in our sets adjusts them to receive the desired signals; each variation in the capacity of the condenser "tuning" its coil to a different frequency, or wavelength.

There is a condenser for every purpose. The illustration of Fig. 16 shows a batch of ordinary fixed condensers employed in receiving circuits as grid-condensers, by-pass condensers, blocking condensers, fixed balancing condensers, etc. They are made in many different capacity values, ranging from .00004 mfd. (40 mmfd.) to about .01 mfd. (10,000 mmfd.). Those shown underneath are designed specifically

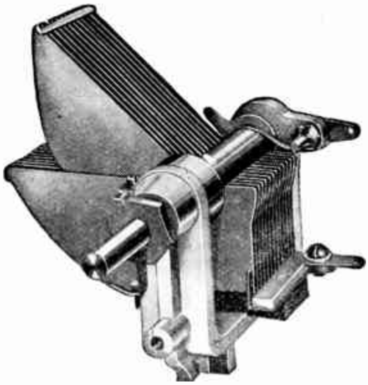


Fig. 26

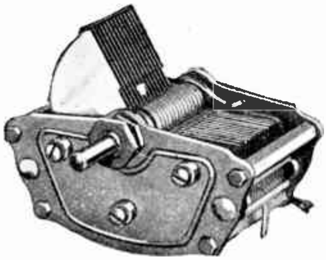


Fig. 27

for use as grid-condensers, and have clips on them for the grid leaks. Their capacity value in most every case is .00025 mfd. which is the size usually employed for this purpose.

Fixed condensers of larger capacity, from 0.1 mfd. to about 2.0 mfd., are naturally of greater size. They are employed primarily as by-pass condensers in radio and audio frequency circuits, as blocking condensers in resistance and impedance coupled audio frequency amplifiers, and sometimes as filter condensers in tone filter circuits. A number of different makes are shown in Fig. 17.

Two condenser-bank units, containing all the capacities necessary for a "B" eliminator filter-network, are shown in Fig. 18. These condensers are also capable of withstanding very high voltages without breaking down.

"Vernier" condensers are nothing more than very small variable condensers, and are valuable in any receiving circuit requiring very fine tuning. They are often employed in connection with tandem or gang variable condensers as a means for making up for any discrepancy in capacity between two of the sections. Like the adjustable condensers, they may also be employed for the purpose of balancing radio-frequency or regenerative circuits. A number of these condensers is shown in Fig. 19.

There are four types of variable tuning condensers: the straight-line-capacity, the straight-line-wavelength, the straight-line-frequency and the straight-line-tuning, which is an evolution from the other forms. The straight-line-capacity variable condenser gives a comparatively uniform increase in capacity as the rotor plates are turned and intermesh with the stator plates. A condenser of this type, used for tuning purposes in a receiving circuit, does not give a uniform increase in wavelength as the dial is turned from zero to maximum.

The straight-line-wavelength condenser (Figs. 20 and 21) does not give a uniform increase in capacity when varied, but does give a uniform increase in wavelength. In other words, the wavelength to which the set is tuned will increase so much for a definite number of degrees on the condenser dial, throughout the entire scale. With a straight-line-capacity condenser it may take only one degree on the lower part of the dial to make a 10 meter change, but five or ten degrees on the upper part of the dial for the same change.

The straight-line-frequency condenser (see Figs. 22 and 23) as the name implies, gives a uniform increase or decrease in frequency, so that every degree on the dial will represent a definite change, say of 10 kilocycles. Figs. 24 and 25 show graphs and typical dial settings

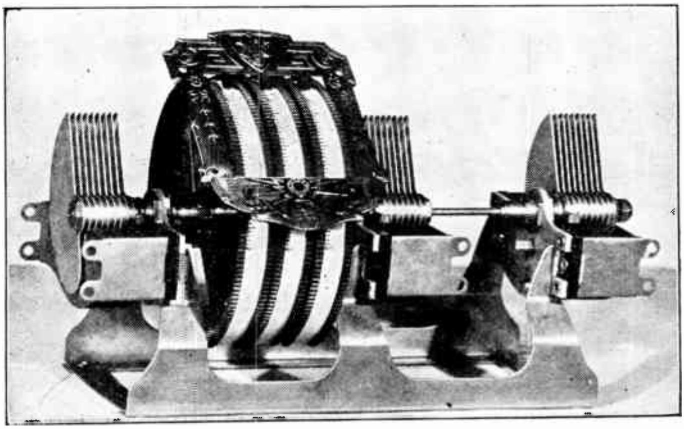


Fig. 28

of three different types of condensers for comparison. The straight-line-tuning condenser (see Figs. 26 and 27) has several advantages of both the S.L.W. and S.L.F. condensers. It provides for a more evenly-spaced distribution of stations throughout the dial readings, and does not tend to bunch them at any one band of wave-lengths or frequencies.

A gang or tandem condenser (see Fig. 28) is designed for use in receiving circuits where it is desirable to group two or more stages of tuned-radio-frequency amplification under a single control. Manufacturing developments have made possible producing accurately-graded condensers of this type. The discrepancy in capacity between the units, from zero to maximum, is usually so small that it can be disregarded in most cases.

PART II

THE DETECTORS

THE most vital instrument in the receiving set is the detector, though this instrument is largely dependent on the efficiency of the telephone receiver for the results.

The student will recall that we have stated in previous lessons the fact that energy radiated from wireless transmitting instruments is in the form of alternating current of extremely high frequency. Now, the student will logically suppose that an instrument could be inserted in the aerial circuit between the aerial and the ground, and that the current would operate this instrument so that an indication of passing current could be obtained. But, a galvanometer cannot be made to indicate such high frequency current since the pointer would have to move with the same rapidity as the periodic changes in the oscillations, and the results would be that the moving parts in the galvanometer would remain stationary, being unable to follow the rapid motion. The same results apply to the telephone receiver, since the diaphram cannot follow the rapid alterations of the received energy. Furthermore, in the case of a telephone receiver, on account of the large self-induction of the instrument, the high frequency voltage generated by the waves would produce in a circuit containing a telephone receiver only extremely weak currents. It is therefore obvious that an instrument must be resorted to, in order to transform this high frequency current so as to make it operative on the telephone receiver.

Such an instrument is known as a detector, and the various types of these detectors operating on a different principle are classified as follows:—

Coherers; Magnetic; Thermal; Crystal Rectifiers; Electrolytic, and Vacuum detectors.

We will first consider the **coherer** type, which has already been described in an earlier lesson. The coherer exists in various forms, the most widely known form being the filings coherer, originally employed by Marconi. Such a coherer is no longer employed commercially, and is only used to demonstrate the principles of wireless telegraphy to an audience. This detector is extremely unreliable, and must be continuously adjusted. If a loud signal is suddenly received by the coherer, it will cause it to "jam," by which is meant that the fine filings will become burnt and permanently connected together, so that the coherer no longer is operative to signals, and must be replaced by a new one. The coherer having a multitude of disadvantages, was quickly abandoned for detectors offering better characteristics.

Another type of coherer which does not employ the filings, is the Branly-Popoff detector, which consists of three oxidized-steel pointed rods in the form of a tripod, resting on a steel plate. The connections are similar to those of the coherer, the detector being connected in series to a relay through a dry cell. The signals cause the small steel rods to cohere more firmly to the steel plate, in such a manner that the resistance of the oxide is broken down and allows the current from the battery to flow through the relay magnets. The relay operates a magnetic device which tilts the tripod arrangement of the small rods, and restores the originally high resistance.

A relay for electrical purposes consists usually of a pair of electro-magnets arranged with an armature or moving contact bar in front of their pole pieces, this contact bar being normally held away from the magnet poles by a spiral spring and whenever a current passes through the electro-magnet coils, the armature bar is attracted and its contact closes an electrical circuit by coming in contact with the stationary electrode. As soon as the current ceases to flow through the magnet windings, the armature bar is released and the contact broken.

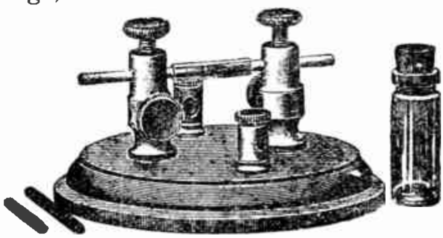
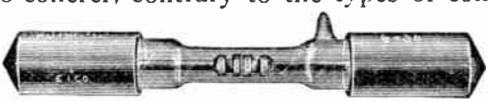


Fig. 1

Another form of coherer is known as the **auto-coherer**, which consists of a small glass tube filled with carbon grains. On both sides of the grains, plugs of brass which have been silver-plated to increase the conductivity are inserted. In some instances, iron or carbon plugs are used, though it is largely a matter of choice. Fig. 1 illustrates the auto-coherer, and it might be interesting to add that this was the type of detector employed by Marconi when he received the first signals transmitted across the Atlantic Ocean at St. John in 1903. The auto-coherer, contrary to the types of coherers described



Slaby-Arco Vacuum Coherer

thus far, does not operate a relay, inasmuch as the drop in resistance is too slight, but it is used in connection with one dry cell connected to a low resistance telephone receiver of but 75 ohms. High resistance telephones are of little value in connection with this detector, since the drop in voltage of the detector is amply sufficient to operate a low resistance receiver. The signals are exceedingly loud, though the disadvantage exists that the detector is microphonic in action, and all sounds in the room or on the operating table will be plainly heard in the telephone receiver. Fig. 2 illustrates the connections employed in the telephone circuit of this detector, a potentiometer may be added in order to allow for a better adjustment of the voltage, though this may be dispensed with if desired. The auto-coherer is but little used except by lecturers who desire to illustrate the principles of radio communication.

The erratic behavior of the coherer led Marconi to develop and perfect his **magnetic detector** which was based on the results of experiments by Rutherford and other scientists. This detector is shown in Fig 3. It consists of a band made of a few insulated soft iron wires passing over two small discs revolved by clock work. In this manner the band continually passes in front of the poles of two small horseshoe magnets arranged as shown in the diagram. The band passes through a small glass tube in front of the magnet; on this is wound two coils, one being connected in the aerial circuit or in

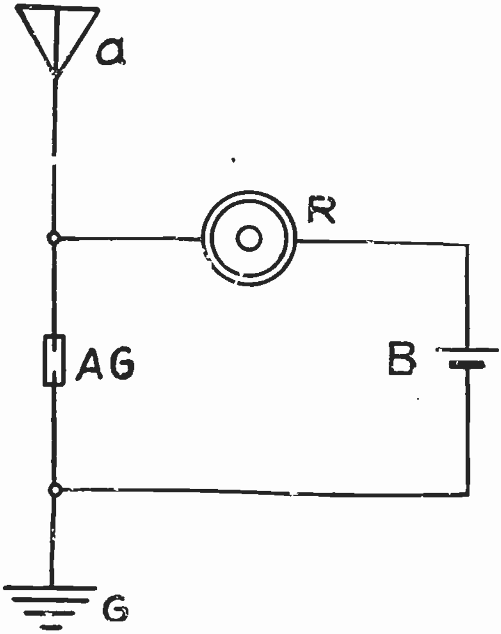


Fig. 2

the secondary of a loose coupler, the other coil being connected to the telephone receivers as shown. The action of this detector is very simple; as the iron wires pass in front of the magnets they become magnetized; their magnetic condition depending upon the arrangement of the magnets. When iron or steel is magnetized it does not lose all its magnetism immediately if the magnetizing force is removed. This retention of magnetism depends in amount on the quality of the iron and is due to what is called magnetic hysteresis. Thus the portion of the iron band passing away from the front of the magnets retains some magnetism but when the incoming signals set up oscillation in the receiving circuit these oscillating currents have the effect of suddenly diminishing the number of magnetic lines in the band. Since the magnetism of the wire forming an iron core inside of the coils is suddenly reduced a current is induced into the coil connected to the telephone, thus producing a sound in the phones which corresponds to the incoming signals. This detector was very reliable and was almost universally used for all ship stations until more sensitive devices came into use.

The **electrolytic detector** functions on the same principle as the electrolytic rectifier used extensively today for transforming alternating current into direct current. It is based on the following action:

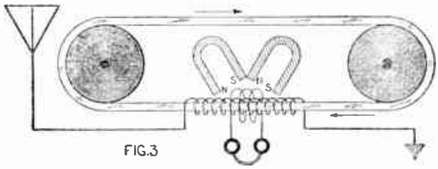


FIG.3

If a current of electricity is passed by means of two electrodes through water diluted with sulphuric acid, hydrogen and oxygen gases are set free, the oxygen being deposited on the positive electrode called anode and the hydrogen deposited on the negative called kathode. Since oxygen is a very active gas the positive plate should be of material such as platinum which the oxygen cannot attack. This

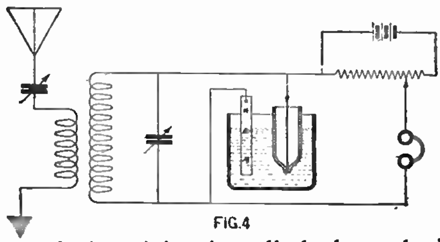


FIG.4

action of a current of electricity is called electrolytic action. When the plates are coated with gas bubbles they are said to be polarized. This polarization not only increases the resistance of the circuit but also sets up a difference of potential between the plates which acts in the opposite direction to the applied voltage and has a value of almost 1.5 volts. Therefore when polarization takes place the cur-

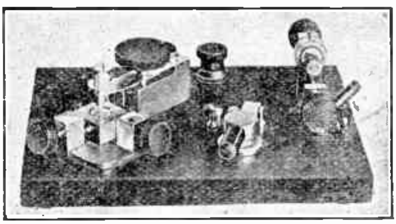


Fig. 5

rents flowing in the circuit is reduced and if the applied voltage is adjusted so as to be about equal to the voltage set up by polarization the current is reduced to almost zero value.

For detecting small electrical oscillations only a very small electrolytic cell is necessary, one plate of which consists of an extremely fine platinum wire sealed in a small glass tube. See Fig. 4. The platinum wire is cut off exactly to the same level as the surface of the glass tip so that only its section is in contact with the electrolyte. The other electrode may be a piece of silver wire or a drop of mercury connected to the other terminal of the cell, both of the electrodes being in a solution of water and sulphuric acid. The polarizing voltage is obtained by means of a small battery and a potentiometer which permits a fine adjustment. Under these conditions a current will flow in the circuit but immediately polarizes the small platinum point. If the polarizing potential is properly adjusted no sound is heard in the telephone when no signals are received but as soon as signals are received oscillations are applied to the electrolytic detector and half of each of these oscillations will be rectified since the current can only pass in one direction depolarizing the platinum electrode and letting the current pass through the telephone receivers. This type of detector is not used any more today but was considered one of the best in the early days of radio.

Under the **crystal rectifier** type we find the many different detectors employed in present day systems. The term "crystal rectifier" was suggested by Dr. George W. Pierce of Harvard University, in place of the cognomen formerly employed to signify certain detectors possessing the electrolytic valve or rectifying action, these having been known at one time as "thermo electric" detectors due to their action not being fully understood.

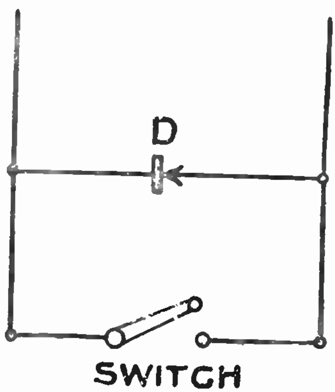


Fig. 6

The crystal rectifying detector, which may consist of a proper crystal or set of crystals of mineral formation, when placed in a wireless receptive circuit possesses the phenomenon of passing a current in one direction many times better than in the other. Hence, when an oscillating or alternating current such as that which surges on an aerial circuit passes through the detector, the rectifying action is set up and results in the produced pulsating direct current acting on the telephone receivers. These pulsations of current flowing in the telephone receivers cause the diaphrams to be alternately attracted and released giving rise to the familiar buzzing sound by which the signals or voices are heard. It will thus be noticed by the student that the alternating current of the high frequency waves flowing through the receiving circuit, is rectified so that all the same polarity impulses are caused to flow through the telephones, while the other polarity impulses flow through the ground. In this manner the telephone receivers operate on direct current of a pulsating nature, resulting in the aforesaid buzzing sound. The property of these crystals to allow current to flow through in one direction often is as marked as 400 to 1, i. e., negative or positive impulses, as the case may be, will flow through 400 times easier in one direction than in the other, thus allowing the telephone receivers to operate practically on direct current.

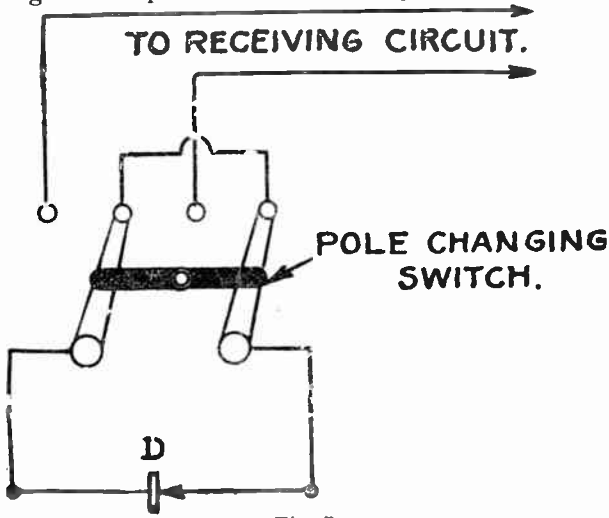


Fig. 7

The **galena** or **silicon detector** is the most popular type of crystal rectifier used today. The latter employs a piece of the artificial product known as fused silicon, which is manufactured in the electrical furnaces at Niagara Falls. Silicon is a black or sometimes grayish material, very hard and brittle, and resembles coal. It has a bright silver lustre, especially after being broken and exposing a fresh surface.

Silicon is usually placed in a metal cup or special clamp. If used in the former, a solder or other metal alloy melting at a low temperature is employed to hold the crystal in place and to make contact with same. Woods Metal, which can be purchased at any chemical supply house, is the most popular material, since it melts at an exceedingly low temperature. The use of this material greatly improves the sensitiveness of the crystal, since the heating which would be applied to the solder if same were used to hold the crystal, is eliminated. Solder should not be used if possible, for it causes the crystal to lose its sensitiveness to a great extent.

A very popular mineral detector is shown in the illustration of Fig. 5, in which the material is held in the square metal cup. A switch on the base places either of the two detectors into the circuit. The square cup is itself held quite rigidly on the base but may be orientated by adjusting the two thumb screws which shift its position. A light tension can be produced between the crystal member and the upper pointed wire contact. This contact is also arranged on a spring which may be varied by the hard rubber knob adjustment screw, allowing the tension at the contact point to be varied at will. In utilizing this detector for other crystals a different standard will be found mounted on the same base.

In the foregoing example the student has been introduced to the most popular type of mineral detector, but there are other professional types in which the relative position of the crystal and the contact points may also be very accurately and positively adjusted. The contact point in the ordinary detector is generally of brass or bronze, but it has been ascertained that generally the best results are obtainable when the metallic contact resting on the silicon is of gold. For this purpose, the student may employ a gold stick pin, which will be found to give excellent results. Steel needles are also found to give good results, and fine copper wire, resting gently on the crystal, is also very effective.

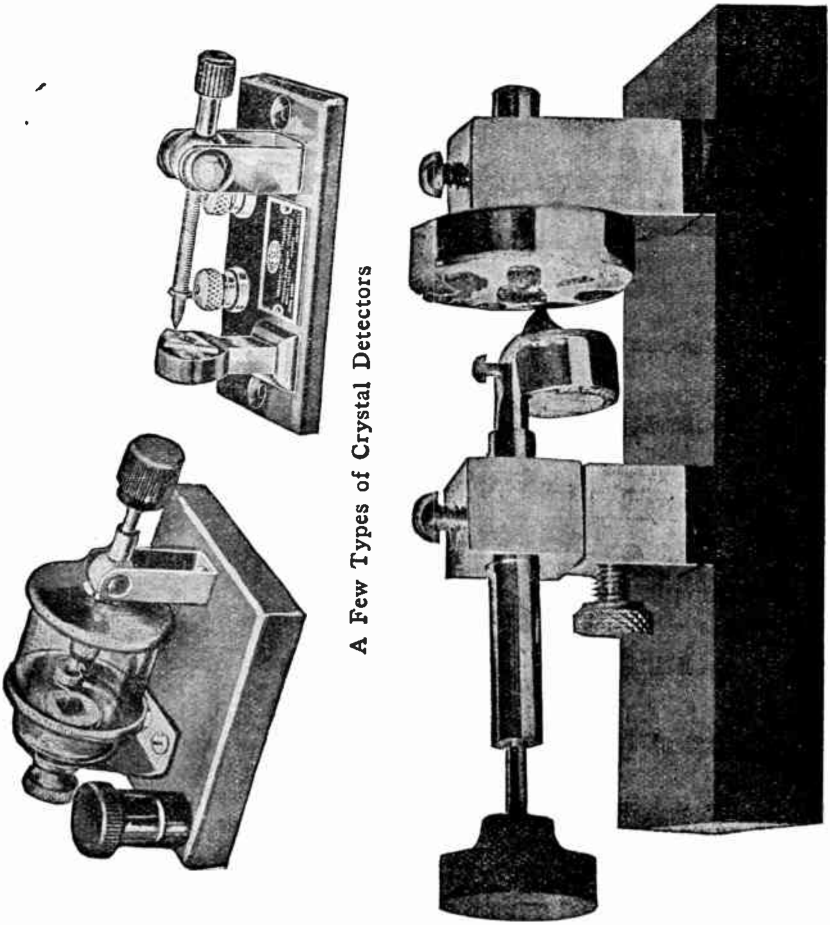
Telephone receivers used with crystal detectors should be of high resistance. For the best results, telephone receivers of at least 2,000 ohms per pair should be used, and slightly higher resistance windings are in some instances found to be even better.

Crystal detectors are subject to disadvantages, the most important of which is the fact that if a nearby station is sending when the detector is being used, the sensitiveness will be destroyed. This is probably caused by the fact that the heat of the oscillations passing through the contact of the detector causes an oxidizing effect, which interferes with the proper action. All crystal detectors aside from the pyron detector, which will be shortly described, and the carborundum type, are subject to this disadvantage on the passing of heavy high frequency current such as that of the home station or nearby transmitters. If the detector is short-circuited, as shown in the Fig. 6, or better still, arranged with a pole-changing switch so that the leads may be completely disconnected and the detector itself short-circuited, as illustrated in Fig. 7, the sensitiveness can be preserved while transmitting. No battery is necessary with silicon detectors, but is sometimes used, the negative pole connecting to the silicon.

The **Pyron detector**, which was developed by G. W. Pickard of Amesbury, Mass., and patented by him, is somewhat similar to the silicon type in form excepting that the upper tension spring carrying the pointed contact is wide and massive, its adjusting screw being of a very fine thread. The pyron crystal is iron pyrites, the former name being the trade name under which the detector is known. Its upper face is highly polished and the detector, while combining high sensitiveness with other numerous features, has the very important merit of withstanding heavy nearby discharges without being knocked out of adjustment, and for this reason was much in use in the United States Navy, on battleships.

Another type of crystal detector which has been developed by G. W. Pickard and is guarded with patent rights, is the **Perikon de-**

tector. This detector consists of two crystals, copper pyrites and zincite, held in firm contact against each other. The mounting of these two crystals is exceedingly clever, the copper pyrites crystal being mounted in a cup on a rod which is so arranged that it can be swung in all directions and contact with any portion of the crystals can be obtained. The zincite crystals are in turn mounted in a large cup; usually a number of these being used. The two crystal surfaces



A Few Types of Crystal Detectors

Fig. 8

are brought into a firm contact by means of a spring the tension of which can also be varied. The Perikon detector is probably the most sensitive of the crystal rectifying types, though this is largely a matter of opinion. The authors, after extensive experiments, have found that Galena, if used according to the method advocated by them and explained in a later description, is probably the most sensitive of the crystal detectors, more so than the Perikon. The Perikon detector is illustrated in Fig. 8, and was formerly used in the Navy and Army wireless stations as well as in the better commercial stations. Its ease of adjustment made this detector one of the most popular, and it produces a sharp clear sound in the telephone receivers. The nearby stations also effect its adjustment as in the instance of the silicon detector. To overcome the effect of the strong oscillations, the Perikon detector has lately been placed in a small pool of oil, so that oxidization of the elements, either by the natural action of the atmosphere, or the more rapid effect of strong signals, are reduced to a minimum.

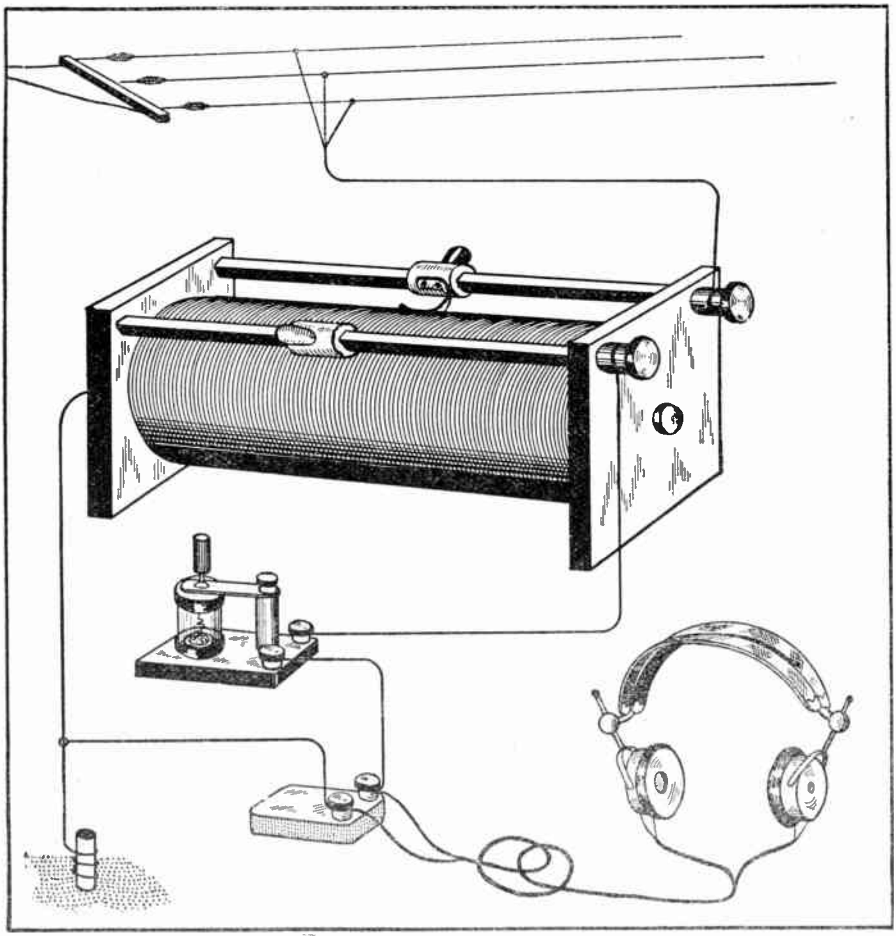


Fig. 9

It is well to state that galena and silicon are also used in the same manner, and in fact the covering of these detectors with dust-proof covers has for years been employed. Such precautions prevent the oxidization of the crystals to a great extent, and the absence of the dust renders the sensitiveness much greater. No battery current is employed with Perikon detectors, the same wiring scheme being used for all other crystal detectors. If battery current is sometimes used, the voltage is very low and regulated by a potentiometer. The polarity of this current must be such that the positive line is connected to the copper pyrites.

Galena is a mineral crystal of lead, and is obtained from mines practically the world over. The crystals resemble a bluish or grayish colored substance, which when broken forms into straight surfaces or cubes. These surfaces have a bright mirror finish. Good galena, more so than silicon or the other crystals, has the great disadvantage of being difficult to obtain for use in wireless telegraphy, inasmuch as some pieces may be very sensitive, while other pieces will be of little use. In fact, pieces taken from the same large piece, will be entirely different, one probably very sensitive, and the other of no use at all. However, by buying either selected crystals, or large single pieces which can be broken into a number of smaller ones, it is possible to obtain several good specimens.

The authors have performed numerous experiments with galena, and have stated that it is the most sensitive of the crystal detectors if correctly used. Galena cannot be employed between two flat discs, for the broad surface contact in this case does not allow the rectifying valve effect to be marked. For this reason, fine contact of little surface should be used.

In the experiments the contact materials of various types were tried. German silver has been found to have remarkable advantages, and was used with success for long distance receiving. Steel needles do not give such good results. The sensitiveness of galena was found to be entirely destroyed by the heating of the solder in which it was placed, and for this reason solder was entirely abandoned. Clips to hold the crystal have been advocated and are today used in some crystal receiving sets. The most satisfactory contact arrangement was found to be a fine wire of about No. 30 B. & S., bare copper, resting lightly on the surface of the galena crystal. This fine wire is usually called "cat's whisker."

Molybdenite is another mineral which consists of many layers compressed together. These layers can be taken apart and resemble lead foil. Molybdenite is usually employed between flat contact surfaces. It can also be used with a point, but owing to its softness, a point is not convenient. The great characteristic of Molybdenite is that it can withstand the passage of powerful electrical oscillations without being materially effected in adjustment. It is, however, little used, inasmuch as the sensitiveness is very low.

One of the most popular types which was universally used in commercial stations through the fact that it withstood powerful oscillating currents, was the **Carborundum detector.** This detector is employed with battery current regulated by an adjustable resistance, the voltage being from 1 to 1.2 volts as found by G. W. Pickard. Carborundum is a product of the electrical furnaces, created at a temperature of 7,000 degrees F. and is a combination of salt, sand, sawdust, and coke. It is an exceedingly hard crystal. When employed in a detector, the student will discover that the results will be better if the lengthwise section of the crystals is used. The blue colored crystals will be found to be the best, though green colored crystals are claimed to be superior to any. The poorest quality are those varying from a black to a gray color. This detector may be used in the same wiring diagram as that of the electrolytic detector.

Aside from crystal detectors, the next class is found under the **thermo-electric detectors.** These operate on the well known principle of thermo-electric couples in which heat applied or developed at the junction of certain different metals establishes an electro-motive

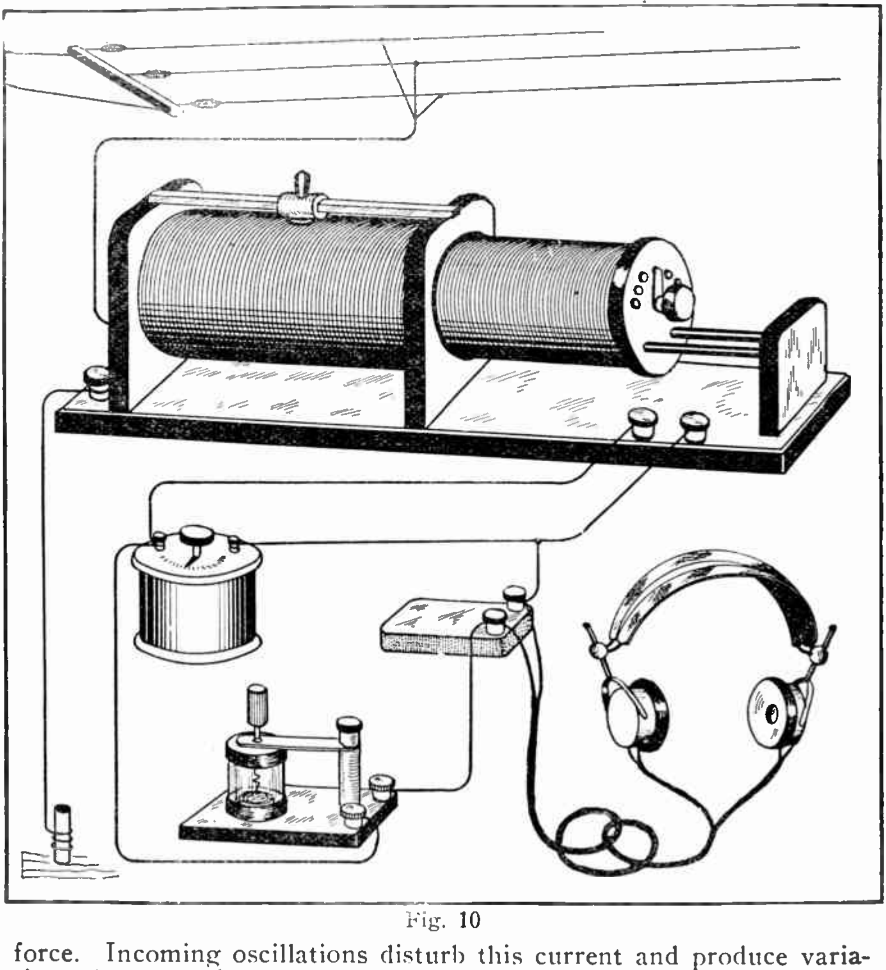


Fig. 10

force. Incoming oscillations disturb this current and produce variations thereof which are perceptible in the telephone receivers.

In Figs. 9 and 10 are shown some suitable circuits to be used with crystal detectors. One of the devices shown is a two slide tuning coil while the other is a loose coupler which permits greater selectivity to be had. These tuning instruments are described in detail in another lesson.

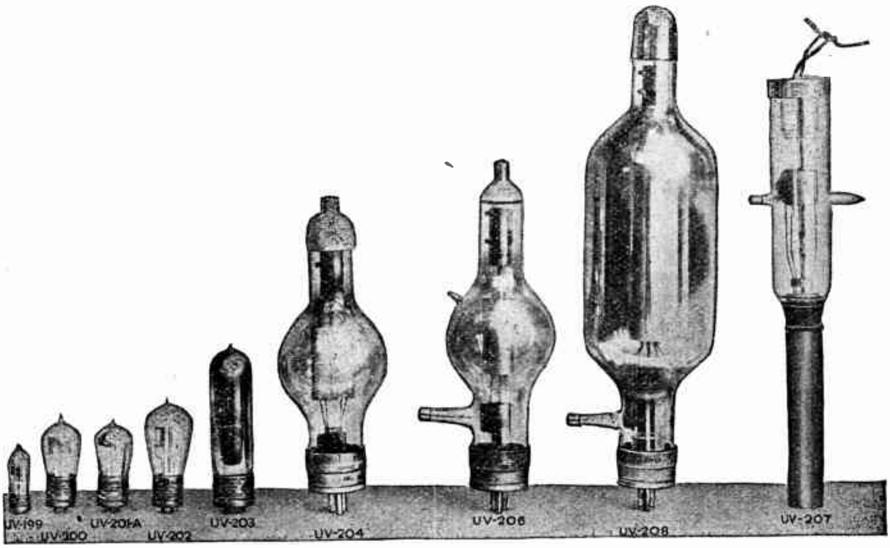
The vacuum tube detectors will be described in the next part.

PART III

THE VACUUM TUBE AS A DETECTOR

IN our study of the various detectors employed in radio communication, we now reach the most important and useful of all—that is the **Vacuum Tube.** The term Vacuum tube has become quite general and popular, but other names are often employed and these sometimes confuse the amateur who wonders whether each name refers to a distinct and separate instrument.

So if you read or hear of such names as audion, vacuum valve, oscillion, pliotron, audiotron, you will know that these are in some cases pet names given by certain investigators while in other cases they are trade names employed by manufacturers to distinguish their own particular product from that of others. We, on the other hand,



A Group of Modern Receiving and Transmitting Vacuum Tubes

shall refer to this wonderful lamp as the Vacuum Tube, exclusively, which is often abbreviated to simply V.T.

It may be said that the entry of the Vacuum Tube has done more for the rapid advance of radio communication than any other given instrument. Not only that, but it is capable of performing more functions than any other electrical device. Its main and most important uses are for the three big factors in the radio of today, which are: **Detection and rectification, amplification of signals, generation of oscillations.** Then, too, new applications of the vacuum tube are gradually being made so that possibilities of further development are certainly promising.

The vacuum tube as it is in its present form, is the result of the work carried on by many scientists. Back in 1884, that great American inventor, **Thomas Alva Edison,** took one of his incandescent lamps and observed that when the filament was heated to a white glow, a very small electric current could be made to flow between the filament to a cold plate closely adjoining it in one direction only. He called his device an "Electrical Indicator" and later it was named the **Edison valve.** Years afterward, **Dr. J. A. Fleming** of England applied the **"Edison effect"** to radio telegraphy for the first time, and he called his device the **Oscillation Valve.** This scientist was the first to apply the emission of electrons from heated filaments for the detection and rectification of radio frequency oscillations in a radio telegraph receiving system.

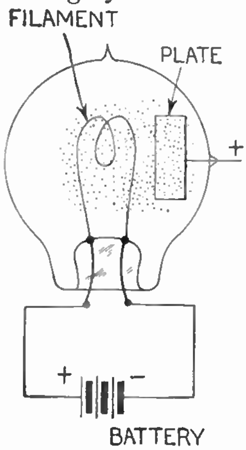


FIG. 1

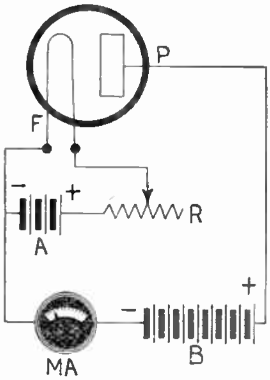


FIG. 2

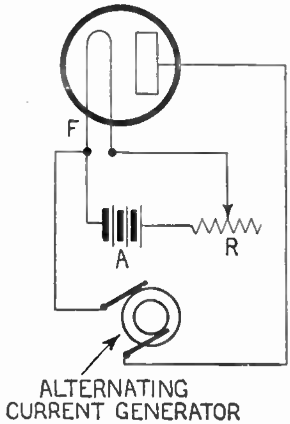


FIG. 3

An Electron is the smallest particle of matter known to science, and it is supposed to carry the smallest possible charge of negative electricity on its travel from one body to another. In other words electrons really consist of very small amounts of negative electricity. In the case of Vacuum Tubes, electrons act as carriers of electricity between the filament and the plate which are separated from each other and placed in a vacuum.

Fig. 1 shows what takes place within the inside of a Vacuum Tube of the Fleming two-element type. By two-element we mean the kind which employ simply a filament and a plate. The three-element vacuum tube is the one employing filament, plate and grid, which we shall describe later.

Referring again to Fig. 1, as soon as the filament of any electric incandescent lamp is heated to a red or white heat the filament immediately begins to emit or throw out electrons in a very rapid manner and in all directions. In the case of an ordinary lamp, the electrons simply hit the sides of the glass bulb and if we connect a set of dry batteries between the filament and plate so that the negative pole of the battery is connected to the negative side of the filament and the positive pole to this metal plate, the negative electrons will be greatly attracted to the plate because it is of a positive polarity.

If the plate be made negative instead, the electrons will be repelled and will try to find other landing places. It is simply a matter of likes attract unlikes, but repel likes as in the case of the permanent horseshoe magnets with their north and south poles which you have often played with.

In Fig. 2, we have a simple form of the original oscillation valve used by Dr. Fleming, and called the **Fleming Valve.** F is a filament heated to incandescence by the battery A, the current of which is controlled by the rheostat R. If we connect a battery of cells between the negative side of the filament F and the plate P so that the positive side of this second battery is connected to the plate, we will find if we introduce a sensitive current meter such as the milliammeter M.A. (which will respond to the thousandth part of an ampere) that a small amount of current is capable of passing through the space separating the filament and the plate in one direction only, that is from the plate to the filament and this small current will register upon the milliammeter. On the other hand, if the polarity of this battery is reversed, i. e., if the plate side is made negative instead of positive, we will find that no current can pass through the system.

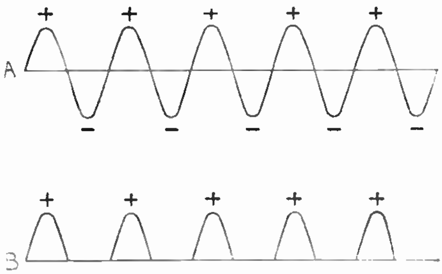


FIG.4

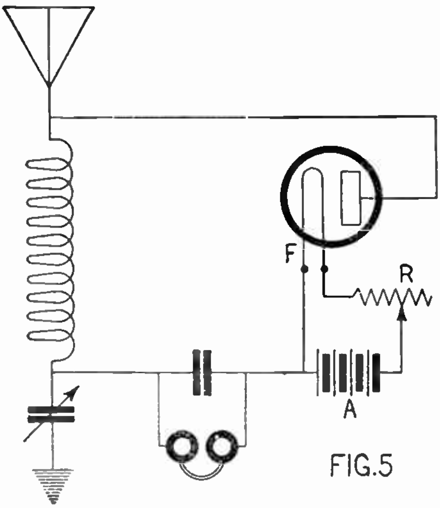


FIG.5

This action means that we have a rectifier at our disposal because if we substitute an alternating current for the battery B as in Fig. 3, we will find that only one-half of a cycle, the positive side, will pass through, while the other half of the cycle (the negative side) will be unable to pass. Fig. 4 illustrates this action where the upper graph A is seen five cycles of alternating current that is constantly changing from positive to negative as it travels along a circuit, and which is the sort of electricity furnished by the A.C. generator of Fig. 3. Graph B of Fig. 4, on the other hand, shows what happens to the A.C. (alternating current) when it passes through the Fleming Valve rectifier. Only one-half of the five cycles remains—the positive half. As for the negative half it is not present. Thus, we have the same rectifying action of the valve and this same rectifying principle is employed to rectify the incoming oscillations of a radio telegraph receiving system.

Since, in order to receive radio waves, it is necessary to first rectify their A.C. nature into a pulsating D.C. (direct current) which will operate the telephone receivers and cause a sound to be heard, the **Fleming Valve** may be used **as a detector** on account of the rectifying action we have just mentioned.

Fig. 5, therefore, shows this two-element vacuum tube being used as a detector of radio oscillations. Although this circuit is a very

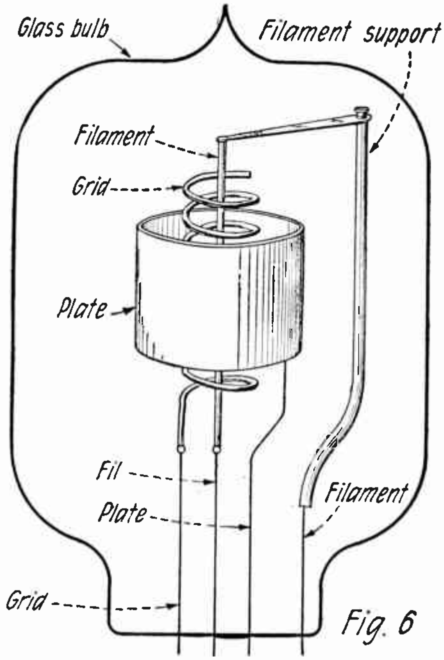


Fig. 6

elementary one, it will function fairly well. In some cases, however, an additional set of batteries are used in the plate circuit with better results. The action of this circuit is a rectifying one; that is to say the incoming radio oscillations which represent the signals are rectified where but one-half of their alternations (that is their positive side) is permitted to pass through to the filament circuit and thence to the phones as previously mentioned in the graphs of Fig. 4.

After years of experiments, **Dr. Lee deForest** produced a valve similar to the Fleming valve but in which a third electrode was mounted (the three-electrode tube). This electrode placed between the filament and the plate is known as the grid, and is composed of a little solenoid surrounding the filament as shown in Fig. 6. It is sometimes made in the shape of a ladder placed on both sides of the filament as in certain transmitting tubes, but its role is the same in all cases.

Now to study the functioning of the three electrode vacuum tubes, we will use the diagram shown in Fig. 7. As already explained, a plate-filament circuit is secured by the electrons traveling from the filament to the plate, since they are attracted by the plate positively charged; and allows the current from the battery B to flow in this circuit from the plate to the filament as in Fig. 8. Thus the electrons act as a conductor. If we connect the grid to the common point 0 including in the circuit a battery and a milliammeter, as in Fig. 8,

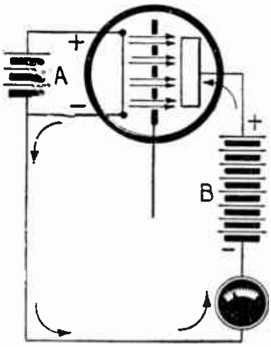


FIG.7

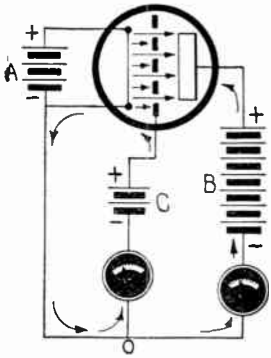


FIG.8

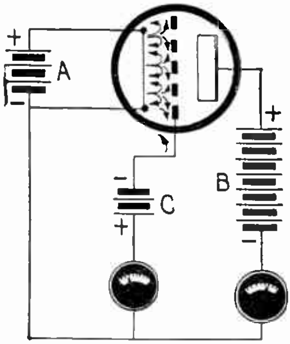


FIG.9

it will be seen that a current flows in the grid circuit because a certain number of electrons are stopped by the positively charged grid and allows the current of the battery B to flow in the circuit, in which case we have a grid-filament current.

Now, if we change the polarity of the grid, what will happen? In Fig. 9 the flow of electrons from the filament, when the grid is negative is repulsed, for in this case the electrons are negatively charged since we know that two polarities of the same nature repulse

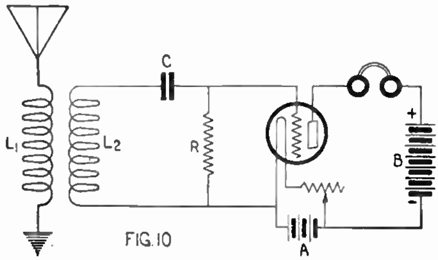


FIG. 10

one another. Therefore, the current from the plate, having no electronic support to travel on, is then quite suddenly stopped.

One can understand from this explanation that the grid acts as an automatic interrupter, but since no mechanical parts are to be moved it has no inertia, and it can therefore open and close the circuit of the plate a tremendous number of times per second.

By properly connecting a three electrode vacuum tube in a receiving circuit, it may be used as a detector which is of the most sensitive type. We shall therefore explain its functioning as a detector.

Since we know that changing the polarity of the grid from positive to negative opens and closes the plate circuit, we can easily accomplish this by means of the alternating current received in an aerial, as shown in Fig. 10, and at the same time rectify this current for reception purposes.

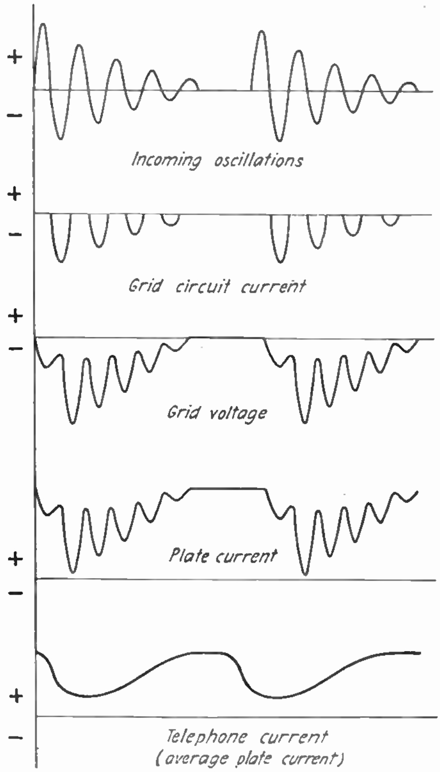


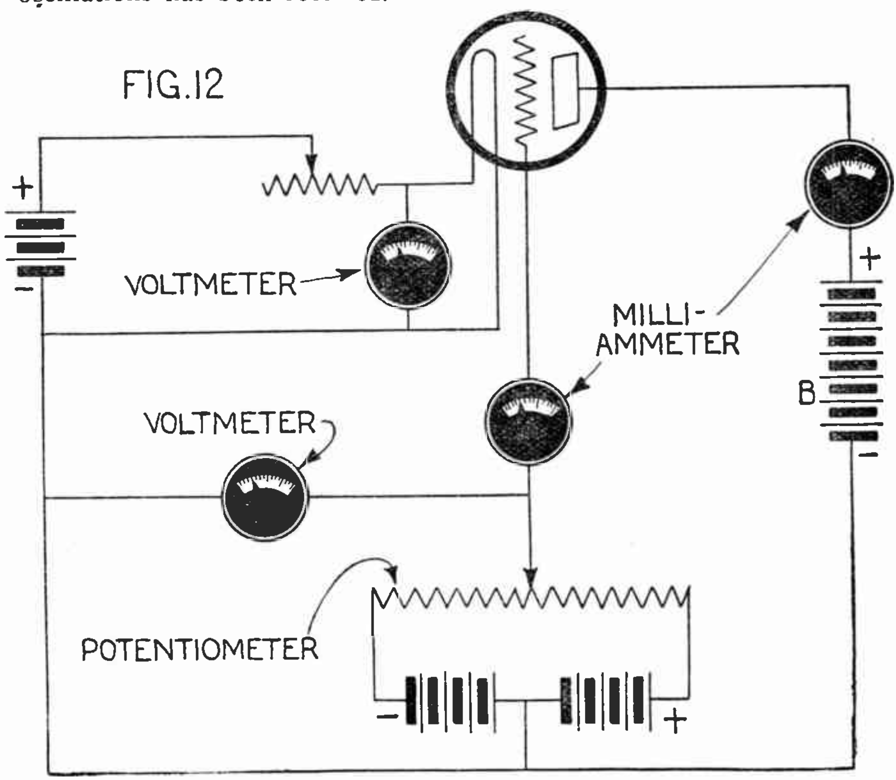
Fig. 11

The receiving set which employs a crystal detector and a telephone receiver has been described in a former lesson and reasons were given, why a telephone cannot respond to radio frequency oscillations. In order to make the vacuum tube function properly at all times as a rectifier of oscillations, you must introduce additional and necessary appliances in the grid circuit. These are the **grid condenser** and the **grid leak** which you no doubt have already heard of. In the case of Fig. 10, when no oscillations are being received in the grid circuit, the grid potential is therefore at a zero value and the result is that no current flows in the circuit, that is to say, none of the electrons are stopped by the grid but instead flow straight through from the filament to the plate without interruption.

Incoming oscillations will induce an alternating current in the circuit L2. The charges of electricity in C will cause the grid to become alternately positive and negative, decreasing and increasing by the same amount. When the grid is negative (with respect to the filament), no current can flow in its circuit, as was just explained. But when the grid is positive, negative electrons will flow to the grid and will be stored up in the grid condenser C. The next oscillation will repeat this process and add a negative charge to the grid condenser C. Thus the grid condenser stores up more and more negative charges as long as the oscillations continue. It will be plainly seen that as the grid condenser becomes more negative, the grid itself becomes more and more negative with respect to the filament.

Now, Fig. 11 shows the relation between plate current and grid potential. As the grid becomes negative, the plate current decreases. Therefore, it may be said that by means of the grid condenser incoming oscillations cause a gradual decrease in the plate current. If the oscillations were to continue, the grid would become so negative that the plate current would be stopped. So it is necessary to remove the negative charge from the grid condenser after each group of oscillations has been rectified.

FIG. 12



Old type audions contained a certain amount of gas which acted as a conductor and permitted the negative charges to leak off the grid to the filament and neutralize themselves with the positive charges on the other plate of the condenser C. The new high vacuum tubes do not permit this action because of the absence of any gas. A conductor of some kind must be connected from the grid to the filament over which the charges can flow. This conductor should be of such a resistance that no current can flow in it until the condenser C has been fully charged, i. e., not until the end of the group of the oscillations. If the resistance is too high, or else entirely absent, the charges will accumulate until they are large enough to pass through the vacuum of the tube. This action will be noticed by a constant "put, put, put" sound in the telephones. The resistance just described is called the "grid leak." It is shown as "R" in Fig. 10. The actual value of it depends upon various things, but is almost always between one and four million ohms.

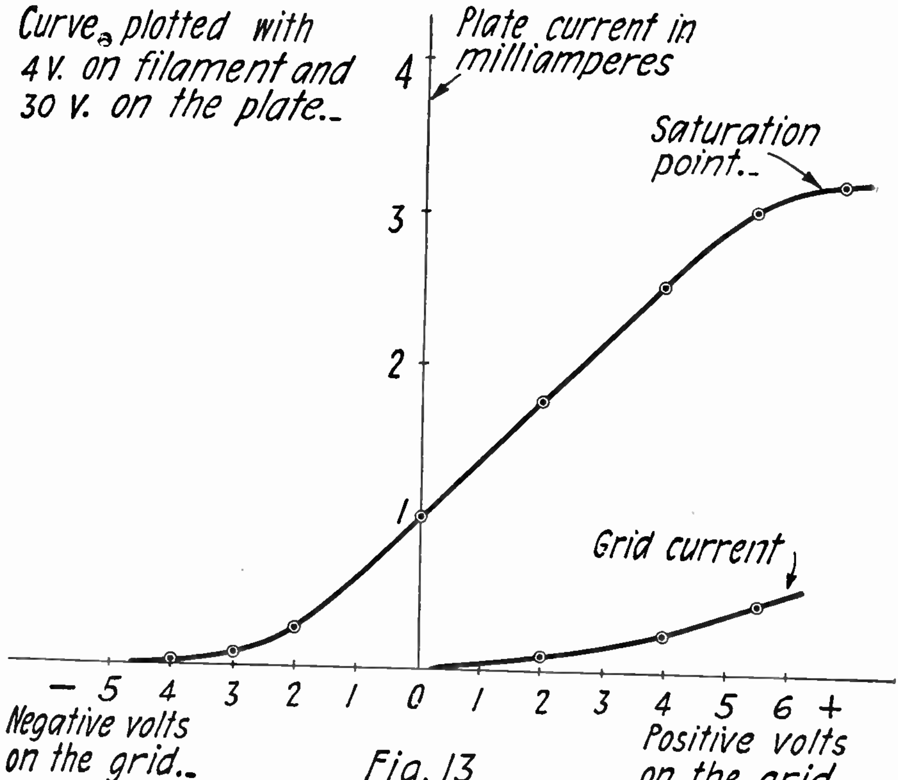


Fig. 13

When oscillations flowing in the circuit, L2, are impressed upon the grid condenser, they pass through the condenser and not through the leak on account of its high resistance but the charge on the grid which is of constant polarity leaks slowly through this high resistance preventing the vacuum tube from "blocking." In a word, it is a safety valve regulating the amount of potential applied on the grid. By varying this resistance up to the proper value, the tube will be made more sensitive for a certain intensity of signals.

Every vacuum tube has some particular characteristics. These may be found by tracing the characteristic curve which shows at a glance the efficiency of the tube as a detector or an amplifier. The curve may be plotted by using the hook-up shown in Fig. 12. The voltage on the grid may be adjusted by means of the potentiometer, in steps of one volt. For each adjustment of the grid voltage, it will be noticed that the current in the plate circuit measured by means of the milliammeter varies. The readings are then marked with dots on a squared paper and all the dots are joined together forming the characteristic curve of a tube. For instance, Fig. 13 shows the characteristic curve of a tube. It will be noticed that when the grid is at zero volt in respect to the negative end of the filament, the plate current is 1 milliampere, while when the grid is at two volts negative, the plate current is reduced to .25 milliampere.

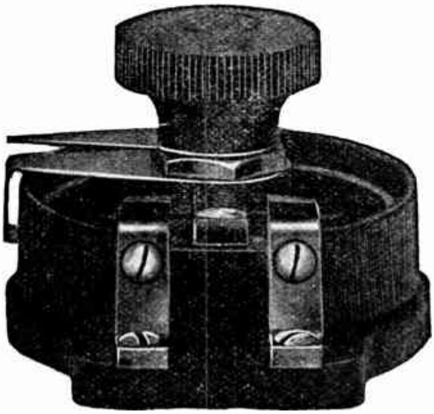


Fig. 14

Every vacuum tube has what is called a saturation point at which no more plate current may be made to flow, even by increasing the plate voltage. This is the limit of the tube operation, as only the straight part of the characteristic curve is useful for amplifying. If a milliammeter is connected in the grid circuit it will be noticed that a current flows in this circuit as the grid is made positive. It is shown with the curve in Fig. 13.

In vacuum tube receivers it is usual to have a special **rheostat** connected in the filament circuit of the tube in order to regulate the amount of current passing through it. The rheostat is generally constructed so that the blade can slide off the wire and open the circuit acting at the same time as an interrupter for the filament current. The resistance of common type of rheostat for receiving tubes is generally 5 or 6 ohms while for transmitting tubes it is generally 1½ to 2 ohms, the size of the wire being larger in order to carry the intensity of the filament current without undue heating. The resistance wire of a rheostat should be tightly wound around the insulating strip upon which it is fixed so that the wire does not become loose after heating and cooling several times. The blade sliding over the wire should provide a good contact and run smoothly so as to touch all the convolutions of the wire equally well. Fig. 14 shows a rheostat as used for receiving tubes.

In order to make contact with the various elements inside of a vacuum tube a special receptacle or socket is used. It is composed of a shell made of metal or insulating material and four blades provided with binding posts touching the prongs of the tube to make contact with the internal elements. The contact blades should be made of strong phosphor bronze or of copper with a steel blade under

Fig. 15

it which provides elasticity while the coupler blade insures good electric contact. The four blades should be strongly fixed in the base so that they cannot become displaced if the binding post is unscrewed as this may cause a short circuit and burn the filament of the tube if they are not in the proper place. It is important that the base supporting the binding posts and contacts be made of good insulating material such as hard rubber or bakelite. If composition or fibre is used, losses may result as these have not sufficient insulation re-

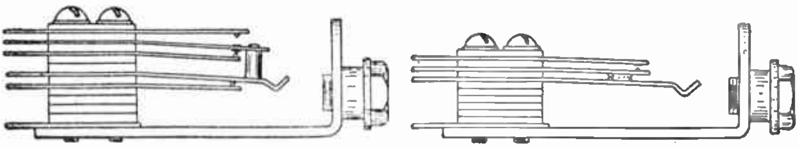


Fig. 16

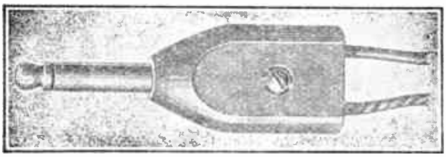


Fig. 17

sistance and sometimes allow some current to pass through especially when high tension is used on the plate of the tube as in transmitting sets, for instance. Fig. 15 shows a good type of socket.

A very convenient method of connecting various apparatus is by means of plugs and jacks somewhat similar to those used in telephone switchboards, but especially designed for radio use. Jacks are now extensively employed in amplifiers, as when a plug is connected to the telephone or loud speaker cord, the connections may automatically be made to the various stages of the amplifier. Some jacks are so designed that when the telephones are plugged in a certain stage of an amplifier equipped with these jacks the unused tubes are automatically disconnected thus reducing the number of controls and permitting the rheostats to be left in the position of best operation. The connections of an amplifier using this type of jacks are shown in the lesson on vacuum tube circuits. Fig. 16 shows two types of jacks which permit several combinations to be made in radio circuits, Fig. 17 shows a type of plug widely used.

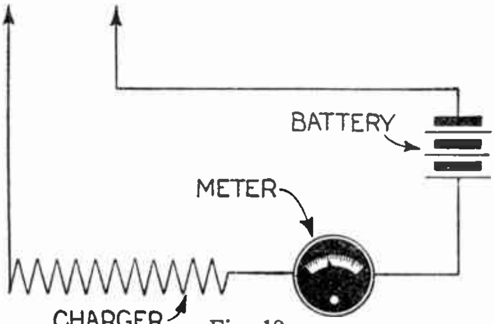


Fig. 18

When vacuum tubes are used in a receiving set, a storage battery usually supplies the necessary current to light the filaments of the tubes. This battery described in a previous lesson, must be recharged every time it is exhausted. Several devices are now extensively used to recharge storage batteries from direct or alternating current lines and are most convenient when a source of current is available, permitting the battery to be recharged over night while the receiving set is not in operation. Fig. 18 represents the diagram of a special resistance box so designed that a 6 volt storage battery may be recharged from a 110 volt direct current line at a rate of about 6 amperes when connected in series with it. A direct current ammeter mounted on the charger shows the amount of current passing through the battery.

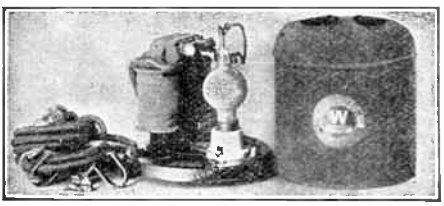


Fig. 19

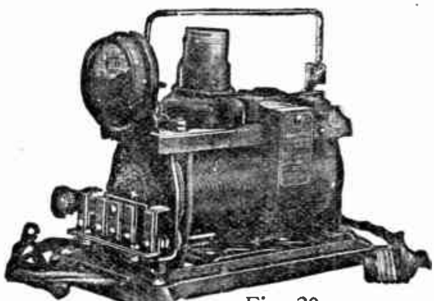


Fig. 20

When only alternating current is available a rectifier transforming this current into a direct one must be used as the storage battery cannot be recharged directly from an alternating current line. Either a mechanical, a vacuum tube or an electrolytic rectifier must be used, the last one being too bulky and complicated to be convenient. There are on the market at the present time some very good types of mechanical and vacuum tube rectifiers designed to charge batteries at various intensities. Fig. 19 shows the general appearance of a vacuum tube rectifier which is quite extensively used. Fig. 20 illustrates a mechanical type of rectifier which gives very good results and has the advantage of using both halves of each cycle of the alternating current, thus reducing the time of charge accordingly.

CHARACTERISTICS OF VACUUM TUBES

GENERAL								DETECTION					AMPLIFICATION						
MODEL	USE	BASE	MAXIMUM OVERALL DIAMETER	MAXIMUM OVERALL HEIGHT	"A" BATTERY VOLTAGE (SUPPLY)	FILAMENT TERMINAL VOLTAGE	FILAMENT CURRENT (AMPERES)	DETECTOR GRID RETURN LEAD TO	GRID LEAK (MEGOHMS)	GRID CONDENSER (MFD)	DETECTOR "B" BATTERY VOLTAGE	DETECTOR PLATE CURRENT (MILLIAMPERES)	AMPLIFIER "B" BATTERY VOLTAGE	AMPLIFIER "C" BATTERY VOLTAGE	AMPLIFIER * PLATE CURRENT (MILLIAMPERES)	OUTPUT RESISTANCE * (OHMS)	MUTUAL CONDUCTANCE * (MICROMHOS)	VOLTAGE AMPLIFICATION FACTOR	MAXIMUM UNDISTORTED OUTPUT (MILLIWATTS)
	DETECTORS AND AMPLIFIERS																		
RADIOTRON UX-201-A	Detector Amplifier	RCA Large Standard UX Base	$1\frac{13}{16}$"	$4\frac{11}{16}$"	6 Storage	5.0	25	+F	2 to 9	00025	45	1.5	135 90	9 $4\frac{1}{2}$	2.5 2	11,000 12,000	725 675	8 8	55 15
RADIOTRON UV-199	Detector Amplifier	UV 199 Base	$1\frac{1}{16}$"	$3\frac{1}{2}$"	Dry Cell $4\frac{1}{2}$ Storage 4	3.0	.06	+F	2 to 9	.00025	45	1	90	$4\frac{1}{2}$	2.5	16,500	380	6.25	7
RADIOTRON UX-199	Detector Amplifier	RCA Small Standard UX Base	$1\frac{3}{16}$"	$4\frac{1}{8}$"	Dry Cell $4\frac{1}{2}$ Storage 4	3.0	.06	+F	2 to 9	00025	45	1	90	$4\frac{1}{2}$	2.5	16,500	380	6.25	7
RADIOTRON WD-11	Detector Amplifier	WD-11 Base	$1\frac{3}{16}$"	$4\frac{1}{8}$"	Dry Cell $1\frac{1}{2}$ Storage 2	1.1	25	+F	3 to 5	00025	$22\frac{1}{2}$ to 45	1.5	90	$4\frac{1}{2}$	2.5	15,000	400	6	7
RADIOTRON WX-12	Detector Amplifier	RCA Large Standard UX Base	$1\frac{7}{16}$"	$4\frac{11}{16}$"	Dry Cell $1\frac{1}{2}$ Storage 2	1.1	.25	+F	3 to 5	00025	$22\frac{1}{2}$ to 45	1.5	90	$4\frac{1}{2}$	2.5	15,000	400	6	7
	DETECTORS																		
RADIOTRON UX-200	Detector Only	RCA Large Standard UX Base	$1\frac{13}{16}$"	$4\frac{11}{16}$"	6 Storage	5.0	1.0	−F	$\frac{1}{2}$ to 2	.00025	$16\frac{1}{2}$ to $22\frac{1}{2}$	1	—	—	—	—	—	—	—
RADIOTRON UX-200-A	Detector Only	RCA Large Standard UX Base	$1\frac{13}{16}$"	$4\frac{11}{16}$"	6 Storage	5.0	.25	−F	2 to 3	00025	45	1.5	—	—	—	—	—	—	—
	POWER AMPLIFIERS																		
RADIOTRON UX-120	Power Amplifier Last Audio Stage Only	RCA Small Standard UX Base	$1\frac{3}{16}$"	$4\frac{1}{8}$"	Dry Cell $4\frac{1}{2}$ Storage 4	3.0	.125	—	—	—	—	—	135	$22\frac{1}{2}$	6.5	6,600	500	3.3	110
RADIOTRON UX-112	Power Amplifier	RCA Large Standard UX Base	$1\frac{13}{16}$"	$4\frac{11}{16}$"	6 Storage	5.0	.5	—	—	—	—	—	$157\frac{1}{2}$ 135 90	$10\frac{1}{2}$ 9 6	8 6 2.5	4800 5500 8800	1670 1435 890	8.0 7.9 7.9	195 120 40
RADIOTRON UX-171	Power Amplifier Last Audio Stage Only	RCA Large Standard UX Base	$1\frac{13}{16}$"	$4\frac{11}{16}$"	6 Storage	5.0	.5	—	—	—	—	—	180† 135† 90	$40\frac{1}{2}$ 27 $16\frac{1}{2}$	20 16 10	2000 2200 2500	1500 1360 1200	3.0 3.0 3.0	700 330 130
RADIOTRON UX-210	Power Amplifier Oscillator	RCA Large Standard UX Base	$2\frac{3}{16}$"	$5\frac{5}{8}$"	Transformer or Storage 8 8 8 6 6 6	7.5 7.5 7.5 6.0 6.0 6.0	1.25 1.25 1.25 1.1 1.1 1.1	—	—	—	—	—	425† 350† 250† $157\frac{1}{2}$ 135 90	35 27 18 $10\frac{1}{2}$ 9 $4\frac{1}{2}$	22 18 12 6 4.5 3	5000 5100 5600 7400 8000 9700	1550 1500 1330 1020 940 775	7.7 7.6 7.5 7.5 7.5 7.8	1540 925 340 90 65 18

† Loudspeaker coupling recommended at this plate potential due to large plate current.
* At indicated "B" and "C" battery voltages.

The above table explains the detailed characteristics of vacuum tubes. Practically every tube will give results on some circuits that cannot be duplicated on others. Many tubes are often found to change with use, which is seldom the fault of manufacture but usually caused by vacuum changes and the varying currents applied through the filament and plate elements.

PART IV

THE REGENERATIVE RECEIVING SET

A RECEIVING SET will receive radio messages sent in code and will also receive Broadcasting programs, sent by radiophone. Very often the mistake is made of calling a receiving set a radiophone. This error should be avoided as a radiophone is really a transmitting apparatus. As stated in another part of this book, a crystal receiving set cannot receive a Broadcasting station at a distance exceeding 25 or 30 miles except under exceptional conditions which cannot be controlled. In general, the power used at the Broadcasting station and the sensitivity of the crystal detector does not permit clear reception of the signals at a greater distance than mentioned above.

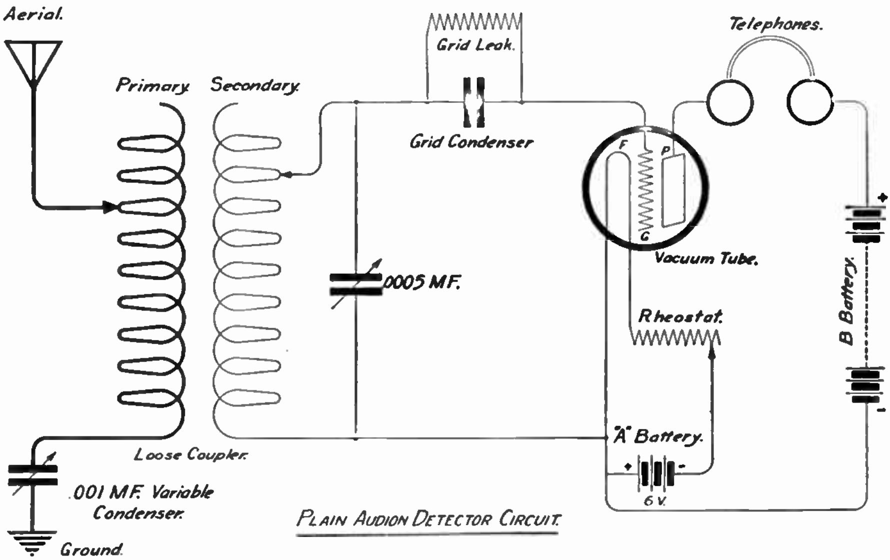
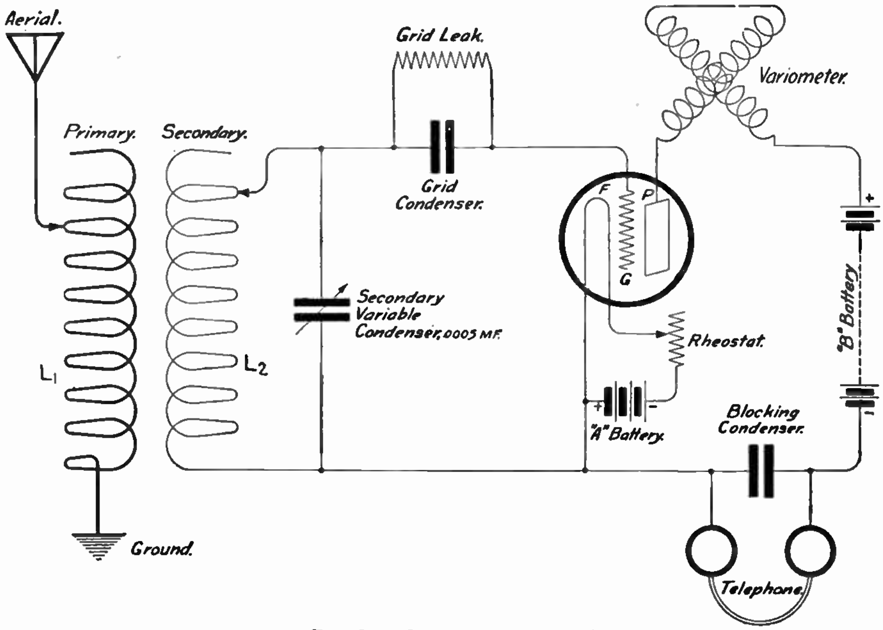


Fig. 1

To cover great distances, a vacuum tube detector should be used as this type of detector is much more sensitive and can be made to amplify the signals tremendously. Fig. 1 shows a hook-up for a standard two circuit receiver with a vacuum tube detector. With this circuit properly adjusted, it is possible to receive a Broadcasting station over greater distances than is possible with a crystal set. Furthermore, a vacuum tube is steady in adjustment and does not require any fussing with a catwhisker on a crystal or other difficult adjustment. The vacuum tube is set in operation by merely lighting the filament with a switch which is generally embodied in a rheostat used at the same time to control the current flowing through the filament.

Major E. H. Armstrong, well known in the radio field, made great improvements in the vacuum tube circuits, the first one being that of **regeneration.** Regeneration consists of reinforcing the weak signals which are received in the aerial circuit by feeding them back from the output side of the detector circuit into the input circuit connected to the grid. This, considerably, reduces the resistance of the circuit which tends to oppose the current induced from the aerial and therefore allows the whole energy received to be utilized upon the detector.



FEED BACK CIRCUIT WITH LOOSE COUPLER

Fig. 2

This method provides such sensitivity that the signals are amplified anywhere from about 100 to 200 times and produce in the telephones very loud response, while the same signal received on a crystal detector, are barely audible. Regeneration is accomplished by connecting into the plate circuit of the vacuum tube a coil, which is brought into inductive relation to the secondary of the grid circuit. Another method which may be used for short wavelengths consists of tuning the plate circuit by means of a variometer or a coil and condenser. When resonance is reached, the energy is fed back into the grid circuit through the capacity of the vacuum tube, for the grid and plate inside of the glass act as a small condenser. Fig. 2 shows how this is accomplished. When a coil connected in the plate circuit of the tube is coupled to the secondary coil, it is merely necessary to turn the coil so as to increase the coupling between the two circuits to obtain regeneration. At a certain point, the resistance of the secondary or grid circuit is so reduced that it is practically zero and the vacuum tube begins to oscillate of its own accord, producing the same kind of oscillations as that of the transmitter. When a receiving set is in this condition, a whistle is generally heard in the telephone receivers, if a station is sending at the same time. This condition should be avoided as when the vacuum tube oscillates, oscillations are radiated from the aerial exactly as if a transmitter was connected to the aerial and this causes considerable interference for the other receivers in the neighborhood. The same condition is reached when the plate circuit of the vacuum tube is tuned to obtain regeneration.

Since the output of the detector tube is equal to the square of the potential applied on the grid, it is easy to realize the importance of having maximum voltage impressed on the grid. For this reason, no variable condensers are used in some circuits; only a variable inductance called variometer is connected between the secondary of the coupler and the grid of the tube to provide for sufficient variation in wavelengths. Another inductance of the same type is connected in the plate circuit to tune it to resonance. In some other circuits, a small variable condenser is connected across the secondary coil in the usual way and either a variometer or a feed-back coil also called tickler connected in the plate circuit in series with the telephones and the "B" battery.

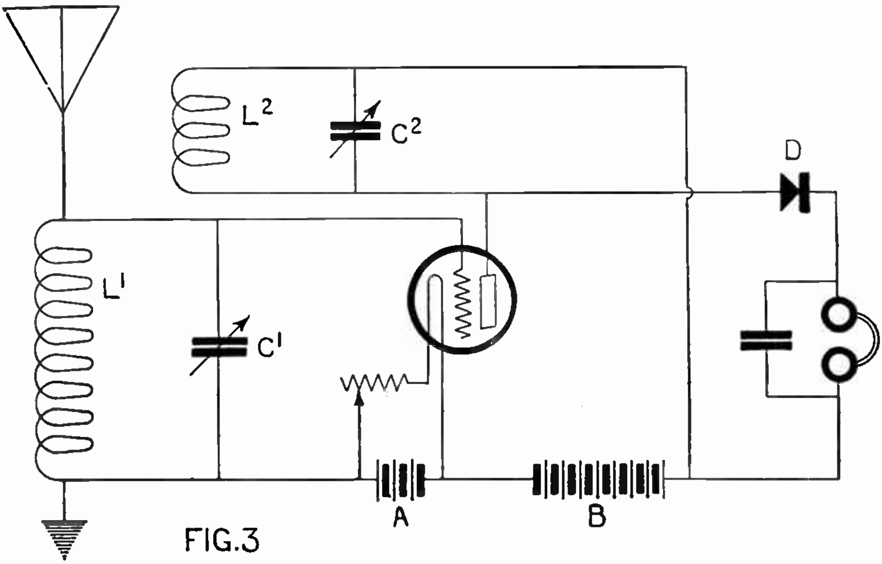


FIG.3

Fig. 3 is a standard circuit in which regenerative amplification is used for receiving signals. The incoming signals produce oscillations in the circuit L1 C1. The oscillating potential across the condenser C1 cause the grid to become alternately positive and negative; these grid potential variations produce amplified plate current variation in the plate circuit of the tube, these variations passing through the coil L2 may be advantageously shunted by a variable condenser C2. Across this oscillating L2 C2 is a crystal detector and telephone receivers. If the circuit L2 C2 has no inductive or other coupling effects on the circuit L1 C1 the oscillations in L2 C2 will be of the ordinary amplified strength, that is to say, they will be several times as strong as the oscillations taking place in the circuit L1 C 1. If the

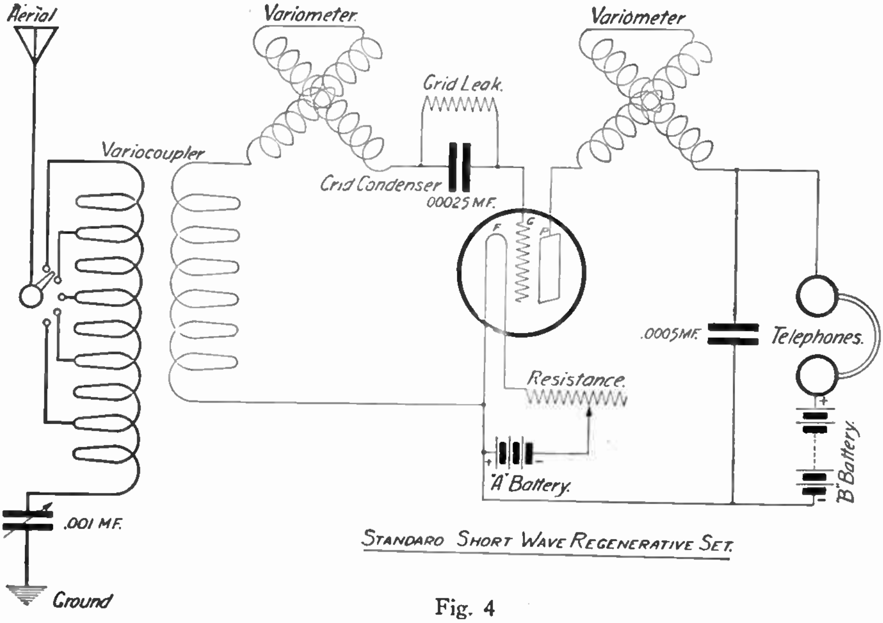


Fig. 4

incoming signals are damped waves such as produced by a spark transmitter each group of waves will be amplified and the amplified oscillations in L2 C2 will be rectified by the detector and give an audible note in the telephones. If now we bring the inductance L2

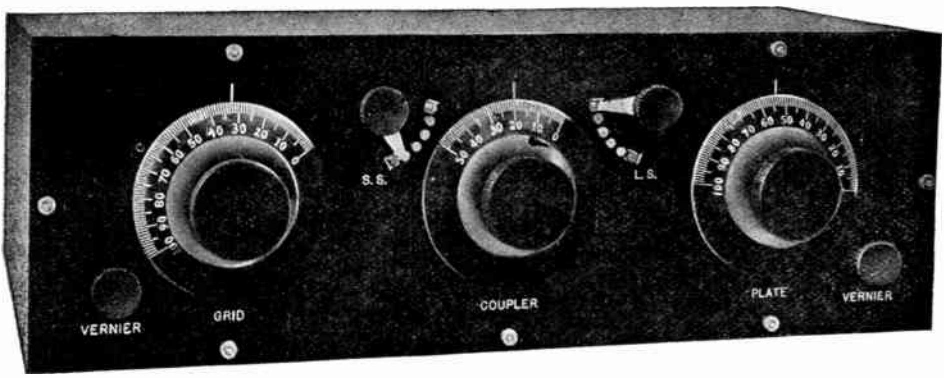
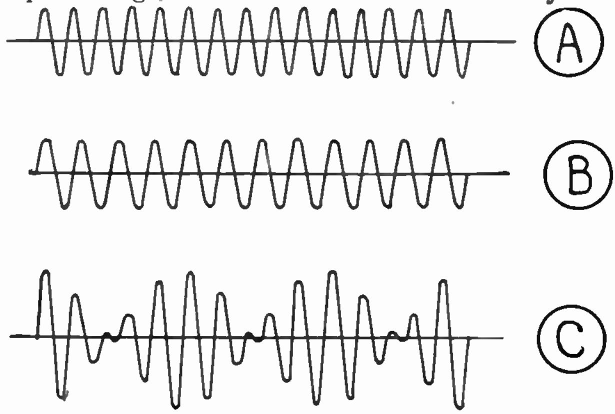
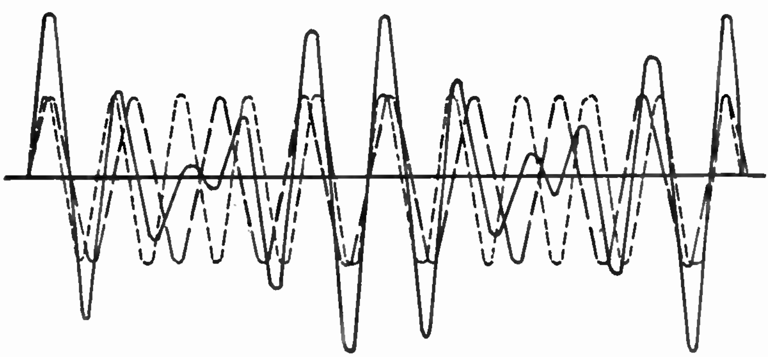


Fig. 4a

close to the inductance L1 so that there is a magnetic coupling between them, the incoming signals will be very much louder; this is because the incoming oscillations in L1 C1 are built up to a greater strength than formerly on account of the amplified oscillations induced by L2 into the circuit L1 C1. These oscillations being exactly in time with those existing in L2 C2, will be several times stronger than the amplified signals which would be obtained by merely using



(A) INCOMING OSCILLATIONS
(B) LOCAL OSCILLATIONS
(C) RESULTANT CURRENT



MODE OF ADDING COMPONENT OSCILLATIONS.

FIG.5

the radio frequency amplification properties of the vacuum tube. The result is that more energy is available for operating the detector and moreover the selectivity of the receiving circuit is increased as the resistance of the circuit L1 C1 is reduced on account of the transfer of energy from the plate circuit.

As we mentioned before, the same phenomenon may be obtained by tuning the plate circuit of the vacuum tube. Fig. 4 shows the standard hook-up of a short wave regenerative set using this principle. In this case, the tuning is accomplished by means of variometers which are continuously variable inductances in order to apply the highest possible potential on the grid of the tube. This type of receiver is extensively used to receive short wave-lengths ranging

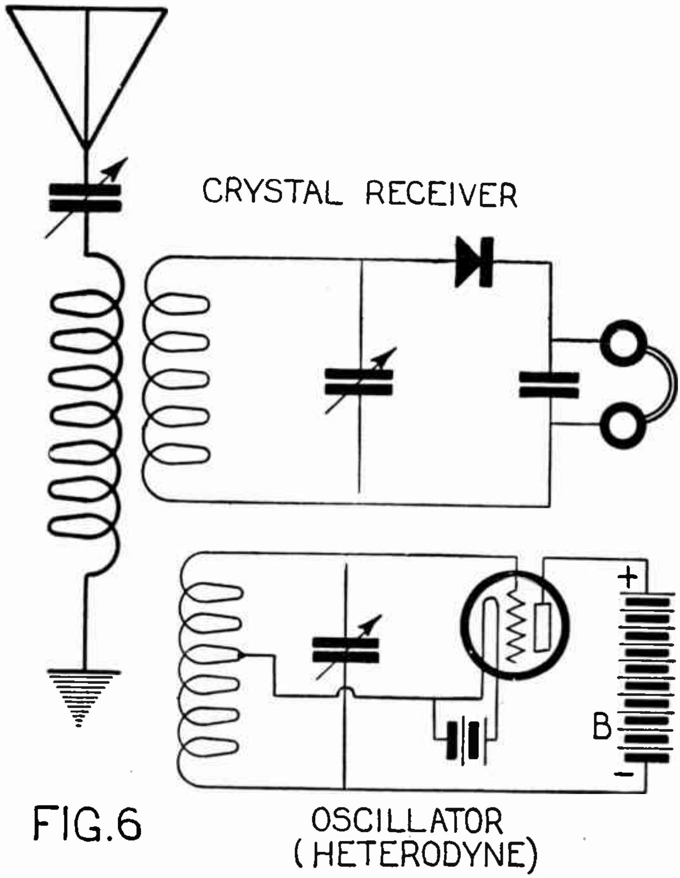


FIG.6

from 175 to about 450 meters. The same system of plate circuit tuning may be employed when an ordinary tuner is used. In Fig. 2, L1 and L2 represent a loose coupler or a vario-coupler, the windings of which are tuned by variable condensers. Regenerative amplification is obtained by turning the variometer in the plate circuit until signals are loudest. Should the variometer be turned beyond a certain limit, where the signals are at maximum intensity, the tube starts to oscillate as in this case the resistance of the circuit is reduced to zero, and oscillations take place of their own accord. In this state the receiver is suitable for the reception of continuous waves by the **beat method.** By slightly detuning the receiver the oscillations produced by the receiver itself interfere with the incoming oscillation, so that beats are produced when both are in phase, as illustrated in Fig. 5.

It is possible to receive continuous wave signals with a crystal detector, or a vacuum tube used as a rectifier by means of an external oscillator producing the interfering oscillations. Fig. 6 shows the hook-up of such a set, and the connections of the oscillating tube. The circuit of this oscillator is tuned by means of a variable condenser which is adjusted so as to produce the desired pitch of whistle. The use of an external oscillator is advantageous when receiving long wave-lengths, but for short waves, below a few thousand meters, the **autodyne method** is simpler and as efficient. The reception of continuous waves with the receiver in the oscillating state is called the autodyne method, meaning that it produces its own force, while, when an external oscillator is used, it is termed the **heterodyne method,** which means external force.

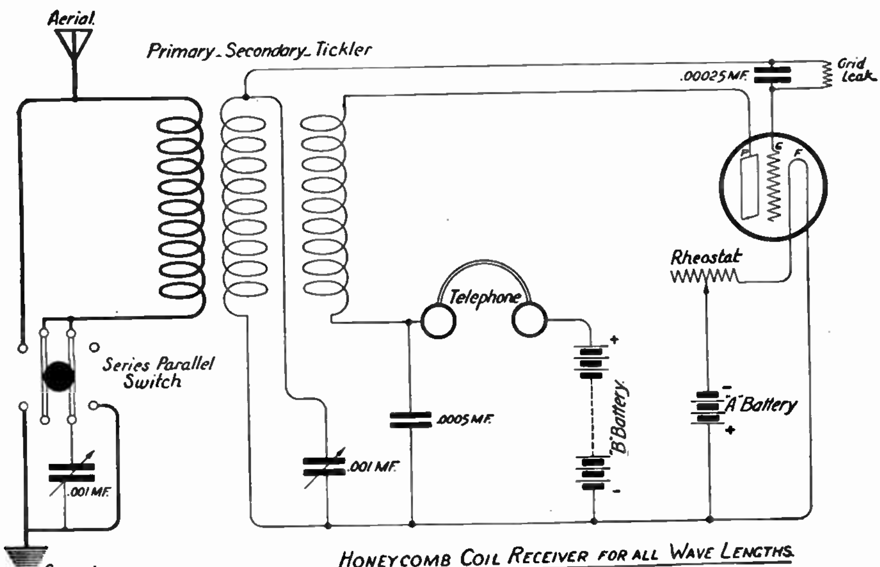


Fig. 7

The reason why it is necessary to use an oscillator or to have the vacuum tube detector in the oscillating state to receive continuous wave signals is that the wave sent from the transmitting station is no more formed of short wave trains, but of a wave of constant amplitude, lasting as long as the key of the sending set is pressed. If the receiver is in the neighborhood of the transmitting station, it is possible to hear on an ordinary set the beginning and the end of each dot and dash at the moment of the production of the wave, or when it ends. The beats produced by the heterodyne are almost similar to the wave trains produced by a spark transmitter, and can therefore be detected and heard in the usual way, though, since their frequency is greater, the note sounds like a whistle. The pitch of this whistle may be varied by detuning the heterodyne condenser, changing the rate at which the beats are formed.

In Fig. 7 is shown a type of receiver which is suitable to receive spark or continuous wave signals, as well as telephony, on any wave-length. It uses special inductances called **honeycomb** or **duolateral** coils, which are tuned by means of variable condensers connected in series or parallel, according to the wave-length which is to be received. This type of coil is quite efficient, as the whole inductance is used all the time, preventing the losses which occur in other types of coils when only a part of the winding is in circuit, as the unused turns vibrate electrically and absorb energy. These coils are so constructed that they may be plugged in a special mounting and are made in several sizes so as to cover the whole band of wave-lengths from 150 to 25,000 meters.

For the reception of short wave-lengths, a very efficient type of receiver is the **Reinartz**, in which the antenna circuit is kept aperiodic, that is, untuned. The secondary circuit is controlled by means of a variable condenser, as well as the feed back circuit, which uses a

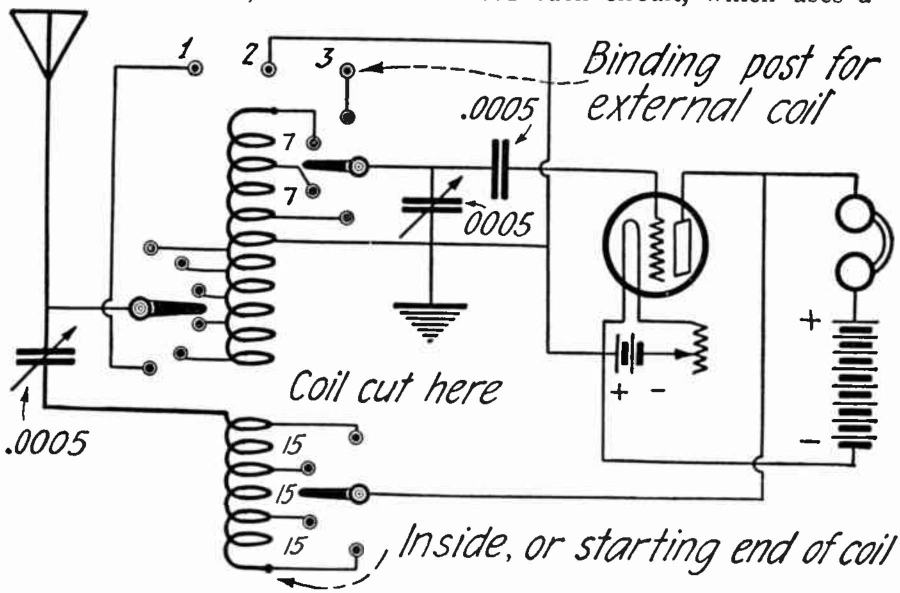


Fig. 8

tapped coil and a condenser in series between the aerial and the feed back coil. As may be noticed in the diagram, Fig. 8, the audio frequency circuit composed of the telephone receivers and "B" battery, are separate. This tuner provides very good selectivity and is very flexible.

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BOOK NUMBER FOUR

PART I

THE VACUUM TUBE AS AN AMPLIFIER

IN the previous book describing the functioning of the vacuum tube as a detector we stated that a small change of current in the grid circuit produced a corresponding change in the plate circuit.

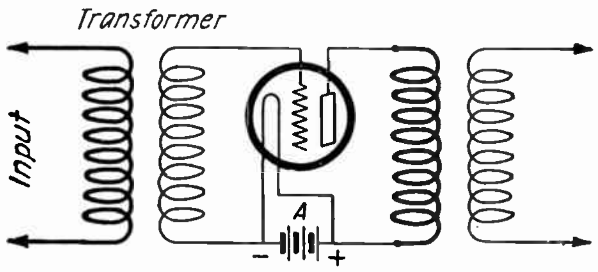


Fig. 1

In the case of the detector this was taken advantage of to rectify the oscillations and make them audible in the telephone circuit. The relay action of the vacuum tube is used in the amplifier as we shall now explain.

Fig. 1 shows how a vacuum tube is connected to **amplify signals** at either **radio or audio frequency.** Fig. 2 is the characteristic curve of the vacuum tube illustrating how a small change in the grid potential produces a correspondingly great change in the plate current. In order that the vacuum tube amplify without distortion, it is necessary

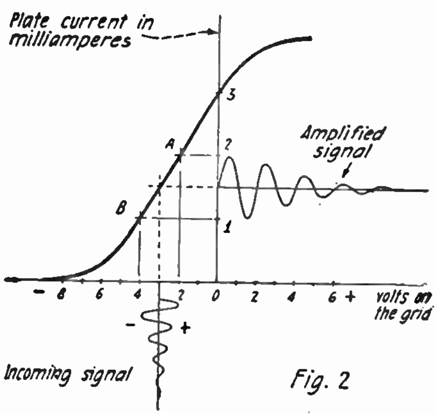


Fig. 2

to operate it along the parts of the characteristic curve which is straight. In the case of Fig. 2 the incoming oscillation varies the grid potential from 1 to 3 volts negative producing a variation in plate current of 1 milliampere. As may be seen, the greatest amplitude of the incoming wave train varies the point of operation from A to B along the characteristic curve which is straight, and therefore we have in the plate circuit the exact but amplified reproduction of the wave train received. If the tube is not operated along the straight parts of the characteristic curve the wave train is rectified as it does not produce in the plate circuit an exact reproduction of the incoming train, since one-half of each oscillation is more amplified than the other as shown in Fig. 2. In this case the wave train is more or less rectified and distortion of the signal results. The voltage to apply upon the

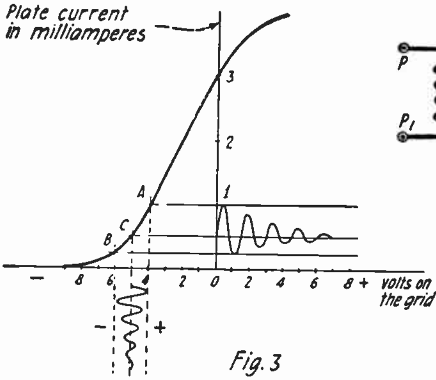


Fig. 3

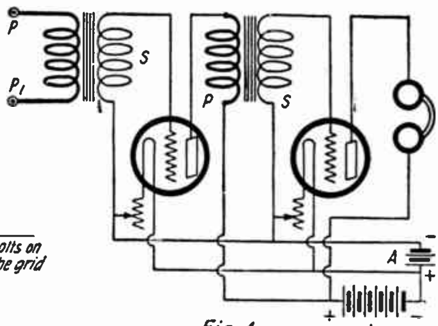


Fig. 4

plate of amplifier tubes varies with each particular make, but for the average types of tubes such as the UV 201, 201-A, VT-2, 216-A and others from 60 to 150 volts produce best results, provided the grid of the tube is kept at the proper negative potential so as to produce the greatest response.

The audio frequency amplifier as its name indicates amplifies the audio or audible frequencies. These are comprised between about 16

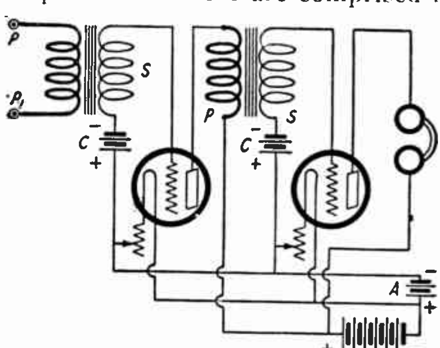


Fig. 5

and 10,000 cycles. In order to obtain true undistorted amplification, the instruments entering in the construction of this type of amplifier should be carefully designed. If transformers are used they should not have a ratio of number of turns between the secondary and the primary exceeding 3 to 1, and the grids should be kept at the proper negative potential either by connecting the secondary of the transformers as shown in Fig. 4, that is direct to the negative of the A battery with the rheostats on the negative lead of the filament, or by means of grid or C batteries as shown in Fig. 5. The former hook-up is suitable when only 45 to 90 volts are applied on the plates of the tubes, but when greater volume is desired for the operation of a loud speaker, a higher plate voltage ranging up to 150 or more may be used with a C battery of 1½ to 9 volts according to the type of tubes used. In any amplifier it is important to keep the connections from the grids and the plates of the tubes to the transformers as short as possible. Such amplifiers as those shown in Fig. 4 and 5 may be used with any kind of detector, the binding post P and P1 of the first transformer being connected in place of the telephone receivers. When great volume of sound is desired to operate a loud speaker in a very large room or outdoors, three stages of audio frequency amplification may be used with the last stage hooked up in the pull push fashion as shown in Fig. 6. In this system two tubes are used in the last stage. This permits the handling of great power without distortion which it is difficult to prevent when the ordinary hook-up is used. Fig. 6-a shows an audio frequency transformer.

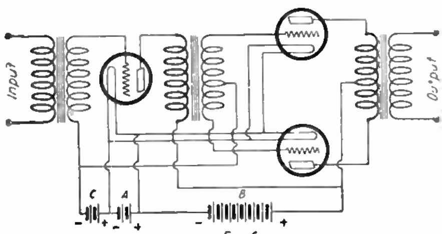


Fig.6

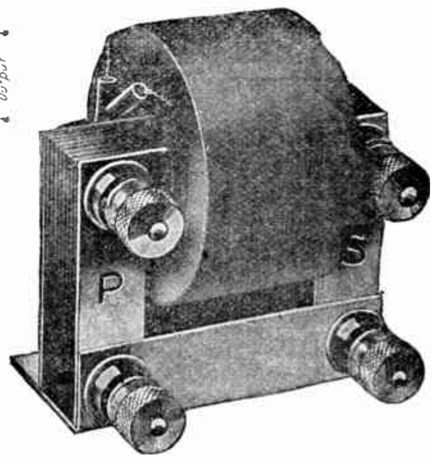


Fig. 6a

A type of amplifier which amplifies all frequencies equally well **is the resistance coupled type.** In such an amplifier non-inductive resistances are connected in the plate circuit as shown in Fig. 7. Of course no step-up action is had in this case and therefore the efficiency is less than when transformers are used between each tube, but the remarkable amplifying properties of the resistance amplifier for all frequencies, sometimes warrants the use of an extra tube to compensate for the loss. This type of amplifier is used as repeater along the long distance telephone lines and in some broadcasting stations to amplify the voice and music before it is sent into the transmitter. With some slight modifications these may also be used as relay for recording radio telegraph signals on tape by means of a Morse inker or other similar systems.

Instead of resistances, **iron core choke coils** may be used in the plate circuit of amplifier tubes, but since the ratio of such coil is necessarily 1 to 1 less amplification is obtained per stage than when step-up transformers are used. On the other hand less distortion is liable to occur for this same reason. Since the grid cannot be connected directly to the coil, a stopping condenser is used between the choke coil and the grid, which is kept at the proper potential by

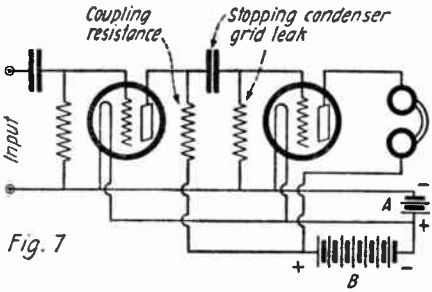


Fig. 7

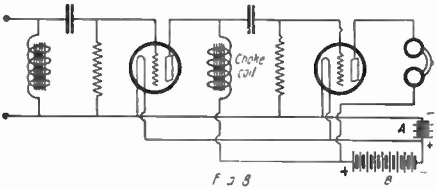
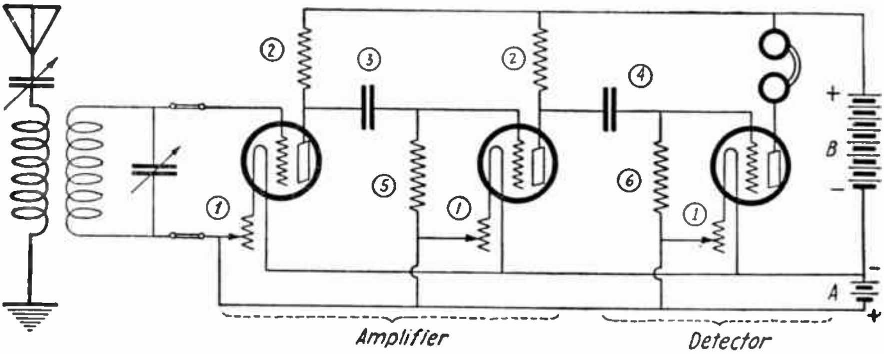


Fig. 8

means of grid leaks and C batteries, if necessary. This system of coupling in audio frequency amplifiers is but little used in practice.

The vacuum tube may be used to amplify the incoming signals at **radio frequency**, that is before they are rectified by the detector. In order to receive weak signals, it is necessary to amplify them by some means before they are rectified, as the detector itself is not very sensitive to very weak signals. The rectified current is about equal

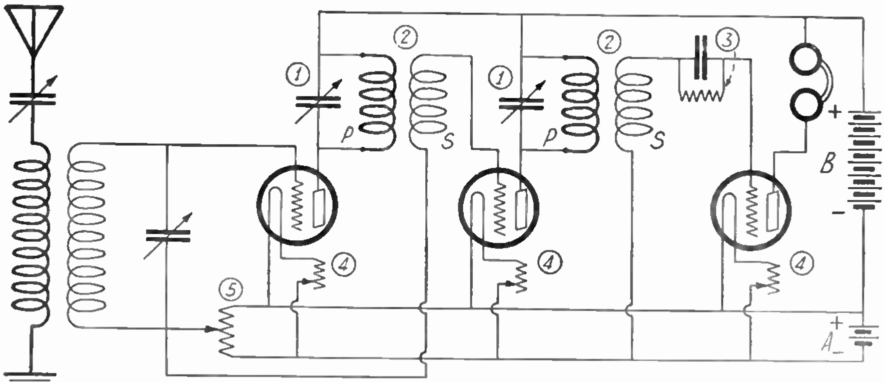


1 = rheostat.. 2 = 10,000 Ohms.. 3 = .0005 M.F. 4 = .00015 M.F. 5 = 4 megohms 6 = 2 megohms

Fig. 9

to the square of the voltage applied to the grid, therefore it produces a loud response for fairly strong signals, while the response is almost negligible when only a weak oscillation is applied to the grid.

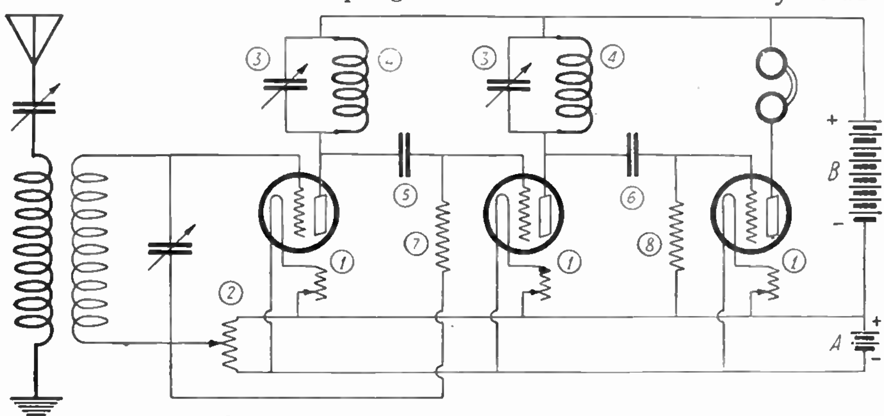
The design of a radio frequency amplifier depends primarily upon the frequency and therefore the wave length band which it is desired to amplify. For wave lengths above 1000 meters either a resistance coupled amplifier such as shown in Fig. 9 or any of the other types using transformers or choke coils may be used, as a wide band of wave lengths may easily be covered with a coil or a transformer. But for the shorter wave lengths from say 200 meters up, the problem is more difficult as at the higher frequencies it becomes extremely difficult to design transformers or chokes not requiring adjustment,



1 = .0005 M.F. V.C. – 2 = tuned transf. – 3 = grid cond. & grid leak – 4 = rheostat – 5 = 200 to 400 ohm pot.

Fig. 10

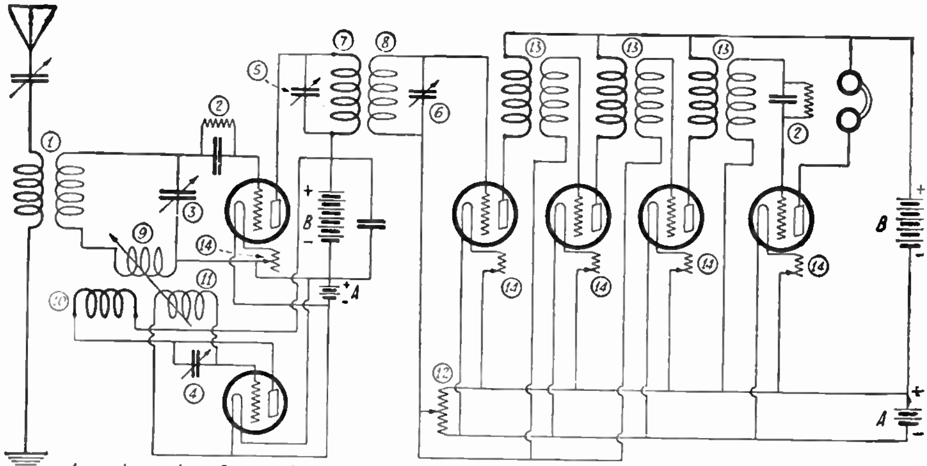
which cover a wide band of wave length. Generally the transformers used in short radio frequency amplifiers respond much better to a certain wave length than to some others, on account of the natural period of the windings. For short wave lengths it is therefore best to use some means of coupling between the tubes which may be adjusted, or tuned to respond about equally well to a wide band of frequencies. Tuned circuits may be used and give, of course, best results since each stage may be adjusted so as to produce maximum amplification at the wave length which it is desired to receive, but one is soon limited along these lines on account of the number of



1 = rheostat – 2 = 200 to 400 ohm pot. – 3 = .0005 M.F. var. cond. – 4 = honeycomb coil – 5 = .0003 M.F. – 6 = .00015 M.F. – 7 = 3 megohms – 8 = 2 megohms

Fig. 11

controls required in this type of amplifier, shown in Fig. 10. As may readily be understood the tuning of each circuit is very sharp and since all the stages must be adjusted, this system becomes unpracticable unless only one or two stages are used, or else when the



1 = vario coupler.. 2 = grid leak & condenser.. 3 = .0005 M.F.. 4 = .001 M.F.. 5 = .001 M.F.. 6 = .001 M.F. 7 = L 500 honeycomb coil.. 8 = L 600 honeycomb coil.. 9 = 6 turns #20 D.C.C. on 3" tube.. 10 = 20 turns #20 D.C.C. on 3" tube.. 11 = 20 turns #20 D.C.C. on 3" tube wound closely to 10.. 12 = potentiometer..14 = rheostat.

Fig. 12

amplifier is permanently tuned to a certain wave length. Another difficulty encountered in tuned radio frequency amplifier is the prevention of oscillations starting of their own accord when all the circuits are tuned to resonance. It is possible to prevent these oscillations to take place, by making the grids of the tubes slightly positive but the amplification is reduced accordingly. Instead of transformers, tuned circuits may be used with the same results. This circuit is shown in Fig. 11.

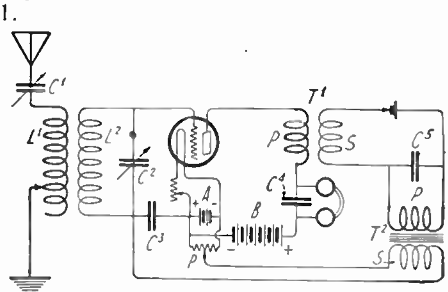


Fig. 13

The ideal radio frequency amplifier for short wave lengths is undoubtedly the super heterodyne invented by **Major E. H. Armstrong.** This system is the most sensitive actually known, and its flexibility makes it the best system to be used for the reception of very distant stations. The system consists in heterodyning or interfering the incoming signals by means of an oscillator, not so as to give audible beats as is usually done, but to give beats of a radio frequency lower than that of the incoming signals. These beats may then be treated as an incoming signal of longer wave length and amplified and detected in the usual manner.

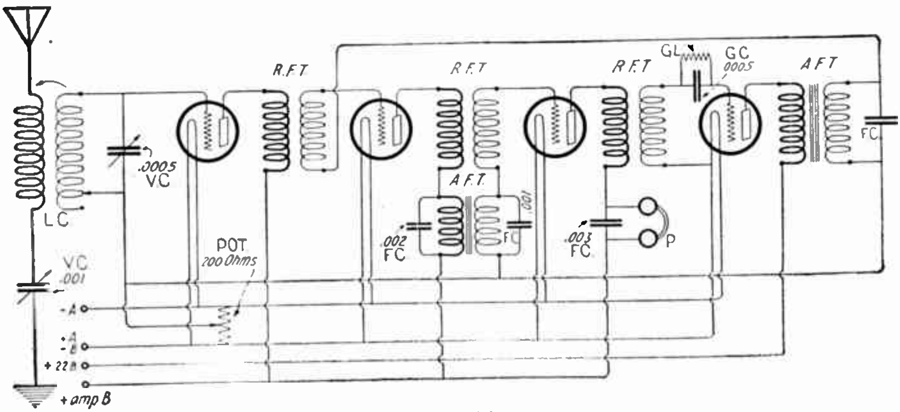


Fig. 14

For instance, in the case of 200 meter signals the oscillation frequency is 1,500,000 cycles per second. If we heterodyne these with local oscillations having a frequency of 1,400,000 equal to a wave length of 211 meters, the frequency of the beat currents will be

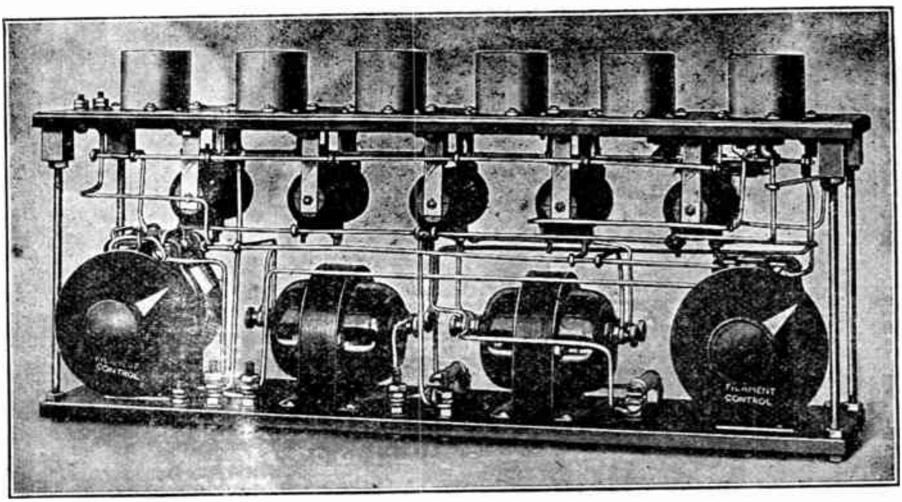


Fig. 15

100,000 cycles per second, corresponding to a wave length of 3,000 meters. Similarly any desired beat frequency may be chosen, which may be amplified without trouble by means of a long wave radio frequency amplifier of the transformer, impedance, or resistance coupled type. These signals, after being amplified, are detected to produce audible sounds in the telephones. Fig. 12 shows the hook-up of a super heterodyne receiver with the constants of the circuit.

It is possible to use the same vacuum tube to amplify signals at both radio and audio frequency at the same time. Fig. 13 shows the hook-up for a one tube amplifier of this type, called Reflex amplifier,

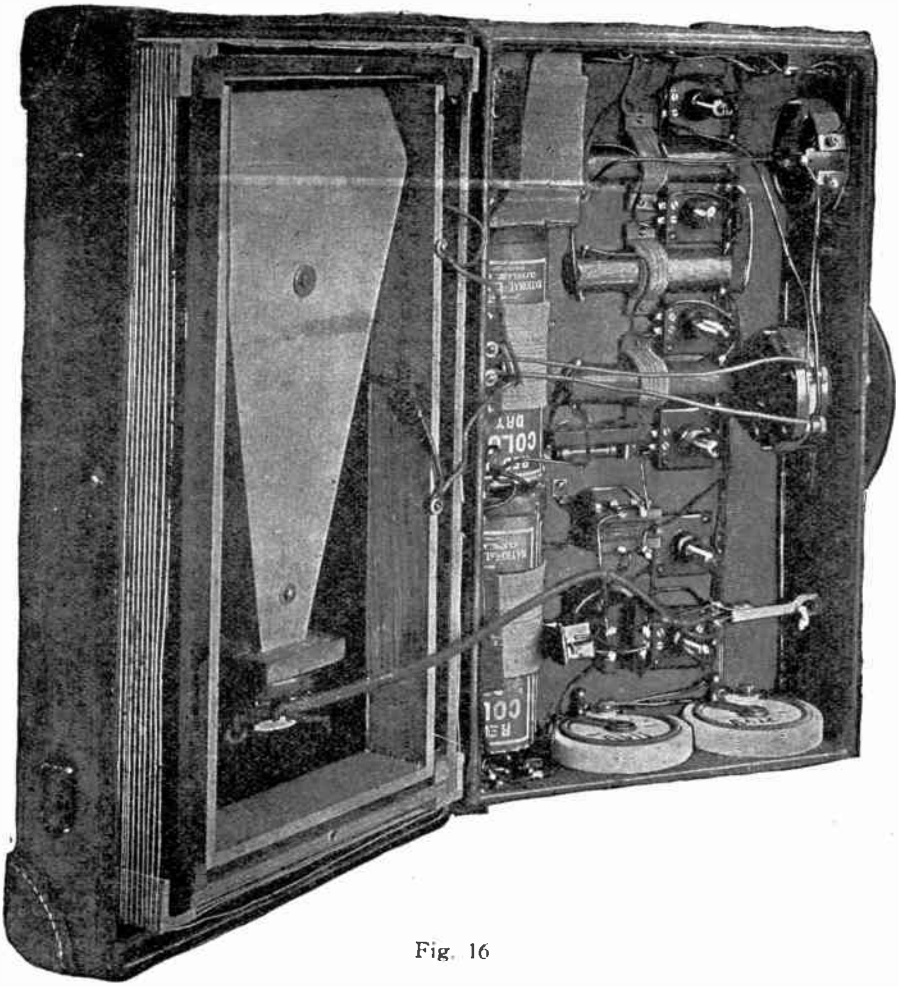


Fig. 16

using a crystal detector to rectify the oscillations after they are amplified at radio frequency and stepped up through the radio frequency transformer. The audio frequency component passes through the primary of the audio frequency transformer and the amplified current from the secondary applied again on the grid of the tube through the tuning circuit. The amplified audio frequency signals can readily pass through the primary of the radio frequency transformer and operate the telephones which are, with the "B" battery, shunted by a fixed condenser providing a path for the radio frequency currents which would be stopped by the impedance of the telephones, should this condenser be omitted. For the same reason, another fixed condenser is connected across the secondary of the audio frequency transformer and the potentiometer, the latter permitting a fine adjustment of the grid potential, which may be regulated for maximum amplification.

In Fig. 14 is shown a three-stage radio and two-stage audio frequency amplifier of the reflex type used with a vacuum tube detector. In this type of receiver, the incoming oscillations are amplified at radio frequency by the first three tubes and rectified by the fourth, which is the detector. The audio frequency is then fed back to the grid of the second tube through an audio frequency transformer, and amplified further by the third tube, acting also as the second stage of audio frequency. Here again the windings of the audio frequency transformers and telephones are shunted by fixed condensers to allow the radio frequency currents to pass without being stopped by the high impedance of the windings.

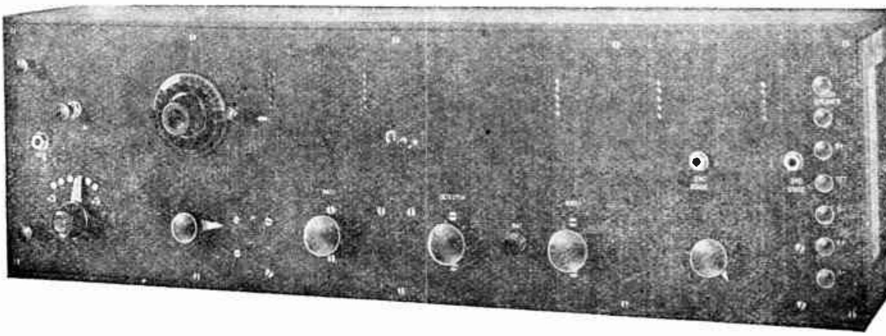


Fig. 17

The reflex system of amplification is now extensively used and gives good results on any wave length, provided the transformers are of the proper design. The greatest advantage of the reflex amplifiers is that maximum amplification is obtained with a minimum number of tubes reducing the operating expense, since the tubes are made to do double duty. Fig. 15 shows another type of reflex amplifier embodying five stages of radio frequency and two stages of audio frequency amplification.

A portable loop receiver with a three-stage radio frequency amplifier, detector and two-stage audio frequency amplifier built in a suit case is shown in Fig. 16. Small vacuum tubes supplied with dry cells are used and a loud speaker mounted in the cover of the case makes the signal audible over a large room. This portable receiver was built by an engineer of the Bureau of Standards. Fig. 17 illustrates a similar receiver as used for direction finding work with a loop aerial.

PART II

SOUND REPRODUCTION AND LOUDSPEAKERS

IT has only been in recent years that intensive efforts have been made to improve the means of transforming the electrical energy into sound waves. In the early years, all efforts were directed towards improving the radio circuits themselves. As the problems dealing with radio transmission and reception were solved, one by one, engineers and designers turned their attention to the reproducing end of the receiving system, the loudspeaker.

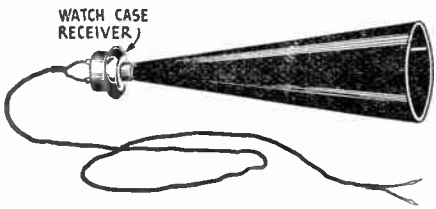


Fig. 1

Perhaps the simplest and cheapest loudspeaker that can be used is one which employs a simple phone unit attached to a horn as shown in Fig. 1. A speaker such as this can be made very easily by anyone simply attaching a suitable harn, either of fibre composition or metal to a high resistance phone unit. It is understood of course that the degree of perfect reproduction will depend entirely upon the unit which is used. Probably the best type to use in a speaker of this sort is one which has a mica diaphragm attached by means of a link to the movable pole piece which is situated between the two poles of the magnet. A combination of this sort when coupled to a good audio frequency circuit will enable the builder to obtain fairly faithful reproduction.

An even simpler method of obtaining louder results from a simple headphone is to place the headphones in a wooden or glass bowl so as to get a reflector effect much the same as that obtained by the reflecting surface back of a preacher's pulpit.

The early loudspeakers were practically all of the horn type with certain refinements in the way of shape or material of the horn and construction of the reproducing unit.

A well-known English speaker which became very popular in America is shown in Fig. 2. This speaker, which gives excellent results, has a very efficient reproducing unit. A large diaphragm, rugged magnet and an adjusting screw which permits an adjustment of distance between the diaphragm and the pole pieces of the magnet produce a strong, well-made speaker unit capable of handling the strongest currents delivered to it by a powerful receiving set.

Two of the outstanding and interesting features of the sound intensifying or amplifying horn are the cast metal neck of the horn to which the reproducing unit is attached by means of a rubber coupling and the "morning-glory" shaped wooden bell attached to the metal neck. Most acoustic experts prefer the wooden horn for this type of speaker because it does not play favorites with any certain sound frequency but reproduces all alike giving a sweet, full-toned distortionless sound.

Fig. 2

One of the greatest strides made in perfecting the reproducing system of a radio receiver came with the invention and development of the cone-type speaker.

This type of speaker uses a large parchment diaphragm in place of the small metal or mica diaphragm used in the ordinary reproducing unit of the horn type speakers. The use of a cone as a diaphragm was known as far back as 1900, but it was not until 1911 or 1912 that it was fully developed for use on the phonograph. Even then it was not applied successfully to radio speakers until about 1924.

The artificial parchment used for lampshades is unsatisfactory for cone speakers. This material is nothing but a heavy paper, oiled to make it translucent. The oil deadens the sound. The paper used by the majority of cone manufacturers is a special paper book cover stock known as Alhambra.

To understand the causes of distortion in loudspeakers, one must investigate thoroughly the character of musical tones. Each tone has a fundamental frequency of its own, giving it a pitch. For example, the lowest pitched note on the piano has a frequency of 27 cycles per second and the highest pitched one a frequency of 4096 cycles per second. Middle C has a frequency of 256 cycles per second. These are the figures of the scientific scale which differ slightly from those of the musical scale. You can see, therefore, that the ideal loudspeaker should operate uniformly over a frequency range of 27 cycles to 4096 cycles per second, which is the range of the piano keyboard. However, each tone is composed of a fundamental frequency and several harmonics of higher frequencies, giving it timbre. To get the true tonal color of the highest notes of the piano the speaker should reproduce the higher harmonics of these notes which include frequencies as high as 8,000 cycles per second. Most speakers operate well up to about 10,000 cycles per second and little trouble is experienced on the high end of the scale. Few speakers, however, reproduce tones below middle C on the piano faithfully as the difficulty lies in designing a speaker to operate successfully on the lower end of the scale so that the fundamental tones as well as their higher harmonics are heard.

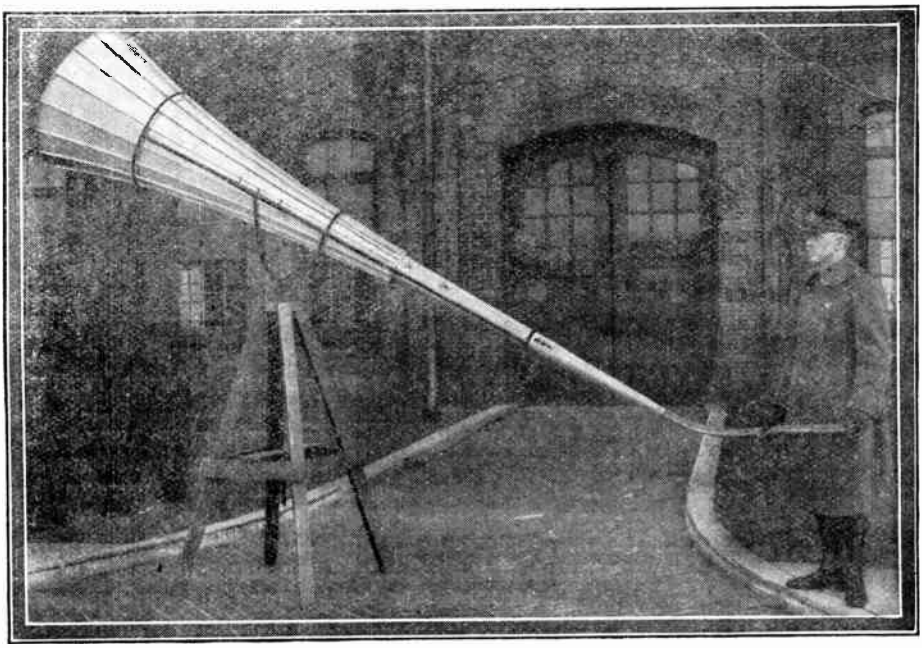


Fig. 3

When the fundamental tones are lost because of the inability of a speaker to respond to them, the reproduced music sounds "tinny," and is lacking in depth.

The average horn type speaker reproduces the higher tones very well. As a rule the larger the horn and the greater the diameter of the diaphragm, the lower the pitch. Cone speakers that may be considered as horn speakers with extra large diaphragms are usually lower pitched than the conventional horn speakers and therefore reproduce the lower pitched sounds to better advantage, giving life-like reproduction of the lower tones. This leaves us with two methods for obtaining low notes from a speaker, the first that of increasing the length or size of the horn and the second, that of increasing the diameter of the diaphragm.

Fig. 4

Fig. 3 shows a horn speaker of great length and size that was actually built for obtaining true reproduction of the lower tones. Note the peculiar shape of the horn; it follows the exponential curve found by test to be the best for proper acoustical effects in this instance. It is needless to say that this horn reproduces the low notes with virtually no effect on the quality of reproduction of the high tones.

Such a speaker is obviously impractical for use in the home. The large cone speaker, shown in Fig. 4, is much more practical and gives results which are really remarkable. The diameter of the cone is approximately three feet and the total height is 49 inches. The design is such that the low notes of the cello, organ and piano and the notes of brass instruments of the lower register are reproduced faithfully. This gives to reproduction of instrumental music true depth and richness.

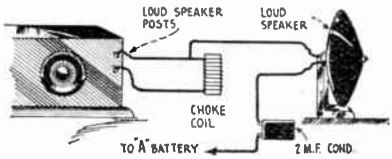


Fig. 5

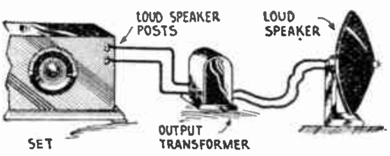


Fig. 6

Of course a cone of this size is not absolutely necessary for ordinary practical reproduction and really good reproduction is obtainable from the 18-inch cones generally available.

With the very large cones, a powerful receiver having several stages of amplification is necessary. In many cases a power stage or

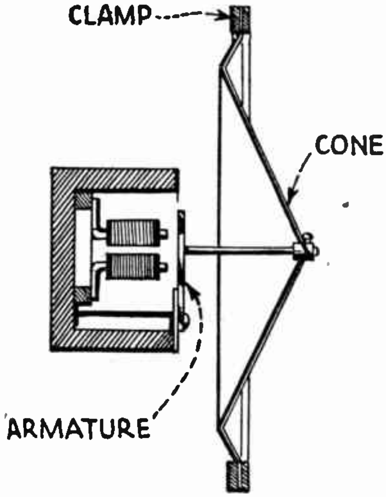


Fig. 7

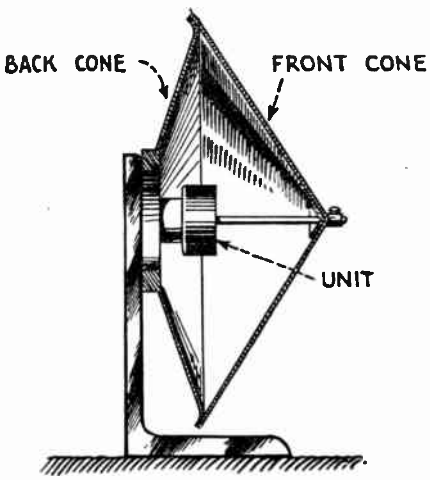


Fig. 8

two is required for efficient operation. This of course is not necessary with the smaller 18-inch sizes of cones, although the use of a power tube in the last stage with suitable "B" battery voltage is recommended for good results.

When more than 135 volts of "B" battery is used in the last stage, it is advisable to use some means of coupling the loudspeaker to the output of the receiver in such a way that the heavy direct current of the battery is not allowed to pass through the loudspeaker windings.

For this purpose either of the methods shown in Figs. 5 and 6 may be used. The former shows the use of an output circuit consisting of a choke coil and heavy duty fixed condenser which prevents the direct current from flowing through the speaker windings while the latter shows the use of an output transformer connected between the output circuit of the receiver and the loudspeaker terminals.

In either case, only the direct current variations or fluctuations are permitted to flow through the loudspeaker windings.

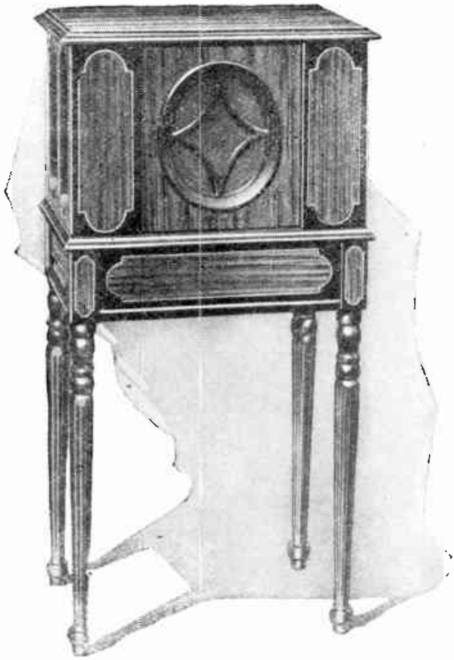


Fig. 9

The operating principles of the driving member and cone of the earliest types of cone speakers is shown in Fig. 7. The cone was securely clamped around the periphery by means of metal rings. An armature was used on the unit in place of a diaphragm and a drive rod connected this armature to the apex of the cone.

Another later and more popular type of construction is shown in Fig. 8. The front cone of this speaker is supported by the frustrum of a similar back cone as shown. The unit is of the floating armature type and is mounted inside. While this type of speaker gives greatly improved results over many of the earlier types, it still has the disadvantage of a slight muffling effect of the sound due to the enclosed air space.

If you make a simple paper cone and attach it to a driving rod, you will notice that the volume of sound is greater on the concave side than it is on the convex side. Therefore the latest models employ cones with the concave side facing out. The cones are of the free edge type or flexibly supported around the periphery.

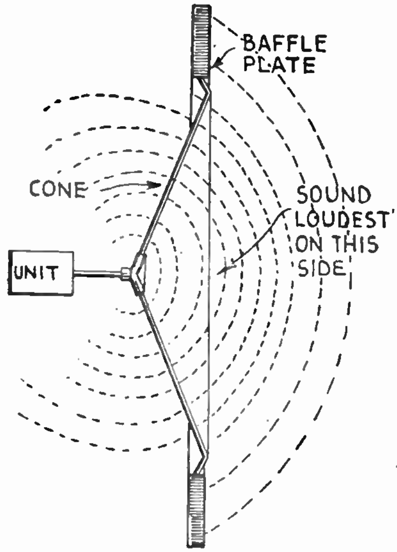


Fig. 10

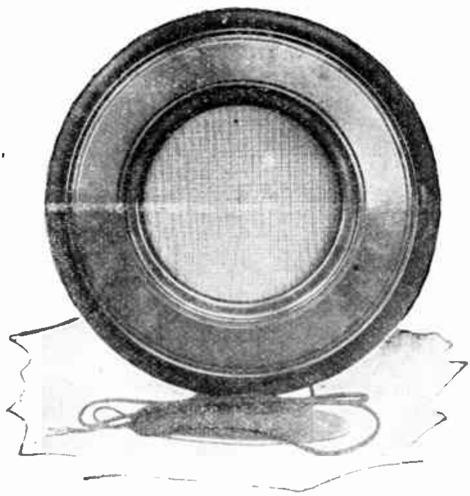


Fig. 11

An example of this type of construction is depicted in Fig. 9, although this illustration does not show the working details of the unit. It seems necessary to add that in this case the ten-inch cone of heavy paper has the convex side facing out. It is mounted directly in back of the oval aperature in the cabinet.

This reproducer not only consists of the loudspeaker but also employs a built-in power amplifier to boost the strength of the current supplied to the unit to that required for efficient operation of the cone. The power amplifier is designed to work direct from the houselighting circuit. Enormous volume with good tone quality can be obtained with such a unit.

If you construct a cone and mount it in a cabinet you will find that the volume is increased. This is due to the fact that the cabinet not only acts as a tone chamber but also reflects the sound waves out from the convex side of the cone. Another way of obtaining the same effect is to place a baffle plate around the cone. This may be a wooden ring about two or three inches wide as shown in Fig. 10.

Note how the sound waves are forced to continue propagating from the front. A speaker built on this principle is shown in Fig. 11.

It is difficult to foretell what new developments may come in later years in the line of reproducing means but it is safe to say that the cone in one form or another is due to enjoy widespread popularity for some time to come.

PART III

EARLY VACUUM TUBE CIRCUITS

THE circuit to be used with vacuum tubes depends upon several factors, and each set is better adapted to certain purposes. When an outside aerial may be installed and it is desirable to use a pair of telephone receivers, only one vacuum tube used as a detector in a regenerative circuit is necessary. If it is desired to use a loud speaker, or to amplify the signals from very distant stations, a one- or two-stage audio frequency amplifier may be added after the detector, as was explained in the previous lesson. Fig. 1 shows the diagram of a short-wave regenerative set connected to a two-stage audio frequency amplifier, equipped with jacks so that only the detector, one, or both stages of amplification may be used by plugging in the telephone in the proper jack. Of course the unused tubes should be

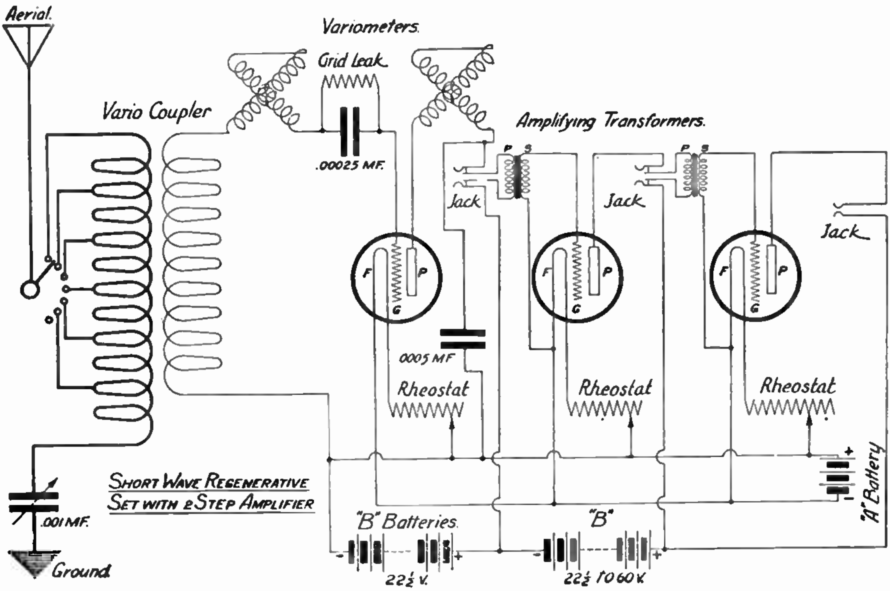


Fig. 1

turned off by means of the rheostat. If it is desired to simplify this operation, automatic filament control jacks may be used in the amplifier, as shown in Fig. 2, so that the unused tubes are automatically disconnected when plugging into any jacks.

Fig. 3 is a combination receiver in which the same vacuum tube detector may be connected to a standard short-wave regenerative receiver or to a honeycomb coil tuner. These may be mounted in the same cabinet, if desired, the switching from one set to the other being accomplished by means of a four-pole double-throw switch.

Fig. 4 is the hook-up for a single circuit tuner which may tune wave-lengths up to 3,000 meters. A special tuning coil is used in this

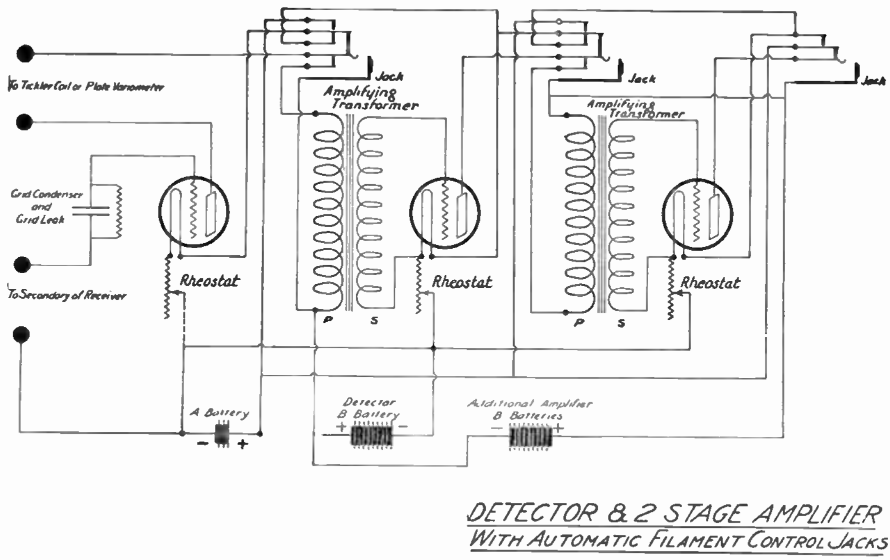

To Tickler Coil or Plate Variometer
Grid Condenser and Grid Leak
To Secondary of Receiver
Jack
Amplifying Transformer
Rheostat
P
S
A Battery
Detector B Battery
Additional Amplifier B Batteries
DETECTOR & 2 STAGE AMPLIFIER
WITH AUTOMATIC FILAMENT CONTROL JACKS

Fig. 2

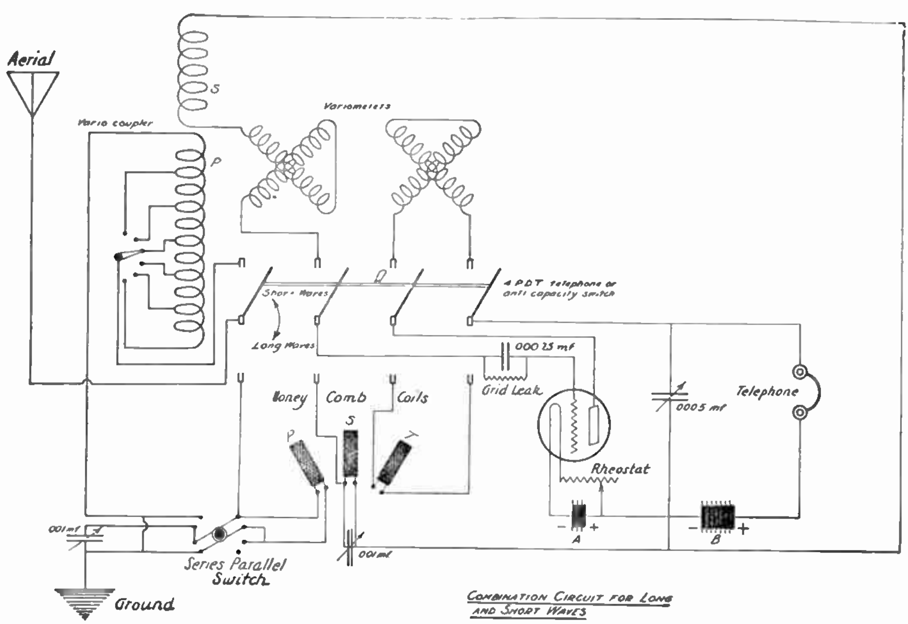

Aerial
Vario coupler
Variometers
Short Waves
Long Waves
4 P.D.T. telephone or anti capacity switch
.000 25 mf
Grid Leak
Honey
Comb
Coils
Rheostat
.0005 mf
Telephone
.001 mf
Series Parallel Switch
Ground
COMBINATION CIRCUIT FOR LONG AND SHORT WAVES

Fig. 3

kind of set with a small movable inductance mounted inside of the main one acting as feed back coil connected to the plate. The coupler used in this circuit is shown in the photograph Fig. 5.

When it is desired to receive very distant stations, radio frequency amplification must be resorted to for the reasons explained in the previous lesson. A very efficient single stage radio frequency amplifier is shown in Fig. 6. The first tube amplifies at radio frequency, while the second is the detector. By tuning the plate circuit of the first tube by means of a honeycomb coil of the proper size and

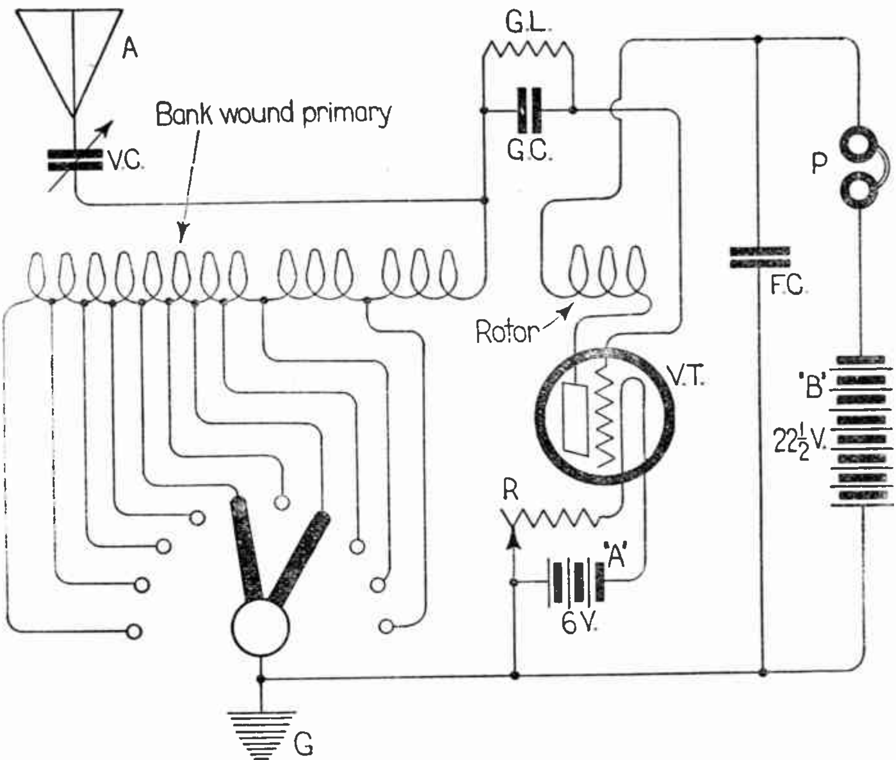


Fig. 4

a variable condenser, maximum amplification is obtained when resonance is reached. For short wave-lengths an L-75 honeycomb coil shunted by a .0005 M. F. variable condenser is suitable in the plate circuit. If this method of amplification is to be used with a standard regenerative set, the plate variometer may be used by changing the connections as shown in Fig. 7. The grid condenser and grid leak are removed or short-circuited, and an extra lead taken from the plate—binding post on the socket and connected to an external detector, as shown.

Another hook-up of radio frequency amplifier and detector, which provides very sharp tuning, is shown in Fig. 8. In addition to the amplifying effect of the first tube, regeneration is obtained by connecting a coil in the plate circuit of the detector and coupling it to the secondary circuit. The inductances used in such a receiver may

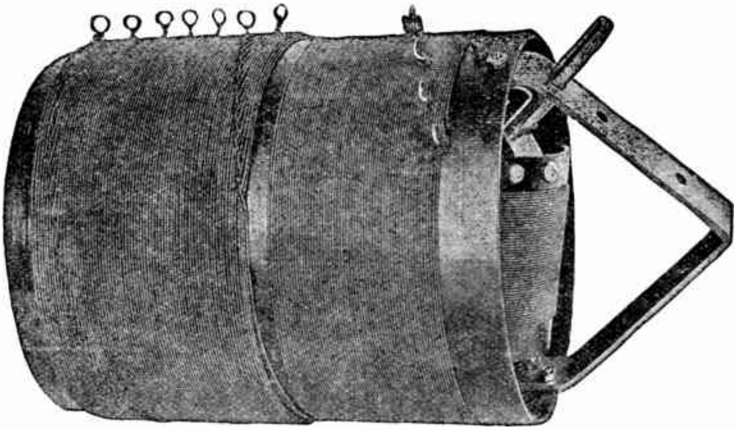
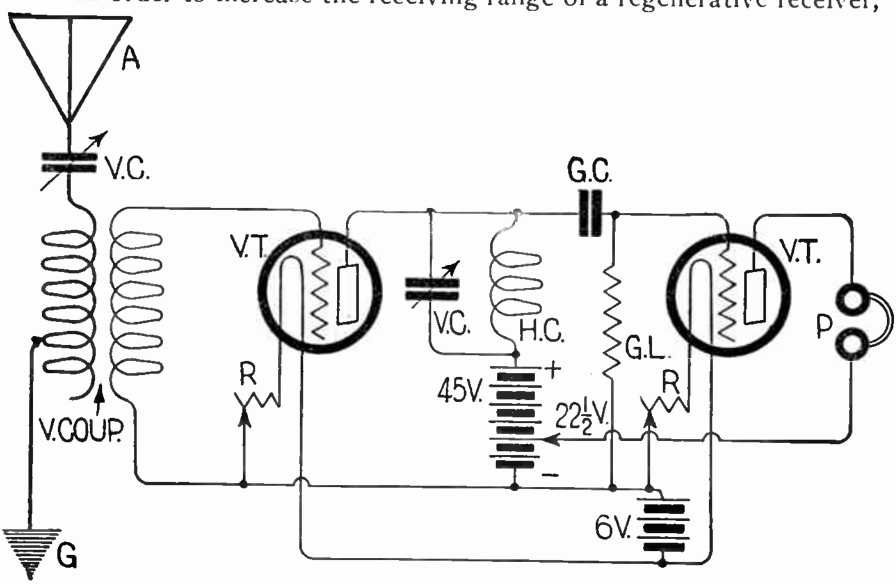


Fig. 5

be honeycomb coils, or any other suitable form of inductances, the coupling of which may be varied.

In order to increase the receiving range of a regenerative receiver,



radio frequency amplification may be used ahead of it. Fig. 9 shows how this is accomplished. A single coil and variable condenser tune the antenna circuit and two tubes coupled by means of a radio frequency transformer amplify the signals at radio frequency. The vario coupler of the receiving set is connected in the plate circuit of the second tube and provides an extra tuning element which helps in

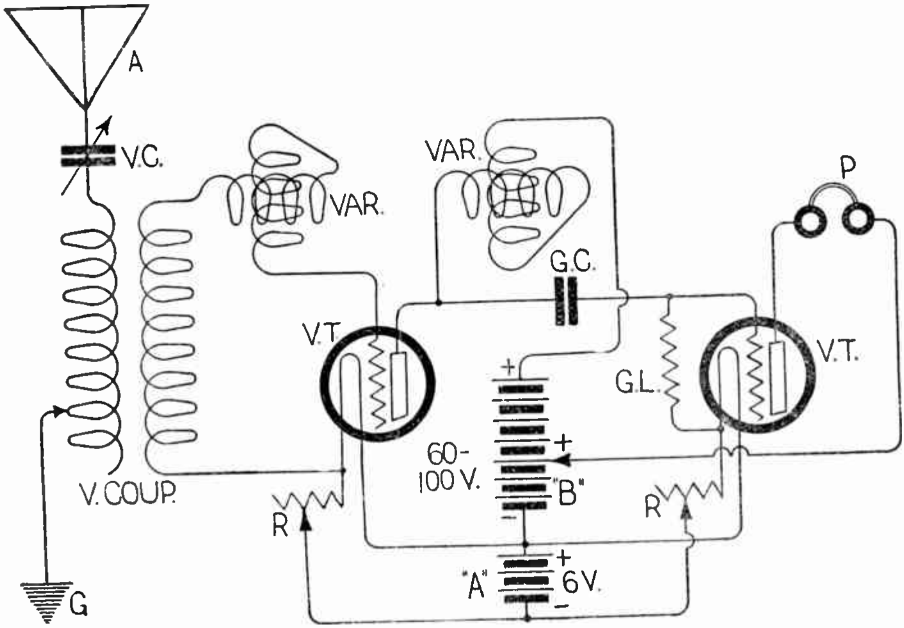


Fig. 7

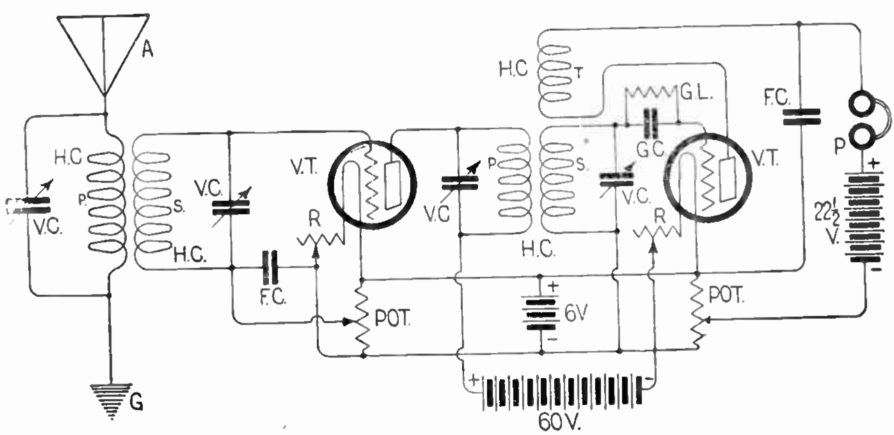


Fig. 8

tuning out undesired stations interfering with the signals being received. The same batteries may be used to supply the amplifying tubes and the detector.

Loop Aerial Receivers

When it is impossible to install an outdoor aerial, or if directional reception is wanted, a loop aerial of the type described in the lesson

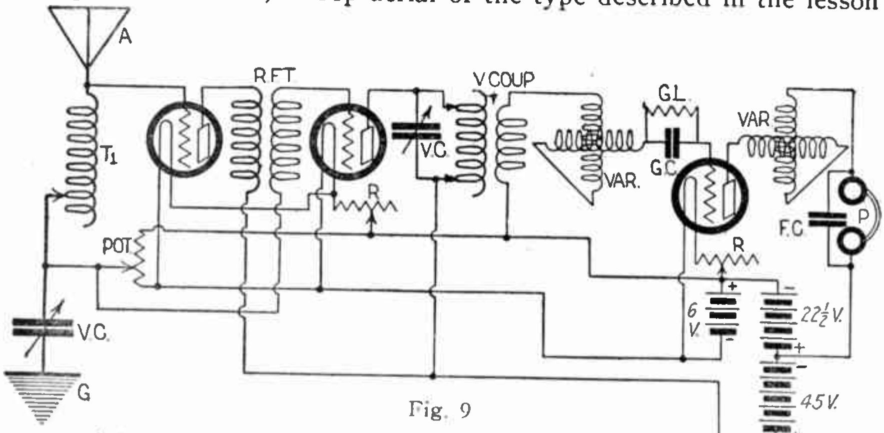


Fig. 9

on aerials may be employed indoors. The hook-up, Fig. 10, provides great selectivity and regenerative amplification; the first tube acts as

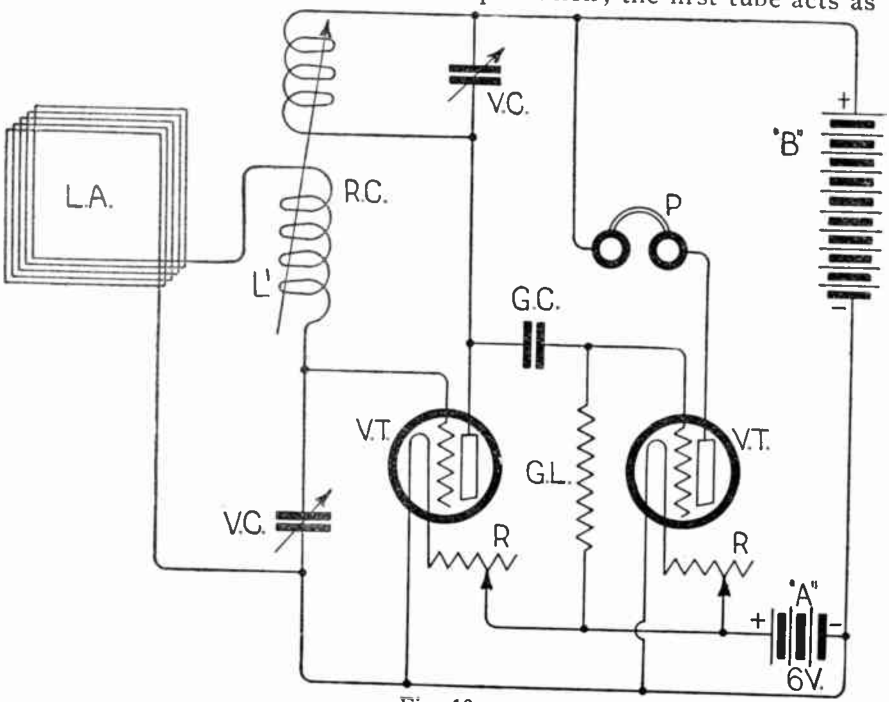


Fig. 10

a radio frequency amplifier and the second as a detector. The coupling between the two coils of the regenerative coupler, RC, is rather critical and a vernier adjustment should be provided on the shaft of the movable coil. This coupler may consist of a vario coupler rewound

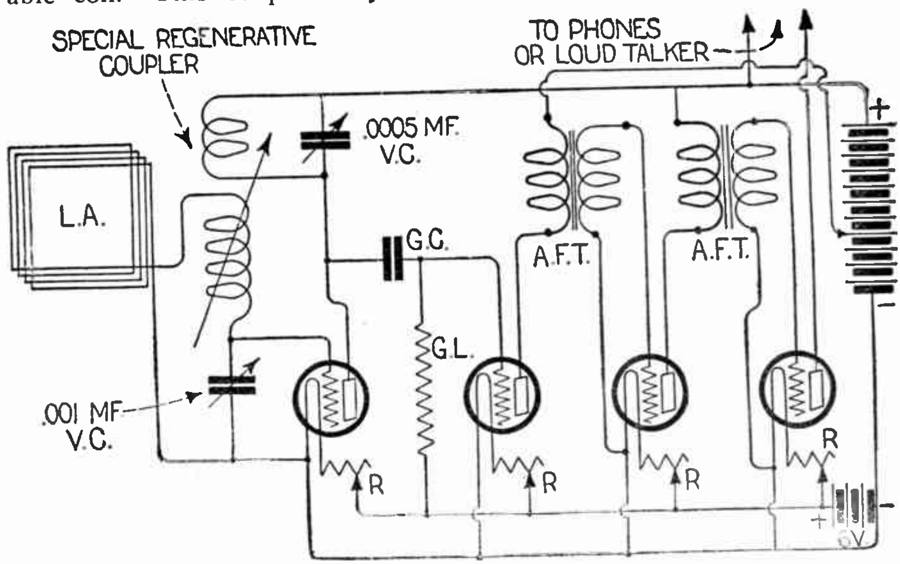


Fig. 11

RADIO AND AUDIO FREQUENCY AMPLIFIER

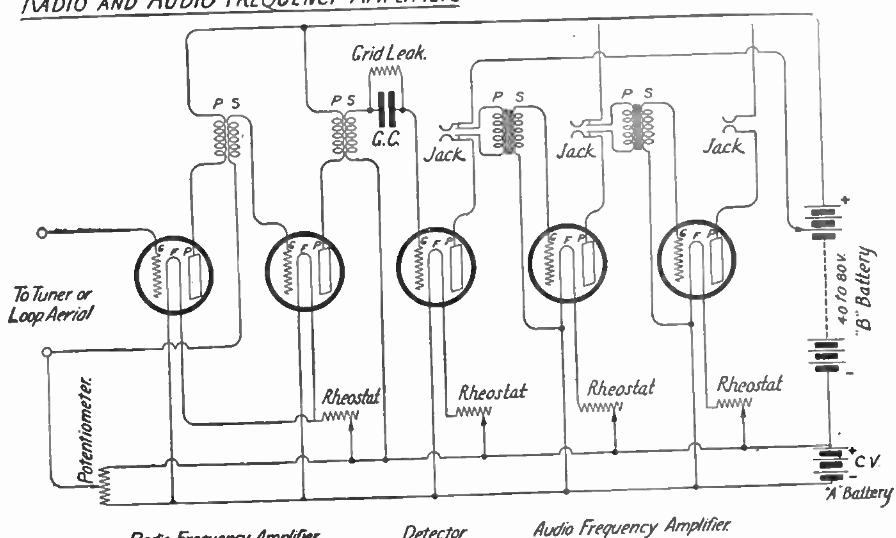


Fig. 12

with about 10 or 12 turns of No. 20 D. C. C. on the primary and about 40 turns of the same wire on the secondary. Fig. 11 shows the same hook-up with the addition of two stages of audio frequency amplification to operate a loud speaker when receiving near-by stations, or to

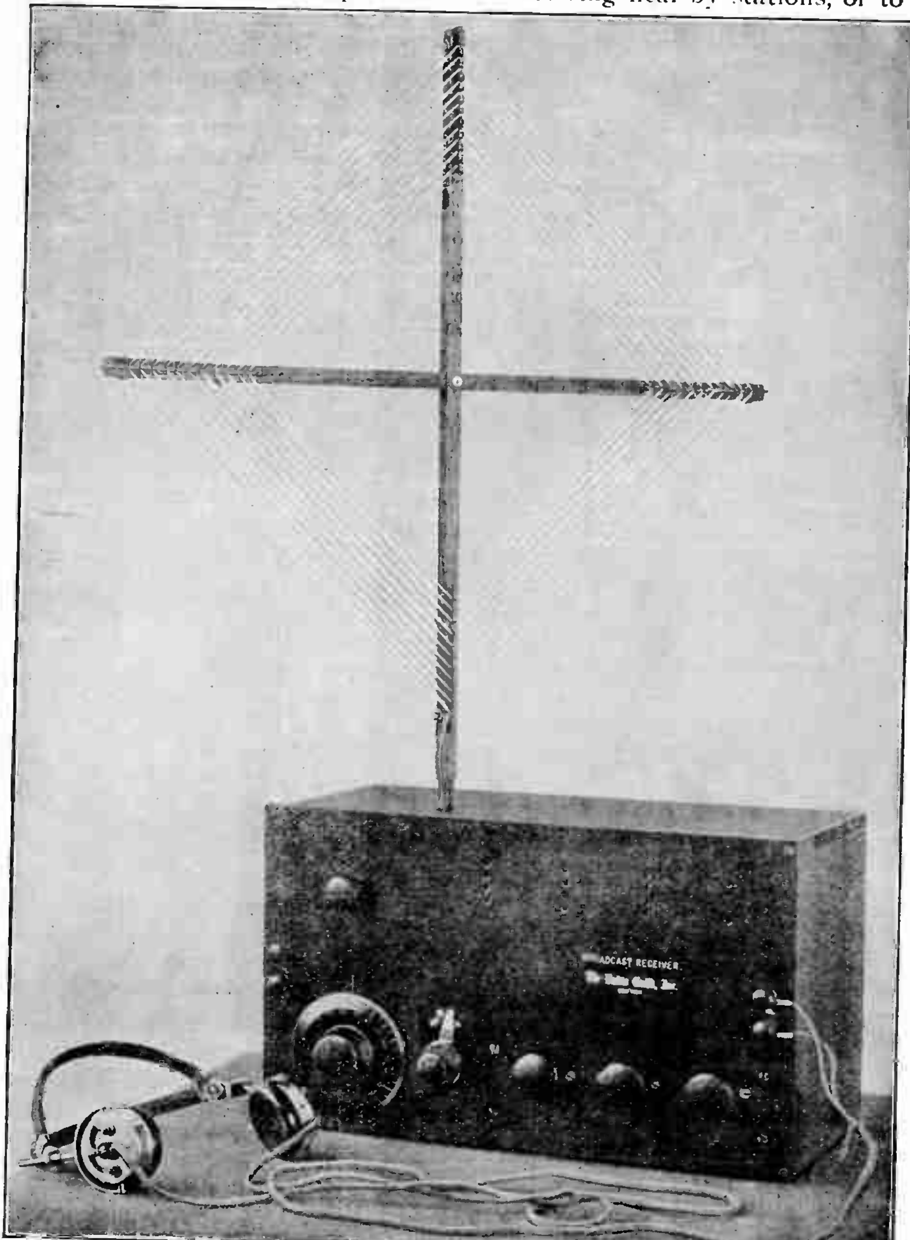


Fig. 13

intensify weak signals when listening to distant stations with head phones.

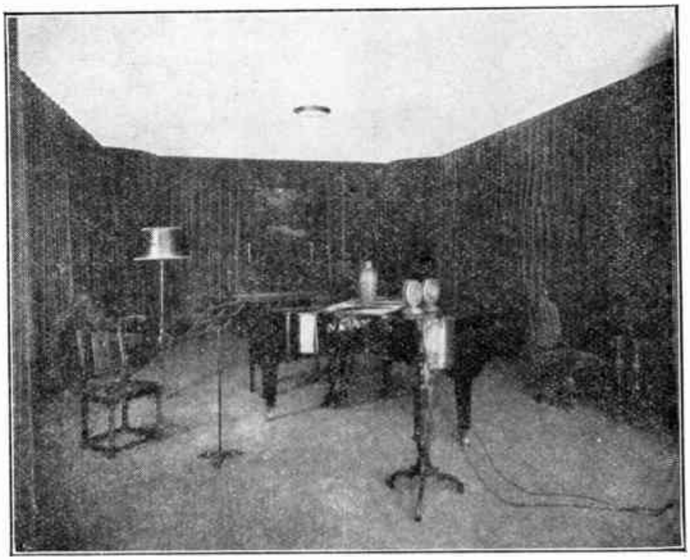
Fig. 12 is the diagram of a combination radio and audio frequency amplifier, using transformer coupling. The main advantage of this type of amplifier is that it does not require any additional adjustments and if a loop aerial is used, only one variable condenser controls the whole receiver. The condenser should be connected across the loop aerial, which is itself attached to the input binding post of the amplifier. For very long distance reception three stages of radio frequency should be used. Fig. 13 shows such an amplifier composed of two stages of radio, a detector and three stages of audio frequency amplification. When a loop is used, the variable condenser alone is turned, while if an outdoor aerial is connected to the set, the inductance in series in the antenna circuit is controlled by means of the switch on the left.

PART V

HOW A BROADCAST STATION OPERATES

PRACTICALLY all of the interest in radio transmission is now centered in the powerful broadcasting stations which are daily sending their programs into every nook and cranny of the world.

One of the best ways of learning the functions of the various departments of a broadcasting station is to take a trip through one of the stations and make a tour of inspection of the equipment which it contains.



The concert studio of a radio broadcast station. Fixtures, draperies and furnishings are so arranged to give the best acoustic properties. Note the two microphone transmitters on the pedestal.

As we enter the station, we are ushered into a commodious reception room furnished with the best of taste and the finest of furniture. There is usually a young lady or man in charge of the reception room and his or her sole duty is to welcome visitors or make artists who come to broadcast comfortable until they appear before the microphone. Adjoining this luxurious reception room is the studio. A glance inside shows heavy draped walls and ceiling, while a thick carpet covers the floor. These draperies, carpets and furniture are so arranged as to give the best acoustic effects, killing foreign noises and detrimental reverberations.

The furnishings in this room are few and simple. In one corner there is piano with its attendant bench. There are two or three chairs placed around the room. Somewhere in this studio you will

An artist broadcasting before the microphone. Note the fact that the microphone is nearer by several feet to the violin than it is to the piano. This is to assure perfect rendition.

see a stand, usually adjustable as to height, upon which is placed what is known as the microphone. In appearance this resembles a disc about seven inches in diameter by two inches thick with a series of holes over both surfaces. This disc is placed on edge and supported by a suitable mounting, which prevents jarring of the microphone member.

A microphone transmitter as used in radio broadcast stations.

This is the usual type of microphone, although there are other types. It is in this room that the artists or entertainers perform. When you enter and close the door, a curious sense of silence is "felt." Even your own voice appears to have taken on different qualities than usual. There is an utter lack of outside sounds and your footsteps on the soft carpet are inaudible. This peculiar atmosphere in the studio is due to the heavy draperies and sound-insulating material placed around the walls.

From the studio we go to the operating or control room. If we enter it during broadcasting hours we would find the air charged with an undercurrent of excitement. Two or possibly three operators are constantly on the alert. One of them is listening in a wavelength of 600 meters for any possible distress or "S O S" signal.

If such a signal should be heard or if orders should come via radio telegraphy to stop the station for any reason whatsoever, this operator will immediately cause the station to be temporarily off the air until the commanding naval station gives him the signal to resume operation.

Besides the man on the "600 meter watch" as the above-described position is called, there is usually an operator continuously watching meters and other instruments which show the quality of transmission. He also has near him a loudspeaker in continuous operation which is

Typical control room of a modern broadcast station. To the right is shown the 600 meter operator watching marine traffic in order that the station may close down in the event of an "SOS" call.

reproducing just what goes on in the studio. In this way he has a visual and aural check on the outgoing programs. At his finger-tips are controls which actuate practically any of the apparatus in the entire station. He can control the volume of the outgoing signals or can throw a switch "cutting" the station off the air immediately.

Then there is usually a third man who is there to do anything that may be required. He has to occasionally watch the filament voltage of the transmitting tubes and keep it at a fixed value. He also makes occasional rounds of all the apparatus to see that everything is working properly and smoothly.

So you can see that the operation of such a station requires no less than five employees and very often many more than that number are needed. Some powerful stations employ over twenty "studio" men.

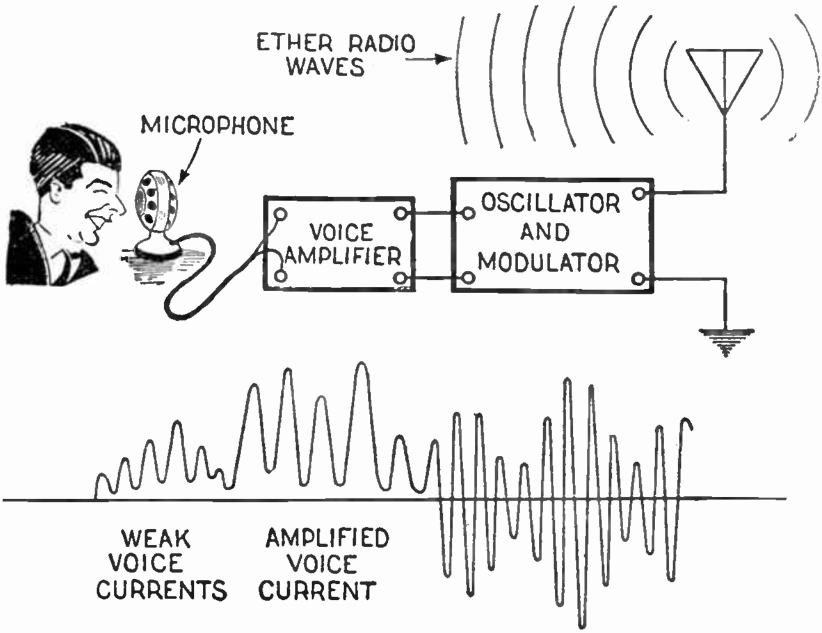
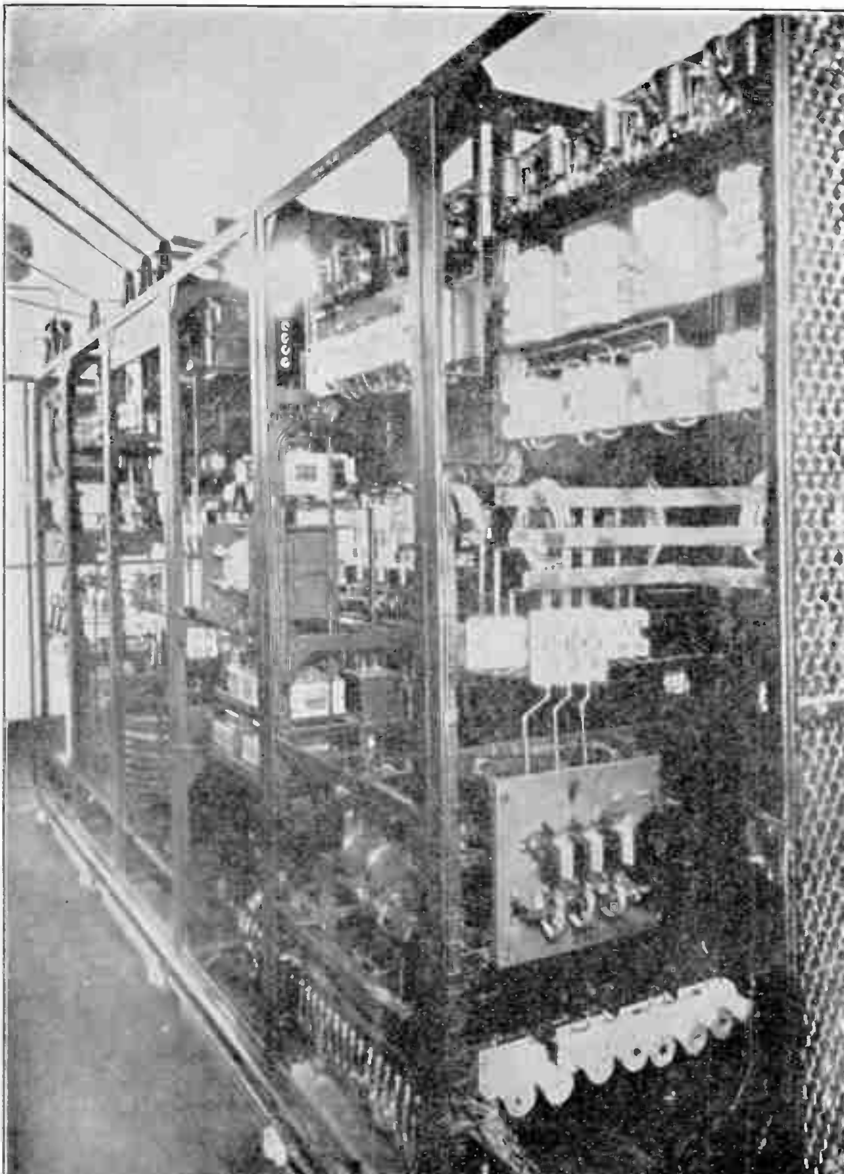


FIG. 1

In a well conducted up-to-date broadcasting station, breaks in the program are few and far between. It is only the strictest of supervision that keeps things going in this way, and that provides the radio audience with continuous amusement and education.

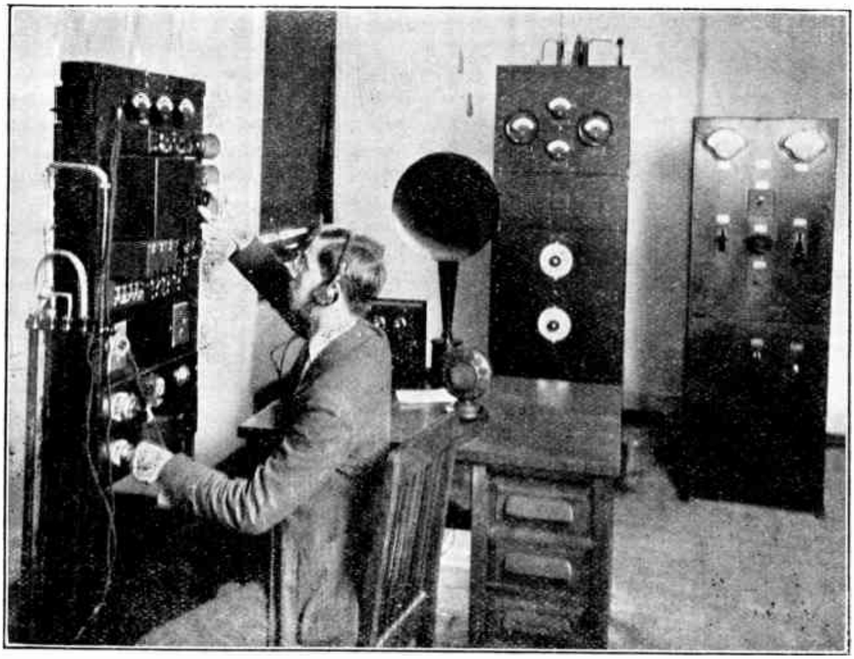
Now that we have touched upon the human interest side of radio broadcasting, let us investigate the technical side. In Fig. 1 we show an extremely simplified diagram of the apparatus in a broadcast station so as to facilitate the explanation of the various steps. The initial impulse that starts a radio signal toward the receiver is furnished by the voice of the speaker, singer or other sound originating



The transmitter of a 5000 watt station. Some idea of the magnitude of the equipment can be gained from a study of this picture.

in the studio. This sound strikes the microphone, the operating element of which is a thin metal disc or diaphragm. The sound waves cause this diaphragm to vibrate. In doing so, the disc causes changes to take place in the electrical circuit. Pulsations of current are set up, the pulsations corresponding in strength to the vibration of the spoken word, music or sound as the case may be. These fluctuations are quite weak when they first come from the microphone and therefore have to be strengthened.

They go through what is known as a "voice amplifier" which uses vacuum tubes to make the current stronger. The next piece of ap-



The operator "listens in" on a monitor and governs the modulation by means of a potentiometer. The tall machine in the rear of the room is the radio transmitter, to the right is the power panel.

paratus to consider is the oscillator. This consists of one or more vacuum tubes, connected in a circuit of such a type that the tubes when lighted and properly furnished with a high voltage direct current will generate another current, alternating in character, which is said to be oscillating (vibrating) at radio frequencies. Upon this current so generated, the voice current is impressed or superimposed. This process is called that of "modulation." The current from the oscillator is known as the "carrier wave" and when voice currents are impressed upon it, it is known as a "modulated radio frequency" current.

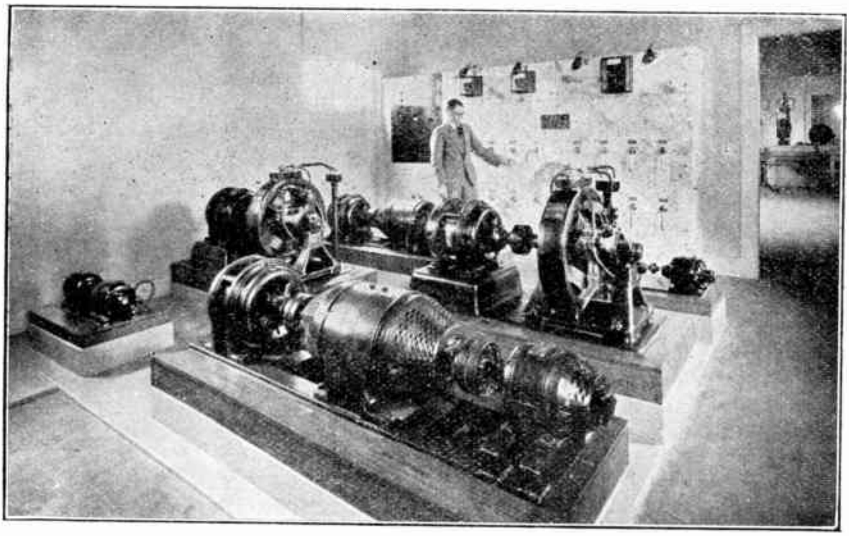
This current flows into the antenna and there sets up radio waves in the ether. These waves travel out from a station in all directions

TABLE SHOWING THE FREQUENCY OF THE VARIOUS BROADCASTING STATIONS AND THEIR CORRESPONDING WAVELENGTHS

Frequency (Kilo-cycles)	Wave length (Meters)	Frequency (Kilo-cycles)	Wave length (Meters)	Frequency (Kilo-cycles)	Wave length (Meters)
550	545.1	870	344.6	1190	252.0
560	535.4	880	340.7	1200	249.9
570	526.0	890	336.9	1210	247.8
580	516.9	900	333.1	1220	245.8
590	508.2	910	329.5	1230	243.8
600	499.7	920	325.9	1240	241.8
610	491.5	930	322.4	1250	239.9
620	483.6	940	319.0	1260	238.0
630	475.9	950	315.6	1270	236.1
640	468.5	960	312.3	1280	234.2
650	461.3	970	309.1	1290	232.4
660	545.3	980	305.9	1300	230.6
670	447.5	990	302.8	1310	228.9
680	440.9	1000	299.8	1320	227.1
690	434.5	1010	296.9	1330	225.4
700	428.3	1020	293.9	1340	223.7
710	422.3	1030	291.1	1350	222.1
720	416.4	1040	288.3	1360	220.4
730	410.7	1050	285.5	1370	218.8
740	405.2	1060	282.8	1380	217.3
750	399.8	1070	280.2	1390	215.7
760	394.5	1080	277.6	1400	214.2
770	389.4	1090	275.1	1410	212.6
780	384.4	1100	272.6	1420	211.1
790	379.5	1110	270.1	1430	209.7
800	374.8	1120	267.1	1440	208.2
810	370.2	1130	265.3	1450	206.8
820	365.6	1140	263.0	1460	205.4
830	361.2	1150	260.7	1470	204.0
840	356.9	1160	258.5	1480	202.6
850	352.7	1170	256.3	1490	201.2
860	348.6	1180	254.1	1500	199.9

as explained in previous chapters, but are often reflected or deflected from their course by large steel buildings or natural mineral deposits in the earth, etc.

This action explains the reason why in certain localities, stations even a comparatively short distance away can only be heard faintly while in other directions from a transmitter, receiving stations can pick up the waves for hundreds of miles around. Obstructions such as those mentioned are also frequently referred to as "dead-spots" where radio reception cannot be accomplished at all or at best very poorly.



Generator room of an up-to-date radio broadcast station. Note the spare set of generators.

There has been some agitation of late to refer to the wave emitted from a broadcast station in frequency (number of vibrations of current) rather than in wavelength. As the length of a transmitted wave decreases, the frequency at which it oscillates, or alternates in its direction of flow increases. This is not in a direct ratio and the table given herewith will show just what variation in frequency there is as the wavelength increases or decreases. During the study of the subject of radio, you will often find it necessary to refer to frequency as compared to wavelength, and you will find this chart to be of great assistance to you.

PART VI

"A," "B" AND "C" BATTERY ELIMINATORS

WHEN radio sets first became well known to the public, and came in more or less general use, a question that was frequently asked was, "Why can I not use my house current for operating my radio set instead of using batteries?" At that time the answer was merely that it could not be done. "B" battery eliminators were almost unknown, and had not been developed outside of the laboratory stage.

The average household is equipped with electric lighting current of the type that is known as alternating, as explained in a previous book of this series. Some few have installed direct current or DC. The majority of the eliminators on the market today, are designed for operation on alternating current, or AC, only. Never attempt to use a DC eliminator on AC, or vice versa.

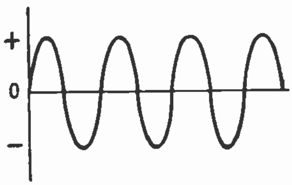


FIG. 1

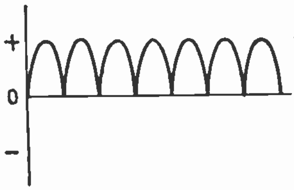


FIG. 2

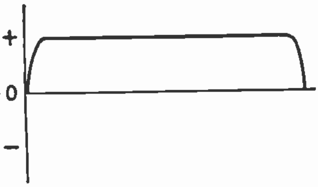
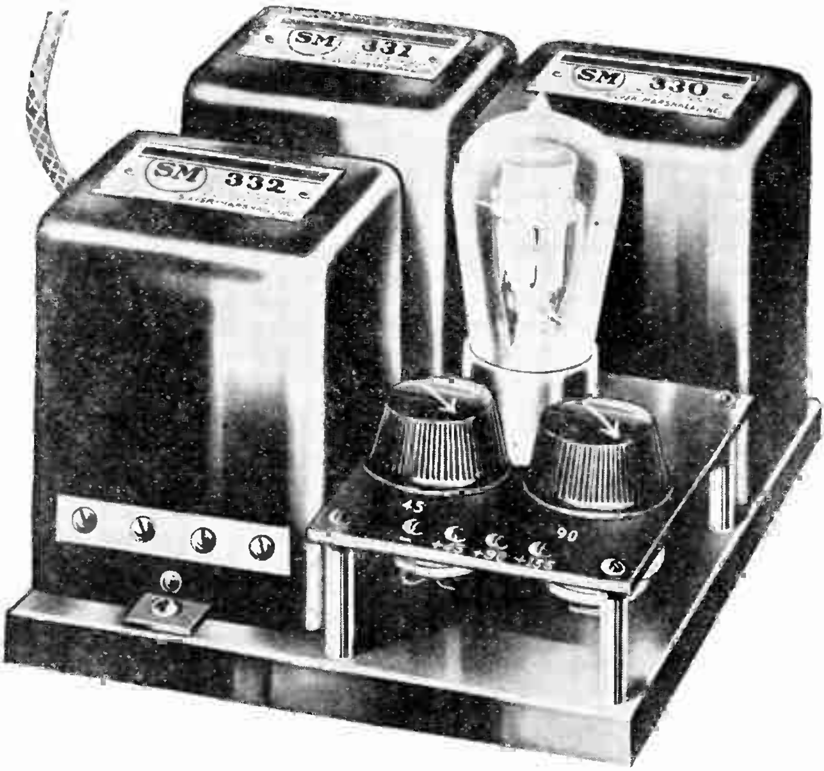


FIG. 3

Let us first review and consider the principles of alternating current and find out why comparatively complicated apparatus is necessary in order to employ this current for operating our radio sets.

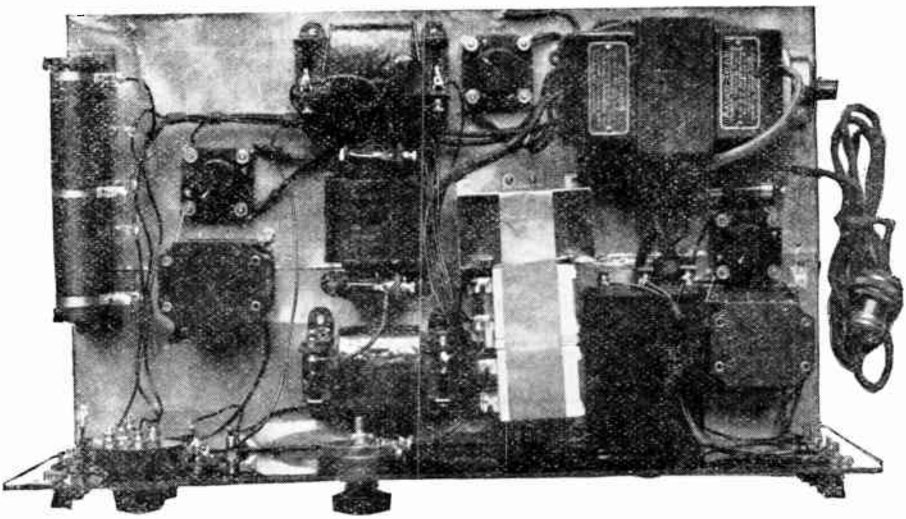
Alternating current is just exactly what its name implies. It does not flow steadily in one direction, but instead, dashes back and forth very rapidly. In what is known as 60 cycle current, this reversal takes place 60 times per second, and an engineer would draw a picture of the current after the manner shown in Fig. 1. Here the straight horizontal line marked zero, indicates the point of zero potential, or the crossing point from negative to positive current flow. The voltage first rises from zero to its full value in one direction and falls to zero, goes to full value in the opposite direction and falls back to zero. This change takes place many times per second, and the exact number of changes is expressed in cycles. A cycle is constituted by the building up of the current from zero to full, its fall to zero, its rise to full in the opposite direction, and its fall to zero once more.

It is comparatively well known that it is necessary to have a very steady source of current for the "B" supply for a radio set. Just notice the trouble that is encountered when the "B" battery falls in voltage due to age, and its out-put fluctuates. The set becomes noisy. This would be the case, only to a far greater extent, if ordinary alternating current were used for the "B" supply. You would get a loud roar in the phones or loudspeaker, making reception absolutely impossible. Therefore, it is obvious that alternating current must be changed before it can be used, and this change is known as rectification. In simple language, what happens is that the current that formerly flowed in the opposite direction to the initial current, is



A modern "B" eliminator of the double wave vacuum tube rectifier type, which is being widely used by radio listeners of today. This tube is known as Raytheon.

forced to flow in the same direction as the initial current. This may be done in several ways. Either an electrolytic rectifier or a tube rectifier may be used. There are manufactured instruments on the market today using both systems. In any event the results are the same, and the direction of the current delivered by the rectifier is shown in Fig. 2. Notice that the current now flows all in one direction, but it still fluctuates in strength. This is still undesirable, and the rectified current is not yet ready to operate a radio set. It must be smoothed out before it can be put to this use, and the combination of instruments which accomplishes this smoothing is known as the filter. The exact action of an electrical filter is rather difficult to explain to the average layman, and, furthermore, such an explanation would mean very little. It is sufficient to say, that just as the pressing iron smoothes out wrinkles in a shirt, so does the filter press out wrinkles in electric current and give a resulting current which appears when pictured as in Fig. 3. Here the current rises from zero to full potential, and continues to flow at that value until the current is turned off. This direct current is now satisfactory for use in connection with radio receiving sets.



A combined power amplifier and "B" battery eliminator.

For those who desire to experiment with the construction of a "B" eliminator and do not desire to spend a lot of money in doing so, the following description will be of value. This eliminator gives quite satisfactory results on receiving sets using not more than three tubes and it will be quite free from any annoying hum. The eliminator uses the electrolytic principle of rectification, and its filter system consists of some small fixed condensers and the secondary of an audio frequency transformer. Possibly you have a transformer, the primary of which has been burned out. If so, this instrument is still in good enough condition to use in an experimental eliminator. You must, however, be sure that the secondary circuit is still complete. This can be tested by means of a battery and phone connected in series with the secondary. If a click is heard in the phones when the circuit is closed, the wiring is continuous and can be used.

The rectifier unit of this "B" eliminator is very easy to construct. Four ordinary jelly glasses and some strips of sheet aluminum and lead should first be obtained. Four strips of each metal ¾ inch wide by 4 inches long must be cut. A hole is drilled in one end of each strip, and a bolt and nut fastened in the hole to be used as a binding post for connections. After the four strips of each metal are cut and drilled, both surfaces of each strip must be thoroughly cleaned and polished with fine sand paper. After this has been done do not touch the polished surfaces of the metal with your fingers. The strips are next placed in the jars and the ends of the strips bent so that they will hang over the edge. One aluminum and one lead strip is placed in each jar, and the eight pieces of metal are connected as shown in the diagram. Each jar is then filled to within about ½ inch of the top with a solution consisting of two ounces of borax to a quart of water. Ordinary household borax may be used and the water need not be distilled. After each jar is filled, a layer of paraffin oil about ¼ inch deep is poured over the surface of the electrolyte. This effectively prevents evaporation and lengthens the life of the eliminator.

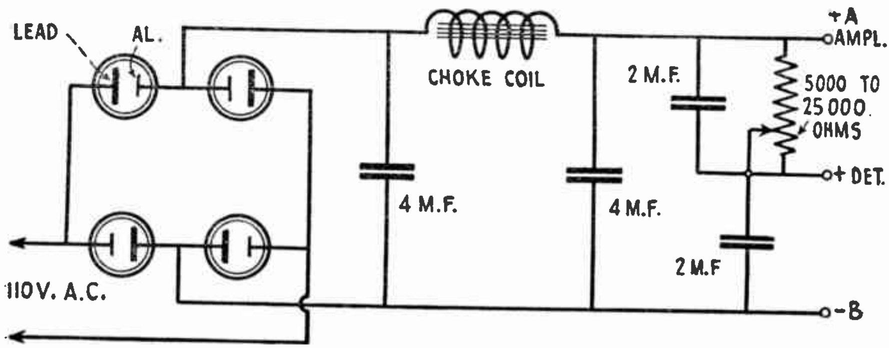
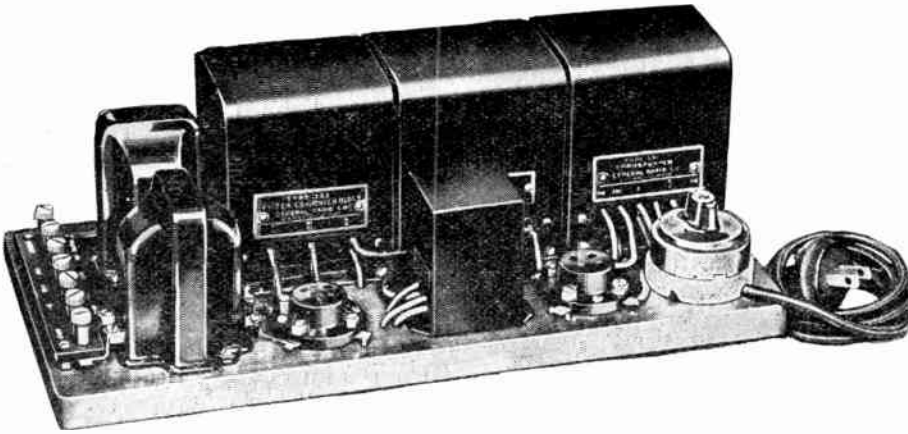


Fig. 4

Besides the rectifier and the filter, it is necessary to have a controlling resistance so that the proper "B" voltage for the detector tube can be obtained. This is an ordinary variable resistance having a range of from 5000 to 25000 ohms. It is connected in the circuit as shown in the diagram, Fig. 4.

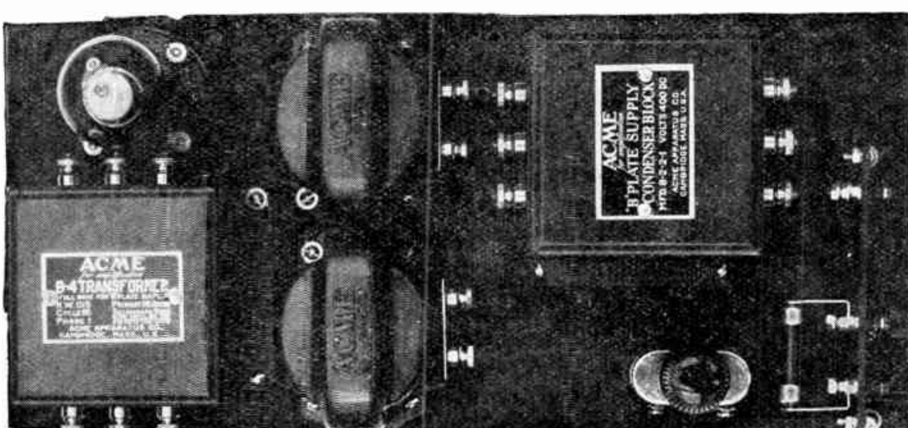
After the eliminator is hooked up as shown, and connected to the radio receiving set, light the filaments of the tubes in the set and turn on the 110 volt AC circuit. This can best be accomplished by having a flexible cord connected to the in-put and a plug connected to the opposite end of the cord. This is then inserted in any convenient receptacle. The set will at once begin to operate, and probably a hum will be heard. This is because the plates of the rectifier are not yet formed, but the hum will persist for only a few minutes and then the eliminator will operate properly throughout its entire life. If, however, the set is not used for a week or more, the film that forms on the aluminum plates may be destroyed, and the forming process will have to be gone through again before the eliminator will operate properly. This forming process is, however, practically automatic, and needs no particular attention on the part of the operator.

The filter system of the home-made eliminator may be seen in the diagram. Every filter system consists of what is known as a choke coil, consisting of several thousand turns of wire on an iron core, and several fixed condensers. In this particular unit, the choke coil is to be the secondary of an audio frequency transformer. Be-



Another type of eliminator, combining a "B" power supply with a power amplifier and out-put filter as a last stage of audio for extremely loud signals.

cause we are dealing with low voltages, the fixed condensers may consist of ordinary by-pass instruments. Two having a capacity of 5mf. each, or four having a capacity of 2mf. each are required. Also



Top view of combination "B" eliminator and amplifier.

it is advisable to have an additional 2mf. condenser connected across the resistance which controls the detector cut-out, and another one from the positive detector wire to the negative. This filter will be found quite satisfactory for all around work with the particular type of electrolytic rectifier described above.

The grid leak value that is used in the average radio receiving set is usually far too high for the same set and detector tube when the plate current is supplied by a "B" eliminator. If such is the case, it will be indicated by an unusual hum from the reproducing unit. If your grid leak is of the fixed type, and this trouble arises, change it for one of a lower value. With a variable grid leak, it is merely necessary to adjust it for best results. In any event, do not neglect the leak. It has a very important function and if it is not right, the operation of the set will not be all that is desired. Find the right value for best results and leave it alone.

Of late, a new type of vacuum tube has appeared on the market, which has made the "B" eliminator very popular. It is a tube that does not need any filter, and serves as a double wave rectifier, eliminating the use of two tubes that are necessary with some other types of vacuum tube rectifier. This tube is illustrated in one of the accompanying photographs. It makes use of a unique principle of rectification, and is practically fool proof. In operation it needs absolutely no

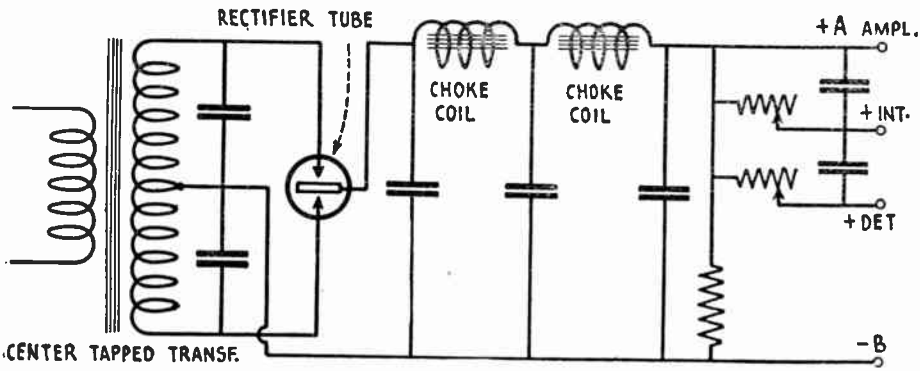
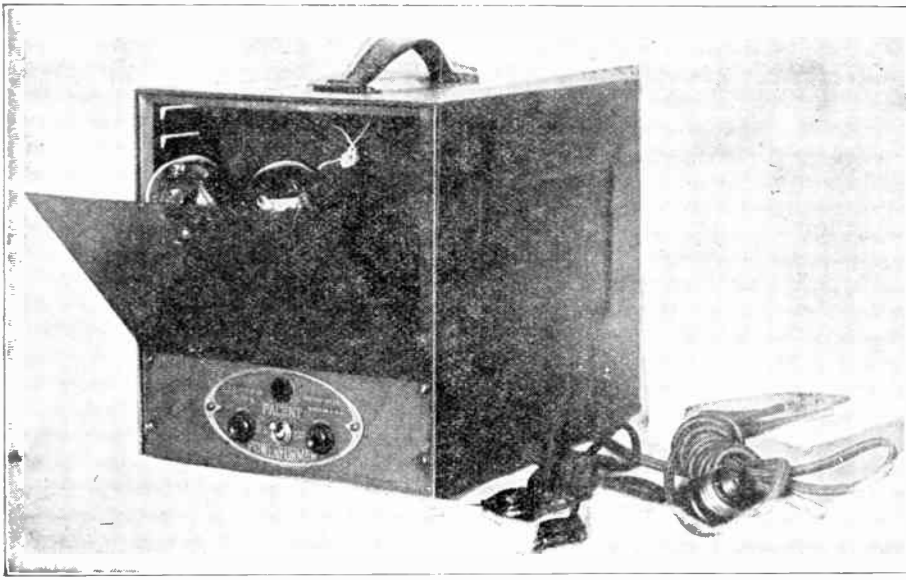


Fig. 5

attention, and has an unlimited life. Tests up to three thousand continuous operating hours have failed to affect the operation of this tube, and no depreciation in results has been found. This tube is always to be employed in connection with a step-up transformer so that the voltage supplied is in excess of 200 volts. The transformer used with this tube is of the type having a tap in the center.

There are several types of eliminators on the market today which use this new type of tube and which are equipped with well designed transformers and filter systems. Several of these manufactured units are illustrated in this article.

Besides the vacuum tube just described, there are others in use of a type similar to the ordinary tube used in radio receiving sets. These tubes use a filament and a plate but do not have a grid as is the case of the ordinary tubes. True, some eliminators have been designed and marketed which use the same type of tubes as those employed in radio receiving sets. However, manufacturers of tubes have made it quite plain that receiving set tubes are not suitable for use in "B" battery eliminators. Used in this way they have a comparatively short life, and are in every way quite unsatisfactory. It is always advisable to shun the use of receiving set tubes in connection with "B" battery eliminators, and to use tubes that are designed for that particular purpose. One of the vacuum tubes using a filament that is designed for "B" battery eliminator use, has only one plate, and accomplished only single wave rectification. Therefore, for all around use, two of these tubes are necessary. There is, however, another one of a similar type, but which has two plates and which accomplished double or full wave rectification. With this, only one tube is necessary.

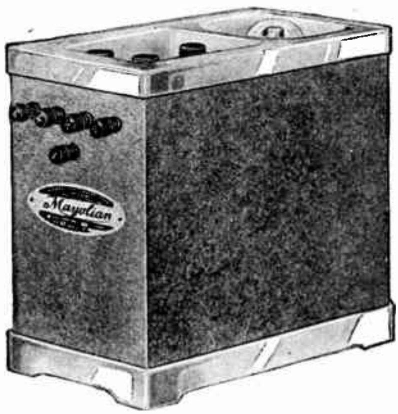


Another type of tube rectifier "B" eliminator and power amplifier.

The circuit of a standard "B" battery eliminator is shown in Fig. 5. We have shown this diagram with the filamentless tube described above. However, in most respects the same circuit is used for the double wave filament rectifier tube or where two single wave tubes having filaments are used. This circuit is given for general information purposes, and is the one that is almost universally employed with the so-called Raytheon tube. Note the filter circuit and the connecting of the two variable control resistances which allow the use of a different voltage in the RF amplifier from that applied to the AF amplifier.

The average experimenter will probably want to assemble his own eliminator and for this reason manufacturers have been simplifying apparatus so that the assembling troubles will be reduced. One of the greatest advances is in the condenser part of the filter circuit. Formerly, it was necessary to use several separate fixed condensers and the result was a lot of wiring and an irksome task. Now, however, it is possible to purchase a block containing all of the filter condensers. This block is equipped with convenient terminals and a lot of the condenser wiring is done inside the casing. With this unit, shown in an accompanying photo, an eliminator can be assembled with the least possible trouble.

The problem of switching a "B" eliminator into and out of the circuit is quite a big one. Under ordinary circumstances the average person only remembers to turn off the filaments of the receiving set. and will often allow the "B" battery eliminator to run. While not



A commercially manufactured "B" power supply unit.

consuming much current when the filaments of the radio receiving set tubes are turned off, still the "B" battery eliminator uses some. and it is always best to turn off the 110-volt AC circuit when not in use. Possibly the best way to accomplish this is to turn off both circuits at the same time. Use a double pole, single throw switch connected as shown in Fig. 6. One blade is in the "B" eliminator primary circuit, and the other is in the "A" battery circuit. Opening the switch cuts off both, and prevents the possibility of leaving the eliminator turned on. It is possible to procure a switch of the snap type that can be used in this particular circuit. Inquire at your local electrician's store, and tell him that you want a double pole, single throw snap switch.

Another switch arrangement that is quite popular for "B" eliminator use is shown in Fig. 7. When the operator is through using the receiving set, he throws the switch to the opposite side from the working position and by doing this disconnects the "B" eliminator and the "A" battery, and at the same time connects the trickle charger to the "A" battery so that the latter will be charged while the set is not in use. By using a "B" battery eliminator and a trickle charger in connection with a storage "A" battery, most of the battery troubles of the radio fan will be solved. If this switch arrangement just described is installed, still more trouble will be avoided, and everything can be carried on with the utmost dispatch.

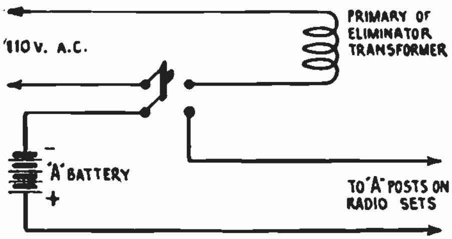


Fig. 6

Whenever a switch is employed that cuts out both the "B" eliminator and the "A" battery, the "A" battery switch that is incorporated in the set should be short circuited so as to prevent its use.

Aside from the "B" eliminators that supply in the neighborhood of 135 volts, there are others that are so arranged to deliver about 350 volts for use on a power amplifier using a tube such as the UX-210. These units usually use single wave rectification with a highly efficient filter system. A rectifier tube having a filament is employed.

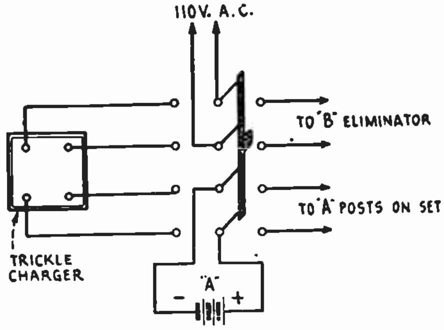
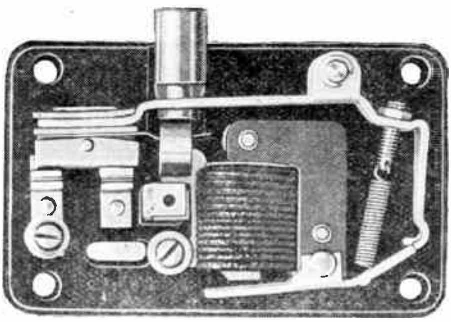


Fig. 7

Some experimenters prefer to combine such a high voltage "B" supply with the power amplifier of one or two stages and one of our photographs shows such an arrangement. All of the parts of such a unit may be purchased on the market and readily assembled by the layman. Variable or tapped fixed resistances are so placed in the circuit that the correct plate voltages can be had. The usual procedure with a unit of this type is to use a UX-201A in the first stage of amplification and a UX-210 in the second. The resistances allow the operator to apply the desired plate voltages. Remember that high plate voltage calls for a high grid voltage. Use the proper "C" battery for the tube and plate potential used.

Since the "B" eliminator is connected directly in the house lighting circuit, some means of protecting the lines and the eliminator should be used. One way is to insert fuses in the circuit at the eliminator, using fuses that will "blow" at about 5 amperes. This



Automatic cut-out and switch for use in "B" eliminator circuit to prevent blowing out main line fuses in house circuit. They can be obtained in a wide range of capacities. "B" eliminators generally call for the 3 ampere capacity type.

arrangement is not very flexible, however, and it is preferable to employ a circuit breaker. One very good type, designed especially for "B" eliminator use is shown in these columns, and is so arranged that it can be used both as a circuit breaker and as a switch for opening and closing the eliminator circuit. It can be obtained with its adjustment set to open the circuit when over three amperes passes. Thus, if a short circuit occurs in the eliminator, the primary circuit will be opened immediately and no damage will be done to either the radio apparatus or the lighting line.

Where direct current is available, a really high powered "B" battery eliminator is not possible or practical. This is because of the impossibility of stepping-up the direct current with any ordinary means and thereby obtaining the high voltage that is necessary for present day sets. However, with 110-volts DC, about 90 volts can be obtained and applied to a radio receiving set, and this will be quite satisfactory for all three-tube receivers and for some five-tube sets. While direct current such as supplied by public service companies does not have as much fluctuation as the rectified alternating current pictured in Fig. 1, still it has a certain ripple that must be smoothed out before the current can be used for radio work. This is accomplished by using a filter system such as is employed in connection with a rectifier for "B" eliminator use on AC. This filter, as described in connection with the electrolytic "B" eliminator, may consist of an ordinary audio frequency transformer and a few fixed condensers hooked up as shown in Fig. 4. This eliminator is comparatively inexpensive to make, and should give quite satisfactory results under all conditions.

In summing up the subject of "B" battery eliminators, the following statements and suggestions are made and should be heeded.

When an eliminator is to be used on a receiving set having four or more tubes and requiring a current of more than 10 milliamperes, one should be chosen that uses a step-up transformer. If this precaution is not taken the eliminator will not deliver sufficient voltage and current for the purpose.

The electrolytic type of eliminator, such as the home-made one described above will not give satisfactory results on a set using more than three tubes. Do not expect it to operate a five or six-tube set.

When installing a "B" battery eliminator make provision for some kind of switch arrangement so that the eliminator will not be left connected to the house lighting circuit when it is not in actual use.

A home-made eliminator should be encased in a metal box and the box should be connected to the ground wire of the radio receiving set. This will aid in eliminating any hum in the reproducing unit.

If possible, the eliminator should be placed two or three feet away from the radio set proper. This will be a further aid in eliminating hum.

Ground the cores of the choke coils and transformer as well as the metal condenser cases.

In all cases where an eliminator is used which does not employ a transformer, a large fixed condenser having a capacity of 1mf. should be connected in series with the ground of the radio set. This is important, because without the condenser a short-circuit may take place through the eliminator which may burn out the tubes in your radio receiving set.

Always have one or more variable resistances in your "B" battery eliminator circuit so that the plate voltages can be carefully controlled. Failure to do this will mean unsatisfactory results, and the operation of the set will not be as flexible as might be desired.

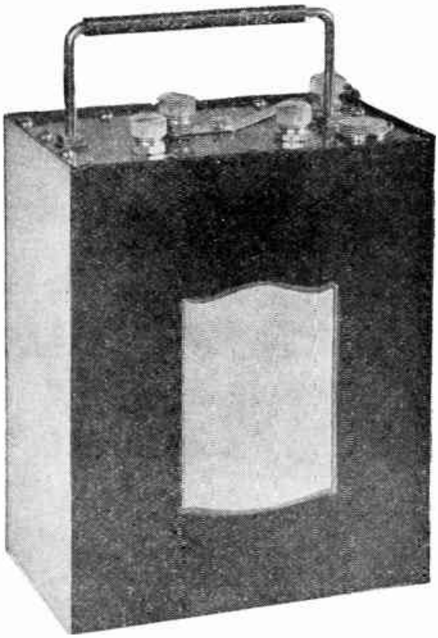
Remember that a "B" battery eliminator is a power device and treat it with respect. A rather painful shock can be obtained from most "B" battery eliminators and, therefore, you should never work around an eliminator unless the in-put current is completely turned off.

Satisfactory results will never be obtained if inferior instruments are used. This is particularly true of the eliminator delivering in the neighborhood of 150 volts out-put or higher. Always use the best apparatus. There are a good many concerns manufacturing "B" eliminator parts today, and there is no excuse for not using good standard apparatus. Reference to the advertising columns of any radio publication will show a variety of apparatus for use with different types of "B" eliminator rectifier.

"A" Battery Elimination

The problem of finding a suitable way of using the lighting current to supply the current for the filament circuit of a radio receiver was more difficult to solve than that of finding a method of using lighting current for the "B" battery circuits.

At last, however, this last remaining obstacle to completely power operated receivers has been overcome and it is now possible to operate a receiver without any batteries whatsoever.



The Abox, a device to eliminate the storage "A" battery. It filters the pulsations from the output current of an "A" battery charger.

One of the earliest methods used to get practically lighting current operation for the filament circuits was that of using what is known as a trickle charger in connection with a small storage battery, keeping the battery constantly on charge during the time when the set is not in use and thus keeping the battery fully charged at all times. The trickle charger, as shown in an accompanying illustration, can be connected or disconnected from the battery automatically by means of a specially designed relay switch which connects the trickle charger to the battery and lighting mains when the set is turned off and connects the battery to the set when the receiver is in use.

Another unit, as shown in an accompanying illustration, is known as the Abox, and is essentially a filter device for smoothing out the rectified current as it leaves the charger and passes on to the set, thus giving a smooth direct current free from hum or noise. This

A chemical type of trickle charger.

unit consists of a large size choke coil with an electrolytic condenser of new design. This condenser according to the measurements of the manufacturers has a capacity of ¼ of a farad, this capacity being equivalent to 250,000 microfarads. The principle of operation is that of gas concentration on the iron and nickel plates which are immersed in a strong solution of potassium hydroxide. The plates of

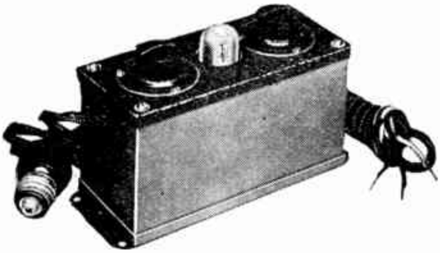
A rectifying tube type of "A" eliminator, the output voltage of which is adjustable.

this electrolytic condenser are sealed into a tank in the upper part of the unit, while the bottom of the unit holds the large size choke coil. This filter unit is also adaptable for direct current service as well as alternating and may be used with a trickle charger to supply the "A" battery current for set having 199 type tubes.

Another "A" battery supply unit for eliminating the storage "A" battery or converting the alternating house current into direct current for lighting a standard six-volt type tube is shown in the accompanying illustration. The system employed in this unit is a transformer, choke and dual vacuum tube method of rectification. The 110-volt alternating current is stepped down to a lower voltage by means of a transformer rectified by the tube and the pulsations smoothed out by means of a filtering system. The maximum output of this "A" battery eliminator at six volts is about 2½ amperes, the eliminator therefore being capable of operating any receiver employing up to ten tubes of the 201-A type or their equivalent.

"C" Battery Elimination

With the advent of higher "C" battery voltages, the "C" eliminator shown in the accompanying photo has been presented to the radio set owner who prefer lamp-socket operation for the "C" source of current supply. This is a battery eliminator as it substitutes for



An eliminator for supplying "C" battery current for the up-to-date radio receivcr.

the "C" battery without any change in the circuit arrangement. A UX-199 type tube is employed as the rectifier, the filament being heated by the alternating current through the tertiary winding on a transformer contained in the unit. The use of the small tube is made possible by the fact that only voltage and no current is required from the "C" supply. The unit is provided with an output cable containing three conductors, one positive "C" lead and two negatives. The voltages are controlled by two potentiometers, the knobs of which are on either side of the tube socket on top of the unit. The scales of these potentiometers are calibrated directly in volts and marked for the voltage output of each of the two "C" negative leads. A lamp socket plug is provided on a separate input cord of the eliminator to be inserted in a lamp socket or baseboard receptacle. The eliminator is especially valuable when power amplifying tubes requiring comparatively high negative voltages are used.

The Radio Educator

by Sidney Gernsback

A Reading Course in Five Books

Book No. V

BOOK NUMBER FIVE

PART I

FUNDAMENTALS COMBINED IN MODERN RADIO CIRCUITS

IN this chapter we will endeavor to outline fundamental circuits and show how these are combined in various ways to produce the many up-to-date receiving circuits.

The fundamental circuit of the three-electrode vacuum tube is shown in figure 1. No matter what kind of circuit is used in the radio receiver, and no matter what name may happen to be given it, this fundamental circuit still forms the basis of the receiver.

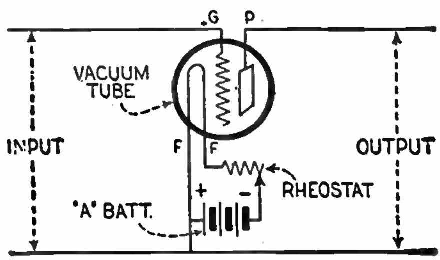


FIG. 1

In this circuit the input of the tube is, as marked on the illustration, between the grid and filament, and the output is between the plate and filament. No sources of voltage have been shown on this fundamental diagram for they may be applied in various ways, as shall be explained. The only battery shown is that which is used for lighting the filament, which is always applied in the same manner, and, to tell the truth, this application is not subject to much variation.

Fundamentally, the action of the electron tube is much the same, no matter whence or how the various electromotive forces which operate it are derived. For instance, in figure 2 we have shown several methods of applying the input voltage to the electron tube, which is to act in the capacity of an amplifier or a detector of the high frequency oscillations which constitute the radio signals. Three methods of obtaining the high frequency voltage to apply to the input of the tube are shown. Even these three do not constitute all the methods that are in use, but are only the most generally used methods. The main thing to remember is that we must obtain somehow, somewhere, a high frequency electromotive force to apply to the input. Where or how we obtain it is a secondary consideration, as far as the operation of the tube is concerned; this does not affect the operation of the tube fundamentally, although it may affect the method of tuning the circuits considerably.

In A of figure 2 we have the most generally used method, viz., the input voltage to the tube is obtained from the potential difference established across the terminals of the variable condenser by the high frequency current flowing in the tuned circuit. This tuned circuit has an electromotive force induced in it by being coupled to another circuit carrying a high frequency current, as for instance the antenna circuit of a radio receiver. In B of figure 2, we have what is commonly known as impedance coupling, that is, the potential difference

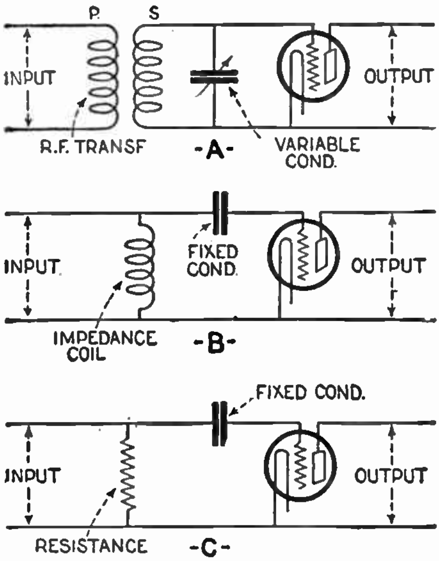
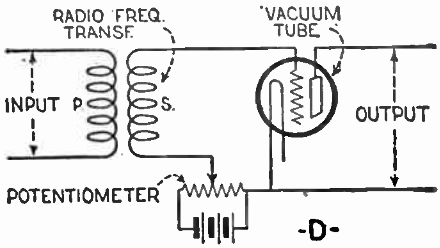


FIG. 2

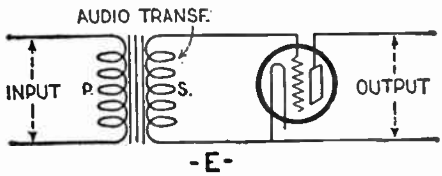
to be applied to the input of the tube is that which is set up across the terminals of an inductance or impedance coil, which may or may not have an iron core, depending upon whether it is to be used for amplifying high or low frequency voltages. The ends of this impedance coil are connected to another circuit carrying a high frequency current, just as in the preceding case; this other circuit may be the output of a preceding amplifier tube, or, again, the antenna circuit.

In C of figure 2 we have shown what is called resistance coupling; here the input voltage is obtained as the difference of potential between the terminals of the resistance indicated, in just the same manner as the potential difference is obtained in the case of the impedance coupled tube.

There is one remaining system shown in figure 3, which is practically the same in effect as that of A, figure 2. This is the untuned transformer system. The tuned transformer system (A of figure 2) is tuned by the condenser indicated. In the untuned system this transformer may or may not have an iron core, depending upon whether it is required to amplify high or low frequency voltages. It is generally used with an iron core for amplifying audio frequency voltages, but the untuned transformer, without an iron core, has often been used for amplifying radio frequency voltages, in which case a potentiometer is used to control the tendency toward self-oscillation. In figures 4, 5 and 6 we have the complete circuit diagrams of high frequency amplifiers using three various systems. In each of the stages in each of the diagrams a capital letter indicates the fundamental upon which the circuit is based, corresponding to the letters used to identify the systems of figures 2 and 3.



~FOR UNTUNED R.F. AMPLIFICATION~



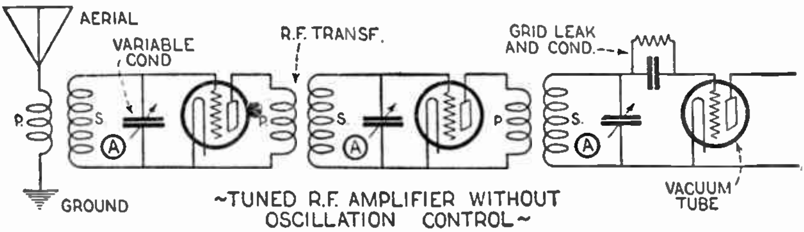
~FOR AUDIO AMPLIFICATION~

FIG. 3

In figure 4 we have the tuned radio frequency amplifier, without any provision made for controlling the tendency toward self-oscillation. Generally stability is secured in this system by making it so inefficient that it cannot oscillate.

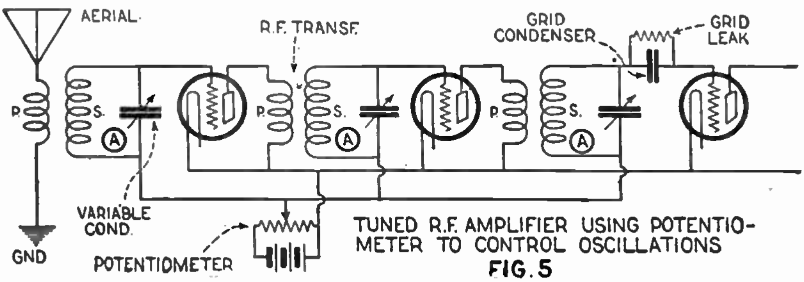
In figure 5 we have the same tuned system, but this time we have added a potentiometer, by means of which the system can be made to oscillate or not, at the will of the operator. The advantage of being able to make the system oscillate is very great, as the greatest amplification is obtained when the circuits are operated just at the point before self-oscillation starts. This condition is easily found in operation, since the instant self-oscillation starts a whistle is heard in the phones when tuned to any station it is desired to receive.

In figure 6 we have the untuned system, with the exception of the first stage, which is required to be tuned so as to be able to tune stations in or out. The tendency to oscillate is likewise controlled by means of a potentiometer.



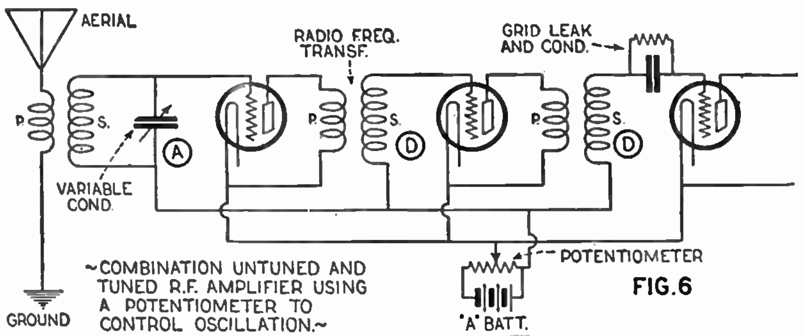
~TUNED R.F. AMPLIFIER WITHOUT OSCILLATION CONTROL~

FIG.4



TUNED R.F. AMPLIFIER USING POTENTIOMETER TO CONTROL OSCILLATIONS

FIG. 5



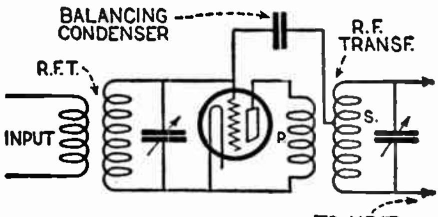
~COMBINATION UNTUNED AND TUNED R.F. AMPLIFIER USING A POTENTIOMETER TO CONTROL OSCILLATION.~

FIG.6

These are the three main systems for amplifying high frequency voltages, but there are often added to these various other things which may or may not facilitate the operation and control of the receiver. One of the most valuable of these additions is a system for automatically controlling the tendency toward self-oscillation. The most prominent of these systems are Neutrodyne and the Isofarad. The diagrams of these two systems are shown in figures 7 and 8. Obviously these may be extended to several stages of amplification.

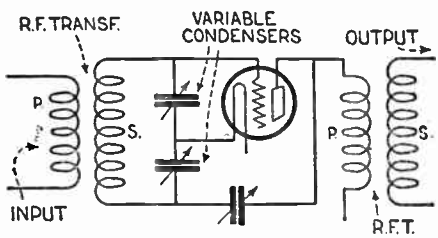
Both of these systems work on what is known as the "bridge" principle. We will not discuss this principle here as it is rather complicated. The circuit diagrams are presented so that my reader will be able to identify them.

In figures 9, 10 and 11 we have three systems of amplifying audio frequency voltages. In figure 9 we have the ordinary transformer coupled amplifier, which, of course, is untuned. The detector tube is shown connected to the amplifier in all three illustrations, as this is generally found to be the case in the usual radio receiver. In



THE NEUTRODYNE SYSTEM
FIG. 7

figure 10 is shown an impedance coupled amplifier connected to the detector. It will be seen that this does not differ essentially from the case of the transformer coupled amplifier, for in this case the one winding of the transformer acts as both primary and secondary winding. The condenser shown connected to the grids of the two last tubes is for the purpose of blocking off from the grids the high "B"

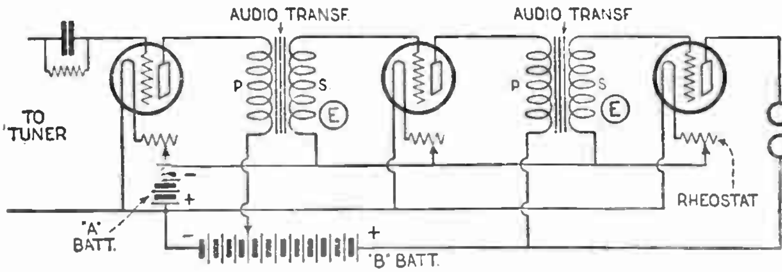


THE ISOFARAD SYSTEM
FIG. 8

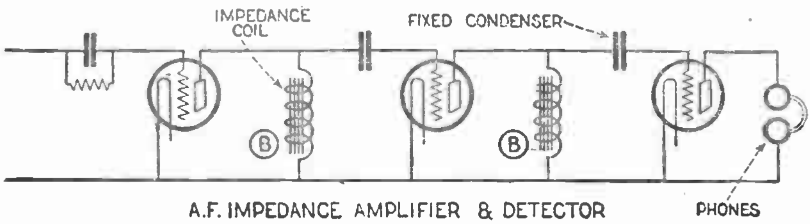
battery voltage which would find its way around through the winding of the coupling impedance and on to the grid. If this should go all the way to the grid the tube would not act properly.

Figure 11 shows the resistance amplifier, which also is seen not to differ much in essentials from the impedance coupled amplifier. The connections are in every respect the same.

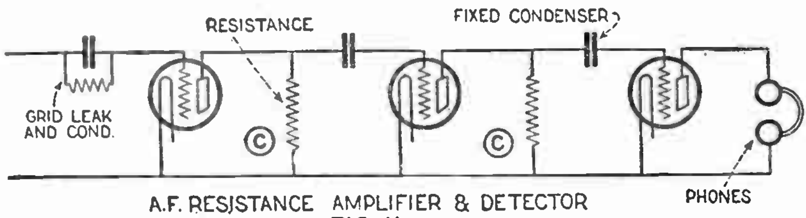
The next important part of the radio receiver to consider is the circuit of the detector tube, which is perhaps more susceptible to variations than the amplifiers. The tube circuit as we have shown it in figure 1 is the unregenerative circuit. There are several methods



A.F. TRANSFORMER AMPLIFIER & DETECTOR
FIG. 9



A.F. IMPEDANCE AMPLIFIER & DETECTOR
FIG. 10



A.F. RESISTANCE AMPLIFIER & DETECTOR
FIG. 11

of obtaining regeneration in this circuit, the three most usual methods of which are indicated in figure 12.

The first method, F of figure 12, is the tickler method, in which a coil in the output circuit is coupled inductively to the input circuit. The second method, G of figure 12, is called the tuned plate circuit method, in which there is included in the output circuit of the tube a variable inductance of some kind, as, for instance, a variometer.

The third method, H of figure 12, is an adaptation of the Hartley oscillator, sometimes called the Reinartz system, which is essentially the same as the tickler method. In all cases a by-pass capacity is

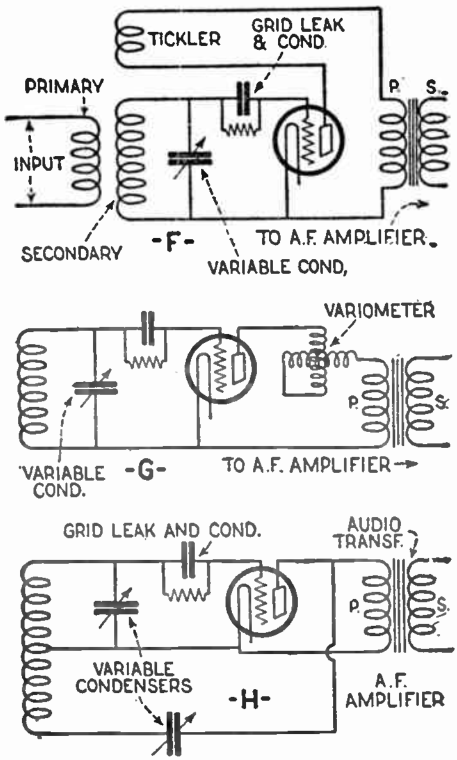


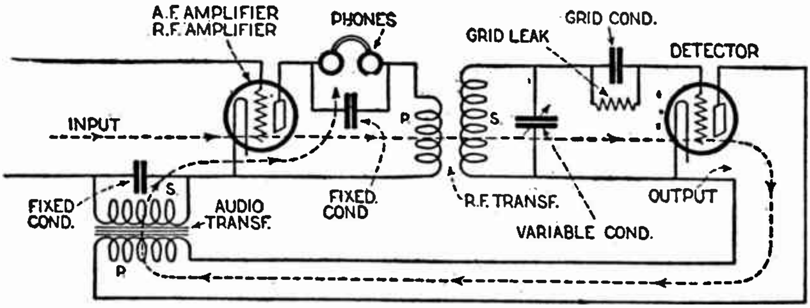
FIG. 12.

required across the terminals of the device which couples the detector to the audio frequency amplifier, whether it be a transformer, impedance or resistance. In many cases it is not necessary to add a special condenser to furnish this capacity, as there may be already sufficient capacity in the windings of the transformer or impedance to by-pass the high frequency currents.

The tickler method may also be used to control the tendency toward self-oscillation by reversing the feed-back and extending it to one of the radio frequency stages in advance of the detector. This is the system employed in the Superdyne circuit, which was greatly in favor during the past few years.

There are many other variations of these systems possible, but after study and the knowledge of the fundamental systems as explained in this part the student should have no difficulty in identifying them.

The reflex systems are often difficult to trace out because of the maze of wiring required in them, and also because of the failure of most radio writers to draw the circuits properly. In figure 13 we have the principle of the reflex system, in which the output of one of the stages is made to pass into the input of a previous stage, so that the latter tube is made to perform two operations simultaneously, viz., first that of amplifying the high frequency voltages and, second, that of amplifying the audio or low frequency stages. The high frequency signal currents enter the radio frequency amplifier at the input, as indicated, and the passage of the signal is as indicated by the broken



REFLEX CIRCUIT
FIG. 13

line and arrows. The high frequency voltages are amplified in the first tube and rectified in the detector. They then pass on from the output of the detector to the input of the first tube again, which now acts as an audio frequency amplifier. The phones or loud speaker are included in the output circuit of the first tube. By-pass condensers are required across the terminals of the reflexing transformer and the phones, so that the high frequency currents can pass by them on into the detector. These by-pass capacities are too small to affect the low frequency or audio frequency currrents being reflexed, and the tuning of the radio frequency amplifier input circuit does not in any way affect the low frequency currents. The first tube is thus made to act in two capacities and the two-tube system acts like a three-tube circuit. All reflex circuits act upon these fundamental principles, and the whole system is easily seen to consist of nothing more than a combination of the elementary systems shown at the beginning of this part.

PART II

COMPARISONS OF MODERN RADIO RECEIVING CIRCUITS

DURING the past five years, or since the time when broadcast reception first started to develop into the present proportions, the art has seen no end of new receiving circuits and so-called developments. Many of such ideas are questionable and in some

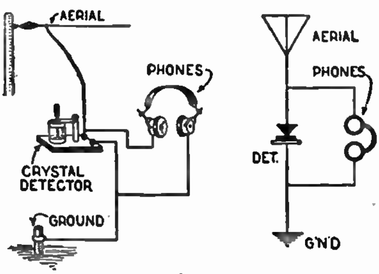


Fig. 1

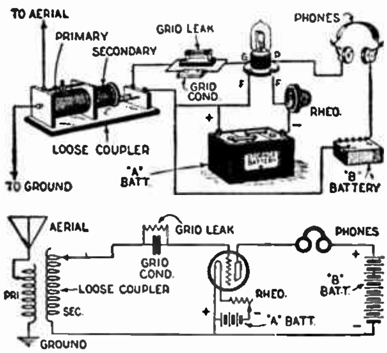
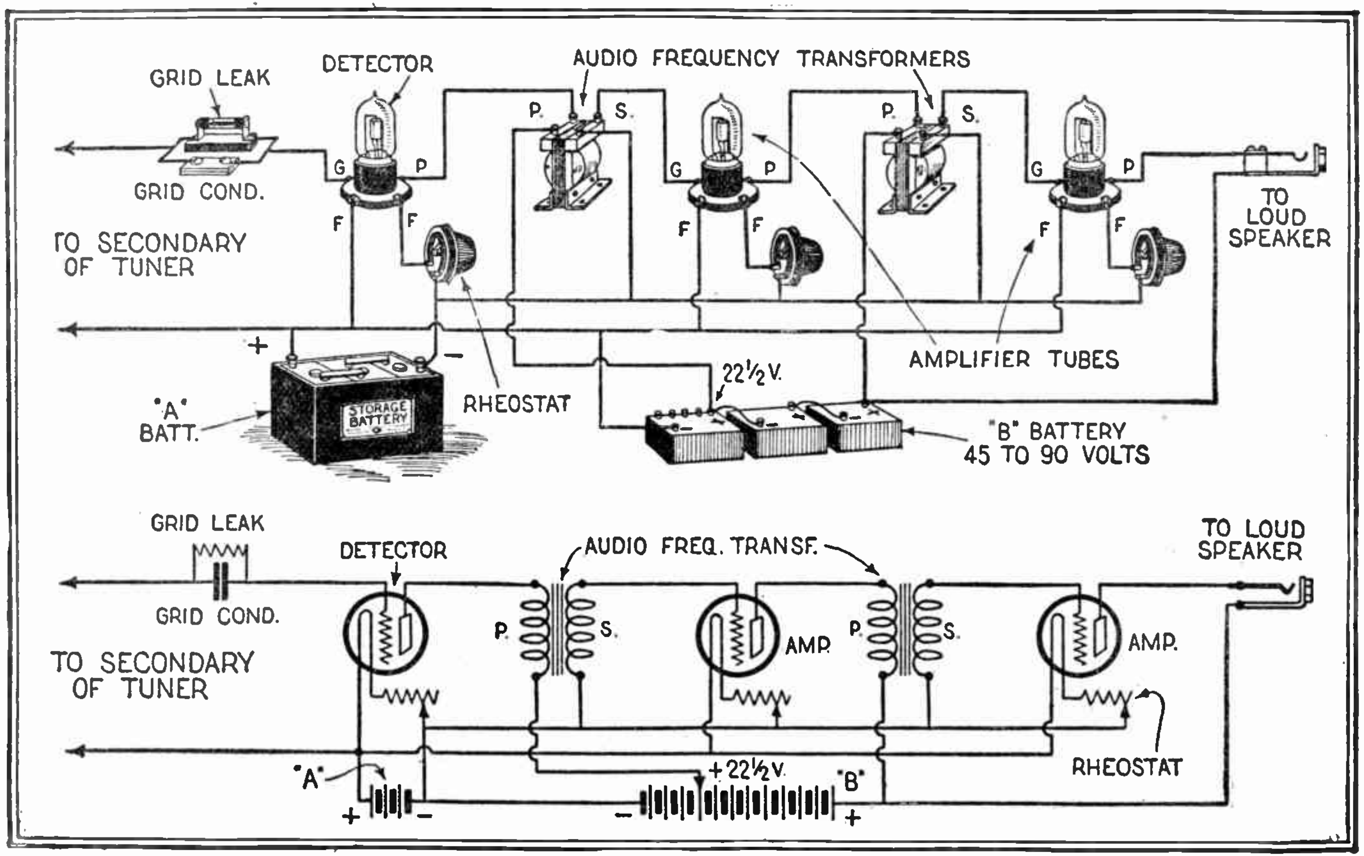


Fig. 2

cases have been open to ridicule. There have been all sorts of "dynes," "flexes" and other names given to supposedly new circuits. Publicity work in connection with them gets into print, telling a story to the eager broadcast public all about either the untold distance such a set will receive, or else a lengthy yarn about its selectivity. All this, plus a thousand and one adjectives, gives the details of still another new development in broadcast reception.

And what does all this really mean? Were our well-known radio engineers behind the times, or incapable of designing and developing efficient long-distance receiving sets and did they fail to grasp the fundamental principles of radio communication until the happy days of broadcasting? The best way to answer such questions is only to say that we have just a limited number of fundamental circuits on which all receiving sets are based, despite the many names given to the present-day offerings. In fact, nothing serves to confuse the layman so much as the appearance every few weeks or so of some new circuit with some high-sounding name. With but few exception, these "new" circuits are little more than new names given to old circuits in slightly revamped form, and in some cases involving added controls which only go to make a set more complicated.

Thus we learn that when the garnishings are removed from the majority of circuits which are claimed to be departures, they will



A vacuum tube detector and two stage audio frequency amplifier.

then be recognized as our regular basic circuits. These basic circuits are: the **crystal receiver,** with the most elementary forms of tuning devices; the **vacuum tube receiver,** with the most simple form of tuning devices and no provision for regeneration; the **regenerative receiver,** in which the plate output of the vacuum tube detector is

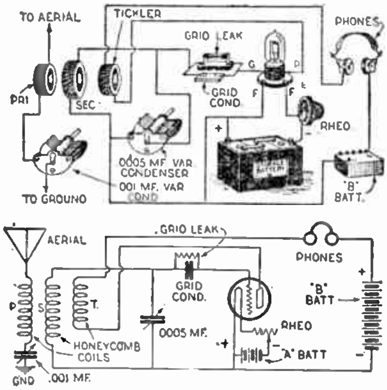


Fig. 4

returned, or fed-back, to the grid in order to increase the effect of incoming signals, and thus produce self-amplification; **audio-frequency amplification,** which is used in connection with all kinds of receivers in order to increase the audio-frequency output so that it will operate telephone receivers with sufficient volume, or operate loud speakers; **tuned radio frequency amplification,** in which each stage is tuned so as to secure the transfer of radio energy from one stage to the next before being detected by the rectifying agent or detector; **untuned radio frequency amplification,** making use of transformers which require no adjustments such as variable condensers or coils for tuning; the **reflexing arrangement** of a circuit, whereby a set of tubes is made to do double duty, first as **radio**-frequency amplifiers and then as **audio**-frequency amplifiers; and then the **super-heterodyne** system, whereby the incoming radio wave is played off against a locally generated wave, so that the difference between the two or so-called "beat" effect is of suitable frequency to be handled efficiently by intermediate frequency amplifiers, and passed on to a second detector for conversion into an audio frequency current.

It should be observed that two or more of the foregoing fundamental or basic circuits are often grouped into one receiver. Therefore, we find regeneration combined with audio frequency amplification, radio with audio frequency amplification; regeneration combined with radio frequency amplification followed by audio frequency amplification, reflexed super-heterodyne systems, etc., until there is hardly an end to the numerous combinations that can be made. Consequently, if the present-day receiving circuits are carefully analyzed they can soon be traced to the basic components.

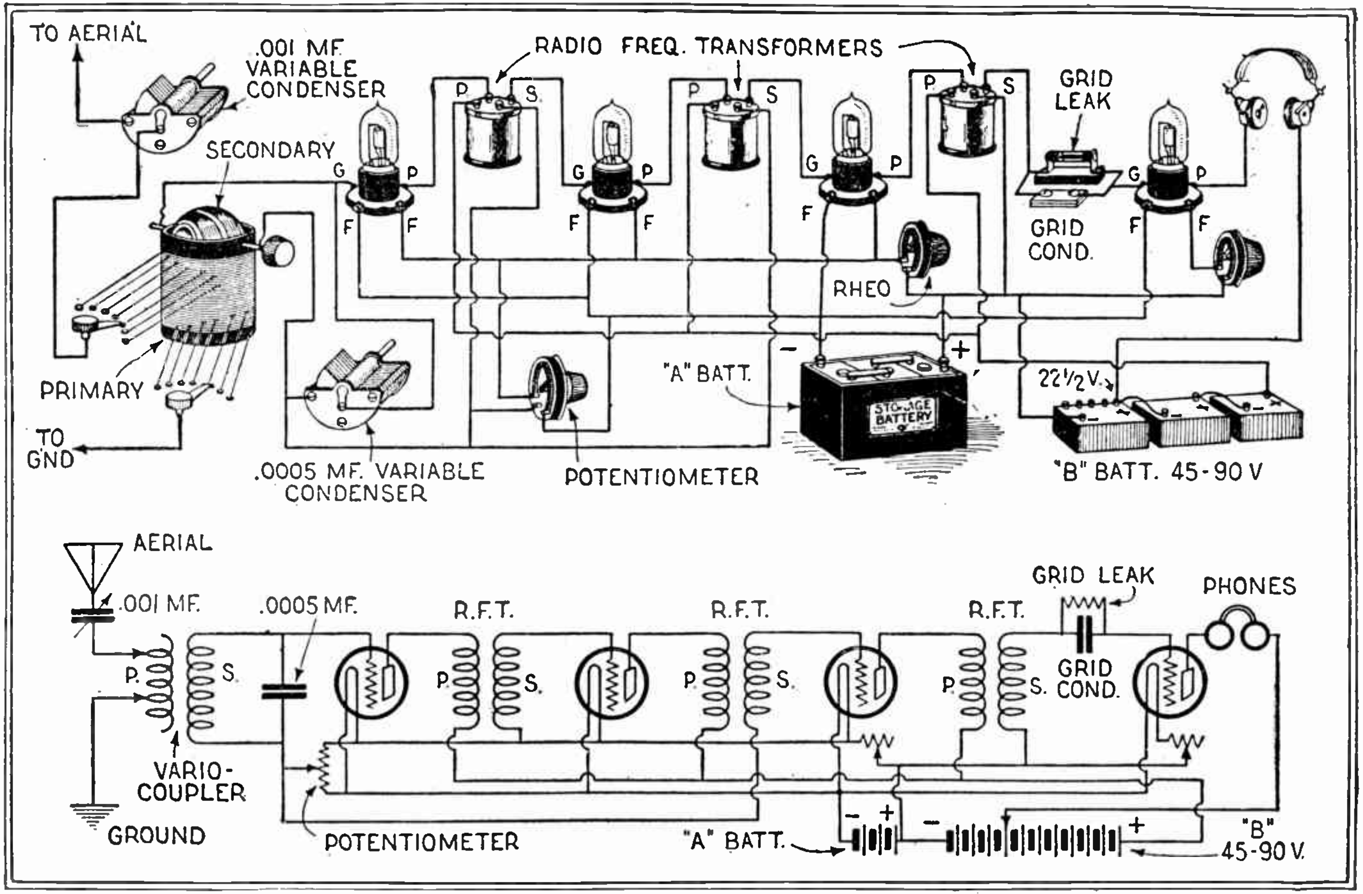

TO AERIAL
.001 MF.
VARIABLE
CONDENSER
RADIO FREQ. TRANSFORMERS
GRID
LEAK
SECONDARY
G
P
S
F
PRIMARY
RHEO
GRID
COND.
TO
GND
"A" BATT.
STORAGE
BATTERY
22½ V.
.0005 MF. VARIABLE
CONDENSER
POTENTIOMETER
"B" BATT. 45-90 V
AERIAL
.001 MF.
.0005 MF.
R.F.T.
GRID LEAK
PHONES
GRID
COND.
VARIO-
COUPLER
GROUND
POTENTIOMETER
"A" BATT.
"B"
45-90 V.

Fig. 5.

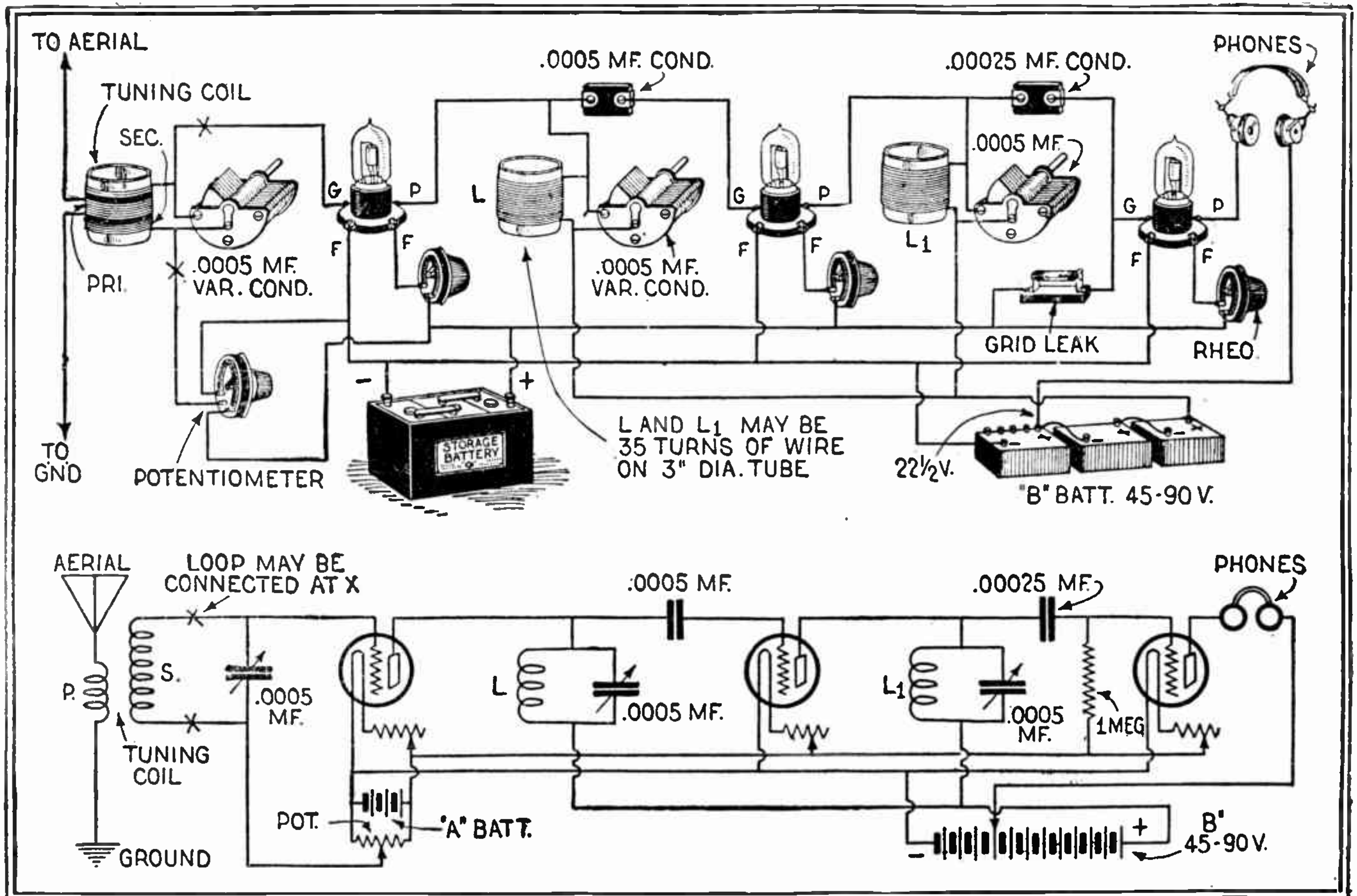
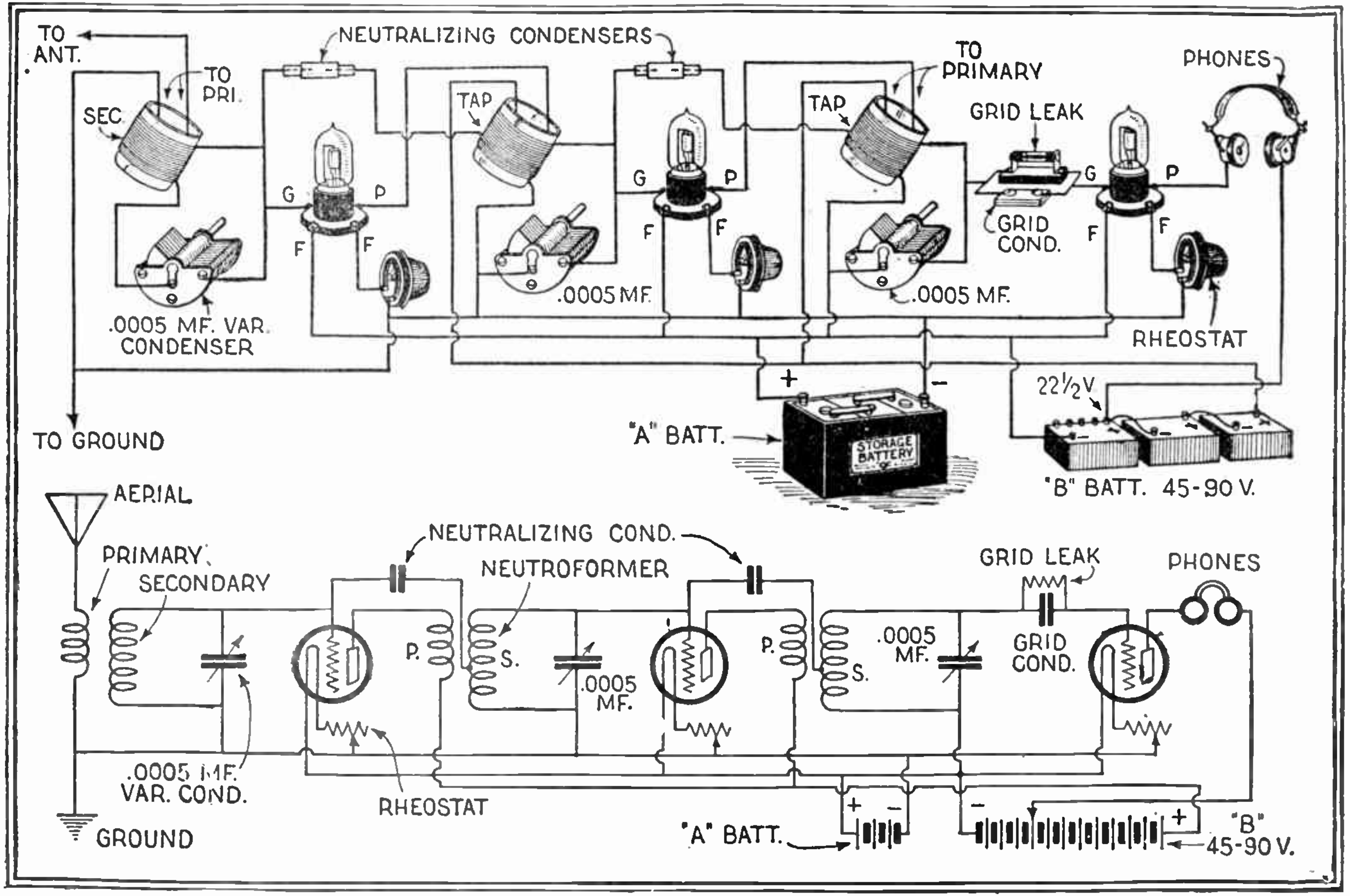

TO AERIAL
TUNING COIL
SEC.
PRI.
TO GND
.0005 MF. VAR. COND.
POTENTIOMETER
G
P
F
.0005 MF. COND.
L
.0005 MF. VAR. COND.
L AND L1 MAY BE 35 TURNS OF WIRE ON 3" DIA. TUBE
STORAGE BATTERY
.00025 MF. COND.
.0005 MF.
L1
GRID LEAK
PHONES
RHEO.
22½V.
"B" BATT. 45-90 V.
AERIAL
LOOP MAY BE CONNECTED AT X
S.
P.
.0005 MF.
TUNING COIL
GROUND
POT.
"A" BATT.
L
.0005 MF.
.0005 MF.
L1
.00025 MF.
.0005 MF.
1 MEG
PHONES
B
45-90 V.

Fig. 6.


TO ANT.
TO PRI.
SEC.
NEUTRALIZING CONDENSERS
TAP
TO PRIMARY
GRID LEAK
PHONES
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GRID COND.
.0005 MF. VAR. CONDENSER
.0005 MF.
RHEOSTAT
22½V.
TO GROUND
"A" BATT.
STORAGE BATTERY
"B" BATT. 45-90 V.
AERIAL
PRIMARY
SECONDARY
NEUTRALIZING COND.
NEUTROFORMER
P.
S.
.0005 MF.
GRID COND.
.0005 MF. VAR. COND.
RHEOSTAT
GROUND
"A" BATT.
"B" 45-90 V.

Fig. 7.

In the accompanying illustrations in which each diagram will be shown in schematic and in conventional manner will be seen various circuits which show different means of tuning arrangements in conjunction with crystal and vacuum tube detectors, and vacuum tubes used in the role of both radio frequency and audio frequency amplifiers. and in reflex circuits employing each certain tube for radio and audio frequency amplification, and the vacuum tube as an oscillator in super-heterodynes.

Crystal Circuits

The crystal receiving set as commonly used is the least expensive. The simplest set consists of a crystal detector, phones, aerial and ground as shown in Fig. 1. By the addition of a tuning coil or vario-coupler it is possible to tune the set. Tuning is to be preferred, of course, as it helps to eliminate stations to which one does not wish to listen.

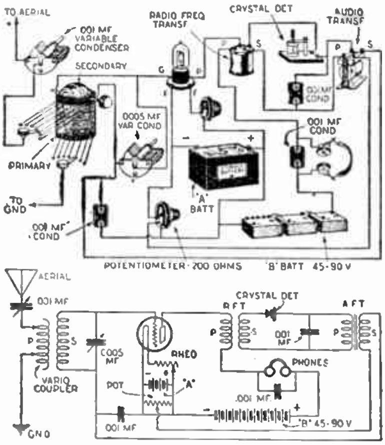


Fig. 8

There are various ways of accomplishing this, i. e., by means of various tuning devices, such as coils and condensers. The range of the crystal set is small, and on the average it is capable only of receiving signals within a distance of twenty miles from the broadcasting station. This range depends entirely on the power of the transmitting station, the size and location of the aerial, and the sensitivity of the crystal. With this type of instrument the music and other programs are almost an exact reproduction of that delivered into the transmitter, as very little distortion occurs. This is due to the faithful rectifying properties of crystal detectors which are not characteristic of the vacuum tube. Head phones must be used with this set, although no batteries are required. Receiving sets of this class are gradually losing their popularity, for as the owner becomes more interested in radio, he feels hampered with only a crystal set and wishes to reach farther out into the ether for more distant stations.

Vacuum Tube Circuits

The vacuum tube receiving set consists of essentially the same apparatus as the crystal receiver, except that a vacuum tube is used instead of a crystal for a detector, as will be noted by studying the accompanying diagram Fig. 2. This set has a distinct advantage over the crystal set, inasmuch as the detector remains adjusted once it is set, while the crystal requires careful adjustment and is easily jarred from a sensitive position. Another advantage of the vacuum tube set is that it is more sensitive than the crystal.

Detector and Amplifier Circuits

The detector amplifier instrument shown in Fig. 3 is one in which the signals are detected by a vacuum tube and then strengthened by means of two stages of vacuum tube amplification to such an extent as to permit the use of a loud speaker. Such strengthening devices are known as audio frequency amplifiers. The diagram given herewith shows the method of amplifying at audio frequency, employing audio frequency transformers.

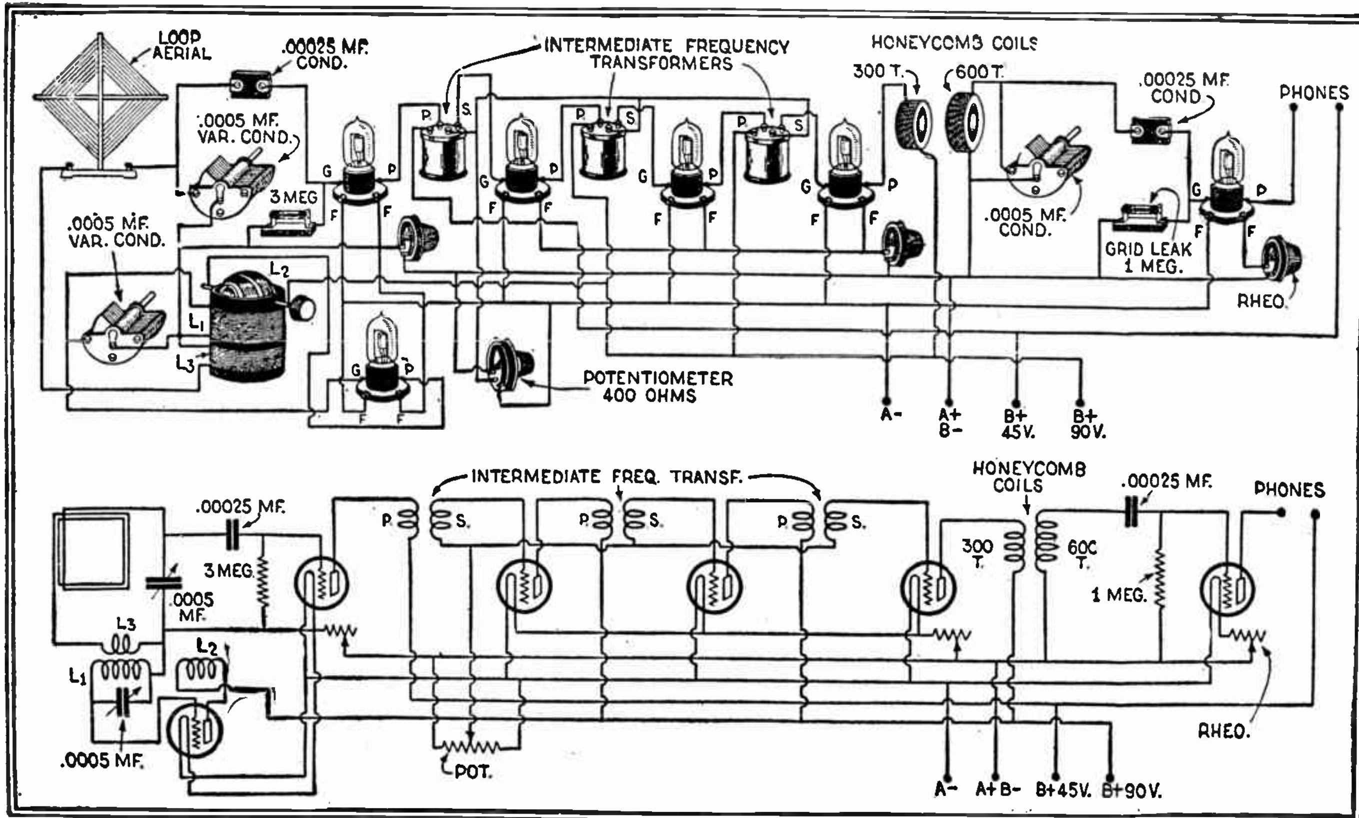
Regenerative Circuits

By means of the regenerative circuit, one of which is shown in Fig. 4, detection and amplification with a single tube may be obtained in a receiver, which will give great sensitivity on distant signals. This set differs from others in that a regenerator or tickler coil is used, and its function is to build up or amplify the received energy. By the use of this circuit very weak signals may be heard. This set requires a little more careful adjustment than the other receivers mentioned, as when oscillating it has a tendency to radiate energy and cause disturbance to other receiving sets in the vicinity.

Regeneration is commonly employed in radio receivers, as this form of circuit produces self amplification, by means of either variable coils or condensers. However, many people are prejudiced against forms of regenerative circuits due to the reason that they have a tendency to howl or squeal. This is not always true, as, when properly controlled, the regenerative circuit gives good tonal quality and does not cause annoyance.

Tuned and Fixed Radio Frequency Circuits

There are several ways in which radio frequency amplification may be accomplished, chief of which is the tuned transformer method. The second important one is the fixed transformer method in which the



LOOP AERIAL
.00025 MF. COND.
INTERMEDIATE FREQUENCY TRANSFORMERS
HONEYCOMB COILS
300 T.
600 T.
.00025 MF. COND
PHONES
.0005 MF. VAR. COND.
3 MEG
.0005 MF. VAR. COND.
L2
L1
L3
.0005 MF. COND.
GRID LEAK 1 MEG.
RHEO.
POTENTIOMETER 400 OHMS
A-
A+ B-
B+ 45V.
B+ 90V.
INTERMEDIATE FREQ. TRANSF.
HONEYCOMB COILS
.00025 MF.
PHONES
3 MEG.
.0005 MF.
300 T.
600 T.
1 MEG.
L3
L1
L2
.0005 MF.
POT.
RHEO.
A- A+B- B+45V. B+90V.

Fig. 9.

various stages of radio frequency amplification are coupled together by means of radio frequency transformers composed of fixed winding. Each method has its advantages and disadvantages. Thus the tuned method is considerably more efficient on short wave lengths employed by broadcast stations than the transformer method. But on the other hand the tuned method involves an additional control for each radio frequency stage. Such receivers are usually provided with a potentiometer adjustment in order to stabilize the circuit; that is to say, the capacity of the tubes in the radio frequency amplifier causes a feed-back of energy from the plate to the grid, and thus gives rise to oscillations. Figures 5 and 6 respectively show how fixed transformer coupled and tuned radio frequency amplification are accomplished.

One of the most popular types of tuned radio frequency receiver employs condenser tuned transformers such as used in the well-known neutrodyne receiver as shown in Fig. 7. In this particular circuit attention is called to stabilization of the regenerative effect of the capacity coupling between plate and grid of the vacuum tubes. Neutralizing condensers are connected between the grids of successive tubes, and can be adjusted to balance or counteract this coupling effect. Similar methods are now being employed in various forms of radio frequency amplifying circuits, as well as reflexing systems, with good success.

Reflex Circuits

In the foregoing we have mentioned various means of amplification, including that of the very popular methods of radio frequency amplification. However, the reader can learn more as to the general scheme employed in various types of circuits by carefully studying the diagrams given in connection with this book than the writer is able to convey in the amount of space available for this subject.

From these methods we can pass on to the reflex, which uses the same tube as both radio and audio frequency amplifier. This type of receiver is very popular nowadays as it means a saving in the number of tubes to be employed for desired results. This ingenious arrangement of components is usually associated in conjunction with a crystal detector, which gives comparatively true tonal reproduction. The reflex idea may be applied in a wide variety of ways, ranging from a single tube crystal detector, as shown in Fig. 8, to a multi-tube circuit for use with loop reception.

Super-Heterodyne Circuits

The modern Super-Heterodyne receiver is based on the fact that amplification of radio signals at radio frequencies is accomplished with much greater efficiency at comparatively high wavelengths. In other words, maximum amplification at radio frequencies cannot be obtained on the wavelengths used for broadcasting in this country, i. e., under six hundred meters. It was found that by increasing the wavelength (decreasing the frequency) of the original signals much greater amplification is possible. The Super-Heterodyne does this by means of oscillations generated within the receiver.

In this system, the incoming signals are intercepted by means of a regular antenna or a small loop aerial. These signals are detected in the usual manner and then combined or super imposed on oscillations produced by a local generating system which is a component of the receiving circuit. The local frequency is arranged in such a manner that the difference between the incoming signals and the local oscillations will be a certain definite frequency, much lower (higher wavelength) than the original signals. This difference frequency is determined by the constants of the oscillator circuit and the new signals are passed to a radio frequency amplifier. In the amplifier circuit only waves of a certain pre-determined frequency will be passed and amplified and therefore the adjustment will automatically have to be such that high wavelengths are employed in the radio frequency amplifier and the result is increased efficiency.

The amplified signals are passed to a second detector and after being rectified are amplified at audio frequency in the standard manner. The main advantages of such a system are extreme sensitivity due to the high amplification at radio frequency, and unusual selectivity. A good Super-Heterodyne may be operated on a small loop for reception over long distances under good conditions and the various circuits that come under this heading enjoy wide popularity.

To better understand the diagrams referred to in this part, we recommend that the reader study the following chapter.

PART III

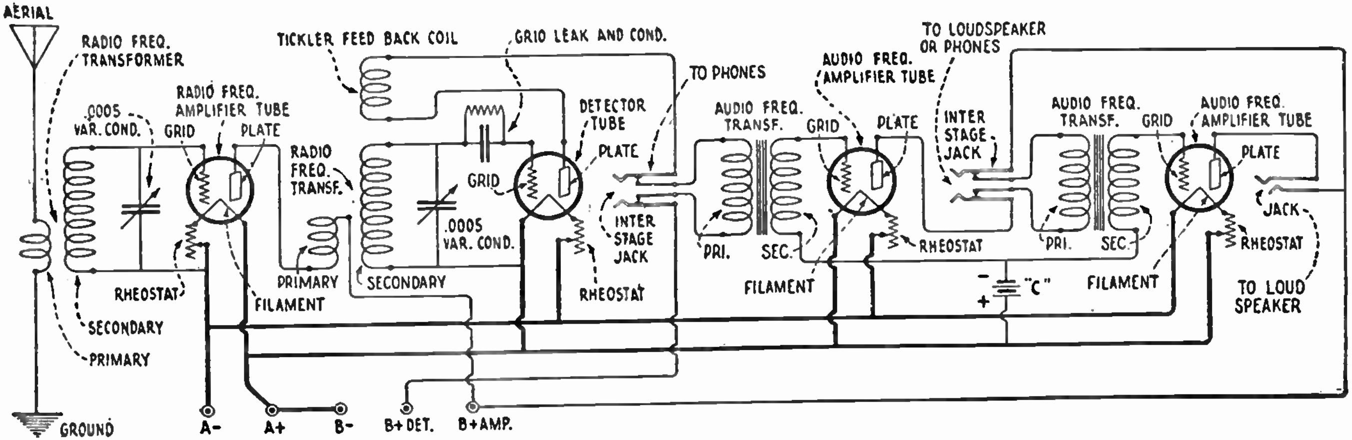
HOW TO READ RADIO DIAGRAMS

IN view of the fact that the student may at first have a little difficulty in interpreting a radio circuit, it is the purpose of this chapter to point out in a clear and concise manner the various parts of a radio receiving circuit, the symbols used therein, etc., so that he will be able to understand the various circuits clearly.

In Fig. 1 we have shown a complete circuit incorporating one stage of tuned radio frequency amplification, a regenerative detector, and two stages of audio frequency amplification. As we proceed with this chapter each element of this circuit will be taken up and discussed, until ultimately the entire circuit will have been thoroughly covered.

Let us refer to the illustration, Fig. 2. This shows in heavy lines the "A" battery circuit, which heats the filaments of the vacuum tubes. At the bottom of the illustration will be seen a small circle marked "A—". In tracing along this line, which represents the wire from the **negative post** of the "A" battery, we come to a wire running at right angles, which joins the upright wire, but for the time being this horizontal wire will be disregarded. Continuing by this point we come to a second horizontal connection, but this is again disregarded as we are not interested in that part of the circuit at present. Next we come to a small arrow pointing to a zig-zag line. This is the electrical symbol for a **rheostat** and this one is the rheostat controlling the filament of the **radio frequency** amplifier tube. The radio frequency amplifier will be explained later on. The filament within the vacuum tube is represented in this instance by an inverted "V". A filament may also be indicated by an inverted "U". Leaving the filament the wire runs downwards again and we come to a small curve in the line, with a horizontal line passing beneath. This means that the wires jump one another and there is no electrical connection between them. Next we come to a joined wire which is also for the moment disregarded, and then we continue on to a small circle marked "A+" representing the **positive post** of the "A" battery, which is usually connected to the **negative post** of the "B" battery, as indicated by "B—" in the illustration. We have now completed the filament circuit for the radio frequency amplifier tube, and the reader will readily see how the current flows from one post of the "A" battery through the rheostat, filament and then back to the other post of the "A" battery.

The reader will recall that immediately after we left the point marked "A—" we came to a line running off at right angles which we then disregarded. We will now take up this line, together with the other horizontal line immediately below it, which is connected to the positive line (marked "A+") of the "A" battery. Starting along the upper one of these two horizontal wires it will be noticed that it connects with the lower horizontal wire, the "A+" lead, rheostat of the second tube (the detector), through the filament, and jumping the first horizontal line, which is the "A—" lead, connects with the lower


AERIAL
RADIO FREQ. TRANSFORMER
TICKLER FEED BACK COIL
GRID LEAK AND COND.
TO LOUDSPEAKER OR PHONES
TO PHONES
AUDIO FREQ. AMPLIFIER TUBE
.0005 VAR. COND.
RADIO FREQ. AMPLIFIER TUBE
GRID
PLATE
DETECTOR TUBE
AUDIO FREQ. TRANSF.
GRID
PLATE
INTER STAGE JACK
AUDIO FREQ. TRANSF.
GRID
AUDIO FREQ. AMPLIFIER TUBE
RADIO FREQ. TRANSF.
PLATE
PLATE
GRID
.0005 VAR. COND.
INTER STAGE JACK
PRI.
SEC.
RHEOSTAT
JACK
PRI.
SEC.
RHEOSTAT
"C"
RHEOSTAT
PRIMARY
SECONDARY
RHEOSTAT
FILAMENT
FILAMENT
TO LOUD SPEAKER
FILAMENT
SECONDARY
PRIMARY
GROUND
A-
A+
B-
B+DET.
B+AMP.

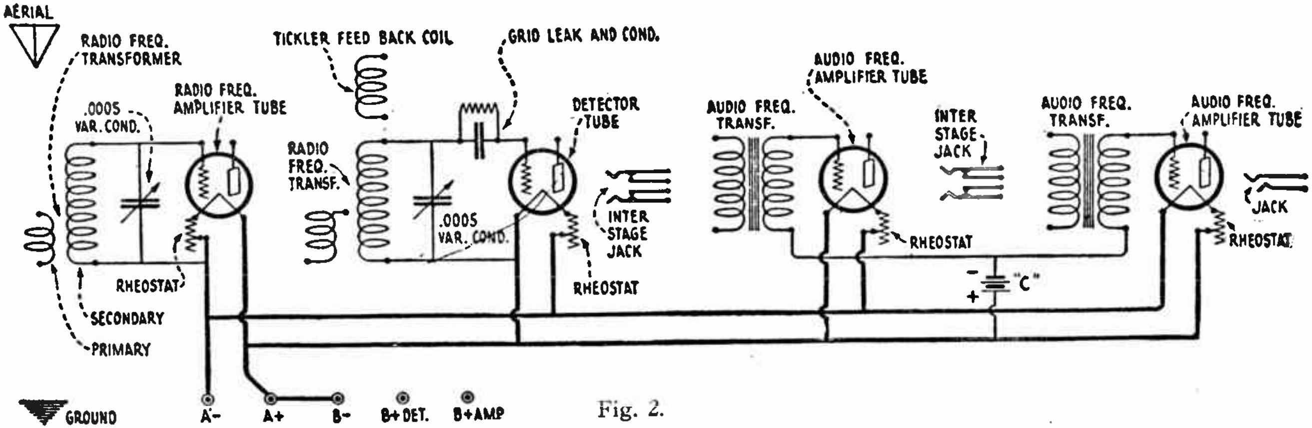

AERIAL
RADIO FREQ. TRANSFORMER
TICKLER FEED BACK COIL
GRID LEAK AND COND.
AUDIO FREQ. AMPLIFIER TUBE
.0005 VAR. COND.
RADIO FREQ. AMPLIFIER TUBE
DETECTOR TUBE
AUDIO FREQ. TRANSF.
INTER STAGE JACK
AUDIO FREQ. TRANSF.
AUDIO FREQ. AMPLIFIER TUBE
RADIO FREQ. TRANSF.
.0005 VAR. COND.
INTER STAGE JACK
JACK
RHEOSTAT
RHEOSTAT
RHEOSTAT
"C"
RHEOSTAT
SECONDARY
PRIMARY
GROUND
A-
A+
B-
B+DET.
B+AMP

Fig. 2.

horizontal wire the "A+" lead, completing the filament or "A" battery circuit for the detector tube. Continuing along the horizontal "A—" line we notice a repetition of the connection just described, i. e., through the rheostat, filament and back to the horizontal "A+" line. This is the filament circuit of the third tube, this tube being the **first stage audio amplifier.** Continuing further along the "A—" line we find the line going first to the filament of the fourth tube (the **second stage audio amplifier**), through the resistance (rheostat) and back to one side of the filament lead of the first audio amplifier, thence back to the detector tube lead, and next to the radio frequency amplifier tube lead and finally to the "A+" post of the "A" battery.

We have now completed the entire "A" battery circuit. In practice the "A" battery is either a storage battery, or dry cells, depending upon the type of tubes used in the receiver.

In tracing the "A" battery circuit we showed how it ran through the filament of the radio frequency tube, the detector tube, and finally through the filaments of the first and second audio frequency amplifier tubes, and it is believed advisable to explain, very briefly, at this point just what duties these different tubes perform. The first tube on the left is the **radio frequency** amplifier which serves to build up the weak impulse received, so that a stronger impulse may be passed on to the detector in order to more readily actuate it. The detector converts this inaudible electrical impulse into sound, making it audible, and the **audio frequency** amplifiers, placed after the detector, strengthen this sound to a degree of intensity sufficient to operate a loud speaker.

Now let us turn to the diagram. We will next take up the "B" battery circuit. The negative post of this battery is indicated by "B—" at the lower left hand of Fig. 3, and in this circuit goes to the positive post of the "A" battery, marked "A+". The post marked "B+ Det." is known as the detector tap on the "B" battery, and may range in voltage from 16½ to 45 volts, depending upon the type of tube used. The lead from this "B+ Det." post goes through the interstage jack, then through the coil marked **"Tickler feed back coil"** and thence to the little oblong within the heavy circle, this oblong representing the plate of the detector vacuum tube, and it always indicates the plate of a tube in any circuit. This circuit is known as the **plate circuit** of the detector tube, and is the only point to which the "B+ Det." post is connected.

The leads from the post marked "B+ Amp." will be noted going to two different points, the lead starting off vertically going through the primary of the radio frequency transformer and thence to the plate of the radio frequency amplifier tube. This is the plate circuit of the radio frequency amplifier. The other lead from this same post "B+ Amp." it will be seen goes to the bottom of the symbol marked "Jack" and thence to the top of the symbol marked "Inter-stage jack", through this to the plate of the audio amplifier tube. This is part of the audio frequency amplifier circuit.

There are three circuits in a vacuum tube, two of these, namely the "A" and "B" battery circuits, have been already covered, and the third—the **grid circuit**—will now be pointed out. Referring back to

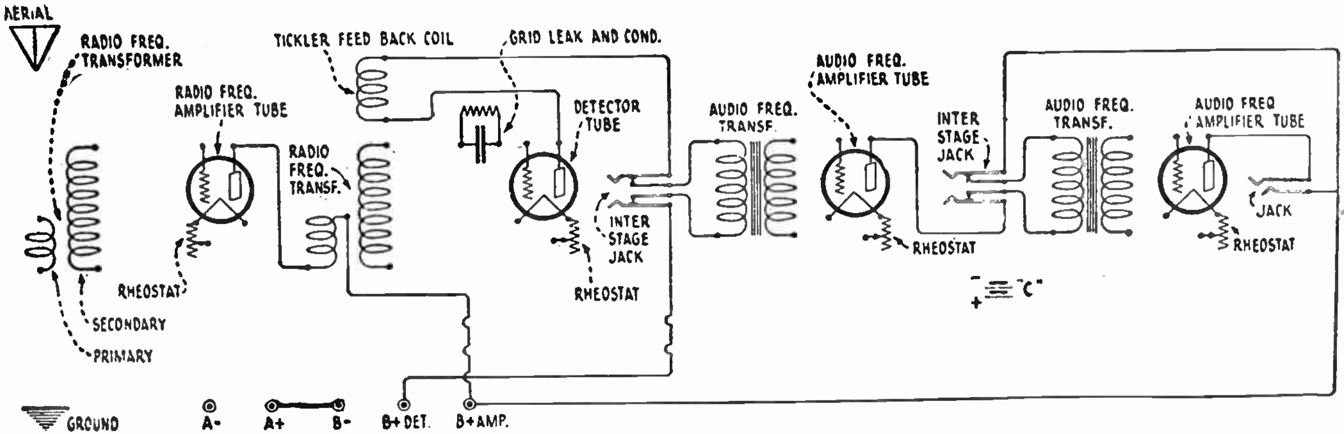
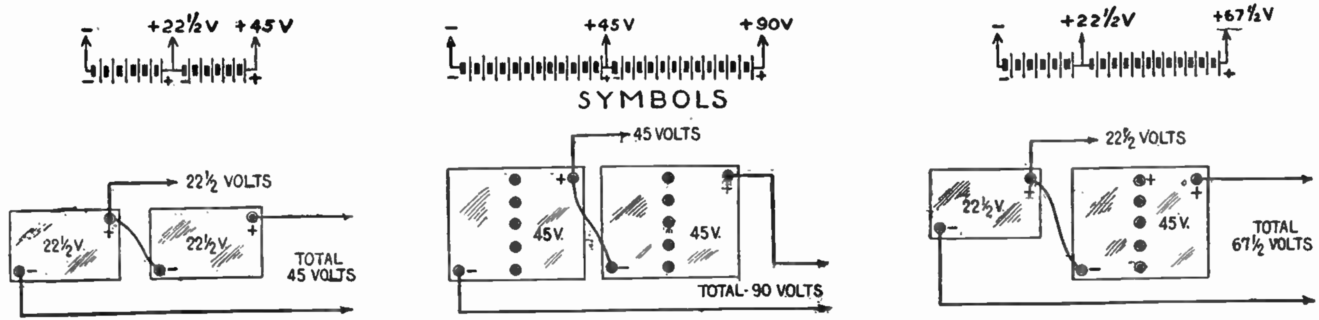


Fig. 3.



VARIOUS METHODS OF CONNECTING "B" BATTERIES

Fig. 4.

Fig. 2, the large circle at the extreme left, within which is a zig-zag line, an oblong and an inverted "V", is as explained the symbol for a **vacuum tube** as used in radio, and in this instance it is the **radio frequency amplifier** tube. Starting with this zig-zag line (the symbol for the **grid**) we come to a series of loops, which represent the secondary of the **radio frequency transformer.** So much of the circuit is called the **grid lead.** Going through the secondary of this transformer we return to the negative post of the "A" battery, the portion of the circuit from the series of loops being known as the **grid return.** Starting from the grid of the second tube from the left, **the detector,** we come first to two heavy vertical lines (the symbol for a **fixed condenser**) above which is shown a zig-zag line (in this instance a **resistance**) these being respectively the **grid condenser** and **grid leak,** and in all circuits these two will immediately enable the reader to locate a detector tube, as they only appear in the grid lead of the detector and never in the grid leads of any other tube. From this grid condenser and lead we pass through the secondary of the tuning transformer (marked **"Radio Freq. Transf."**) and thence back to the "A+" lead. This completes the detector grid circuit. From the grid of the third tube, the **first audio frequency amplifier,** we pass through the secondary of the symbol marked **"Audio Freq. Transf."** to the negative post of the **"C" battery,** through the secondary of the second audio frequency transformer and finally to the grid of the fourth tube, the **second stage audio amplifier.** This is the grid circuit of the audio frequency amplifier. The positive post of the "C" battery marked "C+" goes to the "+" or positive post of the "A" battery.

Thus far we have covered the "A," "B" and "C" batteries and the grid circuits. We will next explain how the radio frequency circuit may be identified. On the extreme left at the top of Fig. 1 will be seen a symbol for an aerial, being so marked in the diagram. The aerial goes to the primary of the radio frequency transformer and thence to the ground. The secondary of this transformer is in the grid circuit of the radio frequency amplifier tube. This secondary coil is shunted (connected across) by two heavy horizontal lines cut by an arrow. This is the electrical symbol for a variable condenser, and it is placed across these terminals to enable the radio frequency transformer to be tuned to each incoming wave. The plate of the radio frequency amplifier tube (indicated by the oblong in the circle) goes to the primary of the second radio frequency transformer (more commonly called the "tuner") and thence to the "B+ Amp." post. The secondary of this radio frequency transformer, or tuner, is in the grid circuit of the detector tube. This secondary coil is also shunted by a variable condenser to permit tuning it to the various waves.

The detector in the circuit illustrated is of the regenerative type. It will be seen in Fig. 3 that the plate of the detector tube goes to the coil marked **"Tickler feed back coil",** thence to the inter-stage jack and to the "B+ Det.". In this system a portion of the current in the plate circuit is fed back through the tickler feed back coil to the grid circuit, and is passed through the detector tube a second time, producing increased amplification.

In a **non-regenerative** detector the "Tickler feed back coil" is omitted and the lead from the plate of the detector tube goes direct to the top of the inter-stage jack.

The "inter-stage jack" just mentioned, and indicated immediately to the right of the detector tube in Fig. 1, is placed in the circuit so that if a telephone plug is inserted in this jack it causes the top and bottom leaves of the jack to separate, and the circuit is then from the detector through the phones to the "B" battery and there is then no audio amplification in use. However, if the plug is removed from this inter-stage jack, these two leaves come in contact with the inner two, as will be seen in the illustrations, and the circuit is then through the primary of the first audio frequency transformer. Each audio frequency transformer has a primary and secondary winding, the signal from the detector being stepped up in volume from the primary to the secondary. The secondary of the first audio frequency transformer goes to the grid of the first audio amplifier tube, and also to the secondary of the second audio frequency transformer (see Figs. 1 and 2). Immediately to the right of the first audio amplifier tube will be seen a second "Inter-stage jack." When the phone plug is inserted in this jack, the circuit is through the phones to the "B+ Amp." post, and one stage of audio amplification is in use, but when the phone plug is withdrawn the upper and lower leaves of this jack resume their normal position and make contact with the inner leaves, passing the signal on to the primary of the second audio transformer, to be stepped up and passed on to the last audio amplifier tube for still greater amplification. The plate of this tube goes to the top leaf of an open circuit jack. The bottom leaf goes to the "B+ Amp." post. Plugging in this jack affords ample volume for loud speaker operation, but it is not advisable to attempt to use head phones in this jack, as the volume will be too great for comfort.

Fig. 4 shows in symbol and picture form how "B" batteries are connected in order that the student may distinguish them in circuit diagrams.

The electrical signs and symbols explained and indicated in this chapter are standard and will apply to all circuits, and it is believed that if the reader will become familiar with them, no trouble will be experienced in understanding any radio receiving circuit that may be encountered.

PART IV

LOCATING COMMON RADIO SET TROUBLES

THERE are so many sources of possible trouble in the average radio set and so great an aura of mystery has been thrown around the subject, that a goodly percentage of broadcast listeners are prone to call for a radio technician at the first sign that all is not well with the outfit. Naturally, if the radio owner has a working knowledge of the nature and purpose of the various parts of his set, he will be quite apt to find any possible trouble with a minimum of difficulty. The great majority, however, are forced to rely on outside assistance or advice.

While there are some hundreds of ways in which trouble may be encountered in a radio set, there are actually very few which are likely to occur under normal conditions. In a good majority of cases troubles with the average radio receiving set can be found and rectified in a comparatively short time.

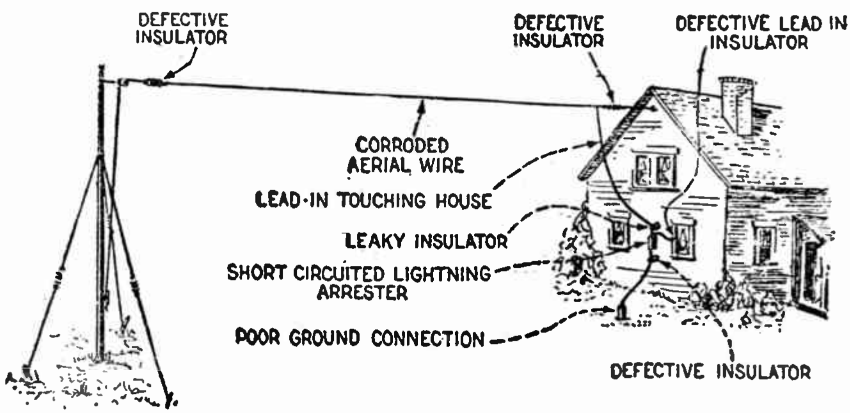
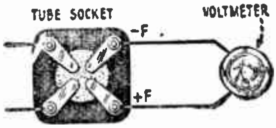


Fig. 1

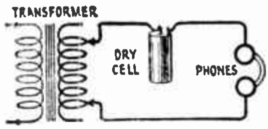
If this were a technical book dealing with radio sets merely from a standpoint of general discussion of prevalent ills, the subject could be handled without any attempt at a regular order of procedure. As it is intended to present a ready means whereby the uninitiated may hope to solve any ordinary problems that may come up in the operation of their sets, it will be necessary to work from effect to cause. That is to say, the common effects will be given, and in the following parts of this book will be found charts and tests for locating troubles.

In addition to any defects that may be found due to developments while the set is in operation, there may also be difficulty in placing a set in actual operation. One of the most important details in the installation of a receiving set, except where a loop aerial is used, is the erection of the Aerial (Antenna). To begin with, the size of the aerial will be a matter to be decided according to local conditions and the nature of the set. If the receiving set is very selective it will be safe to use a rather long aerial, placed as high as possible. If, on the other hand, there are a great many local stations and the receiver is not particularly selective, it will be well to compromise with a shorter aerial in order to eliminate some of the interference. The same rule will apply as far as height is concerned; the higher the aerial, generally speaking, the more likelihood of interference. For ordinary conditions the aerial may be about 125 feet long over all, elevated from twenty to forty feet.

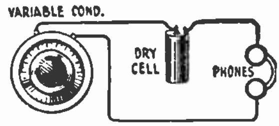
Some care will be necessary in insulating and making the connection for the lead-in. High resistance connections or poor insulation result in loss of energy, which in the receiving of radio signals is never advisable, as the power is feeble at best. Where the lead-in



VOLTMETER TEST ACROSS FILAMENTS
FIG. 2



TEST FOR OPEN CIRCUIT IN TRANSFORMER
FIG. 3



TESTING VARIABLE CONDENSER FOR SHORT CIRCUIT BETWEEN PLATES
FIG. 4

wire enters the house, use some form of tube such as a porcelain lead-in insulator.

The aerial should never be run parallel with and close to power or telephone lines, as interference due to cross induction may occur. The ground connection can be made to steam or cold water pipes (the cold water pipe being preferable), the connection being made tight by use of a clamp. The pipe should always be scraped clean before the connection is made. In use, a well-constructed aerial will seldom give any trouble. It will be well, however, to look at the lead-in connection occasionally to make sure it has not corroded or loosened. For further information refer to Book Two, Part III: **"Aerials and How They Are Installed"** in this series.

The illustration Fig. 1 shows several points in the aerial system where trouble may be encountered. These points should be given close attention to avoid corrosion or break down of insulation.

The common ailments of a receiving set will be taken up now, first as to their general effect, then as to the specific effect or symptom, followed by a list of the parts which may cause the trouble, the test to apply and the cause as indicated by the results of the test, concluding with the remedy in each individual case.

Probably the most common general difficulty will be lack of reception—i. e. **no signals.** Here we may find that the filament does not light. This will be due in practically all cases to difficulty in the following parts: The filament of the vacuum tubes, "A" battery connections, sockets, jacks (where filament control jacks are used), or the filament rheostat. Again it may be found that the tubes light but no signals are audible when the phones are plugged into the detector

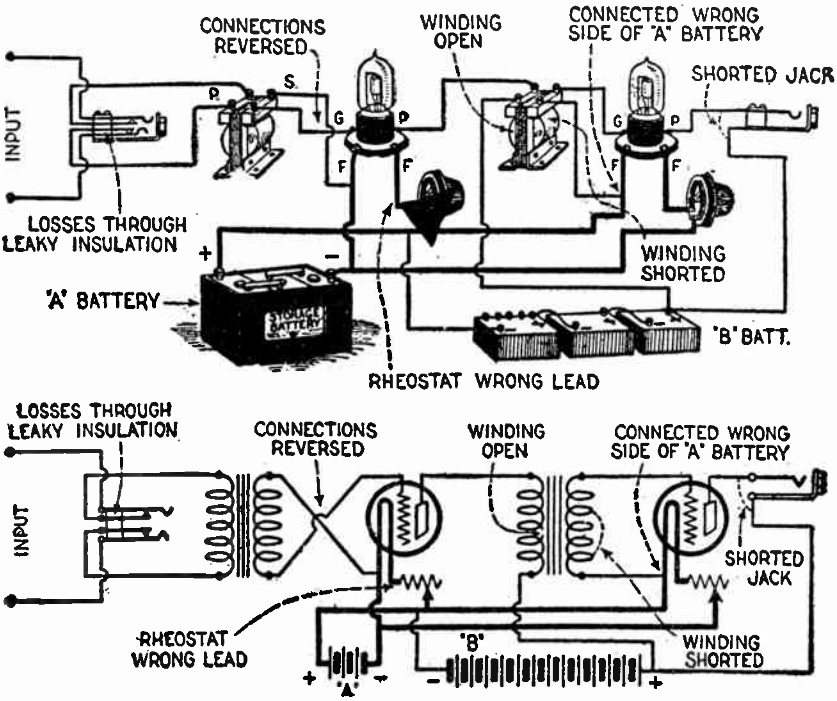


Fig. 5.

stage, or signals may be audible in the detector stage but not in the amplifier stages. These specific effects will now be taken up in sequence, together with the necessary tests and remedies.

A. Filament of one or more tubes fails to light:

Test tubes. Place a voltmeter across the filament terminals of each socket in succession (Fig. 2). If proper voltage is indicated, and examination shows the prongs of sockets to be making good contact, it is a safe assumption that the tube is defective, the remedy being its replacement.

"A" battery connections. If voltmeter test shows no reading, and there is no reading when it is placed across the "A" battery posts of the receiver, the "A" battery may be discharged or worn out, or its connections may be found faulty if storage battery is used. Test battery with a hydrometer and examine the battery leads for a possible break or loose connection.

Sockets. Voltmeter across terminals shows proper reading and tube lights when placed in another socket. This indicates the socket prongs are not making connection with tube. Bend them up slightly to make proper contact.

Rheostat. "A" battery is in good condition but proper voltage is not shown across terminals of tube. Trace wire from filament terminal on socket to its connection on rheostat. Place voltmeter across the input side of rheostat and the other filament terminal on socket (the one not connected to rheostat). If full voltage is shown it

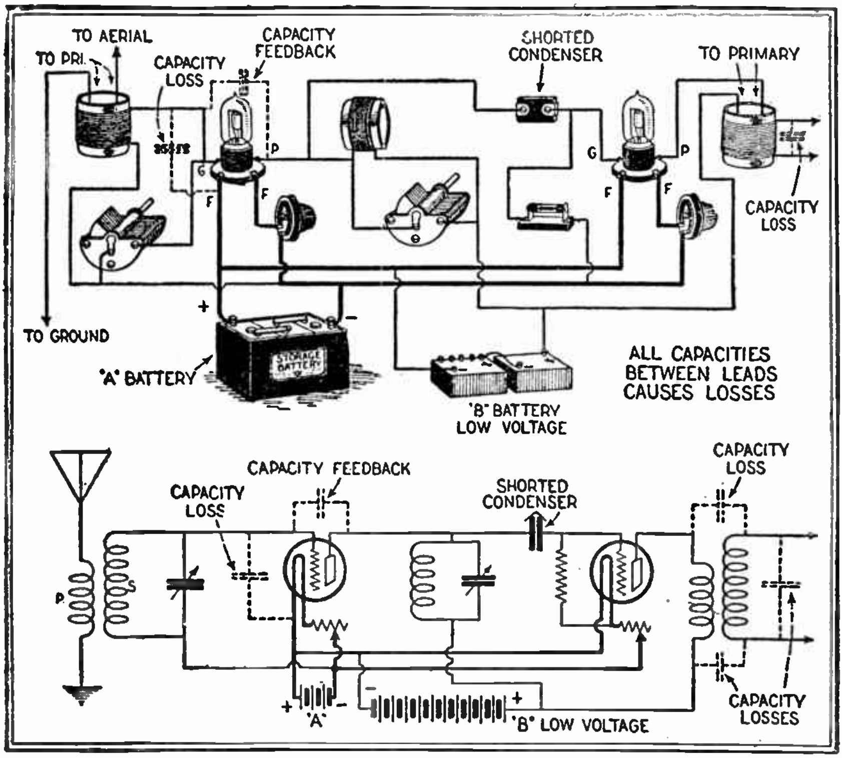


Fig. 6.

indicates that rheostat is faulty. See if sliding contact is making proper connection—if so, a wire from the battery is probably broken, which generally means replacement.

Jacks. If all above tests are made without locating cause, and in the event that filament control jacks are used, take reading across input terminals. If proper voltage shows there, but not at sockets, and the rheostat test as above has been non-productive, clean contact points on jack. If this does not remedy the defect replace with new jack. It may be possible that the contact points are not touching. If this is found to be the case, bend the leaf springs of the jack so as to make proper contact.

B. Tubes light but no click results when phone is removed from jack:

This may be due to dead "B" battery or poor connection, defective jacks, open circuit in phones, of broken wire in tickler coil (in case of regenerative set), faulty sockets or grid circuit connections.

The remedies follow:

"B" battery connections. If test with voltmeter across battery terminals shows little or no reading, replace with new batteries.

Phones. If battery is found in good condition, place a small cell across the two terminals of phone plug. No resultant click means defective plug or dead phones. Try same test across the terminals of phones (not the phone cord) and if the result is still negative, phones are defective. If phones are good but no click is heard when cell is across plug, it means phone cords are loose or broken, or defective plug. Replace either or both.

Jacks. If phones test all right, battery and battery connections are good, but no click is heard on withdrawing plug, the plug is not making contact with jack. Raise prongs of jack and clean contact points.

Sockets. If no click is heard when all above tests show conditions good, adjust prongs of the tube sockets.

Tickler coil. Trace connections of tickler and if no open is found, disconnect coil leads and test for continuity of wiring by using small cell and phones. The illustration (Fig. 3) shows method of testing the windings of an audio-transformer and this method applies to any coil. (It may be necessary to use a larger cell or "B" battery in the case of transformer due to high resistance.)

If above conditions are right and only weak click is heard when plug is withdrawn, examine grid terminal of tube. Make sure connections are all solid in this part of the circuit.

Amplifiers. Fig. 5 shows common faults in the audio amplifier circuit, and Fig. 6 radio frequency amplifier faults.

In the following parts of this book will be given charts and detailed tests for locating causes of troubles in order that the student may use this book as a guide.

PART V

CHARTS FOR LOCATING CAUSES OF TROUBLES

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
No signals when phone is connected to detector jack.	Aerial or ground.	Aerial or ground lead may be disconnected. Is often caused by binding posts working loose. All connections should be cleaned and properly soldered.	6
	Lightning Arrester.	Lightning arrester may be short-circuited which would ground the aerial. Remove arrester and test the set. If signals O.K. replace with new lightning arrester. Do not attempt to repair it.	5
	Tuning coils open circuited.	Open circuit in the windings. This usually occurs where taps are taken from these coils. Also where connections are made to the ends of the coil windings.	7 & 8
	Short circuit in tuning coils.	Usually caused by soldering flux getting on the windings; also due to broken or defective insulation. Coils should be rewound.	11
	Tube socket.	Tube prongs not making contact in the sockets. Clean tube prongs and socket contact springs and bend up the latter slightly to insure good contact.	20
	"B" battery voltage too high.	Too much "B" battery may paralyze the detector tube making it inoperative. Try various voltages until best results are obtained.	29
	Grid condenser open.	Sometimes the heat of soldering will cause an open circuit in the condenser by melting off the internal connections. Replace with new condenser.	1 18 28
	"B" batteries exhausted.	Check the "B" batteries with a voltmeter and if they have dropped to two-thirds of their rated voltage they should be discarded.	2 4
	Grid coil disconnected.	Test for open circuit between grid condenser and filament leads.	1 & 9
	Fixed condenser across phones.	This condenser may be short-circuited, or if amplifiers are used it may be the condenser across the primary of the first transformer.	1 13 33
	Telephone receiver.	May be burned out or short-circuited.	1 30
	Phone plug.	Defective or short-circuited.	1 & 15

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
(Continued)— No signals when phone is connected to detector jack.	Telephone receiver terminals reversed.	The majority of phones using magnets acting directly upon the diaphragm have one of the cords marked with a red thread in the covering. This marked cord should be connected to the "B" battery plus terminals. A reversed connection will cause the plate or "B" battery current to demagnetize the phone magnets and make them inoperative. Reverse the leads.	—
Signals weak when phone is connected to detector tor jack.	Primary circuit not tuned.	When tuning is broad it is due usually to the coupling between the primary and secondary windings of tuning coils being too close together; or may be due to too many turns of wire on primary. Space primary and secondary further apart and remove some of the wire from the primary winding.	—
	Tickler coil reversed.	If the receiver uses regeneration the tickler coil may be reversed. Reverse the tickler leads and test for best results.	—
	Tuning condensers.	Condensers may be poorly insulated. Fibre ends on condensers are subject to leakage and cause trouble which is hard to locate. Use only condensers with bakelite insulation.	1 14
	Tube socket.	Tube prongs making poor contact in socket. Clean tube prongs and socket contact springs, and bend up the latter slightly to insure good contact.	20
	Grid condenser short circuited.	Short circuited. This is often caused when soldering leads to the mica grid condenser, the flux flowing between the metal lugs and over the edges. Discard condenser and use small bolts for connecting up the new one, inserting the bolt through the small holes in the condenser and fastening the leads under the nuts of the bolts.	1 18
	Grid leak.	Resistance of grid leak too low. If the resistance of the grid leak is too low it allows the charges on the grid to leak off too fast and full volume of signal is not obtained. Try different values of resistance and test for best results.	22
	"B" battery.	Too much "B" voltage on plate of tube may paralyze it. Try various voltages for best signals.	29
	Excessive filament current.	Keep filament voltage as low as possible. Burning tubes too brightly causes loss of sensitivity.	—

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
(Continued)— Signals weak when phone is connected to detector jack.	Grid condenser open circuited.	Sometimes in soldering to the grid condenser the heat melts the internal connections. New grid condenser must be used.	1 13
	Batteries run down.	Check the "B" Batteries with a voltmeter and if they have dropped to two-thirds of their rated voltage discard them if dry cells; recharge if storage battery. If dry cell "A" battery replace, and if storage battery test with hydrometer and if below 1.170 recharge.	2 4
	Phone plug.	Defective or short circuited.	1 & 15
	Phone terminals reversed.	Cord with red thread woven in it should go to "B" plus terminal.	—
Scraping, scratching, or knocking sound when connected to detector jack.	Aerial.	Aerial swaying against conducting objects partially or wholly grounded.	5
	Tuning coils.	Coils loose or vibrating. Flimsy construction of the apparatus allows relationship of coils to change with the least vibration. Tighten up the loose parts.	—
	Variocoupler, variometer or variable condenser.	Poor contact at bearings of variocoupler, variometer or condenser. After being used a while this trouble develops with most instruments using current carrying bearings. Can be cured by bringing out flexible leads and arranging stops on instruments to prevent these leads from twisting.	1 9 10 14
	Switch levers.	Poor connections at switch points or switch levers. Use a switch with panel bushing having snug fitting shaft with spring tension. Clean switch occasionally.	—
	Variable condensers dirty, or short circuited.	Dust gets between the plates of variable condensers. Clean with a pipe cleaner. Plates sometimes touch, causing loud clicks; bend plates back into proper shape.	1 14
	Grid leak resistance too high.	The grid leak is intended to allow the charges on the grid to leak off slowly. If too high, the charge collects and makes the grid too negative, thus stopping the action of the tube. The cure is to reduce the resistance of the grid leak.	22
	Rheostat.	Defective rheostat. A loose connection in the rheostat gives an unsteady current. Can be detected by change in brilliancy of tube filament or by change in signals when rheostat knob is jarred.	17
	Plate or grid leads.	Plate lead touching grid leads or running close to them. This results in a feedback either by actual contact or by capacity effect. Separate the leads.	27

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
(Continued)—Scraping, scratching, or knocking sound when connected to detector jack.	Plate lead touching aerial lead.	In a loose coupled tuner this results in a capacity feedback and where the filament is grounded, it short circuits the "B" battery. Separate the leads.	—
	Phone cords defective.	The tinsel cords used often become broken by continued bending and eventually make a very poor contact that is noticeable every time the phone cord is moved. Replace with new cord.	—
Whistles, Squeals and Hisses when connected to detector jack.	Static.	Can only be reduced by using loop or indoor aerial. Cannot as yet be entirely eliminated.	—
	Tickler coil.	Too much wire on tickler coil. The large number of turns in use gives such a strong field that energy is fed back to the grid, regardless of how rotor is turned. Remove some of the wire from the tickler coil, keep on turning the rotor, till the set goes smoothly into oscillation; this is indicated by a dull thud instead of a harsh squeal.	—
	Grid condenser.	Grid condenser short circuited. Replace with new condenser.	1, 13
	Grid leak resistance too high.	Reduce the resistance of the leak until best results are obtained.	22
	"B" battery voltage high.	Too high "B" voltage has a tendency to make a tube oscillate. Reduce voltage until this tendency is eliminated.	29
	"A" battery voltage high.	Filaments should be heated to the lowest degree consistent with good signals. To use excessive filament voltage only shortens the life of the tube.	—
	Plate and grid leads.	Plate and grid leads should not touch or run close together. Keep well separated.	27
	Plate and ground leads.	Plate and ground leads should not run parallel or touch; this causes a feedback effect resulting in howls.	—
	Aerial lead.	Aerial lead should not touch plate leads. In loose coupled sets this results in a capacity feedback and if the filament is grounded, it short circuits the "B" battery.	—
	Batteries run down.	Test "B" battery with voltmeter, if it has dropped to two-thirds of rated voltage it should be discarded, if storage "B" is used recharge it. If storage "A" battery is used test it with hydrometer; if it registers below 1.170 recharge it; if dry cells are used they should be discarded when low.	2 4
	Transformers (radio frequency).	If the set employs radio frequency amplification before the detector, the transformers may be too close. The	24

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
(Continued)—Whistles, Squeals and Hisses when connected to detector jack.		transformers feedback from the plate to the grid and cause oscillations. Space them further apart and mount at right angles to each other.	
	Radio frequency tube filaments too bright.	Radio frequency filaments are rather critical and need close adjustment to prevent them from going into oscillation.	—
Scraping, scratch- and knocking sounds in amplifier circuits.	Tube elements vibrating.	When rigidily attached to the base of the set, slight vibrations will cause the tube elements to vibrate. This is particularly noticeable with the small tubes using dry batteries on the filament. The cure is to use cushioned sockets or mount sockets on sponge rubber. Rubber feet on cabinet will also aid.	20
	Tube sockets.	Moulded sockets usually have poor insulating properties. Metal sockets with a fibre base are just as bad. Use bakelite or porcelain sockets.	20
	Rheostat.	Loose connection in the rheostat gives an unsteady current. Can be detected by change in brilliancy of tube filament or by change in signals when rheostat knob is jarred.	17
	Transformers.	Transformers burned out or partially short circuited should be taken out and replaced with new.	19
	Moisture in transformers.	This would short circuit the windings. A heated electric light bulb hung in the cabinet of the set for several hours will dry out the moisture.	19
	Phone plug.	Defective or short circuited. Disconnect plug and test to see if current will flow from one terminal to the other when disconnected from headset.	1 15
Whistles, Squeals and Hisses in amplifier circuit.	Plate and grid leads.	Plate and grid leads should not touch or run parallel. This causes tubes to oscillate. Keep leads well separated.	27
	Batteries run down.	Test "B" batteries with voltmeter and if they have dropped to two-thirds of their rated voltage discard them; if storage "B" is used recharge it. If dry cell "A" battery is used discard it; if a storage battery is used test it with hydrometer and if reading is below 1.170 recharge it.	2 4
	Transformer primary and secondary leads reversed.	Howling and squealing can sometimes be prevented by changing leads on the transformers. Keep reversing the leads until a stable condition exists.	—
	Transformers too close together.	Audio frequency transformers should not be mounted too close together. When mounting they should be kept well apart and set at right angles to prevent interaction.	19

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
Weak or Distorted Signals through Amplifier.	Tube socket dirty.	Tube prongs making poor contact in the sockets. Clean tube prongs and socket contact springs, and bend up the latter to insure good contact.	20
	Tube socket defective.	Moulded sockets generally have poor insulating properties. Metal sockets with a fibre base are equally bad. Bakelite or porcelain should be used.	20
	Rheostat.	A loose connection in the rheostat gives an unsteady current.	17
	"B" battery voltage too great.	Excessive "B" battery voltage on the plate of tubes has a tendency to cause distortion. Decrease the voltage and note effect on clarity.	29
	"A" battery too high.	Using excessive filament current make tubes have tendency to oscillate, resulting in distorted signals.	—
	Batteries run down.	Discard or recharge respectively if dry cells or storage battery used.	2 & 4
	Phone condenser short circuited.	Phone condenser may be short circuited, or the condenser across the primary of the first audio frequency transformer may be short circuited.	1 18
	Transformers burned out or partially short circuited.	Sometimes caused by excessive plate voltage. Transformers must be replaced.	19
	Phone jack.	Often when soldering lugs on jacks some flux runs into the fibre spacers and causes trouble. Replace jack.	16
	Transformers.	Transformers too close together. Space them well apart and mount at right angles to each other.	24 19
	Dampness in transformers.	Causes partial short circuit. A lighted electric light bulb hung in the cabinet of the set for a few hours will dry it out.	19
	Transformers open circuited.	Often in soldering on the terminals the internal connections are loosened. Can often be repaired by opening the case and repairing broken lead.	19
	Transformer ratio too high.	Replace with transformers of lower ratio. 3 or 3½ to 1 is about the best ratio for general audio amplification.	19
	Transformer leads reversed.	Filament leads from transformer connected to positive instead of negative side of "A" battery. Reverse.	—
	Headset or loudspeaker.	Headset or loudspeaker burned out or short circuited. Replace, or remove the short circuit.	30
	Phone plug.	Defective or short circuited. Remove plug and see if current will flow from one terminal to the other when disconnected from headset or speaker. If so, replace with new plug.	1 15
	Phone or loudspeaker reversed.	The phone cord with the red thread woven in it should go to positive terminal of "B" battery.	—

General Symptom	Part Afflicted	Cause and How to Remedy the Defect	See Test
Humming or Buzzing Sounds.	Tuning coils.	Open circuit in tuner winding. Usually occurs where taps are taken from windings and where connections are made to the ends of the winding. Rewind coils or securely solder connections.	7 8
	Tube elements vibrating.	When rigidly attached to the base of the set, slight vibrations will cause tube elements to vibrate. Remedy is to use cushioned sockets or mount sockets on sponge rubber. Rubber feet on cabinet of set also helps.	—
	Aerial.	Aerial too close to alternating current electric wires. Sometimes reduced by running aerial at right angles to such lines. Sometimes caused by leaky transformer on nearby electric pole, in which case notify electric company.	5
	Aerial lead.	Aerial lead running too near house alternating current lighting wires will cause hum of current to be heard. Keep lead well away from fixtures, etc.	5
Fading or Wavering Signals.	Aerial insulators.	Aerial insulators leaky due to rain, etc. Lead in wire touching side of house. Use glass or glazed porcelain insulators on aerial and to stand off aerial lead in.	5
	Variable condenser leads reversed.	If variable condenser is improperly connected up, the signal will fade when hand is removed from dial, due to "body capacity." The stationary plates of variable condenser should be connected to the grid of the tubes.	14 26
	Rheostat.	A loose connection in the rheostat gives an unsteady current and accordingly causes signals to vary in intensity. Replace or repair rheostat.	17
	Natural phenomena.	For unkown reasons signals fade under certain conditions due apparently to some condition of nature existing between the transmitting station and the receiver. To date there is no known remedy.	—
	"A" battery.	Weak "A" battery causes unsteady flow of current resulting in change in intensity of signals. Replace or recharge battery.	2

PART VI

TESTS TO LOCATE TROUBLES

It is a safe precaution to remove all tubes from the set before starting the tests. It is also good to have an old worn out tube in which the filament will burn, for testing after making changes in battery circuits to save possibly burning out good tubes.

TEST NO. 1.
Phone Test

Connect one tip of a pair of head phones to the positive side of a 1½-volt flashlight battery or a 1½-volt dry "A" battery. To the other terminal of the battery connect a wire long enough to reach all parts of the set. So that your ear will

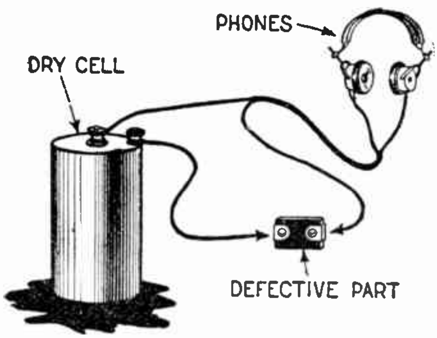


Fig. 5 (Test No. 1). Method of testing parts for defects.

become accustomed to the strength of the click, make and break contact between the other tip of the phone cord and the bare end of the negative wire. This completes the circuit and causes the phone diaphragm to give out a loud click. If a circuit is open the current from the battery cannot pass, hence there will be no click. All coils, whether concealed in shielded radio or audio frequency transformers or whether wound on tubes or otherwise, are intended to be closed or complete circuits and when right the click should be heard. Condensers reverse this order and are open circuit devices, therefore there should be no click except as explained under Test No. 13.

TEST NO. 2.
"A" Storage Battery Run Down

Remove vent caps, use a good accurate hydrometer and take up just enough electrolyte to float the glass bulb in the tube. Then holding the hydrometer by the glass

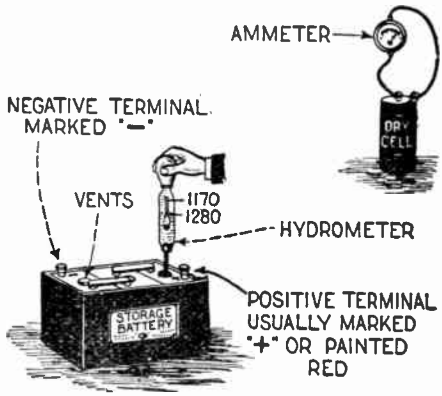


Fig. 6 (Test No. 2). **Testing "A" battery voltage.**

tube read the number or determine the line at the exact level of the top of the liquid. Most standard makes of radio batteries in use today show a gravity of 1.280 when fully charged and should be recharged when they reach a gravity of 1.170. When the battery is fully charged the acid is out of the plates.

TEST NO. 3.
"A" Battery Polarity Reversed

If in doubt as to polarity of either storage or dry "A" battery, insert both wires in a glass of strong salt water. Bring close together but not touching each other. The negative lead will become coated with bubbles. Trace leads to binding posts. From positive "A" on binding post trace through rheostats to positive on tube sockets. If incorrect reverse them. Polarity test may also be made with voltmeter. Indicating needle on voltmeter will turn to the right (clockwise) when positive (+) lead is touched to positive post of the battery. If it turns to left, reverse

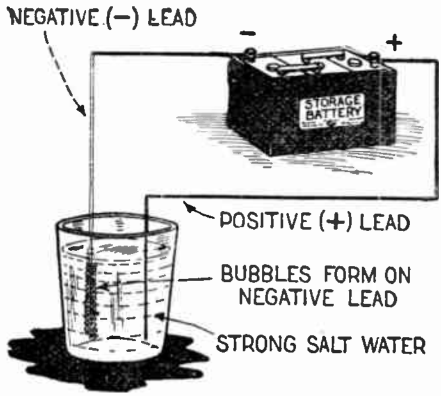


Fig. 7 (Test No. 3). How to determine positive and negative poles of an unmarked battery.

voltmeter leads and try again. This polarity test applies alike to A and B batteries.

BATTERY POLARITY REVERSED ON AMPLIFIER

Where separate amplifier is used, proceed as in Test No. 3.

TEST NO. 4.

"B" Battery Run Down

Storage "B" batteries should be tested the same as storage "A" batteries. Use Test No. 2. Dry "B" batteries must be

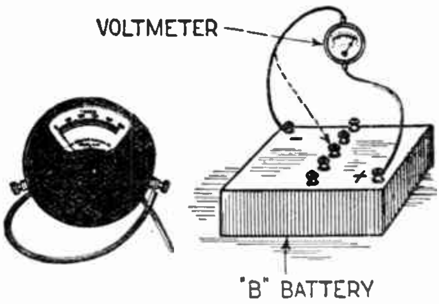


Fig. 8 (Test No. 4). Method of testing "B" battery voltage by means of a voltmeter.

tested with a voltmeter. A new dry "B" battery should test a full 22½ or 45 volts according to the sizes you use. A 45-volt battery will operate satisfactorily down to 36 volts but will deteriorate very rapidly with resulting poor reception after that. If "B" batteries run down very rapidly it may be advisable to use a "C" battery to give the grid a slightly negative bias. This will in many cases improve both tone quality and volume, and in all cases it will prolong the life of the "B" battery very materially.

"B" BATTERY TO AMPLIFIER RUN DOWN

Test the same as No. 4.

TEST NO. 5.

Aerial or Ground Poor

Examine and clean every contact, solder all joints on aerial and lead-in. See that ground wire is making perfect contact. Examine aerial insulators for cracks or break. Never cross lighting wires with aerial. Make aerial tight with rigid supports. See Fig. 2 for illustration.

TEST NO. 6.

Apparatus Touching Shielding On Panel Or Elsewhere

Test from shield to apparatus with phone and 1½ volt battery same as condenser test. Use Test No. 1.

TEST NO. 7.

Open Circuit in Antenna Inductance

If not tapped, test with phones from input to output end if no click coil is open. If coil is tapped, test from input end to first switch contact then each one in turn. If no click is heard that tap is open and should be soldered. If click is heard at all points circuit is complete. Use phone test No. 1. See Fig. 10.

TEST NO. 8.

Open Circuit in Secondary Inductance

Use Test No. 1. See Fig. 10.

TEST NO. 9.

Grid Variometer Defective

Examine all connections to see if making perfect contact. Pigtail may be broken but making intermittent contact. Soldering may be poor. Test all soldered joints to see if tight; if suspicious, resolder. Use Test No. 1. See Fig. 11.

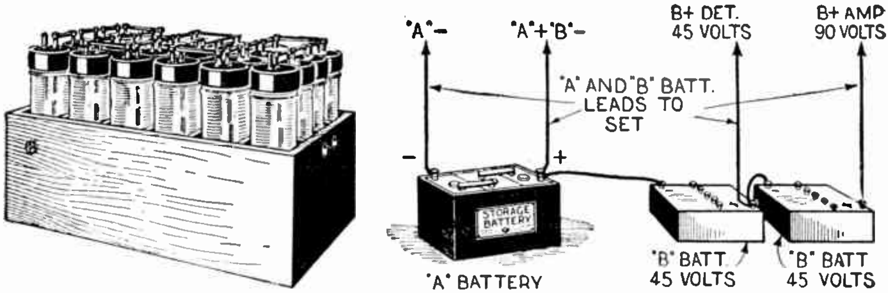


Fig. 9 (Test No. 4). At the left is shown a type of storage "B" battery, and at the right is indicated manner of connecting "A" and "B" batteries to a receiver.

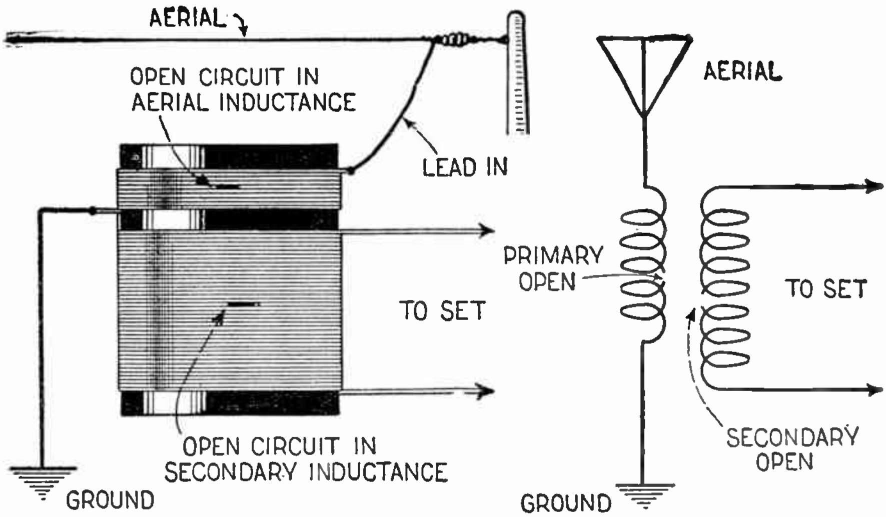


Fig. 10 (Test Nos. 7 and 8). Open circuit in aerial inductance and secondary inductance shown above. The diagram at left is in perspective and that on the right is in schematic form.

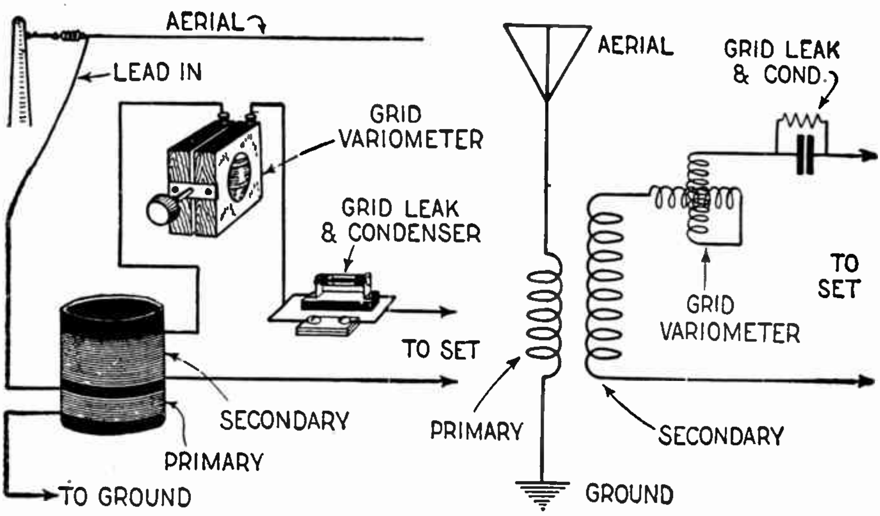


Fig. 11 (Test No. 9). The above diagrams show in both perspective and schematic forms the location of a grid variometer in a regenerative circuit.

TEST NO. 10.
Aerial Variometer Connections Poor
Same test as No. 9. Use Test No. 1.

TEST NO. 12.
Tickler Coil Open
Test for open circuit with phones, same as Test No. 1.

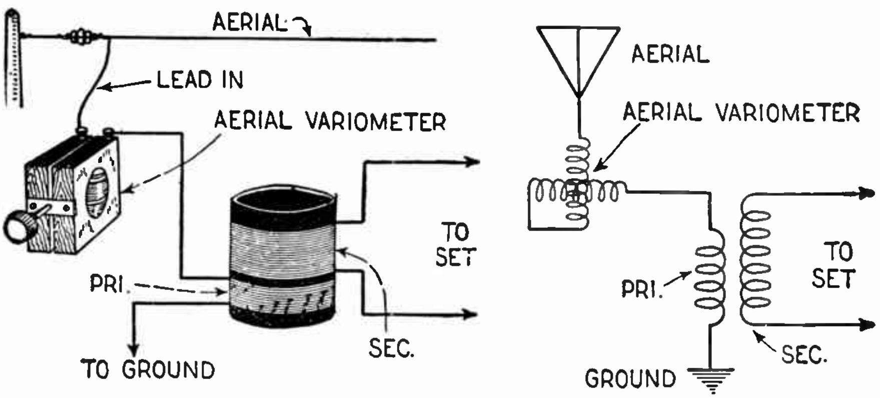


Fig. 12 (Test No. 10). Some sets use a variometer to tune the aerial circuit. The locatiou of this variometer is shown above.

TEST NO. 11.
Short Circuit in Coils
Short circuits between turns of wire on any coil, unless they are visible, can only be found by the use of delicate instruments and complicated figuring. Therefore, if you are reasonably sure the coil is causing trouble, it should be replaced.

TEST NO. 13.
Condensers Defective Or Shorted
Fixed condensers are subject to two principal faults, either short circuit or leakage due to moisture. In either case they should be replaced. Use Test No. 1. If the condenser is shorted there will be a loud click in the phones, the same as if you

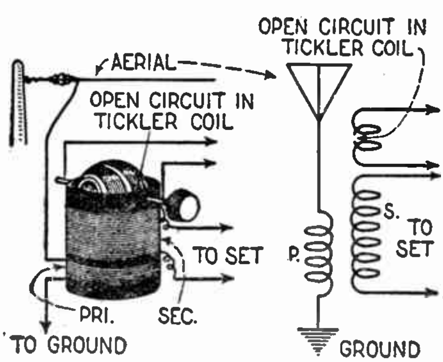


Fig. 13 (Test No. 12). In a regenerative circuit using a tickler coil, this coil may develop an open circuit. The tickler coil of a 3 circuit tuner is indicated above.

touch the other phone tip to the negative wire from the battery. A very faint click will be heard but this does not indicate defect and is due to the loading and unloading of the condenser. Make the comparison suggested above and you will know the difference. A leaky condenser will

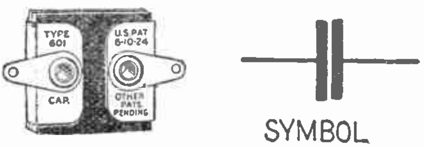


Fig. 14 (Test No. 13). A conventional type of fixed condenser

make a similar click but not so loud and usually makes a scratching sound. Use Test No. 1.

TEST NO. 14.

Condensers—Variable

Variable condensers are subject to similar ills and shows the same symptoms.

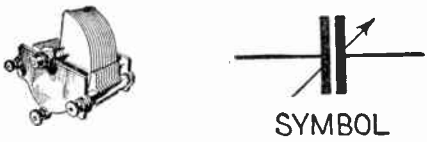


Fig. 15 (Test No. 14). A type of variable condenser.

Disconnect leads, then test the same as fixed condensers. If rotor and stator plates touch loud click will be heard in phones. Moisture, dust, dirt or oil will cause less intense click or rasping click whenever plates are turned. If touching, bend plates carefully back to proper spacing. If dusty or dirty, clean with pipe cleaner. If particles of metal from edges of plates are touching other plates, smooth edges with very fine platinum file and clean out all filings thoroughly with pipe cleaner. Disconnect and take condenser out of set for examination, testing and cleaning. Use Test No. 1.

TEST NO. 15.

Plug Shorted Or Not Making Contact

Examine to see if plug electrodes are making contact with the proper jack springs and that plug does not go so far in that both springs make contact with

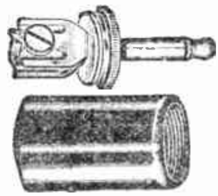


Fig. 16 (Test No. 15). A phone plug with case removed to show interior construction.

same electrode. Test plug with phone as explained in Test No. 1 by making contact with one lead to the tip and the other lead to the sleeve of the plug. If shorted there will be a loud click in the phones; if not, the plug is good.

TEST NO. 16.

Jack Troubles

Jacks are somewhat elusive and call for very careful scrutiny to determine whether they are giving trouble. There are several different plugs for different purposes, making it difficult to give specific data, but the following should not be hard to

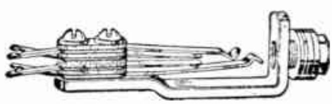


Fig. 17 (Test No. 16). A phone jack much used in radio receivers.

understand. By inserting a good plug in any jack it will be easy to see which springs should make contact and which should not. Disconnect all batteries. Test connection from terminal posts to jack. First test with phones from each prong to the body of the jack with no plug inserted. A click would indicate that the jack is shorted and must be replaced. Then test at the soldering prongs of each pair of springs that should make contact to see that good strong click is made in phones. A good jack is not expensive and if you have any suspicions after making this test, replace it. Use Test No. 1.

TEST NO. 17.

Rheostats

The principle trouble with rheostats are poor connection from the busbar to rheostat terminals; broken resistance wire in rheostat, or poor and interrupted contact between contact arm and resistance wire. First test "A" battery leads at binding posts to see that current is reaching the set. This test to be made with low-reading voltmeter. Then trace to and test

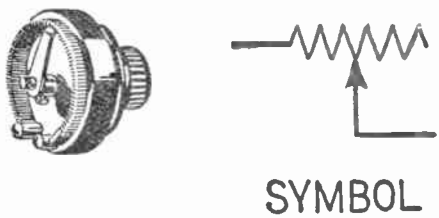


Fig. 18 (Test No. 17). Rear view of rheostat showing resistance wire and contact arm.

across filament contacts in socket, trace from socket to contacts on rheostat. With contact arm in full on position, test with voltmeter from input to output contacts for voltage. If no reading, rheostat is open and should be replaced, providing contact is good at both rheostat terminals. If contact is intermittent causing flickering of filament, contact arm may need tightening against wire just sufficient to make smooth sliding contact. If resistance wire is badly worn replace rheostat.

TEST NO. 18.

Potentiometers

Potentiometer troubles are almost identical with those of rheostats. Examine for poor contacts and loose, broken or worn wire. Replace if found defective. Read over Test No. 17.

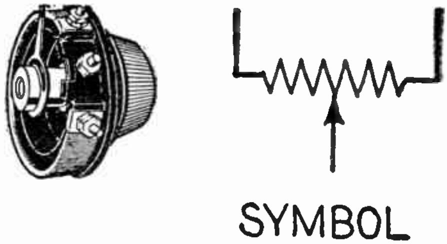


Fig. 19 (Test No. 18). Rear view of potentiometer, showing resistance wire, contact arm binding posts of triple connections.

TEST NO. 19.

Transformers

The principal troubles in transformers are due to abuse of that unit. The leads that form the primary and secondary windings are of very fine wire and should the binding nut which holds the contact screw in place become loosened the lead may be broken off by turning the screw. It is a difficult matter in shielded transformers to resolder this lead. Before attempting to open up the transformer use Test No. 1 across the two primary contacts and then across the secondary contacts to see if either circuit is open. If test shows open, remove one side shield at a time and examine leads. If leads are not broken after

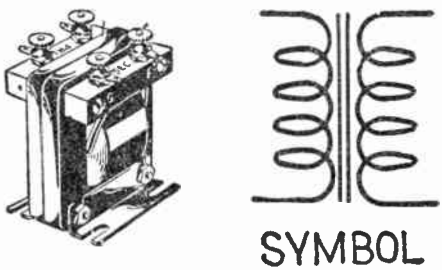


Fig. 20 (Test No. 19). An audio frequency transformer.

test shows open it is useless to go further and unit should be replaced. Broken leads in unshielded transformers can often be seen and repaired. If windings are burned out Test No. 1 will usually show it and such units should be replaced. The best transformer you can buy is the one to use. Be careful to use the correct ratio as recommended by the manufacturer of the set.

TEST NO. 20

Tube Sockets

Thoroughly clean all contacts including springs. Bend springs up so that they will make perfect contact with tube prongs which should also be cleaned. See that all springs are bent up equally. All socket springs should be equally spaced and screws holding them tightened up fully to avoid the possibility of their shifting sideways and making contact with another spring. Should the plate contact spring come into contact with the filament prong

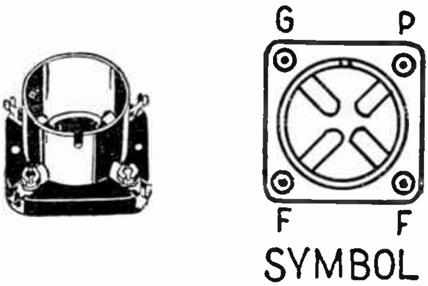


Fig. 21 (Test No. 20). A vacuum tube socket.

of the tube, the filament would be instantly destroyed. If tubes fit very loosely in sockets, it may cause poor contact and such sockets should be replaced. Some sockets allow very little space between the springs and the baseboard; any metallic substance in this space is liable to make contact between "A" and "B" springs and burn out the tubes. Frequently trouble in a socket can be detected by pressing firmly down on the tube but if you go over the sockets carefully and observe the above suggestions you are not likely to have any trouble.

TEST NO. 21.

Grid Leak Defective

Occasionally, due to damp weather, moisture finds its way into some types of grid leaks and causes them to become defective, or the leak is dropped and the internal connections broken. This will prevent the excess charges from leaking off the grid and will cause the vacuum tube to become paralyzed and inoperative. The only test is to take out the grid leak and test different leaks in its place to determine if they produce better signals than the original leak.

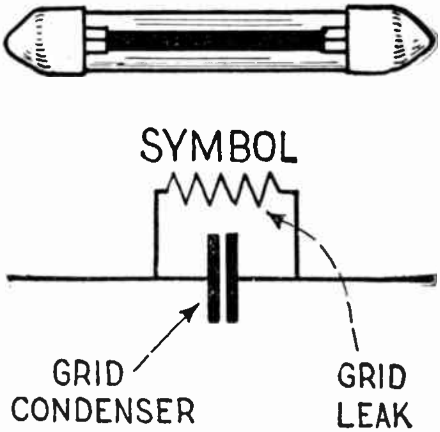


Fig. 22 (Test Nos. 21 and 22). A tubular type of grid leak.

TEST NO. 22.

Resistance of Grid Leak of Improper Value

Try higher and lower resistance leaks as the case may be to determine which gives the best signal response. Improper grid leaks do not permit the excessive charges to leak from the grid of the vacuum tube and cause it to become paralyzed and inoperative. See Test No. 21 for illustration.

TEST NO. 23.

Resistance Used For Coupling Defective

Test different resistances in place of the originals. In some types of radio frequency receivers resistances are used for interstage coupling instead of transformers, and if these resistances should become defective from any cause proper coupling cannot be maintained between the stages.

TEST NO. 24.

Interstage Coupling

Try separating the radio frequency transformers a greater distance. The radio frequency transformers should be separated not less than 6 inches in order to prevent any conflict between their respective electric fields.

TEST NO. 25.

Damp Coils

If the set has been used near an open window or in any other location where it is apt to be affected by dampness the coils may become so damp as to actually short circuit the various turns thereon. The remedy is to place an electric bulb inside the cabinet and allow this bulb to remain lighted long enough to thoroughly dry out the interior of the cabinet, and this should be done as often as the interior shows any indications of dampness.

TEST NO. 26.

Poor Contact or Condenser Leads Reversed

Where condensers are so constructed that the connection to the rotary plates is through the moving bearing instead of through a flexible lead or "pig-tail" the connection is apt to become poor and evidence itself by rasping and scratchy noises as the dials are turned. Tighten the screws on the back of the condenser which regulate the tension on the bearing of the rotary plates. If the leads to the condenser are reversed a "hand capacity" or "body capacity" effect is noticed as the hand is taken away from the dial, the tuned in signal fading as the hand is removed. If this effect is noticed the leads to the condensers should be reversed. The lead from the grid of the tube should always be connected to the stationary plates of the variable condenser. See Test No. 14 for illustration.

TEST NO. 27.

Plate and Grid Leads Too Close Together

If the set has a tendency to oscillate regardless of the various settings, try spac-

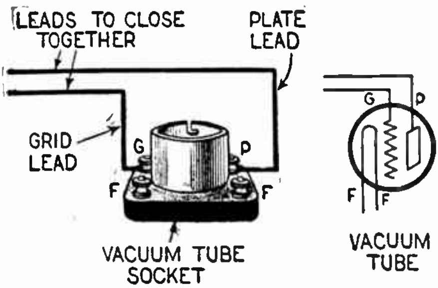


Fig. 28 (Test No. 27). Grid and plate leads from tube socket should be well separated.

ing the plate and grid leads further apart. They should be kept well separated and not run parallel if at all possible to avoid it, as a "feedback" effect takes place whereby some of the energy in the plate circuit may be finding its way back to the grid circuit thereby causing oscillations to take place, resulting in a howl in the receiver.

TEST NO. 28.

Grid Condenser Capacity Too High

The average capacity should be .00025 mfd. for a grid condenser and if the set

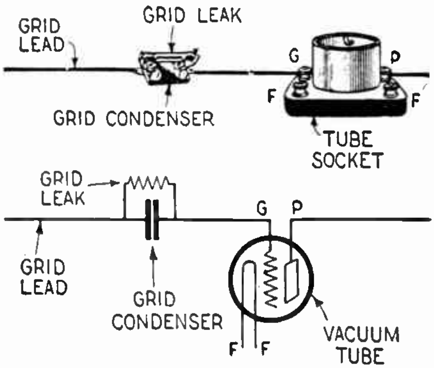


Fig. 24 (Test No. 28). The location of the grid condenser is shown in the illustration.

is critical in its operation and signals are poor, various capacities should be tried until best signals are obtained.

TEST NO. 29.

"B" Battery Voltage Too Great

If the "B" battery voltage is too high in a regenerative set it tends to make the control of regeneration very critical, and in

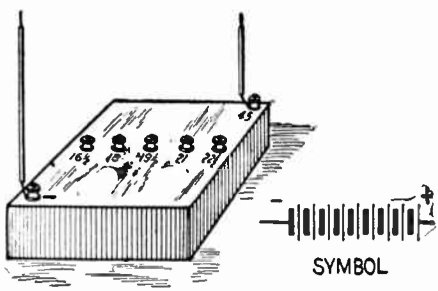


Fig. 25 (Test No. 29). A dry cell "B" battery. Fig. 9 shows a storage "B" battery and Fig. 1 the "B" battery connections for various voltages.

various types of tuned radio frequency circuits it will also cause the detector tube to go into oscillation, an undesirable feature. The remedy is, of course, to reduce the "B" battery voltage until the best results are obtained. Some tubes operate far better with only 16½ volts on the plate.

TEST NO. 30.
Defective Headphones

If it is believed that the headphone is defective or dead the phone should be removed from the set and tested out with a small battery. This should be placed across the terminals of the plug and if no click is heard in the phones when the circuit is closed it is an indication that either the plug is defective, or the fine wire on

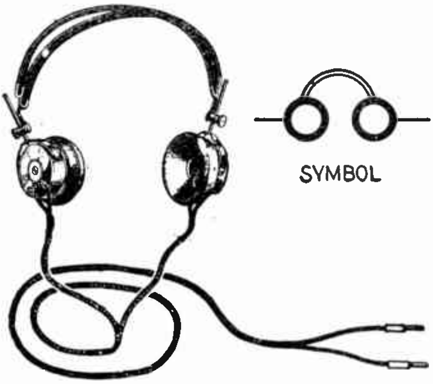


Fig. 26 (Test No. 30). Headphone much used in radio reception.

the magnets within the phones is broken; sometimes the diaphragm is bent inward so that it touches the magnet, which would also make the phone inoperative. Headphones should be very carefully handled and they should not be dropped on the floor or subjected to sudden jars as these would cause any of the defects herein mentioned. First remove the plug and place the battery across the terminals at the end of the phone cord, and if the click is then heard in the phone it is an indication that the trouble is with the plug. If no click is heard with the plug removed examine the diaphragm to see if it is bent in; if this is in good condition (there is, of course, one in each phone), the trouble lies in the winding of the magnets. Attempt should not be made to correct this fault and the phones should be returned to the manufacturer for correction.

TEST NO. 31.
Defective Tubes

Defective vacuum tubes result from the destruction of the high vacuum in the tubes, or from long and continued use the electron flow from the filament to the plate of the tube, through the grid, deminishes and results in decreased signal strength from the tubes, or the entire abscence of signals. Change the tubes around in the sockets and note effect on signals. Sometimes a tube which is inferior as a detector is very good as an amplifier. It

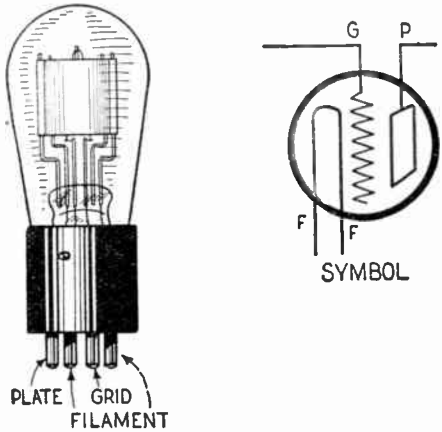


Fig. 27 (Test No. 31). A modern type of radio vacuum tube.

may be necessary to replace the tubes entirely.

TEST NO. 32.
Tubes Not Neutralized

In the neutrodyne set it is necessary to properly adjust the neutralizing condensers, or neutrodons, so that the radio frequency circuits cannot oscillate. If a neutrodyne howls or squeals it is a sign that the neutralizing condensers are not exactly alike in capacity and should be adjusted until the tubes no longer oscillate.

TEST NO. 33.
Phone Condenser Too High Capacity

Try various phone condensers although the proper capacity is usually .001 mfds. This must be determined by experiment. See Fig. 28.

TEST NO. 34.
Catwhisker Not Making Contact with Crystal

In reflex sets care must be taken that the contact wire (called a catwhisker) is making proper contact with the crystal. Try various adjustments and tension of the catwhisker until best response is had from the reflex. See Fig. 29.

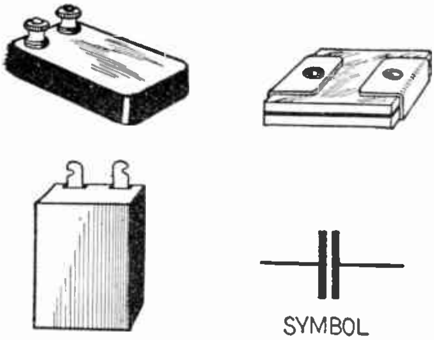


Fig. 28 (Test No. 33). Various types of fixed condensers used across the phones in a radio receiver.

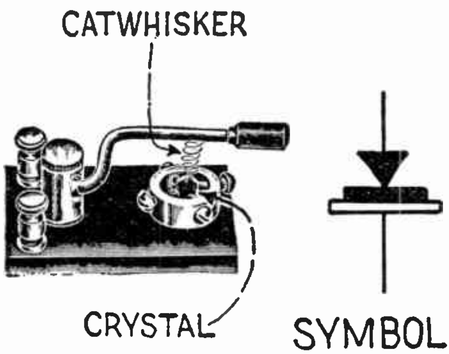


Fig. 29 (Test Nos. 34 and 35). A typical crystal detector.

TEST NO. 35.

Corroded Catwhisker

If all connections in a reflex circuit are correct and various adjustments of the catwhisker have no effect in bringing in signals, it is quite probable that the catwhisker has become so corroded that the corrosion on the wire is in effect a perfect insulator. Sometimes this catwhisker can be cleaned by rubbing same on a piece of find emory paper, but the better method is to remove the corroded catwhisker entirely and replace it with a new clean one. See Fig. 29.

TEST NO. 36.

Crystal Poor or Burned Out

When used in reflex sets the crystal has a tendency to become poor in operation or burn out entirely. This is presumably due to the comparatively high "B" battery voltage which is passed through the crystal in this type of circuit. If this is the case the only recourse is to discard the crystal and install a new one. See Fig. 29.

TEST NO. 37.

Defective Radio Frequency Transformers

Use Test No. 1. Sometimes the wires become broken causing an open circuit in the transformer. Remove defective transformer and replace with one in good condition.

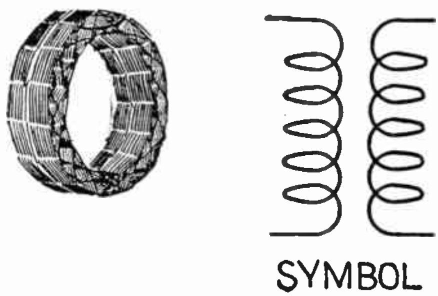


Fig. 30 (Test No. 37). A type of radio frequency transformer in common use.

TEST NO. 38.

Wrong Connection to Oscillator

If turning the oscillator dial has no effect in bringing in any signals it is safe to say that the connections are wrong and that this tube is not oscillating, and accordingly there can be no beat frequency upon which the super-heterodyne operates. Connections to oscillator tube plate leads should be reversed and effect noted on signals; "B" battery increased, or new tube used. See Figs. 31 and 32.

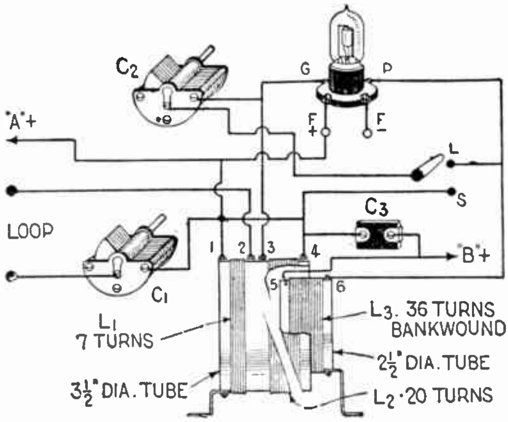


Fig. 81

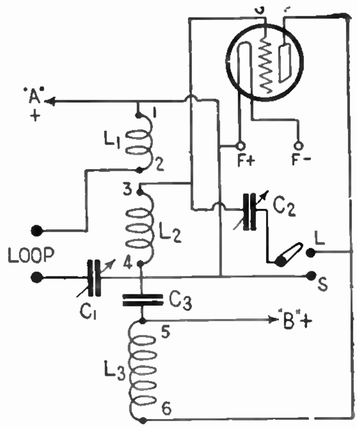


Fig. 82

Fig. 81 shows in perspective form the oscillator of a superheterodyne. Fig. 82 is the oscillator in schematic form. The letters in Fig. 81 will serve to identify the parts in Fig. 82.

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