Radio

WITH QUESTIONS AND ANSWERS

JOHN R. IRWIN

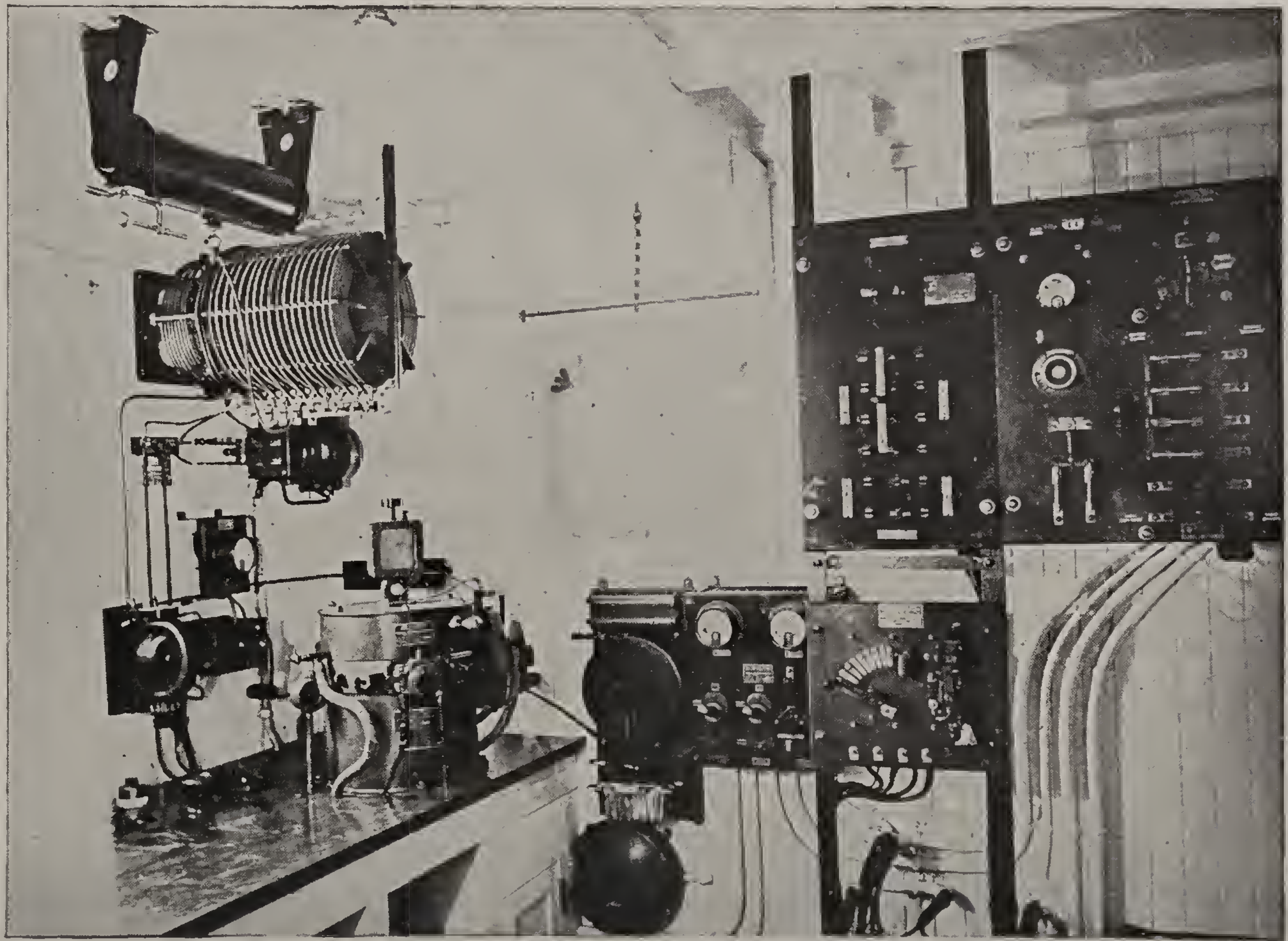

FIG. 24. Complete arc installation on shipboard

RADIO

A PRACTICAL MANUAL WITH QUESTIONS AND ANSWERS

BY

JOHN R. IRWIN

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CONTENTS

APPENDICES

ILLUSTRATIONS

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PREFACE

Within the past half year the radio art has received phenomenal attention from the general public. People who hitherto gave it but passing attention have become enthusiastic experimenters and have made it their exclusive hobby.

There are numerous excellent text books published dealing exhaustively with radio engineering in all its many ramifications, but these works excellent though they be, are more or less technical in their make-up.

Among the many newcomers into the ranks of experimenters are people who have neither the technical knowledge nor the time to acquire it, and who desire a manual as free from technicalities as possible, in order to obtain a working idea of radio. To meet the demand of that class of reader, the author offers this manual. He hopes at least, that it will prepare the reader for a better understanding of radio, which can be supplemented later by perusing more comprehensive works already published upon the subject.

The writer wishes to express his sincere thanks and appreciation to Messrs. C. B. Cooper, W. J.

Roche and J. B. Ferguson of the Shipowners Radio Service for their assistance and advice. Also, to Mr. Philip Farnsworth, Counsellor-at-law, for the loan of valuable reference works.

He acknowledges his indebtedness to the various publications of the Signal Corps, the U. S. Navy, and the Bureau of Standards, for exact data upon many subjects.

JOHN R. IRWIN.

BRIEF HISTORY OF RADIO

CHAPTER I

EARLY DAYS OF RADIO

It is appropriate that any explanation of radio to the uninitiated should include, however brief, something of the origin of the art.

The complete history would require several volumes and would include the efforts of experimenters who have contributed to the final result, but who did not in their day even dream of what they had individually assisted in constructing.

The radio art owes its origin to Professor Heinrich Hertz, a German scientist, who in the eighties conducted a series of experiments which led to the construction of the first apparatus for propagating and detecting ether waves, which he described in 1888 in his book "Electric Waves." Professor Hertz's work, however, was not fully proclaimed until Guglielmo (William) Marconi, then a very youthful Italian student, conceived its commercial advantages and utilizing Hertz's experiments and his own ideas originated the first practical radio stations.

Hertz, the pioneer, had understood and applied the principle of resonance. Marconi took the Hertz oscillator and resonator and adapted them for a transmitter and a receiver, respectively, by making both circuits open instead of closed, and grounding the antenna. Tuning between the transmitting and receiving antennæ in this pioneer work was accomplished by increasing or decreasing the capacity of the plates on top of his aerials.

In his experiments Hertz had used for a detector a microscopic spark gap. Marconi in his work utilized a Branley-Lodge coherer as a detector.

Using the Morse telegraph code, Marconi commenced by signaling a few hundred yards, but with the aid of the Italian and British governments he increased the range of his apparatus until he had demonstrated that radio was a practical commercial possibility with unlimited scope.

It is interesting at this stage to note that Signor Marconi, more fortunate than some famous inventors, surrounded himself with associates who had the foresight and imagination to picture the future possibilities of the new science. It was this that has enabled Marconi to-day, in the prime of his life, to reap the material benefits of his pioneer work.

No historical reference to modern radio would be complete without appreciating the experiments of Sir Oliver Lodge, the famous English scientist who, as early as 1888, experimented along the lines originated by Hertz and contributed valuable aid towards making the art the success of today. Later Professor Lodge was to become associated with the Marconi interests, as also was another eminent Englishman, Professor J. A. Fleming, who has contributed to the radio art several valuable text books. In fact, it might be stated that he was first to write any substantial work on the subject. Later he was to revolutionize radio with his original work on vacuum tubes, which we will deal with in its place or chronological order.

Following Marconi's entrance into the field and the filing of his first patent in 1895, radio telegraphy was taken from the academic to the commercial stage and from that date various improvements by innumerable experimenters have followed with endless repetition.

It may be stated, at this stage, without fear of contradiction, that radio telegraphy and telephony has been productive of more patents and more patent litigation than any other science, art or industry invented by man. Patents issued to date in the United States and foreign countries already number tens of thousands. Litigation upon the subject has littered the courts. Reference to all who have contributed to the art can, therefore, not be made within the scope of this volume, and any neglect to give credit, where credit is due, is not premeditated. We will endeavor to give the reader only the principal events which seem to occur, as it were, as stepping stones in radio engineering.

Following Marconi's commercialism of radio, as we may term it, came rapid developments on both sides of the Atlantic.

Nicolas Tesla, in 1897, introduced the tuned transmitter and receiver, or what was to become known as the two circuit transmitter and receiver, which was eventually to lead to much litigation in the courts. In 1898 Marconi patented his first double circuit receiver, retaining, however, his original plain aerial transmitter. Della Riccia, in the same year, adopted a closed and open oscillatory transmitter, while Braun and Stone, in 1899, both devised inductively coupled apparatus.

Ducretet and Pupin, in 1899-1900, it would seem, were the first engineers to resort to what is known as conductively coupled circuits, which were used most successfully commercially for a number of years prior to the introduction of radio laws and regulations. After the promulgation of these laws, conductively coupled circuits became impractical as the wave emitted did not comply with the requirements of the new regulations.

In 1900 Signor Marconi and Professor Braun shared the Nobel prize for their efforts in the radio field. This was the first public recognition of the new science and an acknowledgement of its importance in the scheme of human events.

High Spark Frequency.—Wireless telegraphy had now reached a stage when its study attracted the brightest minds of the scientifically thinking world.

All the earlier equipments had employed as a primary source of energy induction coils, with various means of breaking the direct current. Owing to mechanical difficulties these ''make and break'' devices were necessarily slow in action, with the resultant low spark frequency. The manipulation of these early equipments required considerable skill on the part of the pioneer operators to maintain a ''spark,'' indeed, the old time radio telegrapher, in despatching a batch of business, necessarily would conduct a series of experiments during his efforts.

These induction coil sets gradually gave way to "power" sets, in other words, alternating current supplied by motor generators, supplied the power source. The usual commercial frequency of sixty cyles was first employed. While the practical operation of radio apparatus was immeasurably improved, the low spark frequency objection still remained.

Fessenden appears to be the first radio engineer to suggest a remedy to low spark frequencies and apparatus known by his name appeared which gave forth a high musical note and did much to overcome "static" or "atmospherics," which has been and continues to be the bugbear or hoodoo of radio.

A German system known as "Telefunken" also utilized a high frequency alternator to produce the high musical note.

These high spark frequency equipments utilized either rotating gaps to convert sixty cycle alternations or "quenched" gaps. The latter are used almost exclusively in modern equipments, owing to their efficiency in their "dampening" effects.

Perhaps we should here remind the reader, that a full or comprehensive study of the above mentioned apparatus will be found in the portion of this work devoted to practical radio, and no effort is made in this chapter to an explanation of their construction or functioning.

While the development of radio was progressing rapidly, during the decade of 1900-1910, the "spark" was practically the only system used in commercial wireless telegraphy. Great progress, however, had been made in what is to-day known as the "continuous wave" or the "arc" systems. As the former term indicates, this system employed a continuous or "undamped" wave as its principle.

Poulsen was the originator of the "arc" method, while Alexandersen produced a high frequency alternator, which, while having a comparatively low rate of R. P. M., delivered an exceedingly high frequency. Both systems are used extensively today by operating companies.

An evolution of the vacuum tube, dealt with later, also produced another form of continuous wave radio transmission, which can be said to have put radio telephony where it is to-day.

Undoubtedly, owing to its greater efficiency, continuous wave radiotelegraphy will eventually displace the spark systems, although, especially on shipboard, both systems are often used in one station. This, however, is merely as a convenience and a necessity under existing conditions, as a complete change from one system to the other would be too radical from a commercial or practical point of view. It is one that will come very gradually.

It will now be necessary to go back to the comparative early days of radio to bring the reader to the development in the science, which possibly, has resulted in the astonishing, and we might say, miraculous results that are obtained to-day.

Vacuum Tube Discovered.—Professor J. A. Fleming, after associating himself with Marconi, developed what is known as the "Fleming Valve." This invention was to be the most important development in the radio field.

The Fleming valve was inspired from the effects of the Edison incandescent electric lamp, and takes us into a study of the "electron theory." Thomas Edison, the inventor of the lamp, had experimented in its pioneer days and discovered that by placing a plate within a bulb separate and untouching the filament, a flow of electrons was observed from the filament to the plate.

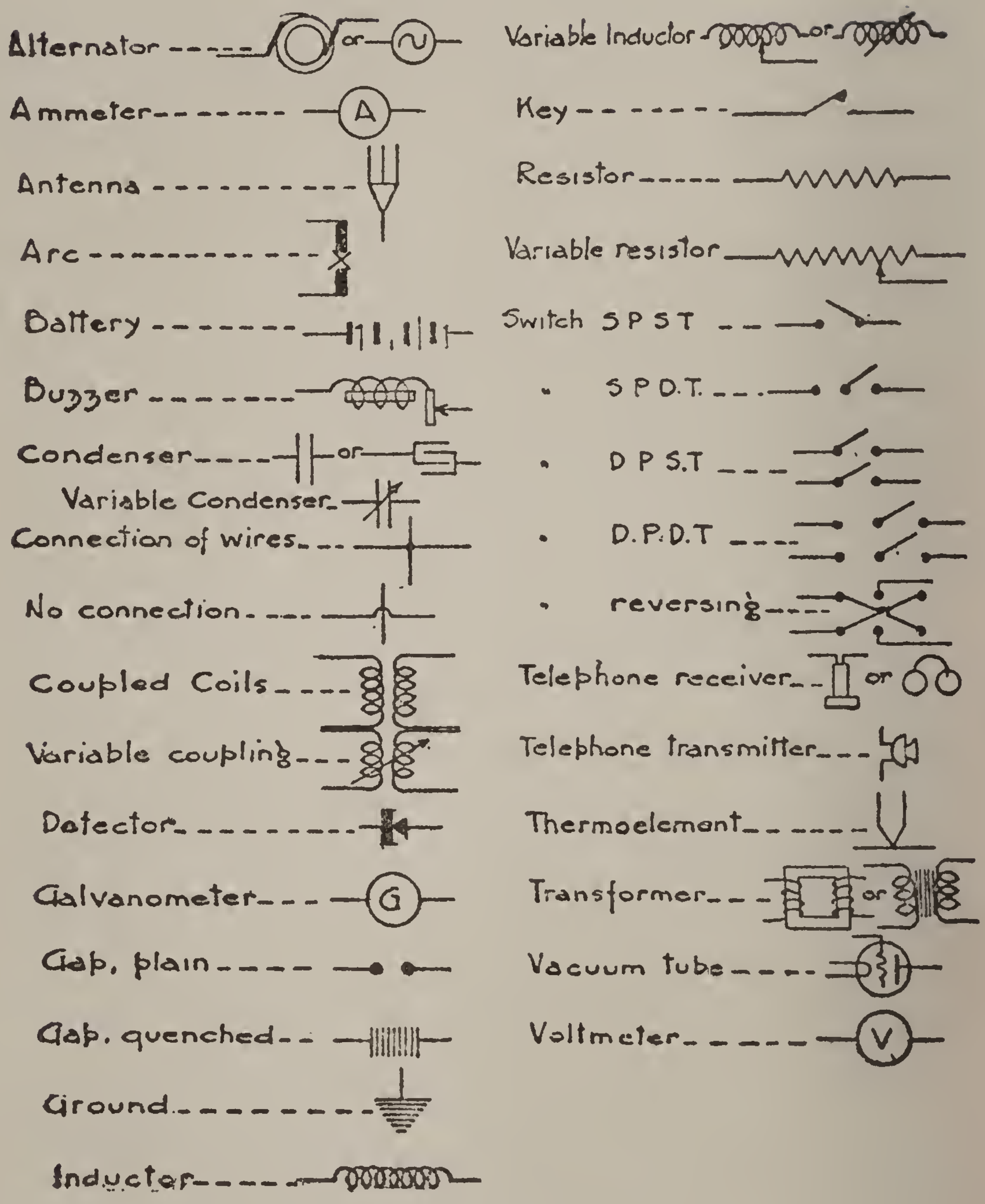
Fleming, casting about for an improved detector, studied this effect and discovered that this flow of electrons was always in the same direction and of a negative nature, flowing from the heated filament to the cold plate. This flow could be controlled by inserting a rheostat in the filament circuit and increasing or decreasing the filament current. These valves when properly constructed made excellent detectors for "spark" radio signals.

After Fleming's valve came the discovery by Dr. Lee Deforrest, of the "three element" vacuum tube, which he called an "audion." Deforrest inserted what he termed a "grid" between the filament and plate. This was possibly the most important discovery yet made in the new science of radio, and during the years of the World War, was to revolutionize the art. With the coming of the audion, methods of amplifying or increasing the intensity of radio signals were devised.

One method of amplification, discovered by Armstrong, then a Columbia University student, was the "feed-back" or "regenerative" circuit, which is now almost universally used in radio practice.

A full description of vacuum tubes and associated circuits is not intended here, but will be found under that caption in the practical course which follows.

STANDARD GRAPHICAL SYMBOLS



CHAPTER II

ELEMENTARY ELECTRICITY

There is a wonderful phenomena, the exact nature of which we know nothing definite, yet we are able to govern, actually measure and otherwise control its action. This peculiar phenomena is called "electricity." In its action we often compare it with water, as it has analogous characteristics, which are frequently used for comparative purposes in teaching the elementary principles of radio or electricity.

It should, however, be carefully borne in mind whenever electricity and water are likened to each other that expressions of "flow" and "current" and other similar terms are merely analogous. They are methods that originated in the early days of electricity, when electricity was considered some form of invisible fluid which actually flowed. These terms and expressions are utilized to-day in explanatory prefaces only as they are useful in forming mental photographs of the theoretical action of electricity in motion.

Electrical phenomena may be placed in two general classes, one of which is termed "static" electricity, when the electrical charges are at rest, and the other is "dynamic" or "current" electricity, when the charges are in motion along a conductor.

When an insulator, such as sealing wax, is rubbed with fur, or a glass tube with silk, it acquires the property of attracting light bodies near it, and is said to be "charged." This action shows that forces exist in adjacent space, and there is said to be an "electrostatic," or, to use another term, a "static field of force," about the charged body. When two charged bodies are brought near together they may either be attracted or repelled, depending on the nature of the two charges. If the rubbed glass is brought near particles touched and

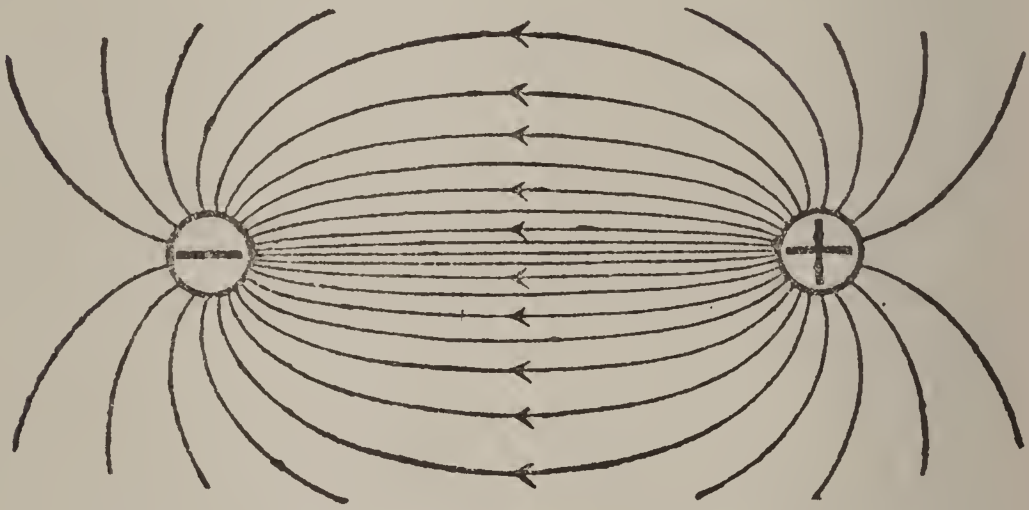


Fig. 1. Unlike bodies attract each other.

charged by the rubbed sealing wax, they will be attracted to it, and similarly, if the rubbed wax is brought near particles charged by the glass, they will be attracted (Fig. 1); but two bodies both of which have been charged by either the glass or the wax, will repel each other. Hence, like charges repel each other and unlike charges attract each other (Fig. 2). The names "positive" and "negative" have been given respectively to these charges.

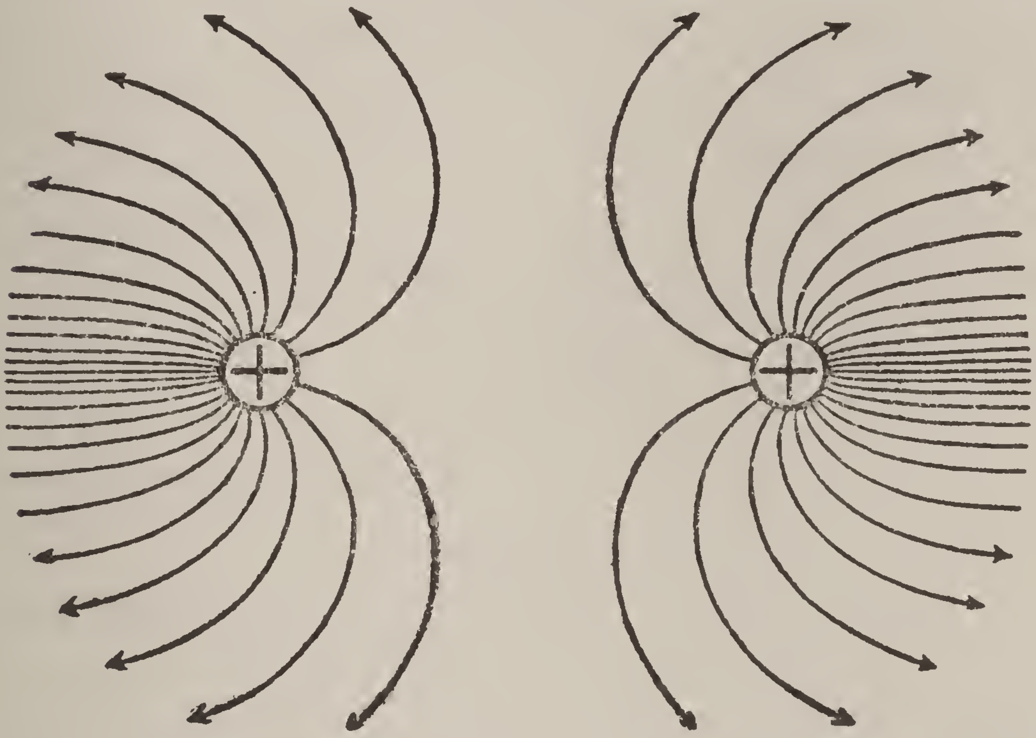


FIG. 2. Like bodies repel each other.

It is common knowledge that a battery or dynamo supplies what is known as a current of electricity. To obtain the current there must be a complete closed or conducting path from the battery or dynamo through the apparatus it is desired to be actuated by the current, and back again to the battery or dynamo. For example, when connecting up an electric bell, a wire is carried from one binding post or terminal of the battery, to one of the bell, and a second wire is brought from the other binding post of the bell back to the remaining terminal of the battery. Any break in the wire immediately causes the current to stop and the bell would cease ringing. This example furnishes an illustration of the easy control of an electric circuit, since it is only necessary to break the circuit at one point to stop the flow of current, or to connect across the gap a piece of metal to start the current going again.

Similar considerations apply when we are using the common house lighting facilities. Wires are brought direct or indirectly, but always in a circuit, from the electric light plant or station to the lamp, a small gap in the socket is provided. When the current is on and the circuit complete this gap is bridged by a metal connection, this is usually controlled by a snap spring. When the light is no longer required, you snap the switch and the metal connection is opened, the gap is formed in the circuit and the current ceases (Fig. 3).

Sometimes the lamps suddenly go out, and it is explained that a fuse has been blown. A short piece of easily fused metal through which current has been passed has suddenly melted. This has caused a gap in the circuit and the current ceases to flow and your lights are extinguished. Electricity must therefore flow in very part of the circuit served, so that it is leaving one side of the battery or dynamo and returning to it at the other side. The current flowing in a circuit is no stronger at one point of the circuit than at another. This is proved by connecting a measuring instrument called an ‘‘ammeter’’ into the circuit. Place the ammeter at different points and it will register the same at whatever point the test is made. A useful

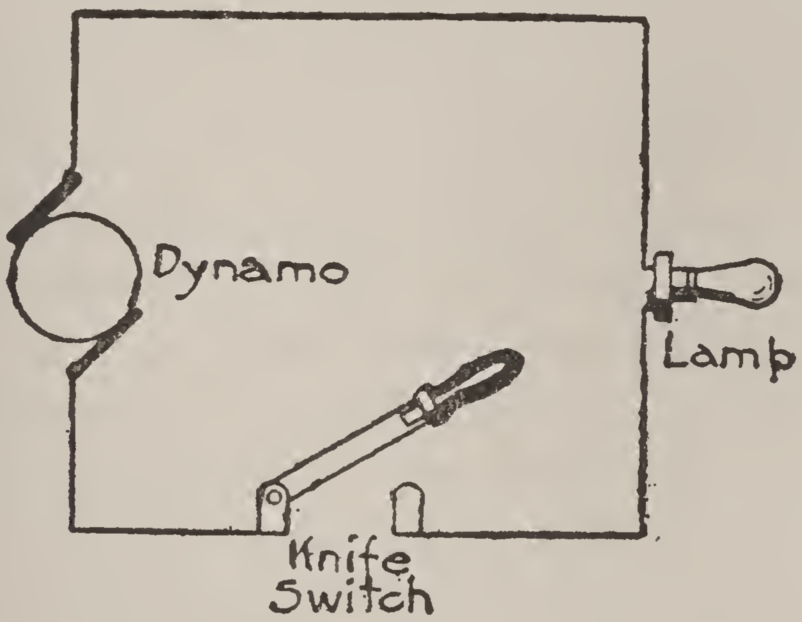


FIG. 3. Simple electrical circuit.

illustration of the electric current is a closed pipe completely filled with water, provided with a pump or some other device for causing a circulation of the water. The amount of water which leaves a given point in each second is just the same as the amount which arrives in the same length of time.

In the electric circuit we have no material fluid, but we suppose that there exists a substance, which we call electricity. This electricity behaves in the above described circuit in very much the same manner as an incompressible fluid in a pipe line. We are very sure that electricity is not like any material substance that we know, we will, therefore, have to imagine current to be a stream of electricity flowing around the circuit.

One way of measuring the rapidity with which water is flowing, is to let it pass through a meter which registers the total number of gallons which pass through. By dividing the quantity by the time it has taken to pass, we may obtain the rapidity of the flow. There are instruments by which it is possible to measure the total quantity of electricity which passes in the circuit during a certain time. If we divide this quantity by the time, we obtain the amount of electricity which has passed in one second. This is a measure of the current strength.

In practice, however, the strength of the current is measured by instruments known as ammeters, which show at any moment how strong the current is. It also enables us to tell at a glance what changes may take place in the current flow from moment to moment. We may, also, by means of an ampere-hour meter, ascertain the amount of energy that has passed over the circuit. These two recording instruments, the ammeter and the ampere-hour meter, therefore, would correspond to the speedometer on an automobile which points out, on one dial, the number of miles the car is speeding at the moment, and on another dial the number of miles the car has traveled.

Electromotive Force.—Water will not flow in a pipe line unless there is some force pushing it along, as, for example, a pump, and it cannot be kept flowing without continuing the pressure. Electricity, also, will not flow in a circuit unless there is pressure brought to bear. In the case of an electrical circuit a battery or dynamo provides this source of pressure, which is called "electromotive force," or, in other words, a force which puts electricity in motion. In common practice this is always abbreviated to emf. The larger the number of cells in the battery, the greater will be the electric pressure and the larger the current which may flow in the circuit. The size of the battery or the dynamo would correspond to the size of a tank or reservoir of water, and the amount of current which may be allowed to flow in the electric circuit would represent a pipe in which the water from the tank flowed. The amount of water in the tank would be expressed in "gallons." In the case of electricity the amount of pressure would be expressed in "volts" (see definitions), and the amount of current would be shown in "amperes" (See definitions).

Resistance and Conductance.—There is always some resistance or impediment to a flow or current of electricity, just as there is always resistance of some kind which hinders a flow of water. In the case of water, some partially closed valve or faucet would check the flow, also there is always a roughness in the pipe line which causes friction. Similarly in an electric circuit there are certain hindrances which are termed by the name "resistance." The greater the resistance the smaller the amount of current which will pass through the circuit (Fig. 4).

Resistance is determined by the kinds of materials of which the circuit is made up, just as the passage of a stream of water is determined by the character of the path over which it passes, or the pipe through which it flows. Just as the amount of water in a pipe line may be limited by the size of a pipe, so may the amount of electricity in a certain circuit be limited by the size and material of the wire conducting it.

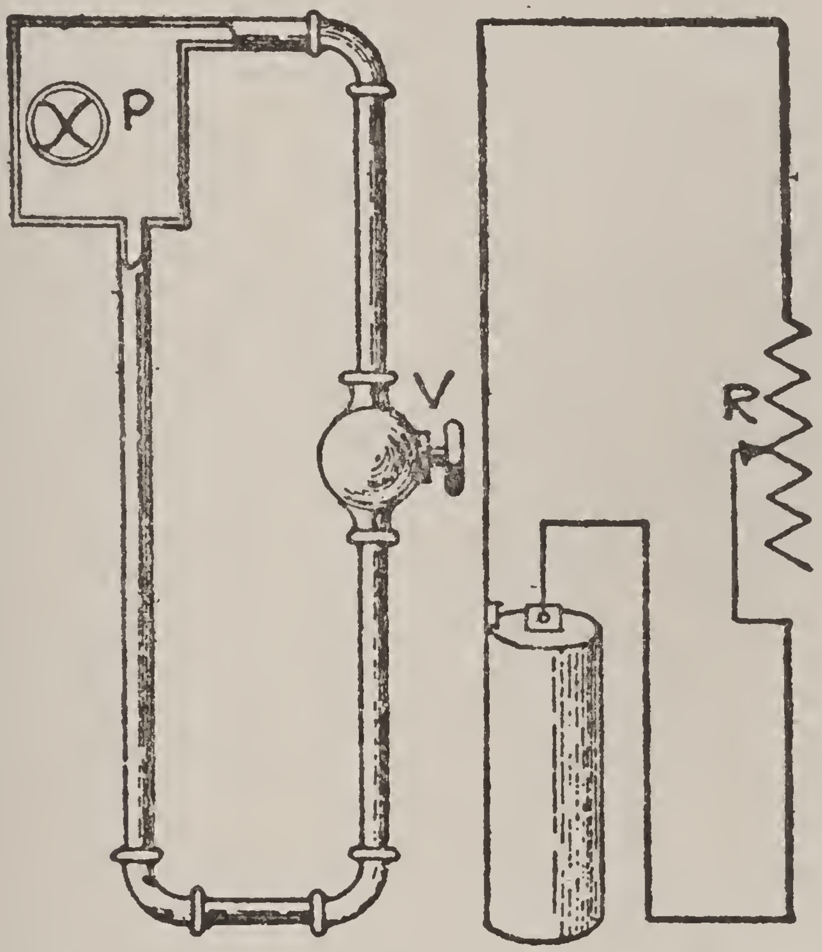


FIG. 4. Illustration of resistance by partially closed valve. P, pump. V, valve. R, resistance in electrical circuit.

In governing the flow of water we use valves or faucets to check the flow of water. In handling electricity we use "resistance coils" to govern the flow of current in any given circuit. There is a well defined law which is used in this relation, which is called Ohm's law, being named after its discoverer, Professor Ohm, and in speaking of a given amount of resistance in any given circuit, we always describe the circuit as having so many ohms resistance, an "ohm" being the unit of resistance.

Certain metals or materials offer more or less resistance to a flow of electricity than others. These are well known and divided into well defined groups. A material through which a current will pass readily and with least resistance is called a "conductor," or described as good conducting material, while those possessing qualities which will oppose great resistance and almost prevent any current of electricity to pass are called "insulators" or good insulating material. We also allude to the latter as non-conductors. Among conductors it is well known what amount of resistance a piece of wire of a given metal will offer. It is from this knowledge that we utilize copper for the purpose of conducting electricity without great resistance, and why we generally use "German silver" to manufacture certain resistance coils when we wish to offer resistance in the passage of a current.

It is also known that materials such as glass, porcelain and rubber possess excellent insulating qualities and are therefore used very largely as insulators. However, there is no material that will permit the passage of no electricity whatever, and for that reason we have what is called "leakage current" and "line losses."

While it is a question of material in determining the factor of resistance in a conducting circuit, it is also the size of the conductor which must be considered. In the case of a given piece of wire of a uniform cross section, its resistance is always found to be proportional directly to its length and inversely to its cross sectional area.

Electrical resistance in all substances is found to depend upon temperature and is found to alter more or less with any change of temperature. All metals and mostly all alloys used in electrical engineering increase their resistance with a rising temperature, while carbons and liquid conductors like electrolyte used in batteries, show a decrease in resistance as the temperature rises.

Electrical Control.—Having discussed the question of resistance, we should now pass to the subject of current control. In radio the need is constantly arising for controlling electrical pressure and current to certain required values. This is generally accomplished by varying the resistance in the circuit by means of resistors. Resistors are made in a variety of ways and known by several names, depending upon their current carrying capacity and their range. Some are called "resistance boxes," others, "rheostats," and are generally manufactured in a form which permits of easy variation and are compact for convenience. However, banks of incandescent lamps are very often used as resistance units and are, indeed, most satisfactory in experimental work where fine adjustment is needed. The change in resistance in such a rheostat is made by switching individual lamps on or off as desired.

Conductors.—Conductors of electricity used in leading a current from one point to another are, as pointed out earlier, usually made of metals or metallic alloys. If the conductor is transmitting energy to a distant point, some of that energy will be wasted in heat. These losses should be kept as small as possible and therefore great care is taken in choosing the material and the size of the wire. For economic reasons it is desirable that the cross section be not too great, and a desirable material must be selected that will accomplish two purposes, economy and efficiency. After much experiment, copper is found to be such a material.

Where light weight is important and increased dimensions not undesirable, aluminum is sometimes used. Steel or iron are seldom used in radio work as a conductor. For conductors in antennæ, where strength and atmospheric conditions must be considered, phospher-bronze and silicon-bronze are almost exclusively used. Copper, however, is the best metal conductor, where all considerations must be averaged.

Now, on the other hand, where resistors or resistance coils are essential, the opposite of good conductivity is desired and a material of great resistivity is demanded. A metal is required high and constant in resistivity, yet not bulky. Iron is neither high enough in resistivity nor constant in action. German silver or manganese are generally acceptable as resistors and found to cause less variations in temperature, in fact, their temperature coefficient in the circuit is practically negligible.

Insulators — Non-Conductors. — We have dwelt upon the subject of good conductivity and must next show the importance of good insulation in the scheme of radio.

In order that the electric energy may be confined to the definite and limited path that we desire in radio, it is most essential that the insulation we use be of the best material. Insulators are also known as dielectrics, and the latter expression will often be used later when we deal with the subject of condensers.

We are all familiar with the fact that electric wires are covered with materials composed of layers of cotton, silk, rubber and compounds of various kinds, known to be non-conducting, and that they are generally supported on or strung along glass, hard rubber, porcelain or compound knobs. An excellent compound insulator is one, now standard in the Navy, called "electrose."

Most insulators employed in radio show a decrease in their power of resistance with changes of temperature and atmospheric conditions. Humidity and fog lower their insulating standards, and in the event that such substances as slate, marble, bakelite, hard fiber and similar materials are used as panel boards, unless they are carefully protected from atmospheric conditions will "sweat" and cause a surface leakage.

Sources of Electricity.—In preceding pages we have alluded to electro-motive force, or emf., and having discussed how electrical energy can be conducted along definite lines or paths, we will go into the question of its source.

There are several methods in which electrical energy may be derived from other sources of power. Each one of these power or energy transformations sets up a condition which causes current or emf. to flow, in short, produces electromotive force.

The two most common and practical methods will be discussed in the following pages. These are "static" or "frictional" electricity and "batteries" or electricity produced by "chemical action."

In earlier paragraphs we described how a piece of sealing wax when rubbed with a piece of fur, acquired new properties and could be said to be "electrified." A force would be required to separate the wax and fur and therefore work is done if they are to be moved apart. After rubbing the wax and fur both bodies would now have the power of attracting light substances, such as pieces of tissue paper or light particles of wheat chaff. The wax is said to have a negative charge, and the fur a positive charge of electricity.

These charges exist in equal amounts and taken together neutralize each other. A body that is uncharged is said to be neutral. When these charges are at rest on conducting bodies they are called electrostatic charges.

Electrostatic charges, as a rule are very small.

There are, in radio practice, two methods of deriving the primary source of power. These are from batteries and from "induced" electromotive force. We shall deal with each in its turn.

Batteries.—In general practice, there are two types of batteries used in radio work, one called a "primary" and the other a "secondary" or "storage battery."

With a primary cell new energy can be obtained by putting in new chemicals or parts, in the secondary cell, energy is renewed by sending a current of electricity derived from a mechanical or some other source, through the chemicals already in the cell, and by charging and recharging can be used over and over again. We shall first describe the primary battery.

Wet or Gravity Cell.—If two metal plates, one of pure zinc and one of pure copper, not in contact with each other, are immersed in dilute sulphuric acid, no chemical action will take place. However, when the plates are connected by a wire or some other conductor outside of the liquid, a current will flow in the conductor, as a chemical action takes place in the cell. The sulphuric acid acting on the zinc plate forms zinc sulphate, and the hydrogen liberated from the acid appears at the copper plate. The direction of this flow of current is always from the copper plate, through the conductor or metallic circuit to the zinc plate and back through the diluted acid to the copper plate. The copper plate is termed the "positive" pole and the zinc plate the "negative" pole, and the direction of flow is arbitrarily said to be from positive to negative. For purposes of simplicity in marking terminals or preparing diagrams, the plus (+) sign is always given to the positive and the negative sign (—) to the negative plates (Fig. 5).

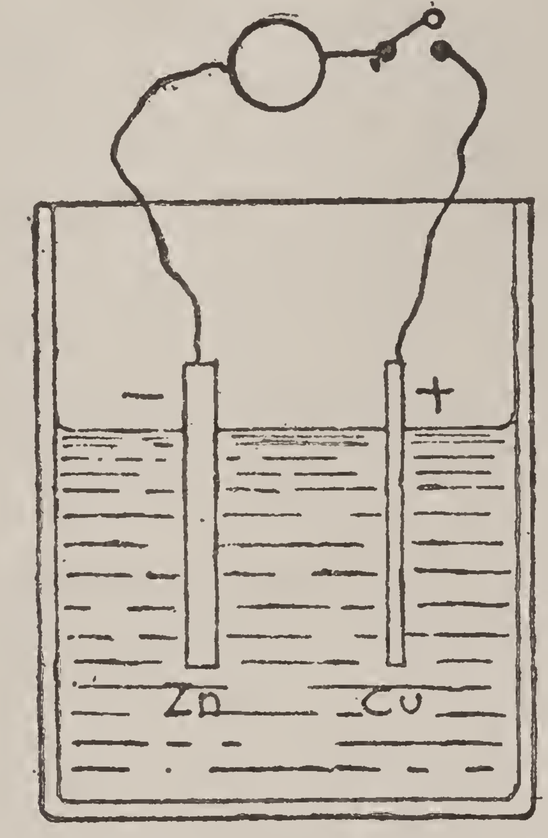


Fig. 5. Simple wet or gravity cell.

The current given by the simple cell described does not remain constant, as it begins to weaken after the connection between the plates is made, or, in other words, the circuit closed. This diminishing current is caused by the hydrogen, liberated from the acid, accumulating in small bubbles on the copper plate. This accumulation of hydrogen bubbles diminishes the area of contact of the liquid on the faces of the copper plate, thus increasing the resistance of the cell. This action is called "polarization." To overcome this, what is known as a "depolarizer" is utilized, in the form of a chemical substance added to the acid, or electrolyte, as the sulphuric solution is also called. The action of the depolarizer is confined to the positive plate and is kept from contact with the negative plate.

There are two principal types of primary cells, the "wet" and "dry" cells. The wet or "gravity" cell, above described, is used largely by telegraph and telephone companies, due to economy and also as it is mainly free from polarization. If a large output is desired, the internal resistance must be low, that is, with a minimum of polarization. In these cells the depolarizer is generally placed in the bottom of the cell and is kept free from the electrolyte by gravity, hence the name. The copper electrode is placed in this solution which consists of copper sulphate. The zinc negative plate is kept separate in the sulphuric electrolyte above.

The voltage given by the average cell is between one and two volts per cell. The voltage of a cell depends upon the substances used for plates or electrodes, and is also effected by the electrolytic solution. Therefore, many varieties of electrolytes are used when the electrodes are copper and zinc, but all give approximately one volt per cell.

When a certain electromotive force is required and no regular source of supply available, it is useful to know that an emergency source of voltage may be obtained by taking two different kinds of metal and placing them in any kind of acid, or even in water. It must be remembered, however, that the solution attacking the plates most violently will produce the best results, bearing in mind the above remarks regarding polarization.

Dry Cells.—The dry or sal ammoniac cell is used largely in radio, not for its superior qualities as compared with the gravity cell, but because of its convenient, compact form. The solution of sal ammoniac used in it is contained in an absorbent material and the cell is thoroughly sealed against spilling or leakage. The outer shell is made of zinc, forming one electrode. The positive electrode is a carbon rod in the center, this is surrounded by a mixture of carbon and manganese dioxide. The latter mixture is saturated with a sal ammoniac solution and takes up most of the interior of the container. This sal ammoniac electrolyte is partly in a depolarizing mixture and partly in a porous separator placed between the zinc and depolarizing mixture.

These dry cells are not as free from polarizing effects as the previously described wet or gravity cells. They are made in several sizes. For heavy or ignition purposes they will deliver a current of thirty amperes when short-circuited, provided they are new or little used. They lose their energy-producing powers very quickly when used constantly, but in intermittent service have a fairly useful term of life, sometimes six months.

Dry batteries for telephones and bells are generally made smaller, delivering about twenty amperes upon short-circuiting, but lasting longer than ignition cells, sometimes they are useful for over a year.

Miniature dry cells for vacuum tube work and for flashlights, are made in varying sizes, but lose their effectiveness quickly, of course, depending upon the period the vacuum tube or flashlight is used.

The emf. developed in an unused dry cell is from 1.5 to 1.65 volts. In purchasing new cells the reader should know that any new dry cell having a less emf. than 1.4 volts indicates a defect or deterioration through long "shelf life."

The amount of energy delivered from the dry cell increases with increasing temperatures, but the higher the temperature, the faster does the cell deteriorate when not in use. It is therefore best to keep them in a temperature below 25 degrees centigrade.

Owing to various causes, due to compactness in manufacturing and its comparatively rapid polarization, dry cells are not useful for delivering a steady current for a long time in service and should only be used in radio when an intermittent current or a very small current is required, such as plate battery service or buzzer ringing. When heavier duty is required, it is much more preferable and economical to utilize "storage" or secondary batteries, described below.

Storage or Secondary Batteries.—The difference between the gravity primary cell, previously referred to, and the secondary or storage cell, is in the method of renewing the active material. While the primary cell is renewed by supplying new electrolyte and replacing the worn out zinc electrode with a new one, dry cells cannot be renewed. In the storage battery, however, the necessary chemical conditions of the plates is restored by the action of a current of electricity from some outer source, usually from a dynamo.

While the cell is supplying emf., it is said to be "discharging" and when receiving a renewal of energy it is said to be "charging." The direction of the current when charging is always opposite to the current when discharging.

Storage batteries in general have low internal resistances when in good order and will therefore deliver relatively large currents, this is a great advantage. Care must, however, be taken to prevent accidental short-circuiting, as this would cause an excessive current and rapid deterioration, or even ruination, of the battery.

Voltage changes during the period of discharge are small and thus fairly-constant current can be maintained.

There are two types of storage batteries in general use, the "lead" cell and the "Edison" or "alkaline" cell.

The Lead Plate Cell.—In the cell type of battery, the plates are made of lead, in the form of a grid. Each plate contains many tiny cells, like honeycomb, and often called by the name "grid."

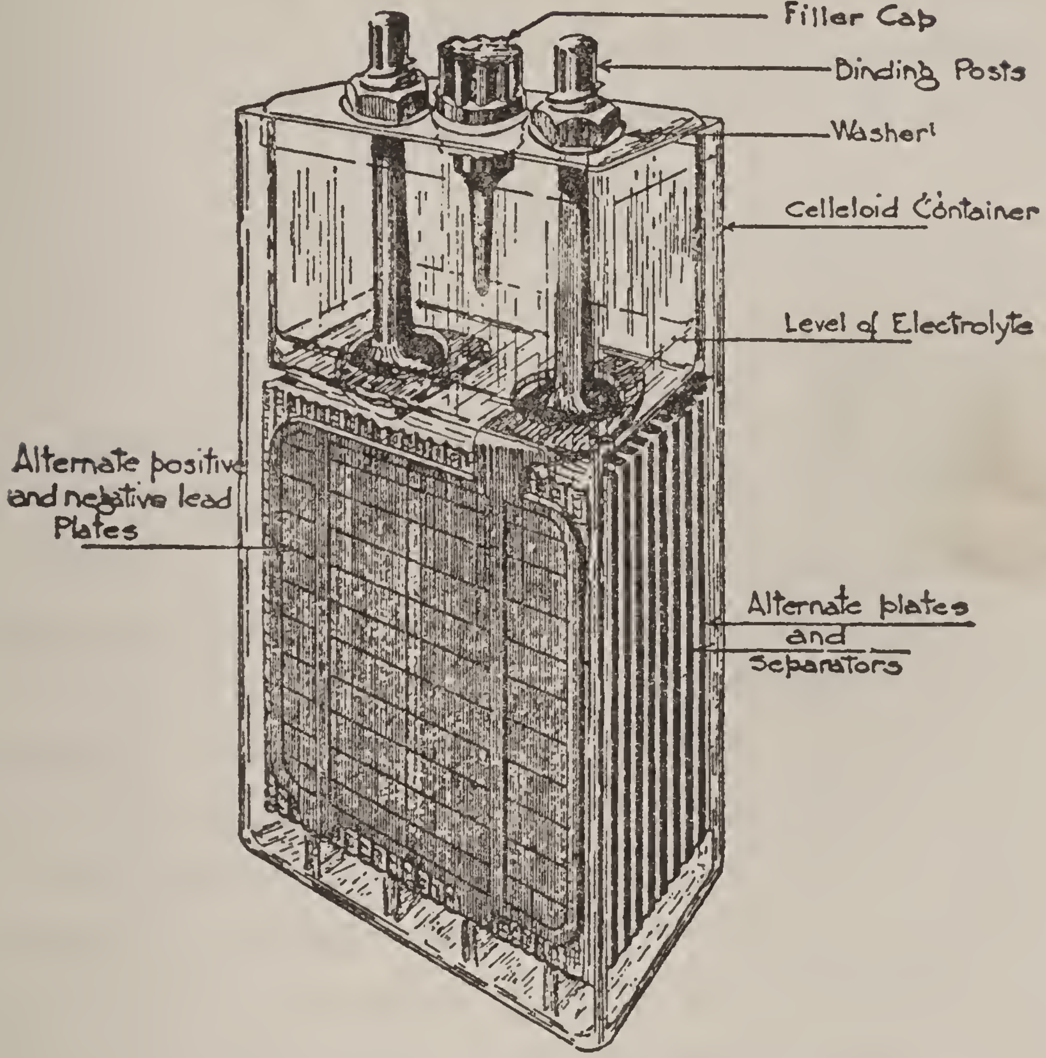


FIG. 6. Lead cell storage battery.

Into these noneycombed cells is heavily pressed, or forced, a mixture of red lead, litharge and sulphuric acid. When two plates thus prepared are immersed in an electrolyte consisting of a twenty per cent sulphuric acid solution, and an electric current passes between them, hydrogen will accumulate on the plate from which the current leaves the cell, thus in one plate the active material is reduced to a spongy lead, and in the other the same material is being changed to lead peroxide, as it takes up oxygen. The cell now contains a lead peroxide plate, called positive (+) and a spongy lead plate, called negative (—) (Fig. 6).

After the charge is cut off, assuming it is fully charged, if the cell is connected in a circuit, current will flow in an opposite direction to that by which it was charged. The cell upon completion of the full charge, should show a voltage, on open circuit, of approximately 2.2 volts, this, however, will quickly drop to about 2 volts. As the battery is discharged the voltage will gradually fall. The discharge should never be carried below 1.75 volts.

The container of a lead cell must be of a material sulphuric acid will not attack and is usually of either glass or hard rubber. The former for large stationary batteries and the latter for the portable types.

The negative plates appear gray and the positive reddish in color.

There are innumerable types and each manufacturer carefully enumerates on the name plate the specific rate, in amperes, of charge and discharge. This is necessary as he is the only one who knows the size, weight and number of plates in the cell, upon which the discharge and charging rate is based, and the life and general efficiency of the battery is greatly decreased if this normal rate is not adhered to.

There is a chemical action between the lead and the electrolyte, which forms lead sulphate during the course of a discharge. This uses up the acid and the density of the electrolyte grows less, this results in the formation of lead sulphate, whitish gray in appearance (when dry) which is dissolved in the solution.

For testing the density of battery electrolytes, an instrument called a ''hydrometer'' is the best instrument to use, as the density of the solution is the best indication of its condition. In other words, the density of electrolyte rises and falls with the charging and discharging of the cell, and a test of the density or specific gravity of the solution readily indicates its condition.

Great care is required in the handling of storage batteries to prevent ''sulphating.''

If a cell is repeatedly charged and discharged at its normal rate, as indicated by the manufacturer's name plate, the amount of lead sulphate formed will be small and not harmful. However, if the battery is misused, for instance, charged and discharged at an excessive rate, or perhaps allowed to be idle when in a rundown condition, there will form an excessive deposit of lead sulphate. As the crystals of sulphate increase they crowd out the active materials, stresses are formed and the plates disintegrate or buckle. This renders the cell into such a condition that it is almost impossible to repair, and certainly the battery will never be normal again.

Storage batteries of all types, both lead and alkaline, are graded when manufactured and rated according to the ampere-hour capacity. This capacity is generally expressed by the maker on the same name plate as the rate of charge or discharge. The larger the plate the greater may be the current used from it. For example, a forty ampere hour battery should yield one ampere for forty hours, or, to put it in another way, ten amperes for four hours. If, however, five amperes is the rate mentioned on the normal discharge and charge rate of the cell, it should only be discharged at that rate and also recharged at that rate, which would give the normal usefulness as five amperes for eight hours.

Batteries are seldom used as they were intended and it is thus that so many experimenters have considerable trouble and do not enjoy the full life of the cell.

Edison Cells.—This is a type of storage battery developed by the famous Thomas Edison, as the name indicates, and also known as the "Nickel-Iron and Alkaline Cell" (Fig. 7).

In construction, the positive plate consists of alternate layers of nickel hydrate and pure nickel flake, packed in perforated nickel-plated steel tubes. Several are arranged in a steel frame. The negative plate is of iron oxide packed similarly. These plates are immersed in a twenty

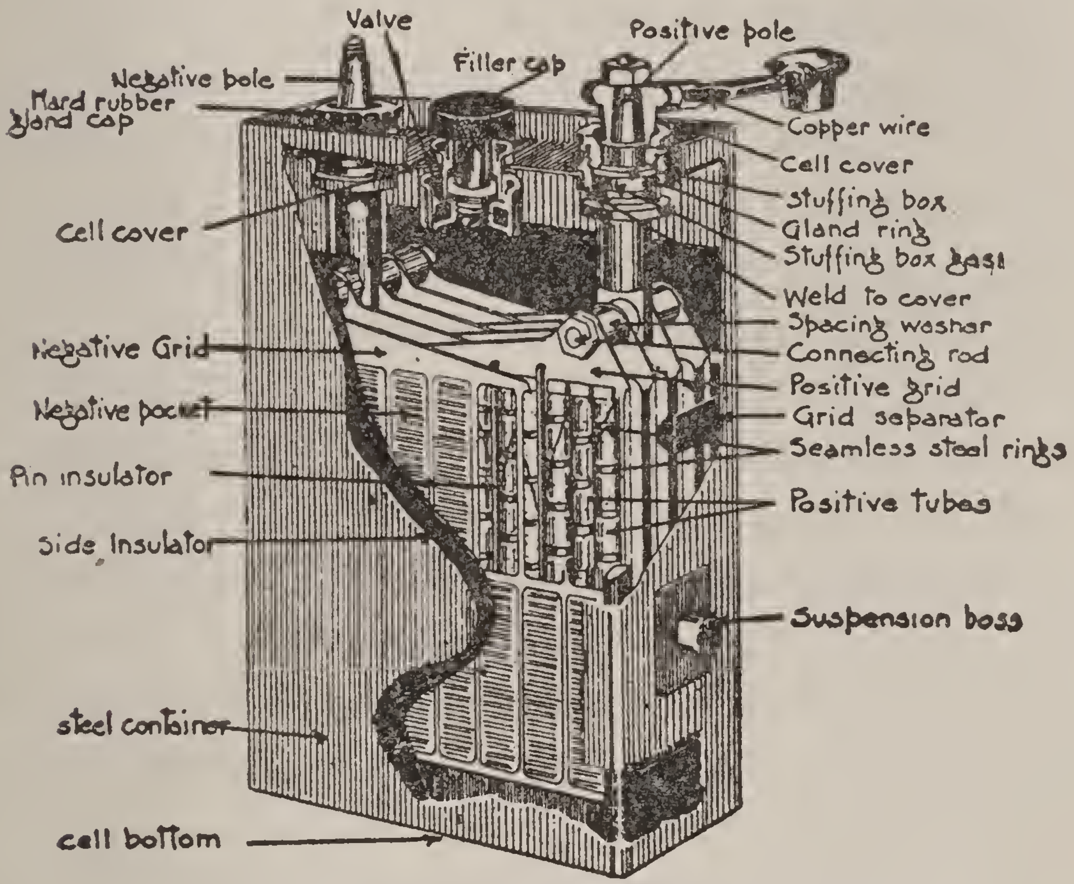


FIG. 7. Edison cell storage battery.

per cent solution of caustic potash and water, and the whole is contained in a tightly sealed sheet steel container. This electrolytic solution carries oxygen between the plates, but does not form chemical compounds with the active materials, remaining approximately constant in density during charge and discharge.

The voltage of an Edison cell while charging may rise to 1.8 volts. When discharging this will drop suddenly to about 1.4 volts and as the discharge continues will drop more gradually to 1.1 volts, near the end of the discharge. Discharge should not be allowed to go below 0.9 volt; when that rate is reached the cell should be recharged.

If it is found after much use that the density of the alkaline electrolyte has fallen as low as, about, 1.16, measured by the usual means of ascertaining specific gravity of liquids, the solution must be renewed. This should be done by pouring off the old and refilling with entirely new electrolyte.

The height of the electrolyte above the plates should always be kept at about half an inch. This applies to both lead and Edison cells. As there is always more or less evaporation of the solutions, this may be accomplished by adding distilled or chemically pure water to bring the height half an inch above the plates.

Comparisons of Storage Batteries.—The construction of previously mentioned types of secondary batteries is so radically different, that a brief comparison of the two is not out of place.

The lead cell will suffer serious injury if not well cared for and if not charged and discharged according to the use for which it is rated. Further, it will deteriorate rapidly if allowed to remain idle without care.

An Edison battery, on the other hand, by nature of its sturdier construction and the materials utilized, may be said to be as near "fool-proof" as anything thus far placed upon the market. It will retain its charge over a long period of idleness. It may remain idle for an indefinite time, either charged or discharged, without injury. It may be completely short-circuited and totally discharged without harm, whereas this would ruin a lead cell. An Edison cell can be charged or discharged at rates differing from its normal rate, while it has been previously shown that the lead cell must be handled at near its normal rate.

Charging Storage Batteries.—While the general method of charging both lead and Edison cells is similar, there are features which are

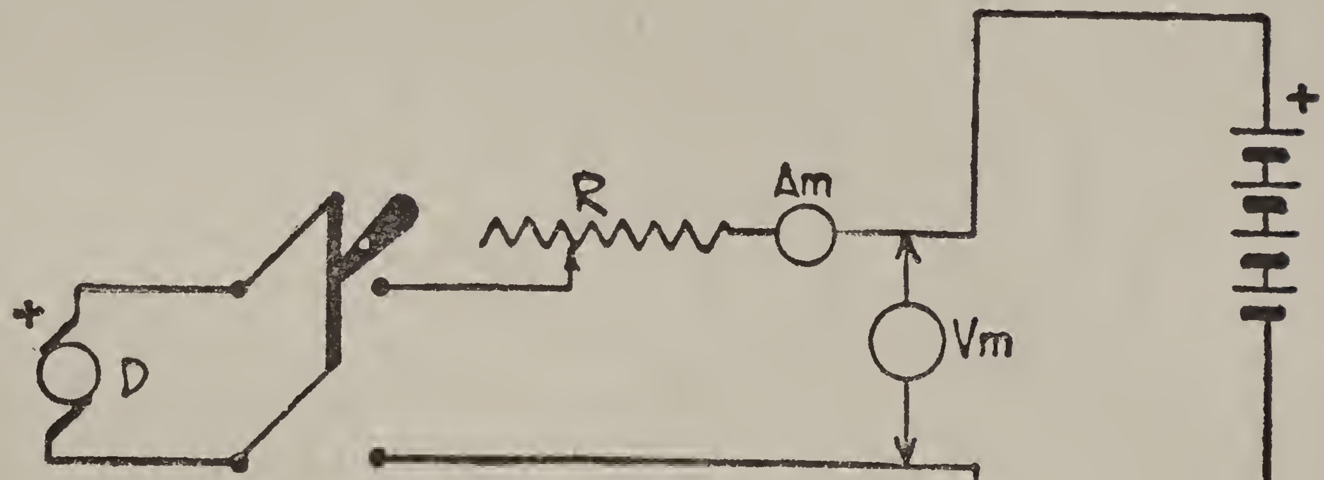


FIG. 8. Storage battery charging circuit.

not alike that would require some differentiation in the description of these charging methods.

Lead Cells.—Previously we have mentioned that there are certain charge and discharge rates prescribed for certain types and sizes of lead cell batteries.

While a battery is receiving a current from some outside source it is said to be "charging."

In Figure No. 8 is given a diagram of a circuit, which is typical for charging batteries. The dynamo, or supply of direct current, is marked D, and is connected through the ammeter and rheostat, marked R, to the battery, so that the positive pole of the supply source or dynamo, is connected to the positive pole of the battery; this will send the charging current against the electromotive force of the battery. To thus connect the positive pole of the dynamo to the positive pole of the battery, is most important, as a reversal of this would cause the storage battery to discharge instead of charge and cause great injury to the cells.

Before charging, an inspection of the electrolyte should be made and if found less than one-half inch above the top, chemically pure or distilled water should be added until that amount of electrolyte shows over the top of the plate. Do not spill the water over the top of the cover of the cell, or a short circuit will result through the water from the positive to the negative poles and a leakage occur, resulting in a total discharge of the cell, if the leakage is allowed to continue.

If suitable measuring instruments, such as a voltmeter and ammeter, are not used, it may not always be known which is the positive and negative line in the source of supply. A very simple experiment may determine this question. Take a glass of water that contains a little salt or acid, place both supply leads in the liquid, being careful to keep them apart, say, by half or one inch. Bubbles will be observed to come from the negative terminal.

For lead cells, in charging, it is necessary to allow two and one-half volts for each cell. If a smaller voltage than that which is to be reached by the cell, you would discharge instead of charge the cell. If the source of supply voltage is not sufficient to charge all your cells in series, they may be divided into groups and these groups may be placed parallel to each other. If this arrangement is necessary, care must be exercised that the negative lead from one bank of cells in series, to the negative pole of the other bank, and from positive to positive terminals of each bank, then the leads from the two banks thus joined will be lead as described previously. From the positive pole to the positive terminal of the dynamo and negative to negative.

Hydrogen is given off from charging batteries, and great care must be taken to keep naked lights from the vicinity of the cells, or an explosion will result. Some very painful accidents have happened to numerous unwary people who have, for instance, lighted a match to peer into a charging battery, in order to ascertain its condition. This precaution applies to both lead and Edison cells.

Edison Battery Charging.—The same circuit utilized for charging lead cells may be employed for charging Edison cells.

The charging source should have a voltage equal to 1.85 times the number of cells in series.

Before starting to charge, open the covers of the compartment, if the battery is in one. See that the solution is at the proper level.

Do not allow the temperature of the solution to exceed 115 degrees Fahrenheit. Excessive temperature on charge will shorten the life of the battery.

As in lead cell charging, be sure to connect the positive side of the line to the positive pole of the battery, and the negative line to the negative pole.

The specific gravity of the solution will not change during the charge or discharge except in cases of extreme low or high temperature and therefore hydrometer readings are of no value in determining the state of charge or discharge of the battery.

The proper length of charge is determined by the extent of the previous discharge. If the battery is totally discharged, recharge it at the normal rate for the proper number of hours. If the battery was only one-half discharged, recharge at the normal rate for one-half the time, etc.

If the extent of the previous discharge is unknown, charge at the normal rate until the voltmeter reading has remained constant for thirty minutes at about 1.80 volts per cell, with normal current flowing.

If necessary, and full capacity is not required, a battery may be taken off charge at any time.

CHAPTER III

MAGNETISM AND ELECTRO-MAGNETISM

There is a form of iron found in the earth known as black oxide of iron, also called magnetite or magnetic iron ore. This particular iron ore has remarkable properties. For instance, if a piece of magnetite is dipped into iron or steel filings, the filings will adhere to it and is known as a "natural magnet." If a small piece of this substance is suspended by a very slender thread, such as silk, it will point in northerly and southerly direction.

If a small rod of iron is brought near a piece of magnetite, or is rubbed on it in a certain way, it will show the same properties as the piece of magnetite. If the rod be made of hard steel this effect will persist after the magnetite has been removed from its vicinity, and is known as a "permanent magnet."

We are almost all acquainted with the horseshoe shaped magnet, and probably have played with them when children.

Magnets are also made by winding a coil of wire around a rod of soft iron and passing an electric current through the coil (Fig. 9). As long as the electricity passes through the coil the

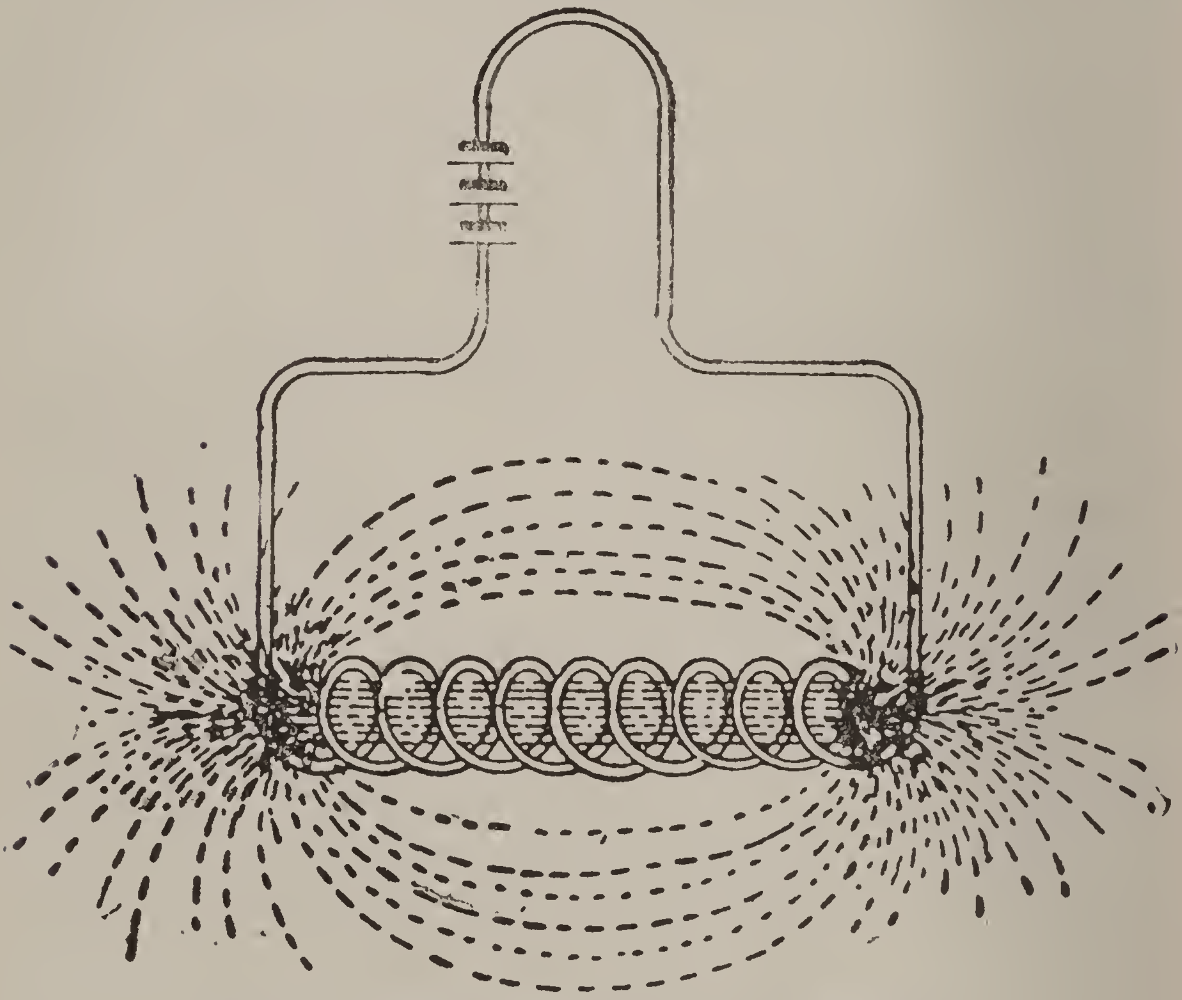


Fig. 9. Magnetic field of a solenoid.

iron is magnetized and is called an "electromagnet." These are the familiar examples we find in electric bells, buzzers and telegraph sounders, and if you screw the ear cap off a telephone receiver you will find an excellent simple electro-magnet. If the bar around which the coil is wound is made of certain hard steel, that bar would be permanently magnetized.

A small steel rod mounted pivocally will turn in almost a north and south direction and is the familiar compass needle used by mariners to determine the direction they are proceeding. The end pointing north is called the "North Pole" and that pointing south, the "South Pole."

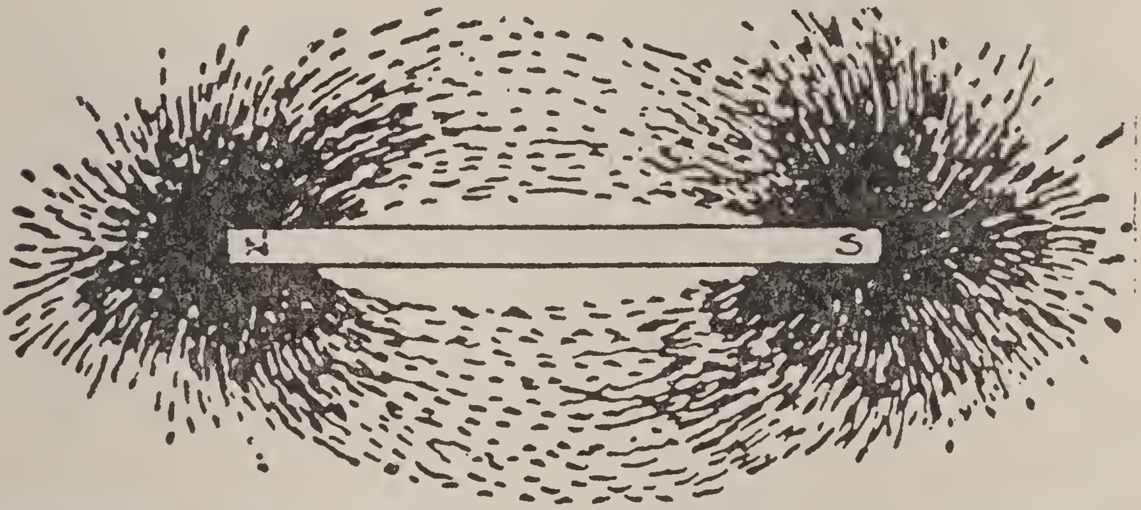


FIG. 10. Magnetic field of bar magnet as shown by iron filings.

Two magnetic poles are said to be alike when they both attract or both repel the same pole. If one pole attracts the other they are unlike, if a pole repels another, they are alike, therefore, as previously explained in the discussion of negative and positive connections of a battery, like magnetic poles repel each other and unlike poles attract each other. It is then very easy to determine which is the north or south pole of a magnet by placing a small compass near the magnet and observing which way the needle points.

Place a sheet of paper over a magnet and sprinkle iron filings upon it and you will find they will arrange themselves in two groups, one group over the north and the other over the south pole (Fig. 10). This indicates that there are forces in the space around the magnet that act on its poles. These forces are called "magnetic lines of force" and appear to center in the two poles of the magnet.

The space around the magnet in which these lines of forces may be detected is called the "magnetic field," and the direction of the magnetic field is the direction in which the compass needle will point, if a compass is used as above described. This needle will always point north.

Experiments with a compass, as shown above, determine that there is a magnetic field about a wire in which a current of electricity is flowing, and that this field is in the form of concentric circles about the wire. These circles lie in planes at right angles to the axis of the wire. If the wire is grasped by the right hand with the thumb pointing in the direction of the current, the fingers will show the direction of the magnetic field (Fig. 11). This field extends to an indefinite distance from the wire, but as it becomes more distant the effect becomes correspondingly feeble and there is greater difficulty in detecting its presence. If the current is cut off, the magnetic field likewise disappears. When a current is flowing in a wire, we must imagine the magnetic field as started and sweeping outward from the conductor, with the axis of the wire as its center.

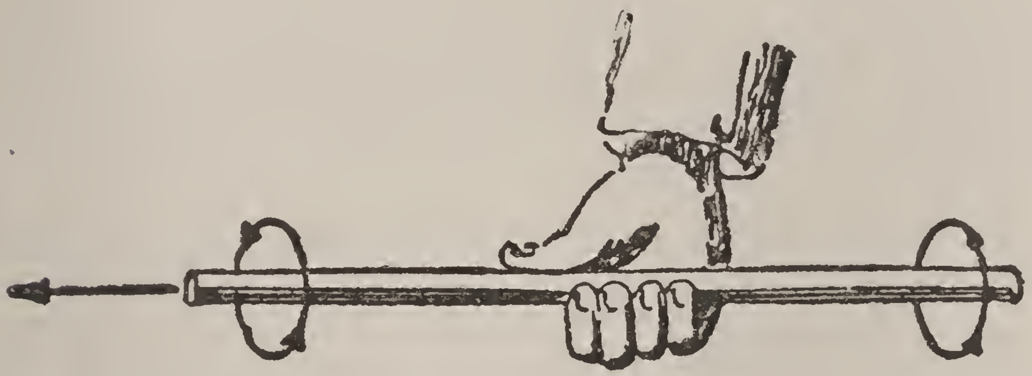


FIG. 11. Right hand rule for determining direction of current and magnetic lines of forces.

If the wire in which a current is flowing is bent into many circles or turns and these turns wound close together the intensity of the magnetic field is increased in direct proportion to the number of turns in the wire.

If the space within the coil is filled with iron, the magnetic lines or ''flux'' is greatly increased. This is due to a peculiar property of iron which is called magnetic ''permeability.'' This is to say that when the space is filled with iron instead of air alone that the magnetism is stronger.

It should be remembered that this magnetic induction in a coil depends upon the number of ampere turns in the coil and the permeability of the iron.

If the current in the windings is reversed the direction of the magnetic field is also reversed.

If two different magnetic fields are brought together in the same space, with their directions parallel, a force is always developed. If the lines of magnetic flux are in the same direction, the two fields mutually repel one another, and if the flux lines are in opposite directions the two fields will be drawn together. When a current flows in a wire which is at right angles to a magnetic field, a force will act on the wire.

When the wire which carries the current is at right angles to the direction of the magnetic field, the pushing force on the wire is equal to the product of the current, the intensity of the magnetic field, and the length of wire which lies in the magnetic field.

If the wire makes some other angle with the direction of the magnetic field, the direction of the force is still the same as for the right angle position, but the value of the force is smaller. In the single instance that the direction of the current coincides with the direction of the magnetic field, the force is zero.

This push on a single wire is in most cases small, but by arranging many wires in a very intense magnetic field, very large forces may be obtained. The powerful turning effect of an electric motor depends upon these principles.

There is always a magnetic field about an electric current. The lines of magnetic flux are closed curves and the electric circuit is also closed. The lines of magnetic flux are then thought of as always interlinked with the wire turns of the circuit. The number of flux lines through a coil will depend upon the current, and any change in the current will change the number of linkings. If there are two turns of wire the circuit will link twice with the same magnetic flux, and so, for any number of turns the number of linkings increases with the number of turns.

Induced Electromotive Force.—Whenever there is any change in the number of linkings between the magnetic flux lines and the wire turns, there is always an emf. induced in the circuit. If the circuit is closed a current will follow. This is called an induced current. As an example we can observe the effects produced by two solenoids fixed in the position

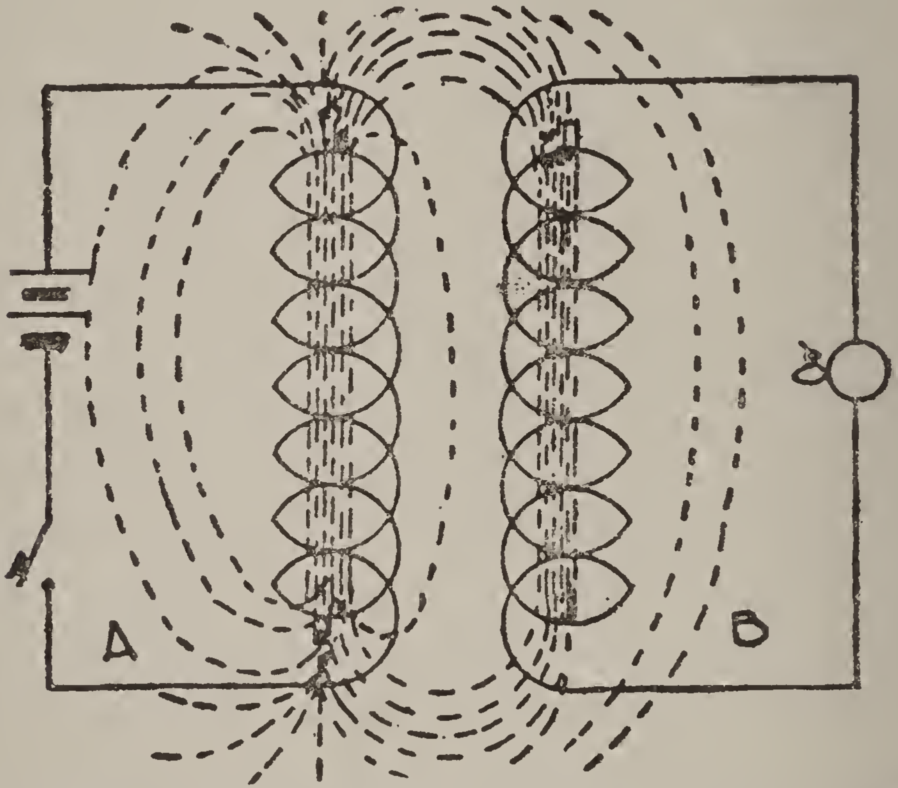


Fig. 12. Illustrating an induced current. Current started in A induces current in B.

shown in Fig. 12. If a current is started in one of them, A, there will be a current induced in the other, which will continue to flow as long as the current in A is increasing. If the current in A becomes steady, there is no current induced in B. If the current in A falls off, the induced current in B is reversed in direction. In all cases it must be remembered that the magnetic field about the induced current tends to oppose the change that is causing the induced current. The magnitude of the induced emf. depends upon the time rate of change of the number of linkings.

Inductance.—The value of inductance depends upon the shape and size and upon the permeability of the medium about the circuit. The inductance does not depend upon the current which is flowing, except when iron is present. By coiling up a piece of wire in many turns and introducing it into the circuit, the inductance of the circuit may be greatly increased. In that case the inductance is said to be concentrated. It must not be overlooked that the entire circuit has inductance. This may be distributed more or less uniformly throughout the circuit.

If a piece of wire is connected to one terminal of a dry cell, and tapped on the other terminal, a very slight spark may be seen in a darkened room. If a coil of many turns of wire is included in series, with this cell, the same process of tapping will show brilliant sparks, particularly if the coil has an iron core. The explanation of this lies in the fact that the cell voltage of 1.5 is too feeble to cause much of a spark. However when the large inductance is included in the current, there is a large number of linkings between wire turns and flux lines. If these flux lines collapse suddenly, as they do when the circuit is broken, there will be a large change in the number of linkings taking place in a very small interval of time. This principle is made use of in ignition apparatus and spark or induction coils.

In mechanics it is well known that a piece of matter cannot set itself in motion and that energy must be supplied from outside. So in the electric circuit, a current cannot set itself in motion, and energy must be supplied by some form of generator or source of electromotive force.

As an illustration of inductance we may use the following example. When a nail is forced into a piece of wood, the mere weight of the hammer as it rests on the head will produce but little effect. However, by raising the hammer and letting it acquire considerable speed, the kinetic energy stored is large and when the motion of dropping the hammer is stopped, this energy is expounded in forcing the nail into the wood. In the electric circuit a cell with its small emf. can only cause a feeble spark. By including a piece of wire of many turns in the circuit, however, a small current will enable a large amount of energy to be stored in the magnetic field, if the inductance is large. Then when the circuit is broken and the field collapses, this large amount of energy is released suddenly, and a hot spark of considerable length is the result.

Alternating Current. — An alternating current is one in which electricity flows around the circuit, first in one direction and then in the opposite direction, the maximum value of the current in one direction being equal to the maximum value in the other. All changes of current occur over and over again at perfectly regular intervals. A graphical representation of this is shown in Fig. 13, the potential commences at A, which represents zero potential, rising to its maximum voltage of, say, 110 volts, then falling to zero at B, the current then reverses itself and flows in the opposite polarity, again rising to 110 volts and drop-

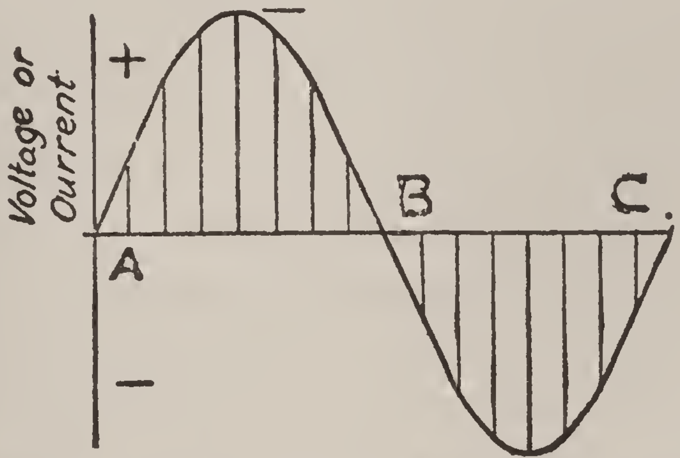


Fig. 13. Showing a cycle of alternating current.

ping to zero at C. From A to B represents an "alternation" and from A to C, a "cycle," thus each cycle consists of two alternations.

The frequency of alternating current is determined by the number of cycles per second. In ordinary commercial use, for lighting and power, 25 to 60 cycles per second is the usual frequency, mostly 60 cycle. In Europe they often use 50 cycle alternators. However, in radio practice higher frequencies are desirable and in modern spark transmitters 500 cycles is considered the standard. This gives the emitted signals a high musical tone, as the spark frequency from such an alternating current would be 1,000 per second, or one spark discharge for every alternation of the current. This matter of spark frequency is only mentioned in passing and will be fully discussed later under the caption of radio transmission.

Alternators.—Alternating current is produced by electrical machinery. Electrical machines are used for conversion of power from mechanical to electrical form, or *vice versa*. If driven by some sort of prime mover like a steam engine, gas engine or water wheel, they convert mechanical power into electrical power and are called "generators." If supplied with current and used to drive machinery, vehicles, or other devices, thus converting electrical power into mechanical power, they are called "motors."

While there are various types of motors and various types of generators, the difference is more in the use than in the appearance or construction. Electric machines may be built for either direct or alternating current. If a generator of alternating current, called an alternator, is driven by a motor, this machine is known as a motor generator.

In general, it is a motor generator that is employed in common radio practice, as a source of power.

CHAPTER IV

EXPLANATION OF RADIO

Radio signals are produced by propagating waves in that peculiar medium known as the ether. These waves are originated by setting up high frequency oscillations radiating from an "antenna" or, as it is also known, an "aerial."

The antenna oscillations cause waves in the surrounding ether to be radiated into space in all directions at the tremendous speed of 186,000 miles per second, which is the same speed at which light travels.

These ether waves, coming in contact with an antenna at a receiving station, set up in the receiving antenna oscillations which, by means of suitable apparatus (hereafter described in this volume), are rectified by means of a detector so as to be audible to the human ear, generally by the use of telephones.

By this means the signals of the Morse code or telephonic speech can be carried on.

The force or amplitude of ether waves depends on the energy developed in the antenna circuit.

The greater the amplitude of ether waves, the farther do they travel and the farther can they be perceived before their force is spent. But the amplitude of the waves in no way affects their rate of travel, nor their frequency.

The speed at which these waves follow each other is termed "wave frequency." Wave frequency depends upon the characteristics of the sending circuit, and is controlled by varying the capacity, inductance and resistance. In other words, by varying the size of the condenser unit or the inductance coil. Details of various types of apparatus, such as condensers, etc., are discussed elsewhere and will be alluded to in these preliminary pages only as aids to a general understanding of radio.

A given circuit will produce oscillations at only a certain fixed rate depending on the factors of inductance, etc., just as a pendulum can swing at only a fixed rate, depending upon its length and weight. In ordinary commercial practice the wave frequency varies from as much as 2,000,000 per second to as little as 100,000 per second.

Wave Length.—We now come to what is known as "wave length," or in other words the distance from the peak of one wave to the peak of the succeeding wave. As an analogy we can picture the distance from the top of a water wave to the top or peak of the succeeding wave, although ether waves may be of different form to water waves.

Dividing the velocity of the waves, 186,000 miles per second, by the number of waves per second, gives us the wave length. We may put this in another form and say that the product of the wave length by the frequency is always 186,000. It will, therefore, be seen that it is of importance that a student should bear in mind the speed with which ether waves travel.

In discussing wave lengths, it should be carefully noted that it is only by means of variations of wave lengths that it is possible to operate a number of radio stations within the same area or region. Any desired wave length can be obtained by varying the circuit which determines wave frequency.

Wave lengths used in commercial practice vary from a few meters to thousands of meters.

Wave length plays such an important part in radio that a perfect understanding of the subject is essential. For illustrative purposes, we may compare several radio stations working in the same locality, on similar wave lengths, to several persons speaking in the same room at the same time. A listener at a receiving station, or another person listening in the same room to the speakers, would be ''jammed,'' or ''interfered with,'' to use radio terms of expression.

Supposing you could devise something that would eliminate all but one of the stations and all but one of the speakers, you would eliminate interference. In radio, interference is overcome by what is known as ''tuning.'' Stations in the same vicinity, by laws, regulations and mutual agreement, employ different wave lengths. By a receiving instrument known as a ''tuner'' or ''receiver'' it is possible to listen to only one station, or if desired, an arrangement of circuits can be made for ''broad tuning'' and ''sharp tuning.'' As the names imply, broad tuning enables the person receiving to listen to several stations, working on various wave lengths (within a certain scope), but with resultant interference, while the latter permits only the reception of signals from one station.

In commercial practice this arrangement for listening in on broad tuning is very desirable, as an operator is enabled to catch any ''call,'' and by arrangement of switches and dials rapidly throw over to the tuning devices providing for sharp or selective tuning. Details of such receivers will be found under that heading within these covers.

Wave Trains or Groups.—A "wave train" is a group of ether waves, sent out at one condenser discharge and contains numbers of individual waves depending on the circuit conditions previously alluded to.

Wherever these waves strike a receiving antenna in their travel from the transmitting station, they will set up in the receiving antenna oscillations identical to those from the transmitting station. These oscillations, as we have shown, are very frequent, usually so rapid (say over a million per second) that they are beyond the range of the audibility of the human ear which can only detect sounds of a frequency not greater than 4,000 or 5,000 per second.

We must therefore utilize some device to detect ether waves. In common practice this is called a "detector" and using a pair of telephones in conjunction therewith we are enabled, as it were, to take the energy from the antenna, which, passing through the detector produces a click in the telephones. The characteristics of the many detectors together with their associated receiving circuits is fully dealt with in succeeding chapters.

Resonance.—From the foregoing, it will be seen that high frequency oscillations, radiated as ether waves from a transmitting antenna, will set up characteristic oscillations in a receiving antenna, within their path or range.

In practice, however, best results are obtained only when the sending and receiving antennæ are "in tune," or as it is commercially termed, "in resonance."

To properly understand this phenomena, it would be well to take examples well known to everybody with even a slight knowledge of music, or through acoustics.

Take the example of two bells of similar tone, strike one and the other bell will respond without being struck. Also, the instance of two tuning forks of the same characteristics, strike one until it gives forth a musical note, it will, on the principle of resonance, sound a similar note in the second fork without the latter being struck. However, neither the fork nor the bell will actuate another fork or bell unless they are similar in every characteristic.

A similar condition exists in radio and is a condition that must predominate in the thoughts of the experimenter who would be successful in his efforts.

CHAPTER V

PRACTICAL RADIO TELEGRAPHY

In the brief history of radio found in the opening pages of this book, we have briefly discussed the earlier types of radio apparatus. While the principles explained in that chapter are still the principles underlying the radio art, in preparing any work upon the subject at this date, it would be a waste of the reader's time to attempt to describe apparatus which is no longer used in modern practice, and in the following pages, except where the old time equipment may be useful in an explanatory sense, we shall describe only radio telegraph apparatus in general use to-day.

Spark Transmitters.—Electric waves, by means of which radio communication is carried on, are produced by transmitting apparatus. Power must be supplied by some kind of electric generator, this must be converted into high frequency currents which flow in the transmitting aerial and cause electric waves which travel out through space. The waves may be damped or undamped, and we shall take each in turn.

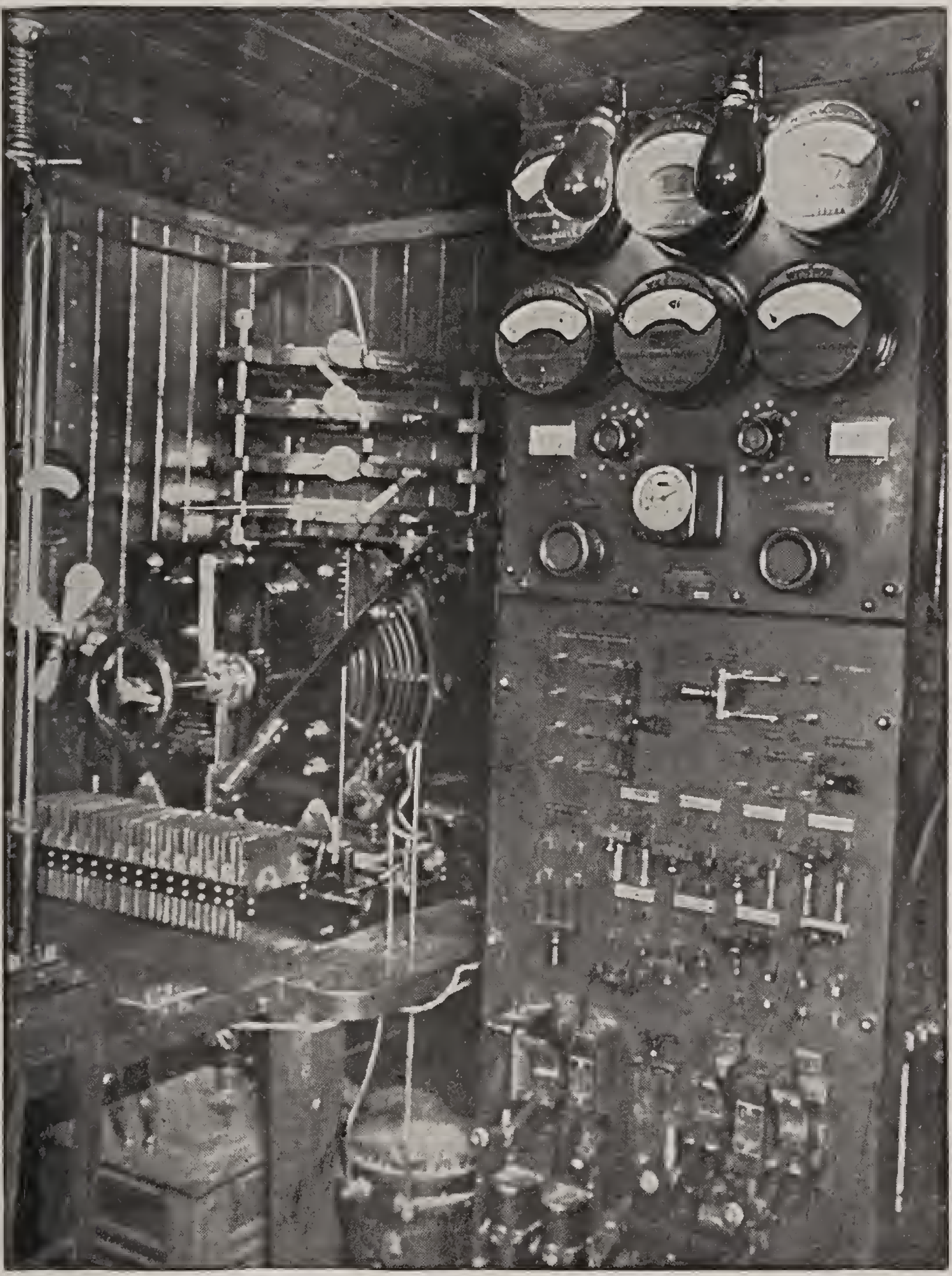


FIG. 21. Complete standard inductively-coupled set, installed on shipboard

Damped waves emanate from what is known as "spark" transmitters, while undamped waves are emitted from arc, high frequency alternators or vacuum tube sets, and are also known as continuous wave transmitters.

Discussing first the damped type of wave. Damped waves consist of groups or trains of oscillations repeated at regular intervals, the amplitude of the oscillations in each train decreasing continuously. The number of these trains of waves per second is some radio frequency. When such waves strike a receiving apparatus (hereafter described), they cause a tone in the telephone receiver. Signals are produced by means of a sending key, which permits the operator to let trains of waves go for a short length of time, making a dot, or a longer period, making a dash.

As above stated, it is our intention to first deal with the propagation of damped waves, as the apparatus is simple and easily adjusted, but the principles of damped and undamped waves are the same in many respects, so that much of what is described regarding damped wave apparatus applies to undamped waves as well.

Damped oscillations are produced when a condenser discharges in a circuit containing inductance. The condenser is discharged by placing it in series with a spark gap and applying a voltage to it high enough to break down or spark across the gap. However, the oscillations thus produced in such a circuit when the condenser discharges are "damped," and soon die out.

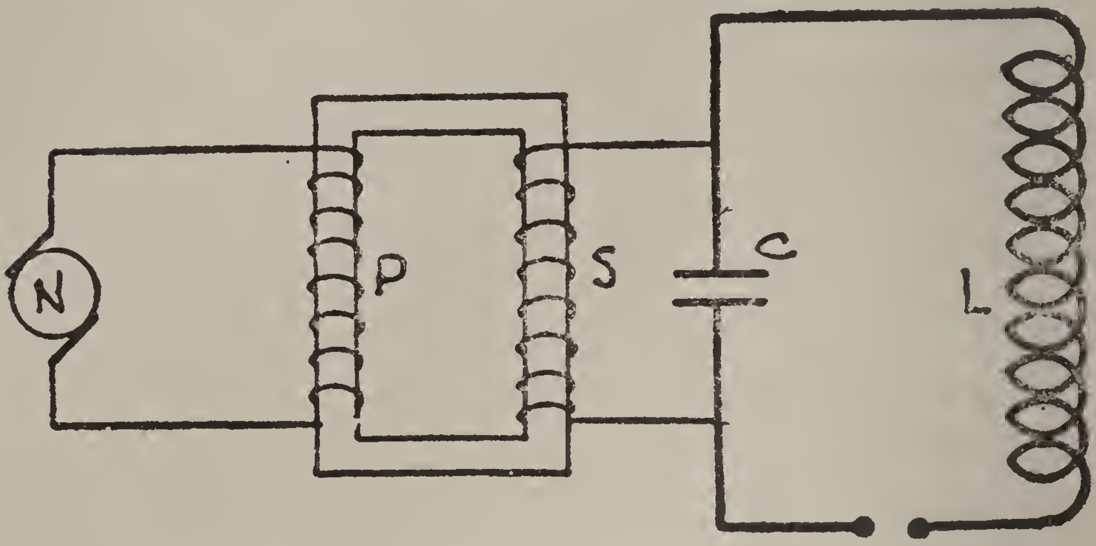


FIG. 14. Simple spark discharge circuit.

Methods of producing a regular succession of such condenser discharges in such a circuit are explained in the following. A high voltage must be applied to the condenser at regular intervals. This is done by means of a transformer. Through the primary of the transformer is passed either an alternating current or a current regularly interrupted by a vibrator, the latter being known as an induction coil. However, the induction coil is seldom used in latter day radio, and the principle is best studied by the alternating current method.

In Fig. 14, P and S are the primary and secondary, respectively, of a step up transformer which received power from an alternating current generator. The primary may be wound for 110 volts, and the secondary for 5,000 to 20,000 volts. That is to say, that from a source of 110 volts supplied to the primary of the transformer, an induced emf. of from 5,000 to 20,000 volts will be produced in the secondary of the transformer. From this high voltage the condenser, marked C, is charged and stores up the energy. When the voltage becomes great enough it breaks down the spark gap and the discharge takes place as an oscillatory current in the inductance coil, marked L, and its leads. The main discharge does not take place through the turns of the transformer secondary on account of its relatively high impedance. In this connection, it may be said that modern sets are still further protected from condenser discharge by inserting choke coils (not shown in Fig. 14) in the leads between the transformer and the condenser. These obstruct the high frequency current, but do not hinder the passage of the low frequency charging current into the condenser. Fig. 15 shows a typical alternating current transformer used in small radio sets.

The standard generator frequency used in modern practice is 500 cycles per second. This causes the condenser to discharge 1,000 times per second, once for each positive and negative maxi-

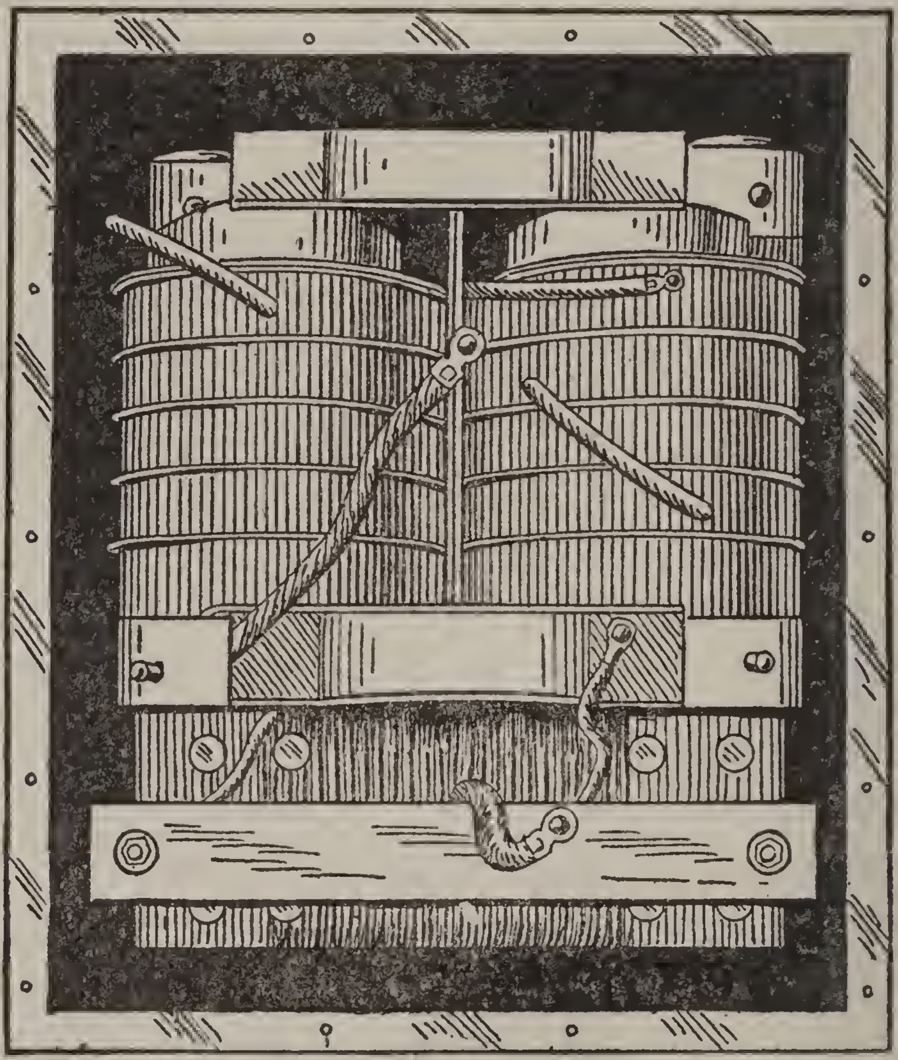


Fig. 15. Closed core transformer.

mum, or half cycle, if the spark gap is of such length as to break down at the maximum voltage given by the transformer. The number of sparks per second is called the "spark frequency." With this standard spark frequency of 1,000 per second the amount of power the set sends out is considerably greater than it would at a low frequency of, say, 60 cycles or 120 alternations per second, because the transmitted radio waves are more nearly continuous.

The radiated wave trains strike a receiving antenna more frequently and their amplitude does not need to be so great to produce the same effect as stronger waves received at longer intervals of time. The higher frequency produces a musical tone in the receiving telephones that is more easily heard, because the average ear is most sensitive to sound waves of about 1,000 per second and also the tone is more easily heard through atmospheric disturbances or "static." However, a 60 cycle supply may be used if the number of sparks per second is increased by utilizing what is known as a rotary spark gap giving several sparks per second, which multiplied by the alternations of the A C, produces a high musical tone similar in sound to the 500 cycle note.

Each condenser discharge produces a train of oscillations in the circuit, and each train of oscillations consists of alternations of current which grow less and less in amplitude.

Condensers.—Before discussing the means of getting the oscillations into an antenna, we should discuss the apparatus used in generating the oscillations, first taking the condenser unit. The most common types of condensers used in radio apparatus use mica or glass as the dielectric, with tinfoil or thin copper plating as the conducting coatings. Condensers with a compressed air dielectric are sometimes used, indeed, this type is considered the most perfect, but is seldom used owing to its bulkiness. For very high voltages the condenser plates are immersed in oil to prevent brush discharge. For some sets using moderate voltages, glass jars covered with tinfoil, or a copper coating, are sometimes used. This type of condenser is known as a "leyden" jar. In this type paraffin wax is coated over the glass at the edges of the metal to prevent brush discharge.

Spark Gap.—When the gap is broken down by the high voltage delivered from the transformer, it becomes a conductor, and readily allows the oscillations of the condenser discharge to pass. During the interval between discharges the gap cools off (if properly constructed), and quickly becomes non-conducting again, allowing the condenser to store another charge of energy. If the gap did not resume its non-conducting condition, the condenser would not charge again, since it would be short-circuited by the gap, and further oscillations could not be produced. This restoration of the non-conducting state is called "quenching." A device called the "quenched gap" for very rapid quenching of the spark is described below.

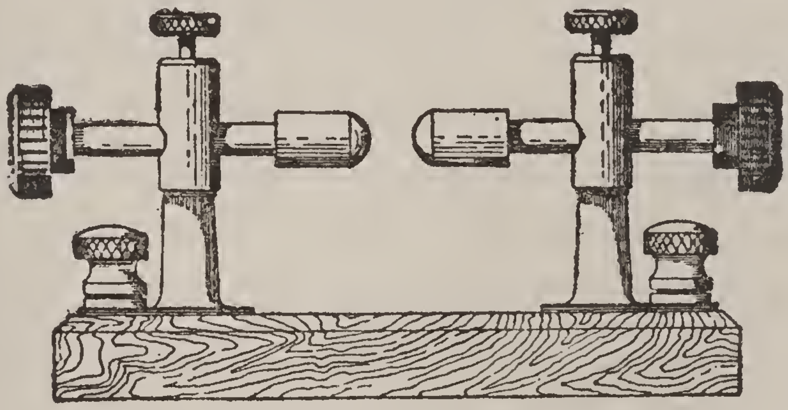


FIG. 16. Plain spark gap.

What is known as a plain gap consists of two metal rods so arranged that their distance apart is closely adjustable (See Fig. 16). It is important that the gap be kept very cool or it will arc; for that reason metal balls are sometimes used on the sparking ends of the rods in order that the sparking surfaces be ample. Sometimes these electrodes have protruding flat surfaces or fins for radiating away the heat. An air blast across the gap will greatly aid the recharging by removing the ionized air or gas which is present after each gap discharge and if not removed is the cause of arcing. At the sparking surfaces an oxide slowly forms which being easily removed in the case of zinc or magnesium, is not very troublesome. With other metals in general for gaps the oxidation is serious and is rapid enough to make operation unstable and inconvenient, requiring constant attention and adjustment.

With a given condenser, the quantity of electricity stored on the plates at each charging is proportional to the voltage impressed, and this can be regulated by lengthening or shortening the spark gap to obtain a higher or lower voltage at the beginning of the discharge. The length of the gap which can be employed is limited by the voltage that the transformer is capable of producing, the ability of the condenser dielectric to withstand the voltage, and the fact that for readable signals the spark discharge must be regular.

If the gap is too long, sparks will pass at only irregular intervals, also the condenser will be endangered and is liable to be punctured. If the gap, on the other hand, is too small it may arc and burn the electrodes and cause arcing at the gap. Arcing also causes a short circuit of the transformers, and the heavy current that flows interferes with the high frequency oscillations. An "arcy" spark gives a yellowish color and is easily distinguished from the bluish white, snappy sparks of normal operation.

Even if no arc takes place the voltage is reduced by using too short a gap and this results in reduced power and range. The length for smooth operation can usually be determined by trial, and is adjusted when a nice fat spark with the above mentioned bluish white appearance and snappy sound is obtained.

The best spark gap is known as the "quenched gap." It has been found that a short spark between cool electrodes is quenched very quickly, the air becoming non-conducting almost immediately after it is broken down, or as soon as the current falls to a low value. This action is also improved, if the sparking chamber is air tight. The standard form of quenched gap consists of a number of flat copper or silver discs of fairly large surface, say seven to ten centimeters in diameter at the sparking surface, with their faces separated by about two-tenths of millimeter. To provide the necessary total length of gap for high voltage charging, a number of these small gaps are put in series so that the spark must jump them all, one after the other. These discs are insulated and separated from each other by rings of mica

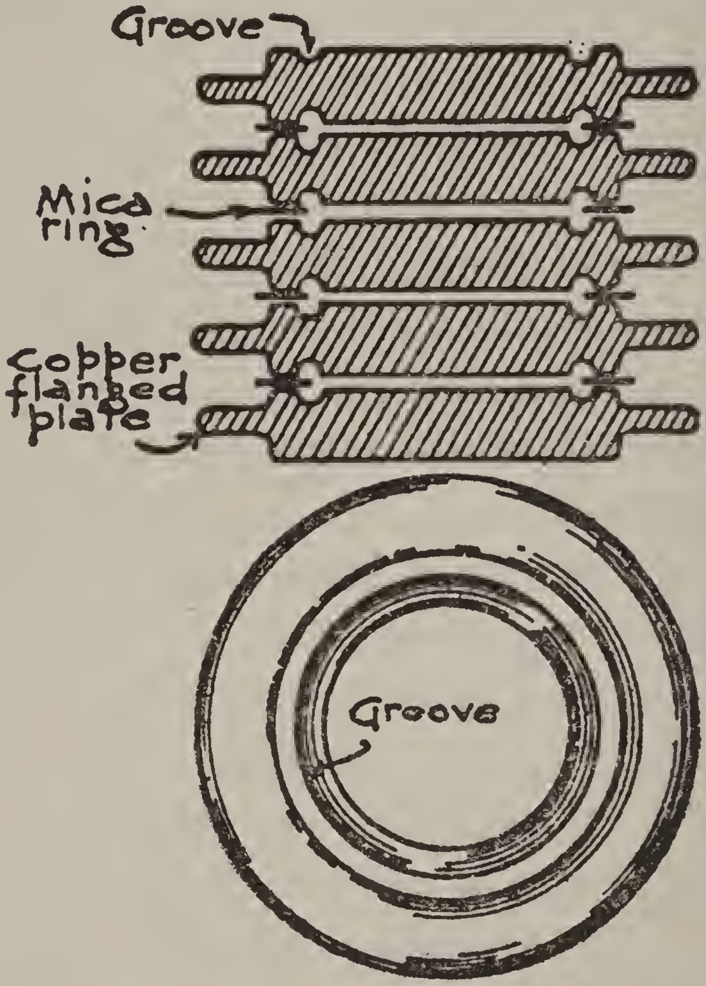


FIG. 17. Quenched spark gap.

or paper specially prepared with certain insulating compounds. For an illustration of an assembled gap see Fig. 17. This gap is cooled by either an air blower attached, when the power used is high, or by copper flanges, acting as heat radiators when the power is small or moderate. The number of discs or gaps used is determined by the voltage, usually allowing 1,200 volts for each gap.

The quenched gap is not used in gaps having a supply voltage as low as 60 cycles per second. The sparks obtained at that frequency are found to be irregular and not of a good tone. For this 60 cycle source of supply a rotary gap is mostly used and is described below. For 500 cycle frequency the quenched gap is adjusted to breakdown at the maximum value of the applied voltage; that is, with its total length so adjusted as to give one spark for each half cycle or alternation of the electromotive force. Discharges at other times are not possible; and as a result of this regularity a clear note is obtained. This quenched gap is considered standard and the most efficient type of gap for power up to about 10 kilowatts. The great advantage of the quenched gap is that it is a great aid to the production of a "pure" wave, which is discussed later in this work. Another excellent quality of the quenched gap is the fact that it is practically noiseless, on account of the short gap between discs and that it is enclosed. On the other hand a plain and rotary gap makes an awful noise.

A rotary gap usually consists of a wheel with projecting points with a stationary electrode on each side of the wheel, as shown in Figure 18. The spark jumps from one stationary electrode to one of the moving points, flows across the wheel, and then, after leaping from the corresponding point on the opposite side of the wheel, passes the gap between wheel and electrode to the second stationary electrode. The number of sparks per second is determined by the speed of the wheel, which is motor driven, or by the number of revolving points or studs. A rheostat is generally introduced in the circuit operating the motor, in order to control its speed and thus adjust the gap to any pitch or tone desired. There are many forms of rotary gaps, however, their

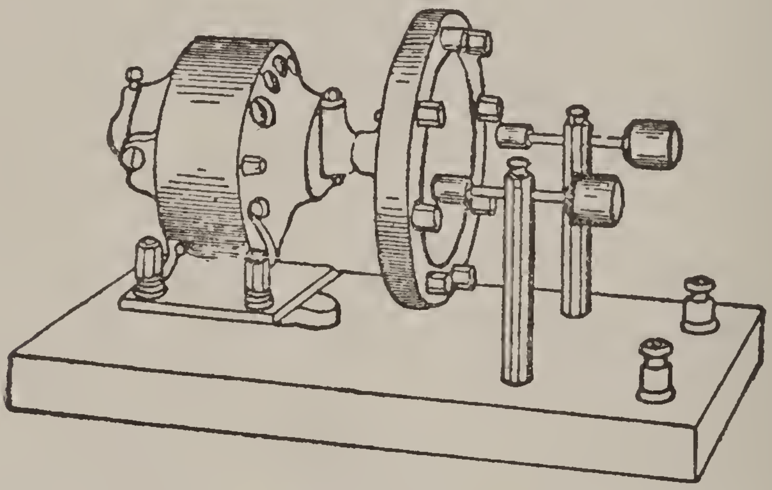


Fig. 18. Non-synchronous spark gap.

principles are similar and the results obtained more or less uniform according to their design and operation. This type of gap is divided sharply into two groups, "non-synchronous" and "synchronous."

In the case of a "synchronous" rotary gap the speed is so maintained as to bring the knobs or studs near together at just the moment when the alternating voltage upon the condenser reaches its maximum value, either positive or negative. Thus 500 cycles will produce 1,000 sparks per second. This regular occurrence of the discharge gives smooth and efficient operation, and a pure musical tone. The synchronizing is made possible by attaching the rotating element or wheel of the spark gap to the shaft of the alternator which supplies the electromotive force which in turn charges the condenser. A gap not so adjusted to the peak of the A.C. is called non-synchronous.

As in the case of attempts to quench a 60 cycle source of emf., attempts to synchronize this source of supply by a synchronous gap giving, for example, 6 sparks per alternation or half cycle, have not given satisfaction, because the applied voltage is not the same at the time of the different sparks, and while the note is of high pitch, it is not musical. Thus it is found better practice to use a non-synchronous gap in such a case, producing a large number of sparks per second and letting them occur whenever they may happen during the entire cycle. The irregularities will somewhat balance up. While sometimes the tone is not strictly musical, it can, by means of the motor control or additional points or studs, be made of high pitch. The non-synchronous gap is best used if nothing but a 60 cycle or other low frequency source of emf. is available. Such low frequencies are now being avoided in commercial radio practice and as has been stated before, the standard is 500 cycles. In amateur circles, however, 60 cycle is often the only source of supply available and rotary gaps are very desirous in that field.

Radiotelegraph Transmitters.—Having discussed the most important units found in a transmitter, we will now turn our attention to a complete radio telegraph equipment. As previously explained, it is intended that the earlier types mentioned in the historical reference of this work will not be discussed. Although they form the simplest form of transmission and are economical in design for a beginner to construct, their use is forbidden in the U. S. A. for the following reasons. In 1912 certain laws and regulations were adopted by Congress to control radio telegraphic communication. A regulation which definitely fixed the type of transmitter that should be used, was one stipulating that a pure wave should be emitted, and that no equipment with a decrement value greater than two tenths would be permissible.

The earlier transmitter, known as plain aerial, could not emit such a wave and propagated a wave very broad in its characteristics. It was a good radiating system but the waves emitted are of such high decrement that they cannot be readily tuned out in receiving apparatus when one does not desire to receive them. This type would emit a wave with what is known as several "humps" and would be heard in a receiver on a number of different wave lengths thus causing much "jamming" or "interference." Its only advantages besides simplicity are its effectiveness in cases where the sending operator wants all possible stations to hear him, as for instance, when a ship needs help, or in war time when it is desired to drown out the enemy's signals.

Inductively Coupled Transmitters.— As it is impossible for the above mentioned reasons for the experimenter tc use any equipment which will not comply with governmental regulations, we shall turn our attention to the only practical types, which are known as "inductively coupled" transmitters, and for illustrative purposes describe a standard equipment using a 500 cycle source of power and a quenched gap. This equipment can be modified to utilize lower frequencies as a power source and other types of gaps, such as previously described.

Every inductively coupled spark transmitter is divided into four circuits which are designated as follows:—

1. The low frequency, low potential circuit which includes all apparatus from the supply of alternating current to the low voltage supplied to the primary winding of the power transformer. Included is a telegraph key to make or break the circuit.

2. The low frequency, high potential circuit, which includes the secondary or high voltage windings of the power transformer and the condensers.

3. The high frequency, high potential, closed oscillating circuit including the condensers, the primary winding of the oscillation transformer and the spark gap.

4. The high frequency, high voltage oscillatory circuit, which includes the secondary winding of the oscillation transformer, also antenna inductance.

Sometimes in commercial equipment a series condenser is inserted in this circuit to reduce the fundamental wave length, enabling the apparatus to transmit on 300 meters, thus complying with a governmental requirement.

The action of this transmitter is as follows:—

Having a source of alternating current, when we depress the telegraph key mentioned in circuit numbered one, this alternating current flows in a circuit from the alternator windings through the primary windings of the power transformer and back to the generator. When the lever of the key is raised the circuit is broken. By means of this key, this primary circuit is made and broken, generally in the shape of the familiar dots and dashes of the Morse Code. Bearing in mind the preceding chapter devoted to electro-magnetism, the following action takes place in the circuit.

As the key is depressed and releases, the alternating current flowing through the primary winding of the power transformer sets up magnetic lines of force which rise and fall, and also reverses in unison with the alternating current, which has previously been described as one which alternates in its direction of flow.

These lines of force in turn cutting the windings of the secondary or high potential windings of the power transformer builds up a high voltage in that circuit, which we have described as number two. The increase in this voltage is proportional to the ratio of turns. For example, if there were ten turns in the primary, and one hundred turns in the secondary, the secondary voltage would be ten times as great as the primary voltage. The alternating current voltages usually employed are from 110 to 250 volts, thus giving a secondary voltage of from 10,000 to 25,000 volts. The primary winding generally consists of comparatively few turns of heavy wire, while the secondary is built up of a great many turns of fine wire. The number of turns employed depending upon the voltage desired and the type of spark gap utilized. With a 500 cycle, quenched gap set, the secondary voltage is relatively small.

The high voltage from the secondary circuit of the transformer is then delivered to a condenser, the construction of which we have previously discussed. This energy is then stored in the condenser until a point is reached when the condenser can hold no more, and the electro-static charge thus accumulated is discharged across the spark gap, creating an oscillating circuit in the circuit we have described as number three. This circuit is generally alluded to as the closed oscillatory circuit. These oscillations are of radio frequency. Radio frequencies are those above the range of audibility and are generally considered frequencies above 10,000 cycles per second.

We have explained in the previous explanatory chapter on radio that this radio or wave frequency depends upon the characteristics of the sending circuit, in this case the frequency of the oscillations in the closed oscillatory circuit would depend upon the amount of capacity and inductance; in other words, it would depend upon the size of the inductance coil and the condenser and may be anywhere from 1,000,000 to 2,000,000 per second. It is customary to construct apparatus wherein it is possible to vary the inductance and capacity. This can be done by varying either or both but in modern practice it is usual to use a certain fixed condenser and make the inductance variable, thus permitting a convenient method of changing wave lengths. This inductance will depend upon the number of turns in the wire and the diameter of the turns.

Having developed by the foregoing means, oscillations in the closed oscillatory circuit, these are now transferred from the primary windings

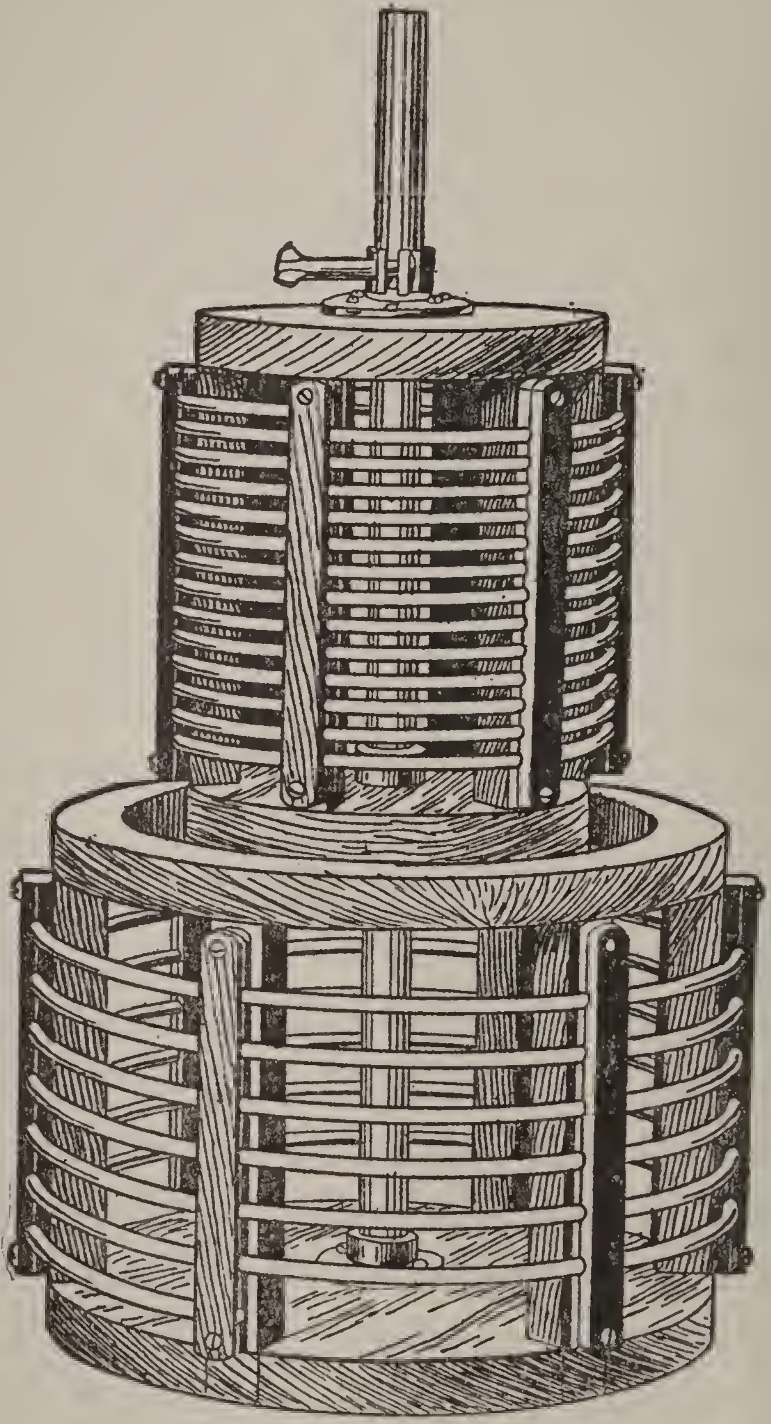


Fig. 19. Oscillation transformer. The secondary moves up and down the rod, inside the primary.

of the oscillation transformer, in circuit number three, to the secondary windings of the oscillation transformer in the open oscillatory or as it is also known, the antenna circuit, which have been previously alluded to as circuit number 4. This oscillation transformer (Fig. 19) is just what its name implies, and is a device for transferring energy (in this case radio frequency current) from one circuit to another, this being done by means of magnetic coupling, just as the low potential alternating current was transferred by means of the power transformer from circuit 1 to circuit 2. While these radio frequency oscillations are flowing in the oscillation transformer primary they set up magnetic lines of force about it, in the manner described in the chapters dealing with magnetism and electromagnetism. These magnetic lines of force cut the secondary windings of the oscillation transformer in circuit 4, inducing therein a current of the same frequency. As these oscillations travel the windings of the secondary and the remainder of the open oscillatory circuit, or, in other words, circuit number 4, electrostatic and electromagnetic strains are set up in the surrounding ether and thus these disturbances give rise to the radio waves, which are propagated into space at the speed of light, 186,000 miles per second.

A complete diagram of the above described transmitter will be found in Fig. 20.

Tuning and Resonance.—Having traced the electrical energy through the above mentioned transmitter and shown how low frequency alternating current is converted to radio frequency oscillations, also the method of propagating this energy into ether waves, we must now study the phenomenon of resonance, which will show us the necessity of placing the closed and open oscillating circuits in "tune" in order that the maximum of energy may be transferred from one to the other. Not only must this be done to obtain a maximum of efficiency, but also that we may ob-

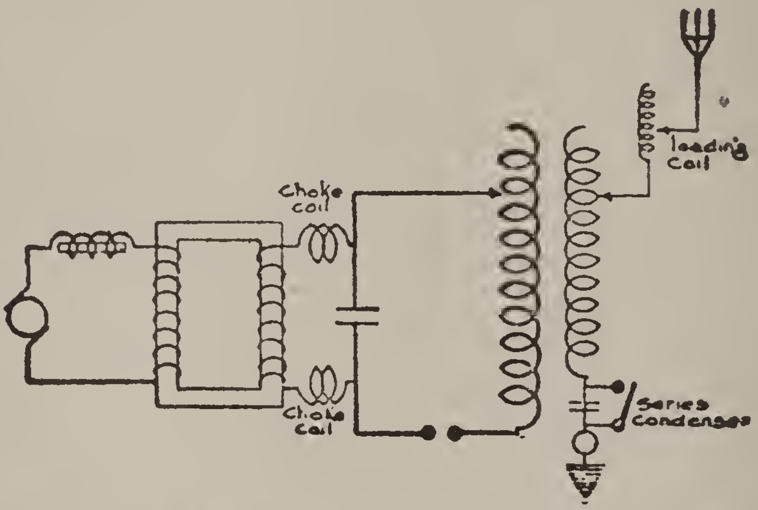


Fig. 20. Inductively-coupled transmitting circuit.

tain a "pure wave" and thereby conform to the above mentioned laws and regulations.

A very pronounced maximum of current in the open or antenna circuit is obtained when its natural period of oscillation is the same as that of the primary circuit. This occurs when the secondary or antenna inductance and capacity equals the primary inductance and capacity. The inductance in the antenna circuit includes the antenna itself, the lead in wire, the secondary windings of the oscillation transformer, and, if one is used, the additional antenna inductance coil, or as it is also known, the "loading coil." It is important that the wiring between the units in the closed oscillating circuit be as short as possible, therefore with the leads so short almost all the inductance is in the primary windings of the oscillation transformer, also as the capacity of the condenser in that circuit is large, most of the capacitance is contained in that unit. As previously explained, the condenser unit in this circuit generally has a fixed value, and the inductance made variable to provide easy adjustment. The additional inductance coil (if used) and the secondary windings of the oscillation transformer in the open or antenna circuit are invariably made variable.

To obtain resonance between the closed and open oscillatory circuits the following simple procedure may be used. Only two instruments will be required to obtain results, a wave-meter and a hot-wire ammeter, which are both fully described in the pages devoted to "Definitions."

We will assume that the desired wave length required is to be 600 meters.

The coupling between the open and closed oscillating circuit should first be as far apart as possible and the antenna and ground disconnected from the secondary of the oscillation transformer. The wavemeter should be placed first in close proximity to the primary of the oscillation transformer. A rough calculation of the number of turns of primary inductance should be made, which would give the desired wave length. Oscillations should then be set up in the closed circuit by depressing the key. A reading of the wavemeter will then determine the wave length of the closed circuit. If the first rough calculation was incorrect, and the desired wave length not found, it will be easy to add or reduce the number of turns of inductance as required, according to whether the wavemeter has indicated a wave length shorter or longer than that required. Several adjustments of this description will eventually enable the operator to obtain the desired wave. In this method of tuning, it will be found desirable, for better results, to make the indicated wave length of the primary oscillating circuit slightly lower than that which is required for working purposes, as it is found in practice that when the open and closed circuits are coupled the wave length of the transmitter will slightly increase over that indicated in the primary reading. A better wavemeter reading will sometimes be available if the wavemeter is withdrawn from too close proximity to the coil, until the indication is at a minimum value. If this withdrawing is done undisturbingly, a reading may be observed while the motion is taking place, or readings taken at various distances. This will tend to greater accuracy.

Having adjusted the closed circuit to the desired wave-length, the antenna and ground connections should then be re-connected to the open oscillatory circuit. The hot-wire ammeter should be placed in series between the ground and the secondary of the oscillation transformer. Having separated, as far as possible, the primary and secondary coils of the oscillation transformer during the previous adjustments, these two coils should now be brought somewhat closer together.

An arbitrary adjustment of the secondary of the oscillation transformer can be made, bringing all its turns into the circuit, unless perhaps the natural period of the antenna is so large that it is necessary to reduce the amount of inductance to obtain the desired wave length, in that event it would be necessary to carefully adjust the number of turns needed by means of the wavemeter. In this connection it is well to note that a station is generally built with some definite object in mind, and that the antenna is generally so constructed that its natural period is considerably less than the wave length to be utilized. An arrangement that gives excellent results is to figure in constructing the antenna to have it with a natural period or fundamental wave length of approximately two-thirds of the wave length it is desired to radiate. This allows, as a rule, the full secondary of the oscillation transformer to be utilized, it also permits us to use an antenna loading coil to tune to resonance and maximum radiation. Of course in many circumstances this may not be feasible and we must govern the adjustment of the open circuit accordingly.

Having joined the antenna and ground connections to the secondary of the open circuit, another reading of the wavemeter should be taken. It is possible that some slight readjustment of the primary of the oscillation transformer may be necessary to obtain the exact wave length desired.

Having by means of the wavemeter accomplished this, the next step is to obtain maximum radiation. This is done by adding or reducing the number of turns in the aerial loading inductance. A few trials either way will soon show, by reading the hot-wire ammeter, when this maximum is reached. If a hot-wire ammeter is not available, a flashlight electric lamp of about 4 volts may be placed in series with the ground connection, and maximum radiation is denoted when this lamp lights up brightest.

The next step is to adjust the coupling between the primary and secondary of the oscillation transformer, in order that the wave emitted complies with the regulations. This may be accomplished by means of the wavemeter. Having coupled the two circuits to obtain maximum radiation, a wavemeter reading should be taken, covering the entire range of the wavemeter range. It is possible, indeed probable, that it will be found that two or even more waves will appear. The coupling in that case must be opened until it is noted only one point of resonance, or one ‘‘hump’’ appears, and that on the desired wave length. A readjustment of the loading coil for maximum radiation should again be made and then another wavemeter reading of the coupling taken.

Relation of Spark Gaps to Resonance.—In the matter of coupling, it will be found that the type of spark gap used is a big factor. It is desirable to have as sharp a resonance curve or as pure a wave as possible, hence it will be found that a very loose coupling will be found necessary when a plain spark gap is used. On the other hand, a synchronous rotary gap or a quenched gap permits a closer coupling and generally speaking a greater transfer of energy from the closed to the open circuits.

The action of the quenched gap is to open the primary circuit by the suppression of the spark at the end of its first train of waves. This prevents the secondary from inducing oscillations in the primary again, that is, from re-transferring energy back to the primary. The secondary or antenna oscillations are not thereafter interfered with by the primary and the antenna goes on oscillating until the energy is all dissipated as waves or heat. The length of the train will depend only upon the decrement of the antenna circuit. By reducing the resistance, the dielectric losses, the brush or corona discharges and other leakage, the antenna current may be made to oscillate for a comparatively long time, at the frequency for which the set was adjusted. This rapid or sudden quenching of the primary avoids double waves, even with close coupling. In fact, the coupling should be close for good operation with the quenched gap. Great care must be taken with the adjustment of the coupling, but it is well worth the care, as it gives a high pitched clear note when properly adjusted. As previously pointed out, the wavemeter will readily show when a single sharp wave is obtained, and the sound in the telephone receivers will indicate the proper adjustment for a good note.

It is well to note that the principles of operation of the quenched gap and the plain gap are exactly opposite. The former aims to stop the primary oscillations quickly, after the secondary has been brought to full activity. The latter aims to keep the primary oscillations going as long as possible, all the time giving energy to the secondary as it is radiated away; the coupling is loose and primary decrement is kept low. The rapid decrease of the oscillations in a quenched gap circuit are assisted by having a large ratio of capacitance to inductance. This has the incidental advantage that the voltages across the condenser and coil are thus kept low.

Damping and Decrement.—If the energy in the antenna circuit is dissipated at too rapid a rate, owing either to radiated waves or heat losses, the oscillations die out rapidly and not enough waves exist in a received train to set up oscillations of a well defined period in a receiving antenna. Such waves are strongly damped and have a large decrement. They produce received currents of about the same value for a considerable range of wave lengths. Thus selective tuning is not possible. To increase the number of waves sent out in each wave train from the open circuit, that is, to make the oscillations last longer, the resistance of the circuits must be kept low. When using a plain gap the coupling between closed and open circuits must be small enough not to take energy too fast from the closed oscillating circuit. At each condenser discharge the primary has a train of oscillations which at best die out long before another train starts, these oscillations are stopped more quickly, however, if the energy is drawn rapidly out of the circuit by the antenna. Close coupling is permissible only when a quenched gap is used, as previously explained. With any other kind of gap, the secondary is kept oscillating by energy continually received from the primary.

A great many factors contribute to the resistance of the antenna circuit, and this must be kept as low as possible. The antenna must have a good, low resistance ground, must use wires of fairly low resistance, must not be over trees or other poor dielectrics. The resistance of the closed oscillatory circuit must be very low. Heavier currents flow there than in antenna wires. For this reason the closed circuit wires must be short and of large surface, preferably stranded copper wires or copper tubing should be used. The condenser should be a good one, free from power loss.

Changes of Wave Length.—In many sets of apparatus it is customary to have connections arranged by which different chosen wave lengths, say 300 or 600 meters, can be transmitted without the necessity of a readjustment of the apparatus after each change and also permits of a rapid change-over from one wave length to the other.

An antenna alone, without any inductance coil has a natural wave length of its own, dependent upon its inductance and capacitance. The antenna as a rule is so designed that its natural wave length is shorter than the wave length to be used, and the wave length is brought up by adding inductance in series or merely by added inductance of the secondary of the oscillation transformer.

In the case of a small antenna, such as that on a small vessel, it is necessary to use a large antenna inductance. Since it is desirable to have a convenient method of coupling the closed and open oscillating circuits, in order that fairly critical adjustments may be made, a part of this secondary inductance can be in a separate coil called the antenna ‘‘loading coil.’’ This is connected to the secondary of the oscillation tranformer in series with the antenna. For a quick change of wave lengths, the apparatus can be designed so that by means of a switch with a mechanism of levers, changes simultaneously the adjustments of all three coils. From these coils are taken out taps over which three switch blades pass, adjusting all three inductances to the values needed for the particular wave length desired, keeping the circuits in resonance. However, a change of coupling may be necessary for each change. This can be determined by tests and the change of coupling, if necessary, marked on the apparatus for the operator’s guidance.

In the event that the natural period of the antenna is greater than the wave length it is desired to work with, an arrangement can be made as follows:

In the lead between the secondary of the oscillation transformer and the ground a condenser should be placed in series. This must be capable of withstanding high voltages similar to those in the main transmitter. By using a small capacitance the wave length can be reduced to approach one-half of the natural wave length. It should not be reduced that much, however, for the radiation of the set would be inefficient if the condenser is too small.

Over-all Efficiency.—To maintain good efficiency all resistance in the circuits must be kept as low as possible. A number of suggestions have been offered in the preceding pages which will do much to accomplish this.

It is very necessary to avoid brush discharges or corona losses and arcing. Keep all connections tight, condenser plates and other parts of the circuits free from dust and moisture. It is most important that the antenna be well insulated. Brush discharge may be curtailed by eliminating sharp edges or points on conductors, and by coating the edges of metal condenser plates with paraffin wax. The guy wires of an antenna should be divided into short lengths and strain insulators placed between each length to reduce the flow of current in the guys. Inductance coils must be properly designed, the wire or copper ribbon of which they may be constructed must have sufficient surface to carry the high potential they must handle. Unless this is done, great loss is caused by heating. The proper design of the spark gap is most essential.

Impulse Transmitters.—The apparatus we have dealt with in the preceding pages is known as the four circuit transmitter, and as we have shown, requires critical adjustment between the various circuits. There is, however, another type of inductively coupled transmitter in commercial use which is known as the "impulse" transmitter. This type was developed by Mr. R. E. Thompson, an American radio engineer who for many years was in the United States Government service, and the transmitter bears his name. Apparatus similar in principle is also marketed by several manufacturers, all operate under the principles of the Lodge patent, alluded to in the chapter devoted to historical reference (Figs. 22 and 23).

Briefly described, the action and characteristics of this transmitter are as follows:

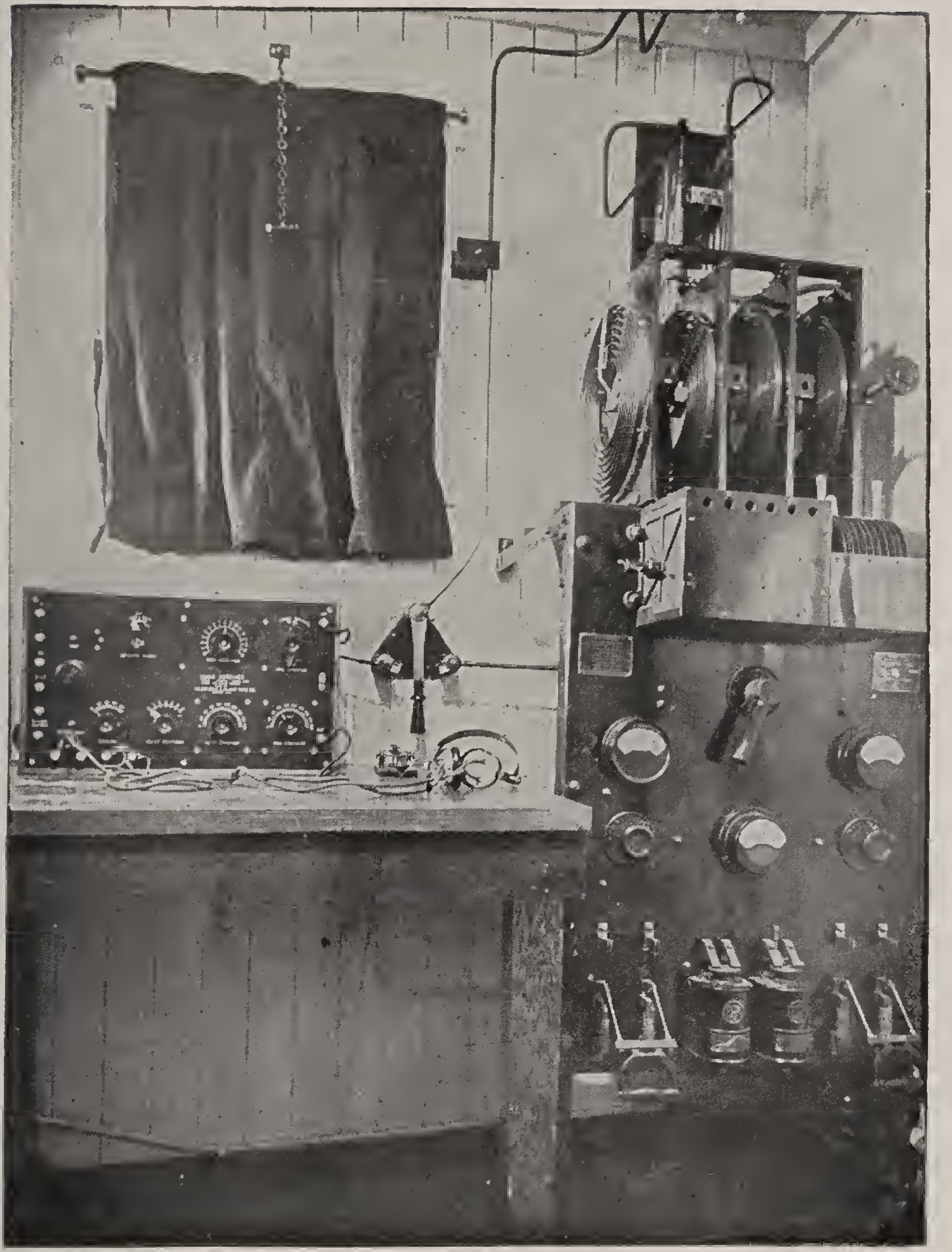


FIG. 23. Complete installation, impulse type transmitter

In the above described set, it was shown how the primary windings of the oscillation transformer consisted of numerous turns of wire and was variable. In the impulse type this is the reverse and the primary is fixed, as also is the condenser, which contrary to the 4-circuit variable type, is of a very high capacity. The spark gap consists of two high resistance units of high resistance. Taken throughout the closed circuit inductance is kept at minimum. Wherever possible leads and connecting wires are done away with. This is carried to such an extent that the gaps and condensers are mounted directly on the panel board

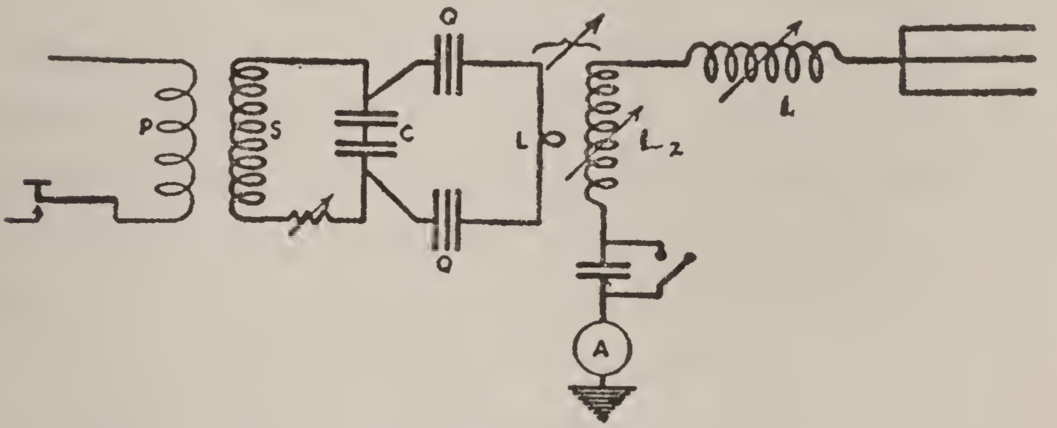


Fig. 22. Circuit diagram impulse transmitter. P S, transformer. C, condenser. Q, quenched gaps. L and L_2, primary and secondary oscillation transformer. C_2, short wave condenser. L_3, antenna loading inductance. A, ammeter.

and from them is taken a single loop of heavy wire or tubing as an oscillation transformer or primary, or, it may be termed a transfer agency. This arrangement permits of only one wave length in the closed circuit. As this type of transmitter has been used exclusively on shipboard, where the range of wave lengths is arbitrarily fixed by regulations, the wave length of the closed circuit is generally fixed about 700 meters. The open or antenna circuit is similar in design to the previously described set, and bearing in mind that the closed circuit wave length remains constant, this antenna can be tuned to wave lengths varying from 600 to as low as 200 meters without a change in the closed circuit. This makes the impulse transmitter a non-resonant one. The action in actual transmission is best described by the use of a well known analogy. Suppose we strike the "C" note on a piano, all other "C" notes in the instrument will respond in unison without being touched, but no other note will vibrate. This has been fully discussed under resonance in the explanatory chapter on radio in these pages. However, if we were to lift the piano and drop it, or give the case of the instrument a mighty blow with a heavy projectile, all the strings in the piano would respond and vibrate. Hence we find that although the strings of the piano vibrated with the blow, it was not because of any resonant relation between the blow and the strings, but because of the "kick" or "crack" imparted to them. Now, in the case of the impulse transmitter we find that the antenna circuit consisting of inductance and capacity, has a natural period of its own, and will oscillate at that period, depending upon the amount of capacitance and inductance contained therein. The closed circuit, however, is considered non-oscillatory, but given a large condenser discharge, it corresponds to the heavy blow or kick given the piano, and will cause the antenna to oscillate. This method of excitation is termed "impulse" excitation, "shock" excitation, or "whip-crack" excitation.

One of the advantages of this type of apparatus is the absence of numerous adjustments. Having an arbitrary, steady, closed circuit, the only adjustments necessary are those in the antenna circuit. Within certain limits, it will radiate several wave lengths without any attempt at resonance.

Undamped Wave Transmitters.—Undamped oscillations are not broken up into groups like damped oscillations. Exactly similar current cycles follow one another continuously, except as they are interrupted by the sending key, or subjected to gradual fluctuations of intensity as when used in radio telephony. Undamped oscillations are produced by a high frequency alternator, an arc or by vacuum tubes. In this chapter we do not propose to take up transmission by vacuum tube, as this is treated in succeeding chapters covering vacuum tubes and radio telephony.

The main advantages of undamped, or as they are also known (especially in Europe) continuous waves, are the following: 1. Extremely sharp tuning is obtained and consequent reduction of interference between stations working close together. A slight change of adjustment throws a receiving set out of tune, and the operator may pass over the correct tuning point by too rapid a movement of the receiving adjusting dials. 2. Radio Telephony is made possible. 3. Since the oscillations go on continuously instead of only a small fraction of the time, as in the case of damped waves, their amplitudes need not be so great, hence the voltages applied to the transmitting condenser and antenna are much lower. 4. With damped waves the pitch or tone of received signals depends entirely upon the number of sparks per second of the transmitter. With undamped waves the receiving operator controls the tone of the received signals, and this can be varied and made as high as desired, within certain audible limits, to distinguish it from ‘‘atmospheric’’ or ‘‘static,’’ and to suit the sensitiveness of the receiving operator’s ear and the telephones used in reception.

These advantages, freedom from interference from other stations through selective tuning, the high tones and low voltages, and the greater freedom from strays combine to permit of a higher speed of telegraphy than could otherwise be obtained with other classes of transmission.

High Frequency Alternators.—The scope of this work, primarily intended for the use of readers unacquainted or with slight knowledge of the radio art, will not permit of a lengthy discussion of this type of transmission. However, in conjunction with the other contents, a brief outline of this, the latest form of radio-telegraphy, may prove of interest.

For the production of continuous oscillations an alternating current generator of very high frequency can be used. Alexanderson and Goldschmidt both developed alternators which generate alternating currents of *radio* frequency. This alternator is connected directly or inductively to the antenna and ground, and constitutes the simplest possible connection for producing continuous or undamped waves. However, to obtain a wave length of say 1500 meters, the frequency of the A.C. must be as high as 200,000 cycles per second. The generator speed required to produce this frequency is so high that a special time of construction is necessary for such a machine. It is also necessary to secure apparatus for keeping the speed of the machine constant, so that the wave length will not change. This system is impossible for very short waves and therefore arc and vacuum tube apparatus is utilized for the shorter wave lengths and less powerful stations.

Goldschmidt employed a radio frequency alternator, with a "frequency changer." An initial A.C. of about 10,000, which by means of what is known as a "reflection" process, is changed to 40,000 cycles, giving a wave length of 7,500 meters.

The Alexanderson machine is one of great speed and many field poles, and frequencies as high as 200,000 cycles are obtained. This radio frequency, which is impressed on the antenna circuit, is actually taken from the terminals of the machine.

Undoubtedly for long distance work employing very long wave lengths, these high frequency alternators will be used to a very large extent, in fact, the large radio corporations, competing with the submarine cables are using them to-day with most successful results.

Arc Transmitters.—The arc system of radio-telegraphy was invented by a Danish scientist, Valdemar Poulsen. Much of the success of the system, however, can be claimed by American engineers employed by the Federal Telegraph Company of San Francisco, who acquired the American rights to Poulsen's invention. Possibly the chief of these being Mr. C. F. Elwell.

The method used for producing undamped waves of rather great wave length (generally over 2,000 meters), is by means of a direct current arc operated on about 500 volts. It has been discovered that an electric arc between proper electrodes, shunted by an inductance coil and a condenser, will produce undamped oscillations through the shunt circuit. The operation is as follows: The current through the arc is always in the same direction but may vary in magnitude. It is found that when the current in the arc increases, the voltage at its terminals falls off. Suppose the arc to be burning steadily with the capacitance and inductance circuit disconnected.

If now that circuit is connected, the condenser begins charging with the left plate positive, and draws current away from the arc. The potential difference of the arc increases and helps the charging. The charging continues until the counter electromotive force of the condenser equals that of the applied. As the charging nears its end, the charging current becomes gradually less, and the arc current as a whole increases to its normal value, with a corresponding drop in voltage. The condenser then begins to discharge downward through the arc, increasing the arc current and lowering its voltage. Lowering the voltage across the terminals of the arc aids the condenser to discharge, and the effect of the inductance in the circuit tends to keep the current flowing and a charge is accumulated on the condenser plates of the opposite sign from the first one. As the charge now nears its end, the charging current downward through the arc becomes gradually less, and the arc current decreases, causing the voltage to rise. It is seen that the rise of the direct current voltage is such as to attempt to charge the left plate of the condenser positive, and the positive charges on the right hand plate begin at once to come back, going up through the arc and decreasing the current.

There is a consequent further rise of voltage, and in a direction to assist first the condenser discharge, and then the recharge in the opposite direction (on the left hand plate). The action now begins all over again, and thus continuous oscillations take place through the circuit.

The arc burns in a closed chamber having hydogen passing through. The positive electrode is of copper and the negative solid carbon, both being of large size and cooled by a water jacket. The key is arranged to short circuit some of the turns of inductance in the antenna circuit, the correct number of turns being adjusted for resonance with the key closed. Then with the key open, the antenna circuit is out of tune with the arc oscillations and the current is negligible, thus forming the intervals between dots and dashes.

Tuning Continuous Wave Sets.—With high frequency alternator apparatus the frequency and hence the wave length are determined by the speed of the generator and the number of poles. The inductance and capacitance of the antenna should be of such values as to give the circuit the same natural frequency as the generated current. This is brought about by adjusting the antenna loading coil to give maximum current in the hot wire ammeter.

Much of the same method is used with arc sets. The desired wave length is obtained by adjustment of the condenser and inductance, the antenna circuit being opened, and the wave length being set on a wavemeter which is brought near. The antenna circuit is then adjusted to the same wave length by varying the loading coil until the hot wire ammeter gives a maximum reading. A pilot lamp can be substituted instead of the hot wire ammeter, since it can be adjusted by a shunt to light only when the circuits are in resonance. Sometimes this lamp is connected inductively by a loop of wire instead of being directly in the ground wire.

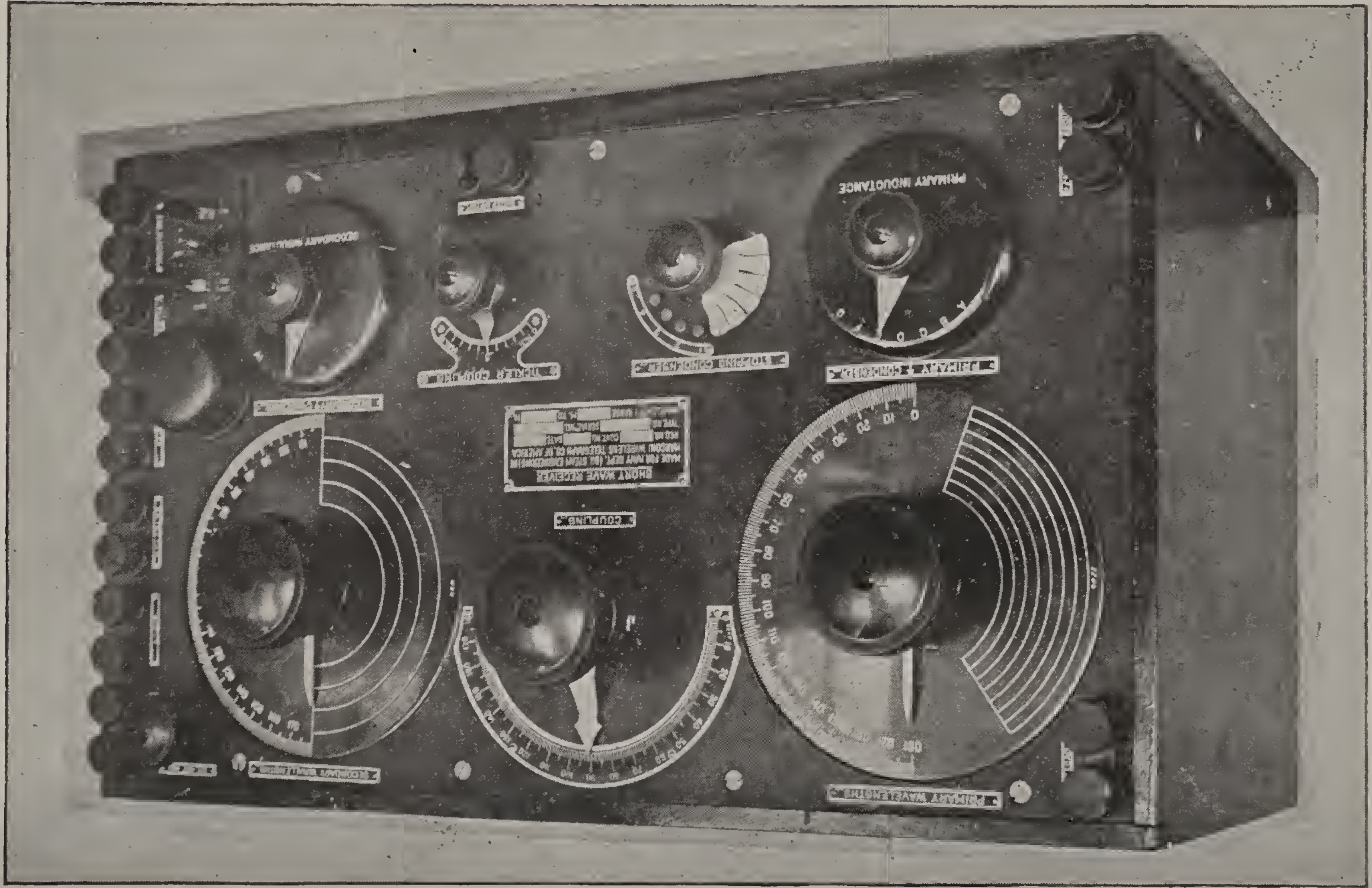


Fig. 34. Front view, standard commercial receiver

CHAPTER VI

RADIO RECEPTION

Introductory.—Receiving sets are divided into two well defined classes, those for damped waves, and those for undamped waves. In modern practice a receiver is so designed that, included in its general construction are methods for rapidly changing from damped to undamped reception and *vice versa.*

Sets for damped wave reception in practice involve the simpler connections and form a good starting point for any explanation of the subject, although it will be found that later, in discussing undamped wave receivers, very slight modifications of the damped wave apparatus will give one method of receiving undamped waves. Before proceeding with a discussion of the various receiving circuits, it will be well to digress and explain the principles and construction of the individual units which comprise a receiving equipment.

Crystal Detectors.—A very simple and convenient form of detector is obtained by the contact of two dissimilar solid substances, properly chosen. The number of substances which have been found suitable for use in such detectors is large. This type of detector is easily portable, but requires frequent adjustment and is less sensitive than the vacuum tube.

Among the combinations of solid substances which have been used as contact detectors may be mentioned silicon with steel, carbon with steel and tellurium with aluminum. The most important contact detectors, however, are crystals, natural or artificial, in contact with a metallic point. Examples of such minerals are galena, iron pyrites, molyb-denite, bornite, chalcopyrite, carborundum, silicon, zincite, and ceruscite. The first three are respectively lead sulphide, iron sulphide and molybdenum sulphide. Bornite and chalcopyrite are combinations of the sulphides of copper and iron. Carborundum is silicon carbide, formed in the electric furnace. The fused metallic silicon commonly used is also an electric furnace product. Zincite is a natural red oxide of zinc.

Probably the three most widely used crystals are galena, silicon and iron pyrites. Sensitive specimens of iron pyrites are more difficult to find than sensitive galena, but they usually retain their sensitiveness for a longer time than galena.

These sensitive pyrites detectors are often sold under the trade name of "Ferron." The detector sold under the name of "Perikon" consists of a bornite point in contact with a mass of zincite.

Fig. 25 shows a typical crystal detector. This particular sample being of silicon with an antimony contact point. Another excellent crystal is ceruscite and is sold under that name.

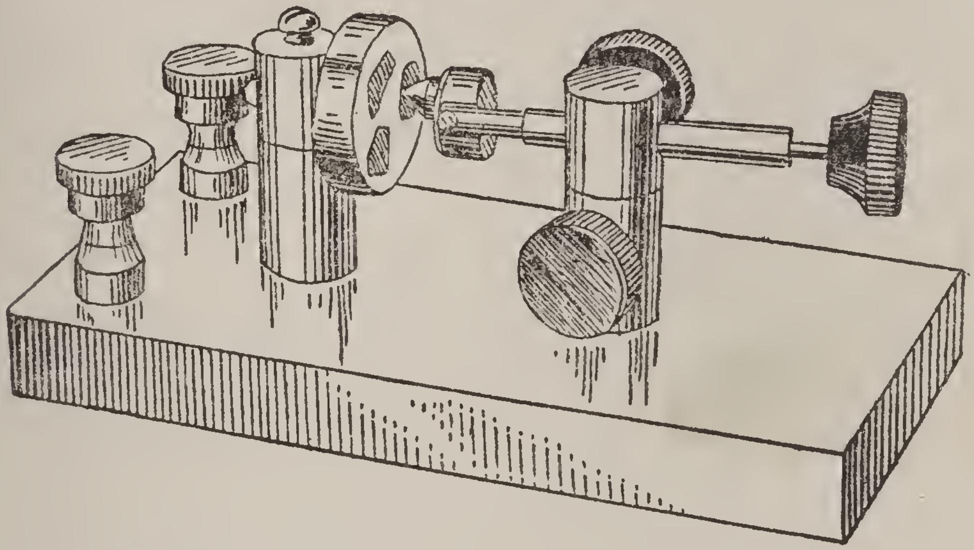


FIG. 25. Typical crystal detector.

In order to act as a detector for radio signals a crystal contact should either allow more current to flow when a given voltage is applied in one direction than when it is applied in the opposite direction, or its conductivity should vary as different voltages in the same direction are applied. Practically all detectors formed by contact of two dissimilar substances possess both of these properties, at least to a slight extent.

To make use of the latter property, a battery is required in series with the crystal, as explained below. Some crystals, such as galena, silicon, ceruscite and iron pyrites give about as good results as simple rectifiers as when the battery is used, and as a matter of fact, in common practice no battery is employed with them, thus making the apparatus more simplified and effecting economy.

In order to make use of the second property, a local or ''booster'' battery is inserted in series with the crystal. Generally a small battery of 2 to 4 volts, controlled by a potentiometer is employed.

Telephones.—The distinctive features of telephone receivers for radio work are lightness of the moving parts and the employment of a great many turns of wire around the magnet poles. The lightness of the moving parts enables them to follow and respond to rapid pulsations of current. The large number of turns of wire causes a relatively large magnetic field to be produced by a feeble current. The combined effort is to give a very sensitive receiving device. Inasmuch as the size of the wire used is always about the same (No. 40 copper), the amount of wire and therefore the number of turns is usually specified indirectly by stating the number of ohms of resistance in the coils. Telephone receivers of fair sensitiveness for radio work have about 1000 ohms in each receiver (measured in direct current), while the better ones usually have 1500 to 2000 ohms per receiver.

The most common type, called the magnetic diaphragm type, has a U-shaped, permanent magnet with soft iron poles, and a thin soft iron diaphragm very close to the poles, so that it vibrates when the attraction is rapidly varied, producing sounds to correspond with the frequency of the pulsations of current.

The impedance of a telephone receiver to alternating current increases rapidly with frequency, and at radio frequency is so great as to permit no passage of current. By the use of detectors, however, the current that passes in the telephone consists of a series of pulses of audio frequency, usually from 500 to 1200 pulses or vibrations per second. A typical telephone receiver having a direct current impedance (resistance) of 2000 ohms was found at 400 cycles per second to have an impedance of 2900 ohms, and at 800 cycles per second an impedance of 3900, rising to 4400 ohms at 1000 cycles per second. This is an excellent illustration of the ratio of the frequency to the resistance of telephone receivers.

Receiving Coils and Condensers.—The coils used in receiving apparatus are very simple in construction, being usually wound in a single layer of wire on a bakelite, pasteboard, or other insulating tube. The wire is usually covered with an insulation of silk or cotton, both solid and stranded wire being used. In the older type of apparatus, one or two sliders make contact with any desired turn of wire, the insulation being scraped off on top of the wires along a narrow path lengthwise of the coil. More modern sets use no sliders, but have switches whose points are connected by tap wires to turns of wires in the coil. One switch takes care of single turns, and the other switch makes contact to groups of, say, ten turns each. The construction of a rough example of this type is explained in the chapter explaining how to construct a receiver, found later in this volume.

Loading coils are merely large coils used to increase the inductance of the circuit when the inductance of the receiving oscillation transformer is not great enough to be tuned to the wave length received.

Fig. 26 shows a typical receiving variable condenser with air dielectric, which is generally used. The maximum capacity of these receiving condensers for short wave receivers, is usually 0.0005 microfarads, adjustable to a minimum of nearly zero. A set of semi-circular metal plates is rotated between a corresponding set of fixed plates, forming alternate layers of air dielectric (insulation) with adjacent conductors of opposite polarity. In damped wave reception the finer

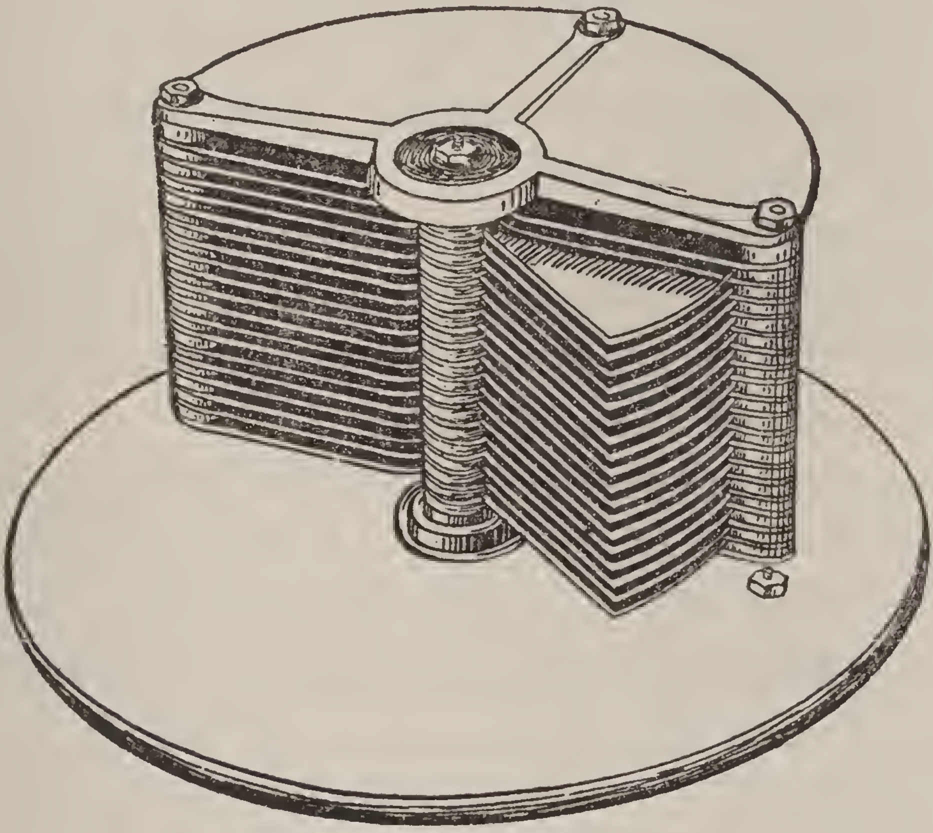


Fig. 26. Typical receiving condenser with air dielectric (insulation).

secondary tuning is done by a variable condenser. In working with vacuum tubes most of the tuning is done with variable condensers. In the primary it sometimes happens that, with undamped or continuous waves, the tuning must be closer than that afforded by single turns of the primary inductance coils, so a variable condenser is placed in parallel with the primary and used for fine tuning.

Receiving Tuners.—Having discussed the principal units composing a receiver or tuner, we shall now turn our attention to the various types of tuners and their circuits.

The fundamental principle of the reception of signals is that of resonance, which has been discussed fully in the portion of this work devoted to transmitters. If the receiving circuits are tuned to oscillate at the same natural frequency as the incoming waves, these waves, though extremely feeble, will after a few impulses, build up comparatively big oscillations in the circuits. In reality, then, for the reception of signals, all that is needed is an antenna circuit tuned to the same wave length as that of the transmitting station, and an instrument capable of evidencing the current which flows in the antenna connecting wire.

In Fig. 27 is shown the simplest connection for the reception of signals with a telephone receiver. It is suitable only for damped waves, and also will receive only waves from a transmitting station that correspond to its own, or nearly its own natural period. At D is shown the rectifier, commonly called a "detector," although really, it detects nothing and merely alters the waves, so that the telephones may receive them. It must be remembered that the waves received are of radio frequency, which are inaudible to the human ear. The upper limit of audio frequency for the human hearing is about 15,000 sound waves per second, so that even if the telephone receiver diaphragm could, without the detector (rectifier) follow the radio frequency, the ear would not hear the sig-

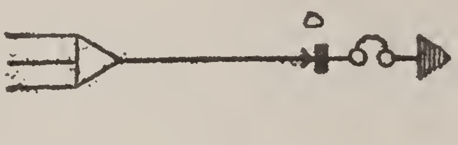


FIG. 27. Simplest form of receiving apparatus.

nals; what the detector does is rectify the radio high frequency current, that is, allow but one alternation to pass through it, and lopping off, so as to speak, the other alternation of the opposite direction, thus reducing the alternating to direct current and permitting audible signals to be heard in the telephones. In the above circuit it is true that the presence of the detector and telephones offers high resistance in the antenna circuit and renders it not very selective, so that it will respond to a wide range of wave lengths. Tuning to resonance is made possible if a tuning coil is introduced into the circuit, in series with the antenna, such as L in Fig. 28, to vary the inductance of the circuit and hence the wave lengths.

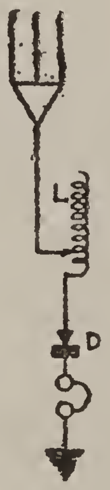


FIG. 28. Simplest form of tuned receiving apparatus.

It is well to observe how simple is the apparatus actually needed for reception, contrary to what the uninitiated person supposes. Three pieces of apparatus, telephone receiver, dectector (rectifier), and tuning coil will effectively receive damped wave signals. The main disadvantage of the circuit shown above is not being able to tune out stations that one does not wish to hear. Also the amplitude of the oscillations is much diminished by the high resistance of the detector and telephones. The principal resistance is that of the detector.

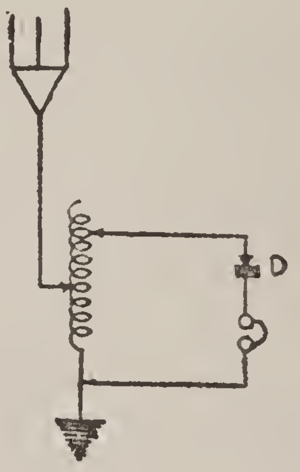


FIG. 29. Simple coupled receiving set.

To avoid the difficulties attendant upon the presence of the detector in the antenna circuit, it is customary to place the detector in a separate circuit coupled to the antenna; or in other words, that the detecting instruments are placed in shunt to the tuning coil. For instance, Fig. 29 is an improvement and requires no more apparatus than that previously described, except that the tuning coil has two adjustable connections instead of one. Oscillations now take place freely between antenna and ground. Two telephone receivers are shown, connected in series, one for each ear.

A further improvement, as regards selectivity,

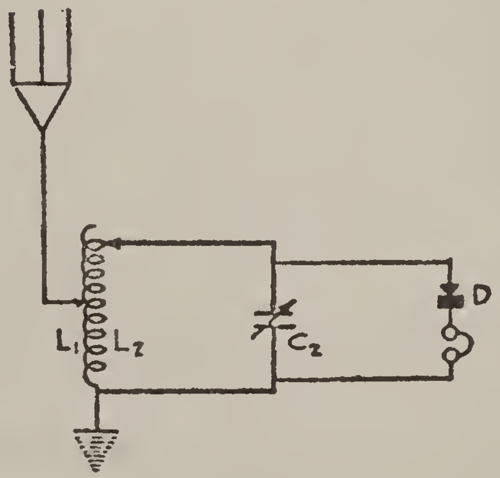


Fig. 30. Direct coupled receiving set.

that is, elimination of undesirable signals, is shown in Fig. 30_3, where a variable condenser has been added, C_2. This is called the direct coupled connection. The antenna circuit is called the primary or open circuit and consists of the inductance and capacitance of that circuit. The secondary in L_2 and C_2, known as the closed circuit. In the same manner in which the transmitting antenna circuit is a good radiator of power, so is the receiving antenna a good absorber. It is tuned to resonance with the incoming wave by adjustment of the inductance L_1. The power is given over magnetically to the secondary, which is tuned to resonance by adjustments to L_2 and C_2. Comparatively large oscillations result in the secondary, producing voltages across the condenser which are detected by the crystal and telephone, and which are not in either oscillating circuit, but shunted across the condenser of the secondary. The oscillations are not damped thereby and sharp tuning is obtained.

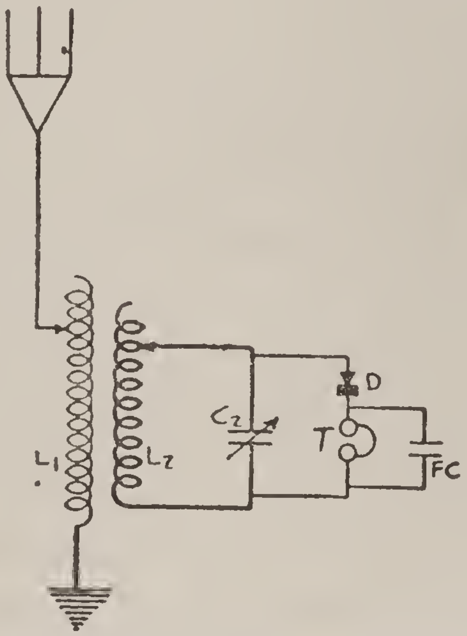


FIG. 31. Inductively coupled receiving circuit.

Inductively Coupled Tuners.—Hitherto, we have dealt with the simplest circuits possible for receiving damped or spark radio signals, circuits employing the least amount of apparatus and fewest adjustments. In Fig. 31 is shown an inductively coupled receiving set, which may be said to be the standard set of modern practice, and the one upon which all later changes are based. A fixed condenser (F.C.) of about 0.005 microfarads is shunted around the telephone and this increases the strength of the signals. Its action is explained as follows: Suppose the principal current flows downward through the detector (D) and telephone (T). While the current flows, the fixed condenser (F.C.) is charged with top plate positive. When the reversal of the radio oscillations comes, the current through detector and telephones ceases. Then the condenser discharges down through the telephones and tends to maintain the current till the next oscillation downward through the instruments. In this way, the gaps between the successive pulsations of rectified current are filled in, and the cumulative effect of a wave group is strengthened. In practice the telephone cord, containing as it does two conductors separated by rubber, cotton and silk dielectric, forms a condenser which in many cases is sufficient so that an added fixed condenser gives no improvement.

The connection in this set is similar in its action with the direct coupled arrangement above described. In either case, on account of the coupling between primary and secondary coils, there are reactions of each coil upon the other, with consequent double oscillations when the coils are near together. It is found, however, that if the resistance of the circuits is low, by varying the coupling, extremely sharp tuning is possible. The

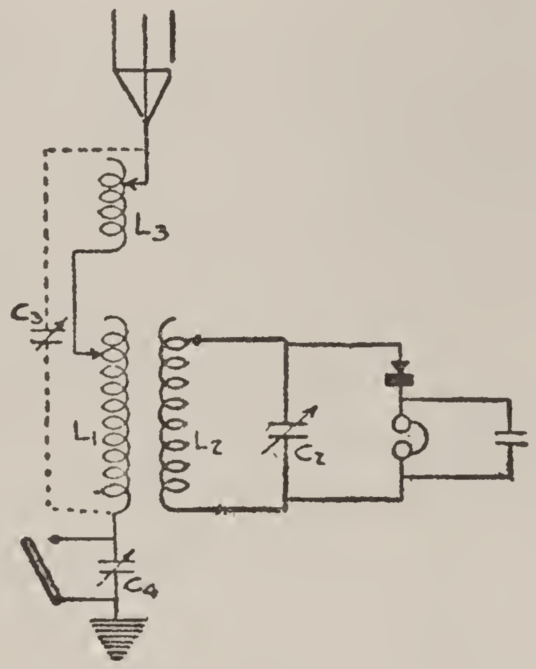


Fig. 32. Receiving circuit for both long and short waves, showing loading inductance and short wave condenser.

antenna is tuned to incoming waves, by changes of the inductance L_1. If very sharp tuning is desired, a variable condenser is shunted around L_1, and fine adjustments are made therewith. The secondary is tuned to the primary, the operations of tuning being done alternately until the telephone gives the best response. In the secondary the coarser tuning is done by changes of the inductance L_2, and the finer tuning with the variable condenser C_2.

For receiving a longer wave in the primary circuit than is possible by using all of the inductance L_2, a series inductance L_3 called a loading coil is added. This is shown in Fig. 32. Also, a variable condenser may be connected as shown at C_3 to increase the wave length and afford fine tuning. The secondary may also be provided with an extra inductance in series with L_2 if needed. For receiving short waves on a large antenna, series condenser C_4 is inserted in the ground wire. It is short circuited when not in use.

In the set described above, a crystal detector or rectifier is used as the detector. The principal disadvantage of this type of detector is that it cannot be depended upon to stay in adjustment. Much time would be spent and annoyance caused if the operator had to search for incoming signals. To obviate this trouble, auxiliary apparatus known as a "buzzer" is incorporated into the set. This arrangement is shown in Fig. 33. By setting the buzzer in action, its notes are heard in the telephones, and by careful adjustment of the detector, when the loudest buzzer signals are heard so will the loudest response be heard from incoming radio signals. This buzzer thus enables one at all times to rapidly ascertain whether the detector is functioning.

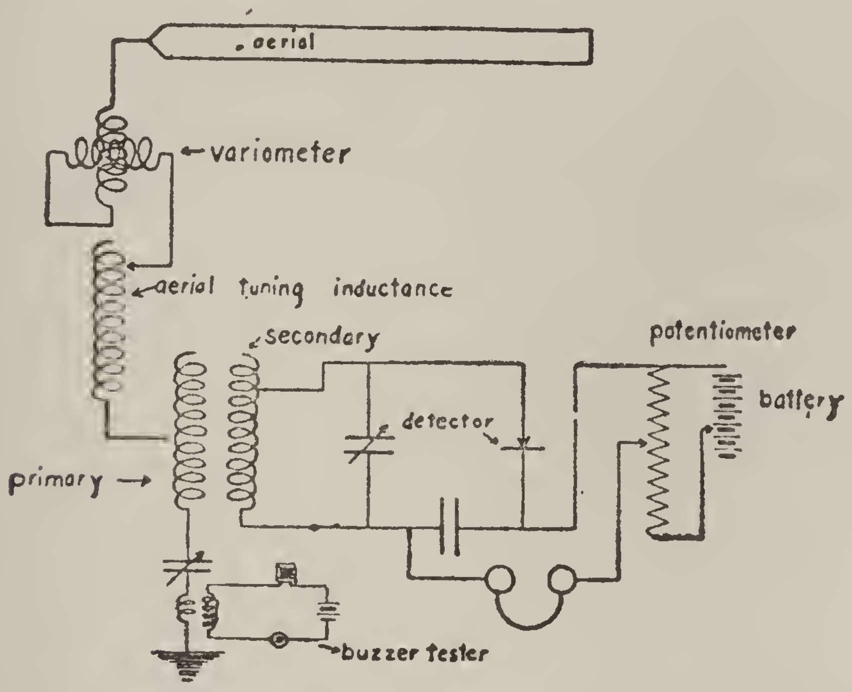


FIG. 33. Inductively coupled set with buzzer testing circuit.

Having dealt with receivers and circuits employing as a detecting device crystal rectifiers, we can turn to circuits utilizing vacuum tubes. These are rapidly replacing in modern apparatus the types we have just discussed.

It will be necessary, however, before entering into the receiving circuits using vacuum tubes to discuss as briefly as possible, the theory of vacuum tubes, or as it is known, the ‘‘electron theory.’’ This will present a clearer understanding of their value in the various uses in which they are employed.

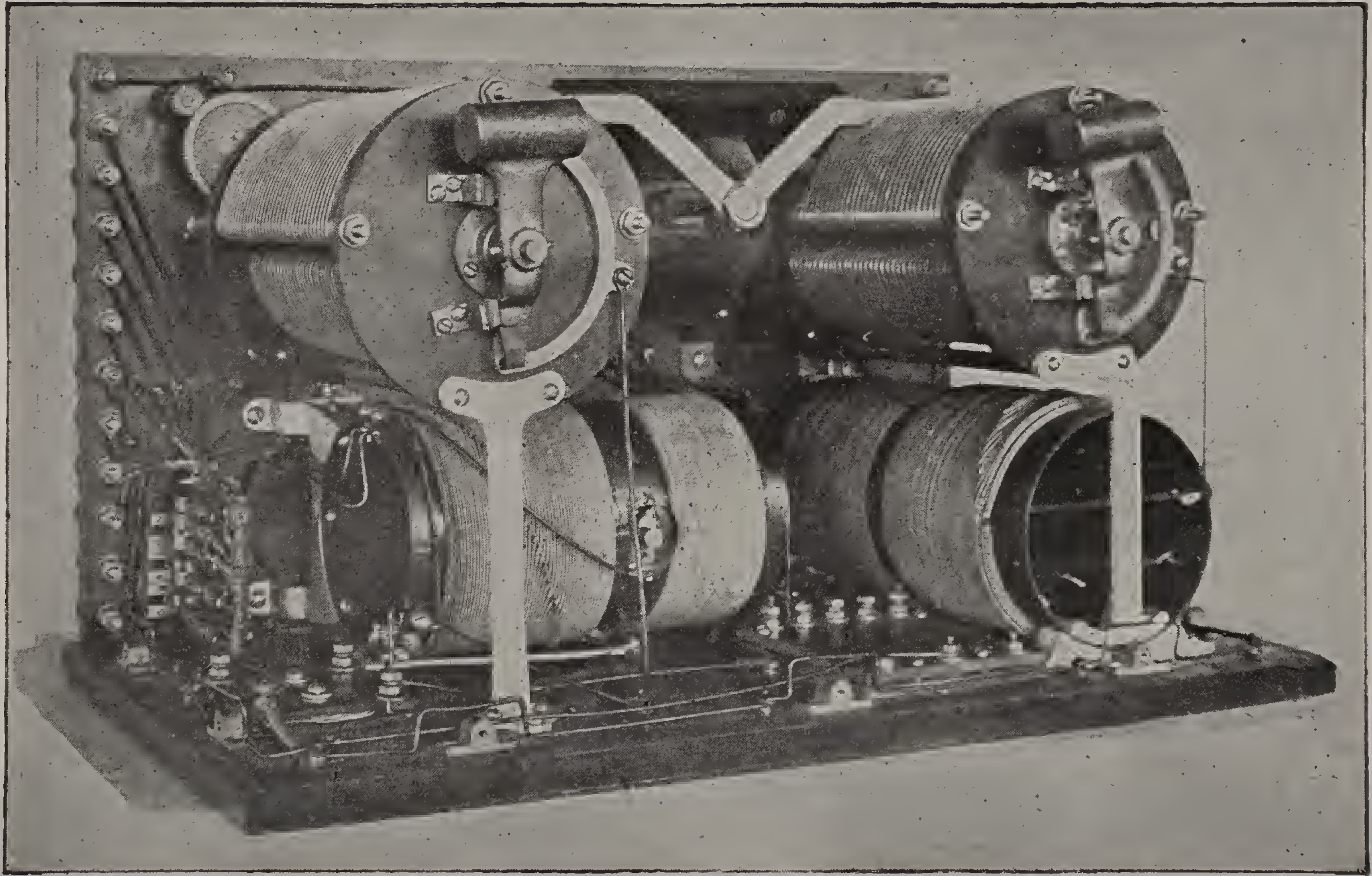


Fig. 35. Rear view of standard receiving apparatus

CHAPTER VII

VACUUM TUBES IN RADIO

The introduction of vacuum tubes, also known as audions, audiotrons, vacuum valves and numerous other technical and trade names, resulted in remarkably great advances in radio communication. Such tubes may be used for many purposes, to generate, to modulate radio oscillations, to detect or rectify, as well as to amplify radio signals, and they are now used in all types of modern equipment. The further development of the tube is rapidly progressing and new applications of its use develop so rapidly that one engaged in radio work must be an assiduous reader to keep in touch with these new developments. Therefore, it is of the utmost importance that the principles underlying the use of vacuum tubes and their operation under the widely different conditions met in actual radio practice, be given careful study.

If two wires are connected to a battery, one to each terminal, the other ends may be brought very close together in air, yet so long as they do not touch, no current flows between them. The two ends may be enclosed in a bulb like an ordinary incandescent lamp, and the air pumped out, leaving a vacuum, and still as long as the ends are separated, no current flows. A common experience will illustrate this. When the filament of an electric lamp breaks, the current stops and the light goes out. But if one of the two wire ends mentioned above, is heated to a bright red, or hotter, it is an interesting fact that a current can be made to flow across the apparently empty space between them.

Call the two ends of wire the "electrodes" of the tube. The current between the hot and cold electrode is made possible by the electrons given off by the hot electrode and is a large enough current to be measured by a sensitive instrument and to have highly important uses in radio communication, as will be shown in the succeeding pages.

The Two-Electrode Vacuum Tube.—The question will perhaps arise as to how a single electrode can be heated when it is inside of a glass bulb. That is simply done by shaping it into a loop and both ends brought through the base of the bulb, in exactly the same manner that the filament of an incandescent lamp is used. These ends are connected to a battery of a few cells, generally giving a voltage of about six volts. The current from this battery heats the loop in a similar manner as the filament of the above mentioned electric lamp. Thus the hot filament becomes one of the electrodes. For the other electrode a little plate of metal is used. A bulb containing a hot and a cold electrode as thus described forms a "two electrode vacuum tube" and was originally designed by Professor J. A. Fleming.

The action of these tubes depends upon the fact that when a metal is heated in a vacuum it gives off electrons into surrounding space. A study of these electrons is important, the reason for this is that all matter contains them. Matter of all kinds is made up of atoms, which are extremely small portions of matter (a drop of water contains billions of them). These atoms in turn contain electrons which consist of negative electricity. The electrons are all alike and are much smaller than the atoms. Besides containing electrons, each atom also contains a certain amount of positive electricity. Normally the positive and negative electricity are just about equal. However, some of the electrons are not held so firmly to the atom, but what they can escape if the atom is violently knocked or jarred. Therefore, when an electron, negatively charged, leaves an atom, there is then less negative electricity than positive in the atom; in this condition the atom is said to be positively charged. The atoms in matter are constantly in motion, and when they strike against one another electrons are jarred from an atom. This electron then moves about freely between the atoms. Heat has an effect upon this process. The higher the temperature, the faster the atoms move and the more electrons given off. It is this action of electrons that is made use of in the vacuum tube.

As the electrons have a negative charge, the charge remaining on the metal is positive, therefore few of the electrons go very far, but are attracted back to the metal, so that there is a kind of balance established between the outgoing and the returning electrons. Now, suppose a battery is connected between the two electrodes, that is, between the hot filament and the plate. This battery is so connected as to make the plate positive with respect to the filament. The electrons, being of negative electricity, would be attracted by the plate and retained, returning no more to the filament. Thus the battery causes a continuous flow of negative electrons from the filament to the plate. In other words, a current of negative electricity is flowing in space between the two electrodes of the tube.

The current ceases when the filament is cold, because no electrons are then escaping from the metal. No current will flow if the battery is wrongly connected, since, when the plate is negative with respect to the filament, the negative charge of the plate will repel the electrons back into the filament.

The distinction between direction of current and direction of electron flow must be carefully noted. It happens that for a great many years the direction from the positive toward the negative terminal has been arbitrarily called the direction of the current. It is now found that these little electrons travel from the negative toward the positive electrode. The direction of current and the direction of the motion of the electrons are therefore opposite.

Ionization.—The foregoing explanation of the action of the flow of current between filament and plate, commonly called the "plate current," in a vacuum tube applies to the case where the vacuum of the bulb is very complete. If there is more than the merest trace of gas remaining in the tube, the operation is more complicated, and a larger current will usually flow with the same applied voltage. This is accounted for in the following manner:

In a rarefied gas, some of the electrons are constituent parts of atoms and some are free. These free electrons move about with great velocity, and if one of them strikes an atom it may dislodge another electron from the atom. Under the action of the emf. between plate and filament, the newly freed electron will acquire velocity in one direction, which will be similar to that of the colliding electron and the positively charged remainder of the atom will move in the opposite direction. Thus both of the parts of the disrupted atom become carriers of electricity and contribute to the flow of current through the gas. This action of a colliding electron upon an atom is called "ionization by collision," and on account of it relatively large plate currents are obtained in vacuum tubes having a poor vacuum. The earlier tubes were of this sort, but modern tubes, as a rule, are made with a better vacua than formerly, so that ionization by collision is responsible for but a small part of the current flow. However, tubes such as those above described are often in demand in radio practice for certain uses and are alluded to as "soft tubes."

In the earlier use of vacuum tubes it would seem an advantage to have ionization by collision, because a larger plate current can be obtained, but there are two difficulties which have proved so great that tubes are now usually made to have only a pure electron flow. One of these difficulties is a rapid deterioration of the filament when a large plate current flows. The positively charged parts of the atoms are driven violently against the negatively charged filament and since they are much more massive than electrons, this bombardment, so to speak, actually seems to wear away the surface of the filament. Another disadvantage of tubes of poor vacuum is that too large a battery voltage may cause a "blue glow" discharge. This action applies more particularly to the efficiency of "three element tube," described below.

The tube described above was the first used in radio practice and after its inventor is called the "Fleming valve." The Fleming valve was originally used as a detector, but has been replaced by the three-element tube discussed below because the latter has proved so much more sensitive, and as previously described, can be utilized for a variety of purposes.

However, before proceeding to the modern vacuum tube, it is well to consider that types of two-electrode tubes are most useful in another field of electrical work. One type, known as the "Kenetron," developed by the General Electric Company, has a higher vacuum than the Fleming valve and is made in larger dimensions. It is used as a rectifier of currents of high voltage, but low frequency. It changes alternating current into a pulsating current all in one direction. Small currents, well below one ampere, are rectified by these tubes, and power up to several kilowatts can be handled even if the applied voltage exceeds 25,000.

Another type, known as a "Tungar rectifier" is utilized for charging storage batteries from a 110 volt alternating current circuit. This type contains rarefied argon gas and relatively large currents are produced mainly through ionization by collision, in the manner before described.

The Three-Electrode Vacuum Tube.—A great improvement upon a two-electrode tube for radio purposes, consists in the addition of a third electrode or element, inside the tube in the form of a metallic gauze, or, as it is known, "grid." This grid consists of an electrode of fine wires between the filament and the plate of the vacuum tube. This makes it possible to increase or decrease the current between plate and filament through wide limits. In order to understand how this result is obtained, it will be necessary to first consider what happens in a two-electrode tube having a good vacuum, when either the voltage of the "B" battery or the temperature of the filament is varied.

Suppose that the filament temperature is kept constant, then a definite number of electrons will be sent out per second. The number of electrons that travel across the tube and reach the plate per second determines the magnitude of the current through the plate circuit. The number of electrons that reach the plate increases as the voltage of the "B" battery increases. If this voltage is continuously increased, a value will be reached at which all the electrons sent out from the filament will arrive at the plate, therefore we arrive at what is termed the "saturation" current, as no further increase of the electron flow can be obtained by increasing the voltage.

Suppose now that the voltage of the "B" battery is kept a constant value, and the filament temperature gradually raised by increasing the current from the heating battery, known also as the "A" battery. The number of electrons sent out will continue to increase as the temperature rises. The electric field intensity, due to the presence of negative electrons in the space between the filament and plate, may at last equal and neutralize that due to the positive potential of the plate so that there is no force acting on the electrons near the filament. This effect of the electrons in the space is called the "space charge effect." It must not be supposed that the space charge effect is caused by the same electrons all the time. Electrons near the plate are constantly entering it, but new electrons emitted by the filament are entering the space, so that the total number between filament and plate remains constant at a given temperature. After the temperature of the filament has reached the point where the effect of the electrons present in the space between filament and plate neutralizes the effect of the plate voltage, any further increase of the filament temperature is unable to cause an increase in the current. The tendency of the filament to emit more electrons per second because of the increased temperature, is offset by the increase in space charge effect, which would result if electrons were emitted more rapidly; or, to put it more exactly, for any extra electrons emitted, an equal number of those in the space are repelled back into the filament.

Thus, whether the "A" battery is kept at a constant value and the "B" battery varied, or *vice versa,* in either case we find that the electron flow or plate current can only rise to certain value.

In the three-electrode tube, by inserting a grid between the filament and the plate, as stated before, in the form of several small wires, the grid is placed in the path of the stream of electrons which constitute the plate current. When this grid is charged positively, the space charge will be neutralized, as it is of a negative character and thus a greater plate current will result. Also, if the grid be charged negatively, the space charge will be increased, and a greater number of electrons driven back to the filament, with a lessening of the plate current. Thus it will be seen that the value of the plate current can be controlled by means of the third element or grid in the vacuum tube. This control is accomplished in a variety of ways, depending upon the use for which a given set is designed, also, upon the characteristics of the particular vacuum tube used. Various tubes have a variance of characteristics.

Circuits that may be utilized in the employment of the vacuum tube, showing various methods of vacuum tube control are to be found in the following pages.

As a Damped Detector.—We shall first take a simple detector circuit and an explanation of its action. In order to understand how a vacuum tube acts when used as a detector, consider the circuit shown in Fig. 36. Suppose the receiving antenna picks up a signal. Oscillations in the tuned circuit L C, are set up, because L is inductively coupled to the antenna circuit. The radio frequency alternating voltage between the terminals of L is impressed between the filament and grid, and brings about changes in the plate circuit. On the average the plate current is in-

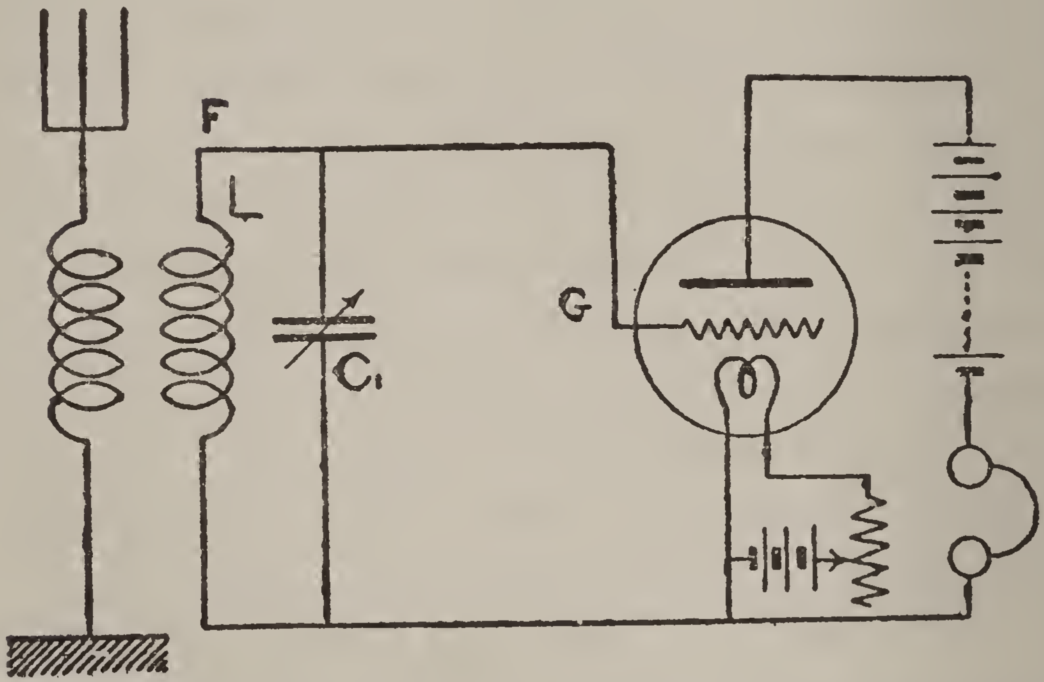


Fig. 36. Connections for using vacuum tube as a simple detector.

creased while the signal is passing. The frequency of the wave trains should be within the range of audible sound, preferably between 300 and 2,000, because the telephone inductance smooths out each train of high frequency oscillations into a single pulse and the pulse frequency must, therefore, be within the audible range in order that signals may be heard.

In some cases it may be necessary to use a "C" battery between points f and g in Fig. 36 in order to bring the plate current to a correct value. This, however, does not change the action; the variations of the plate current are brought about by the alternating emf. between the terminals of coil L just the same as when the C battery is absent.

If the grid battery voltage is adjusted so that the plate current has a value near the upper bend of the plate current-grid voltage curve instead of the lower bend, the action will be essentially the same, but the effect of the arrival of a wave train will be to decrease momentarily the plate current instead of to increase it. As before, there will be fluctuations of the plate current keeping time with the arrival of train waves, and a sound in the telephone of a pitch corresponding to the number of wave trains per second.

Care must be taken in the use of receiving tubes that the B battery voltage is never high enough to cause a visible "blue glow." The tube becomes very erratic in behavior when in this condition, and is very uncertain and not sensitive as a receiver. This is because the plate current becomes so large that it is unaffected by variations of the grid voltage. Furthermore, the tube gets hot and its safety is endangered by the blue glow discharge.

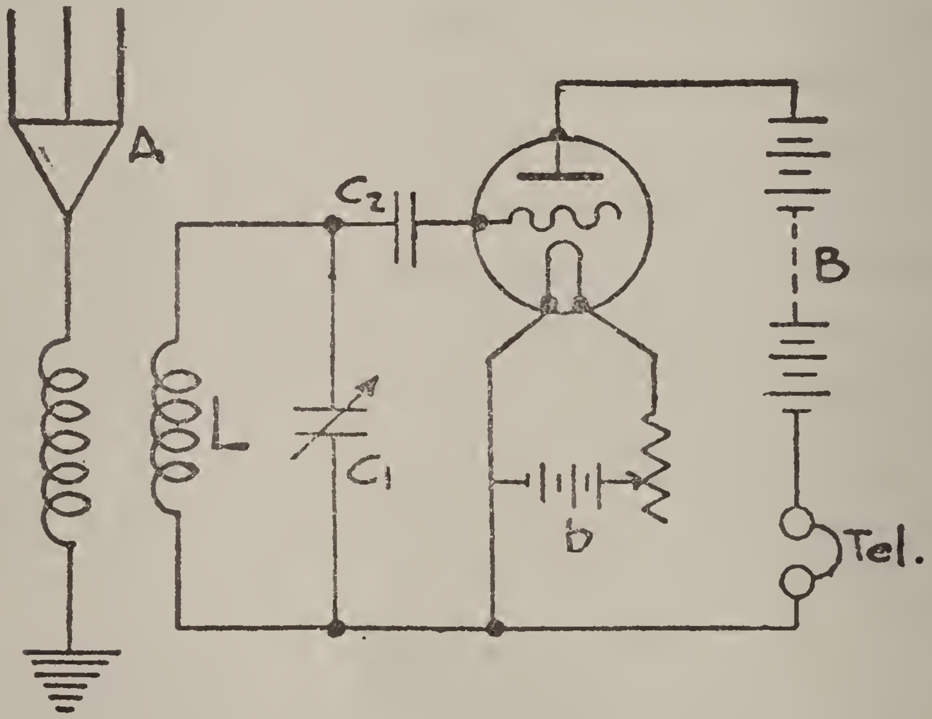


FIG. 37. Vacuum tube as detector of undamped waves. Condenser in grid circuit.

If the circuit shown in Fig. 37 is used, having

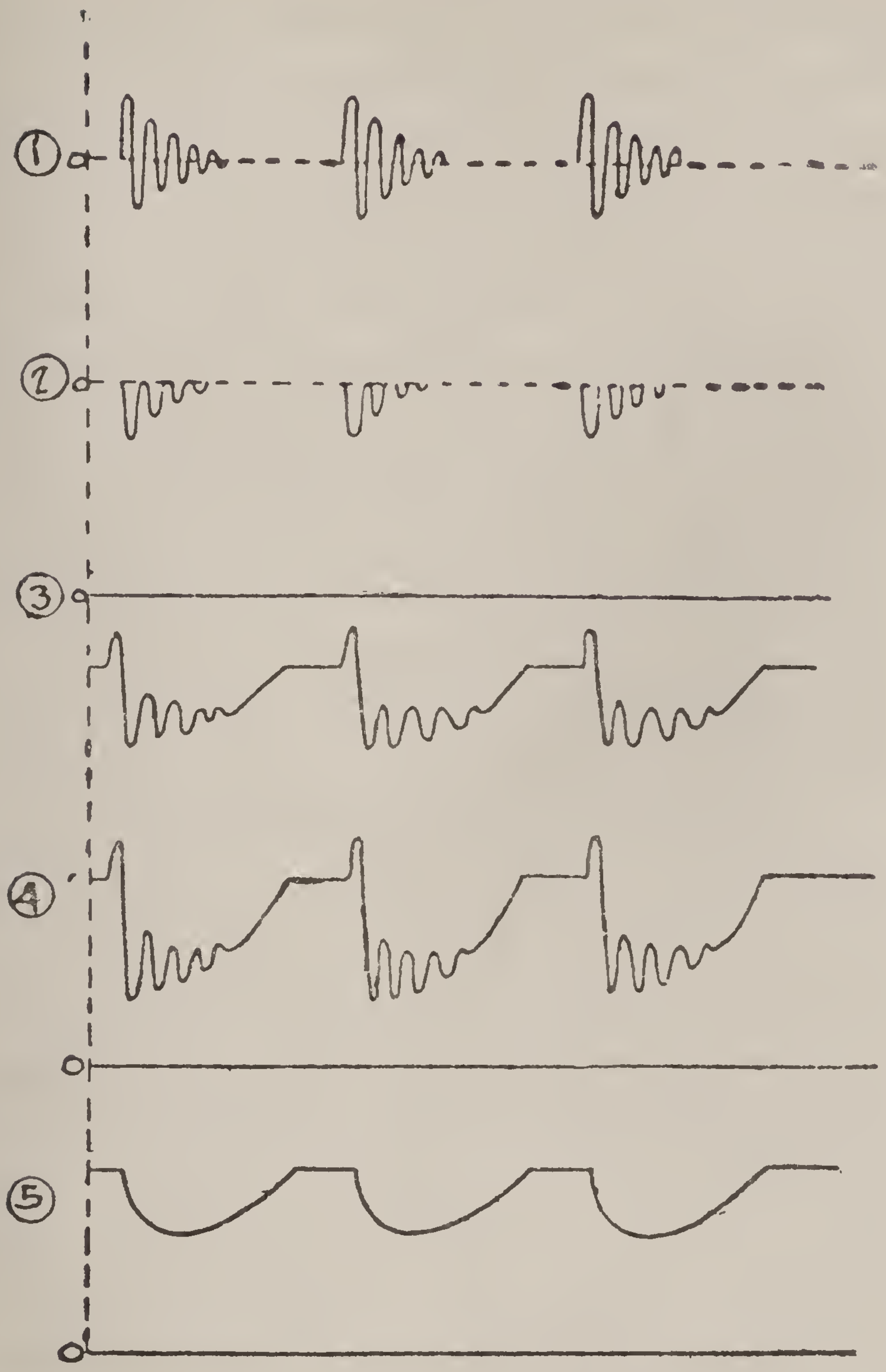


Fig. 38. Reception with grid condenser in circuit. (1) Incoming oscillations, (2) grid current, (3) grid potential, (4) plate current, (5) current in phones.

a condenser in series with the grid, the action of the tube as a detector is different. When the grid voltage is the same as that of the filament and there are no oscillations, the grid current is zero; that is, no electrons are passing from the filament to the grid. Now suppose that a series of wave trains falls upon the antenna of Fig. 37, as shown in (1) of Fig. 38. If the circuit LC. is tuned to the same wave length as the antenna circuit, oscillations will be set up in it, and similar voltage oscillations will be communicated to the grid by means of the stopping condenser C_2 (A suitable capacity value for this condenser would be 0.0001 mfd). Each time the grid becomes positive, electrons will flow to it, but during the negative half of each oscillation no appreciable grid current will flow. This is shown in curve (2) of Fig. 38. Thus during each wave train the grid will continue gaining negative charge and its average potential will fall as shown in (3) of the same figure. This negative charge on the grid opposes the flow of electrons from filament to plate, causing on the whole, a decrease in the plate current. At the end of each wave train this charge leaks off through either the condenser or the walls of the tube (or both) and the plate current rises again to its normal value as shown in (4) of the same figure. This should happen before the next wave train comes along, but sometimes the leak is not fast enough for the discharge to take place. In this case a better result is secured if a resistance of a megohm or so is shunted across the condenser. Such a resistance is called a grid leak.

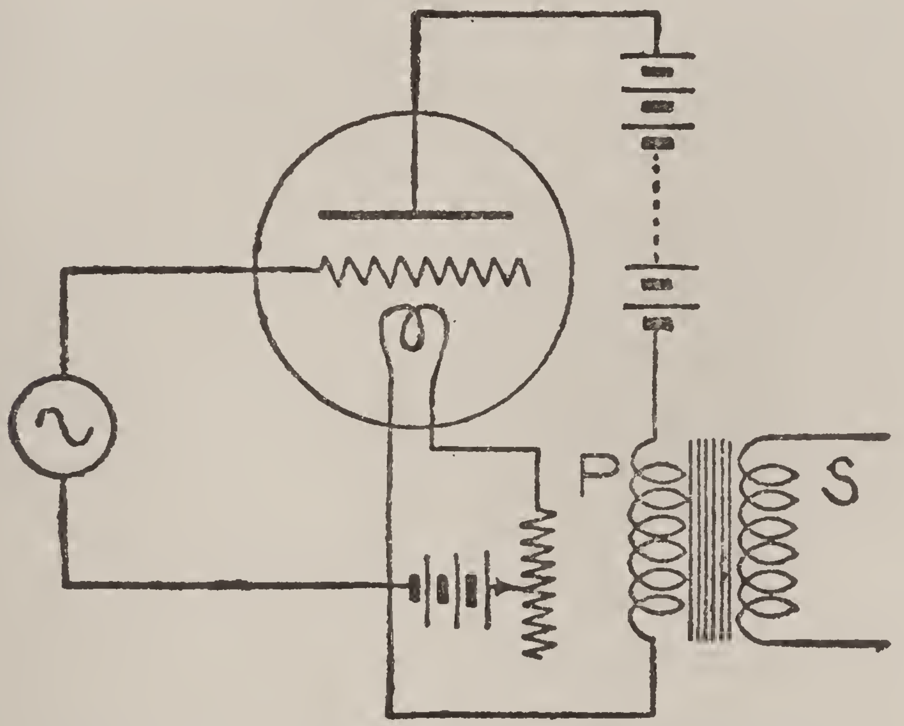


Fig. 39. Vacuum tube as an amplifier.

The telephone diaphragm cannot vibrate at radio frequency, but the high inductance of its coils smooths out the plate current variations into some such form as shown in (5) in Fig. 38. Thus as in the case of the circuit in Fig. 37, the note heard in the telephone corresponds in pitch with the frequency of the wave trains. To receive undamped waves which are not divided up into groups of audible frequency, vacuum tubes may be used in special ways called the heterodyne and autodyne methods, which are explained later in this chapter.

The Vacuum Tube As An Amplifier.—If, as in Fig. 39, a source of alternating emf. were interposed between the filament and grid of an audion the potential of grid with respect to the filament would alternate in accordance with the alternations of the generator. These variations of the grid potential produce changes in the plate

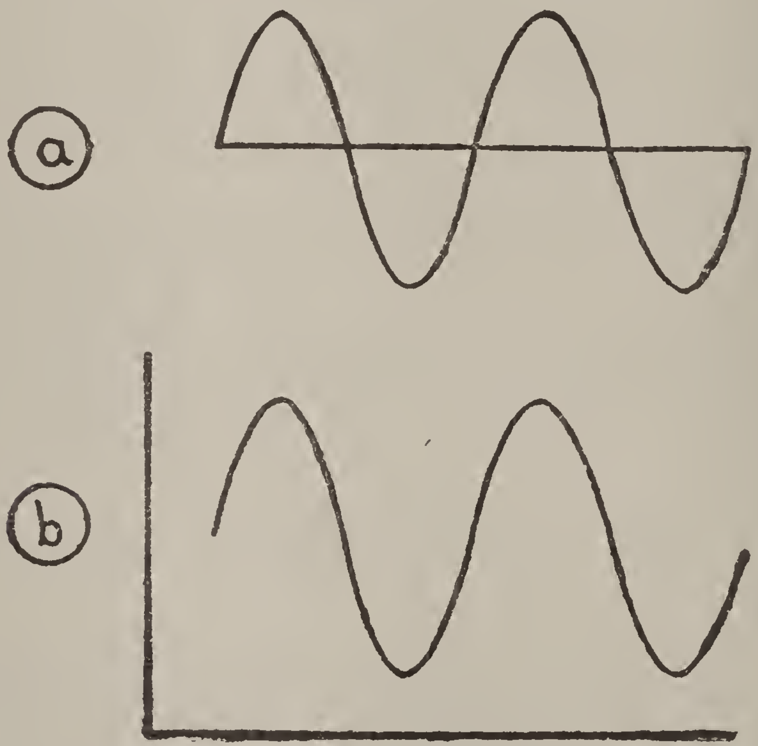


Fig. 40. Variations of plate current with grid voltage.

current corresponding to the plate characteristic. If the mean potential of the grid and the amplitude of its alternations are such that the plate current is always in that portion of its characteristic where it is a straight line, then the alternations of the grid potential will be exactly duplicated in the variations of the plate current and the latter will be in phase with the former, at least in a high vacuum tube. Thus, if (a) of Fig. 40 represents the alternating potential of the grid, then (b) would represent the fluctuations of the plate current. For a given amplitude in (a) the amplitude of the alternating component in (b) will depend upon the steepness of the plate characteristic, increasing with increasing slope. The alternator in the grid lead supplies only the very small grid filament current, thus the power drawn from it is extremely small. The power represented by the alternating component of the plate current is, however, considerable; thus there is very large power amplification. This larger source of power might be utilized by inserting the primary P of a transformer in the plate circuit, as in Fig. 39, in which case the alternating component above would be present in the secondary S. This illustrates the principle of a vacuum tube as a relay. The voltage in S might again be inserted in the grid lead of a second vacuum tube and with proper design a further amplification obtained in the second tube. This may be carried through further stages and illustrates the principle of multiple amplification.

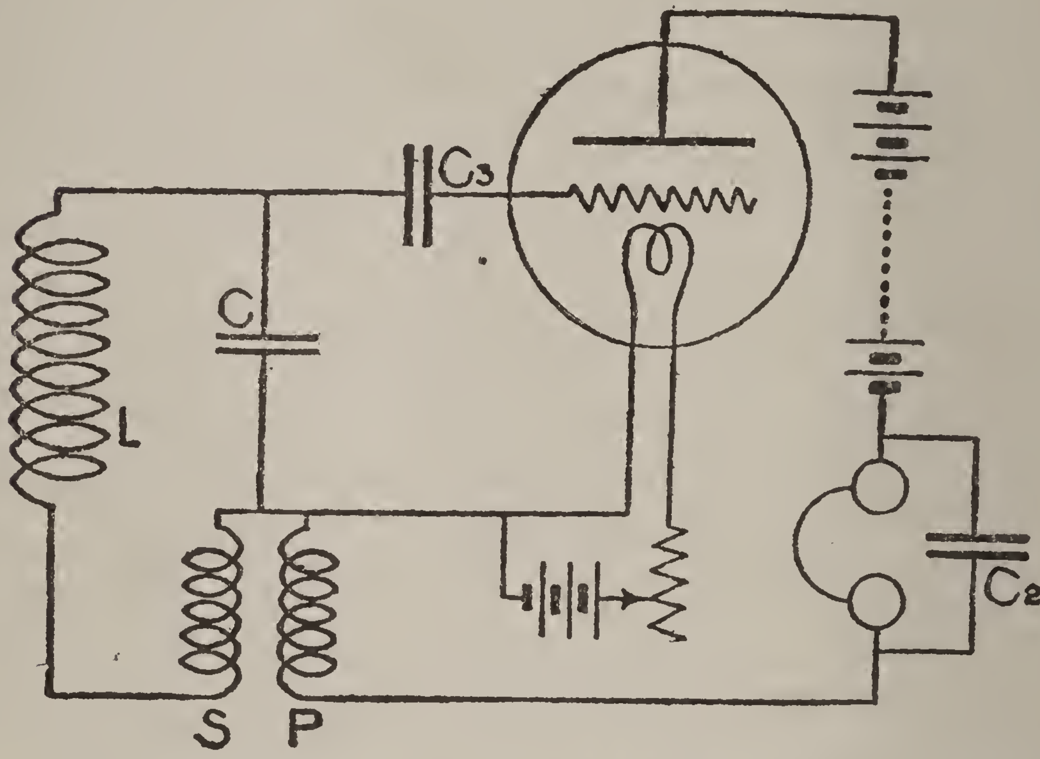


FIG. 41. Use of vacuum tubes as a regenerative amplifier (feed back circuit).

Regenerative Amplification.—It has been shown by Mr. E. H. Armstrong, that amplification similar to that obtained with several stages may be secured with a single tube. Instead of feeding the voltage of the secondary coil S into the grid circuit of a second tube it is fed back into the grid circuit of the same tube so as to increase the voltage operating upon the grid. This results in an increased amplitude of the plate current alternations, which likewise being fed back into the grid circuit increases the voltage operating upon the grid, etc.

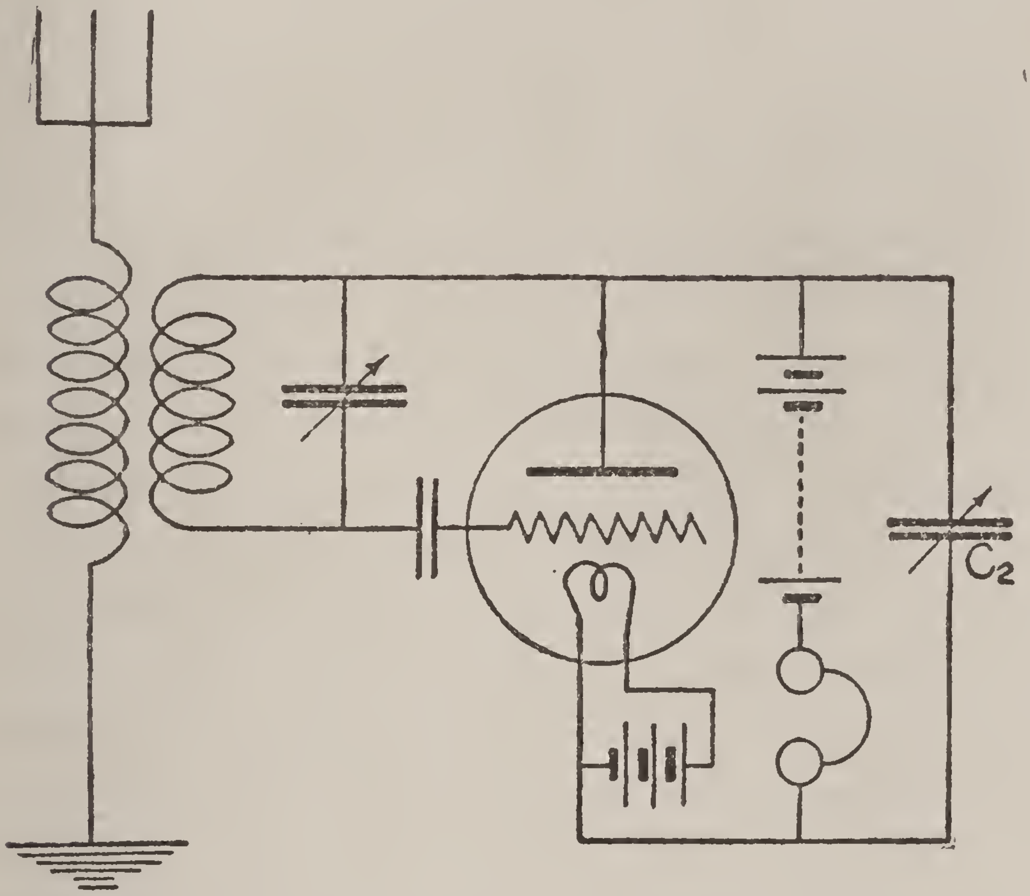


FIG. 42. Circuit for use of vacuum tube for reception of undamped waves.

One form of the so-called feed-back circuit for rectifying and amplifying damped oscillations is shown in Fig. 41. The operation of the circuit, used as a receiving device, is the same as that described above for the case of a condenser in the grid leak. The condenser C_2 is merely to provide a path of low impedance across the phones for high frequency oscillations. The coils P and S constitute the feed back by means of which the oscillations in the tuned circuit are reinforced. The mutual inductance between S and P must be of the proper sign, so that the emf. feed back aids the oscillations instead of opposing them.

Reception of Undamped Waves.—In Fig. 42 is shown the connections for the reception of undamped waves. This circuit was used by Dr. Lee DeForrest, the inventor of the three electrode vacuum tube, which he called an audion. He termed this circuit the "ultraudion." The oscillatory circuit is connected between the grid and the plate with a condenser in the grid lead. The variable condenser C_2 shunted across the plate battery and phones is important in the production of oscillations; in general, its value cannot be increased beyond a certain point without stopping the oscillations.

By this beat method high sensitiveness and selectivity are attained in receiving. Interference is minimized because even slight differences in frequency of the waves from other sources result in notes either of different pitch or completely inaudible.

Heterodyne and Autodyne Reception.—If two tuning forks mounted on resonance boxes, one vibrating 256 and the other 260 times per second are sounding together, a listener a short distance away will hear a sound alternately swelling out and dying away four times per second. These tone variations are called "beats." Similarly if two sources of undamped electrical oscillations act simultaneously upon the same circuit, one of a frequency of 500,000 and the other of 501,000, the amplitude of the combined oscillation will successively rise to a maximum and fall to a minimum 1,000 times per second. If rectified by a vacuum tube (or a crystal) their variations will produce an audible note of frequency 1,000 per second in a suitable telephone receiver. If one of the two oscillations is the received signal in the antenna and the other is generated by a circuit in the receiving station, we have "heterodyne" or "beat reception." In the receiving telephone a musical note is heard, the pitch of which is readily varied by slight variation of tuning of the local generating circuit.

If a regenerative circuit similar to that of Fig. 41 is used (L being coupled to the antenna), the same tube may be used as a detector and as a generator of local oscillations. This is called the "autodyne" reception. The procedure is to tune the antenna circuit to the incoming signals and adjust the local oscillating circuit so that it is slightly out of tune with these incoming signals. Thus beats of audible frequency are produced.

By these methods of reception very faint signals can be received. Also interference from other stations is reduced to a minimum, because a slight difference in frequency of the interfering signal would give a note of an entirely different pitch, or even inaudible. For instance, if the local oscillation had a frequency of 500,000 the received oscillation 501,000 and the interfering oscillation 502,000, the interfering note would have a frequency of 2,000, or be a whole octave higher in pitch than the received note. If the interfering source had a frequency of 530,000, its beat tone would be so high as to be entirely inaudible.

CHAPTER VIII

RADIO TELEPHONY

THE principles of radio telephony are the same as those of radio telegraphy by undamped waves except that the sending key is replaced by apparatus which varies the sending current in accordance with the sound waves produced by the voice. A wave of radio frequency is sent out by the antenna, the intensity of which varies with the frequency of the voice sound waves. The sound waves have a frequency much lower than the radio frequency, so that each sound wave lasts over a considerable number of radio alternations, as in the lower curve of Fig. 43. The radio wave is

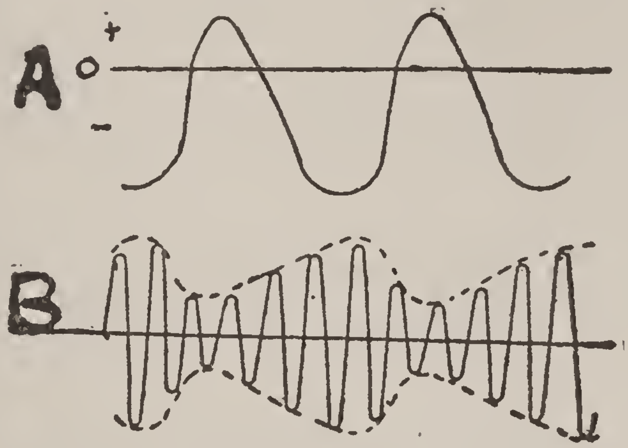


FIG. 43. Voice modulations of antenna oscillations. A, fluctuations in grid voltage. B, varying amplitude of oscillations.

thus transmitted in pulses, and is received on any ordinary apparatus used for receiving damped wave radio telegraph signals, such as previously described.

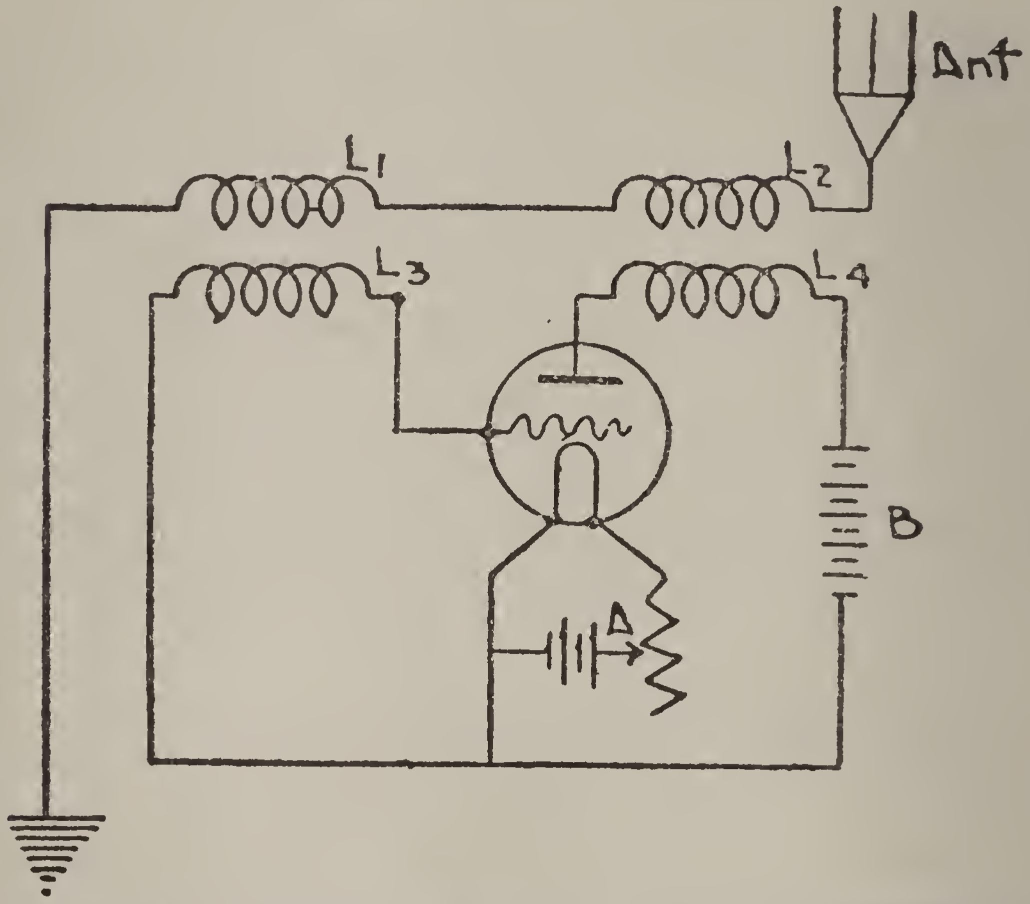


Fig. 44. Circuit for vacuum tubes as a generator of undamped waves.

The power involved in the sound waves generated in ordinary speech is relatively very small, yet this must be made to control a kilowatt or more of radio frequency power in long distance radio telephony. The effect of the sound waves must therefore be amplified. The way in which the audio frequency is made to control the amplitude of the radio oscillation will now be explained.

Suppose a generator of radio oscillations is

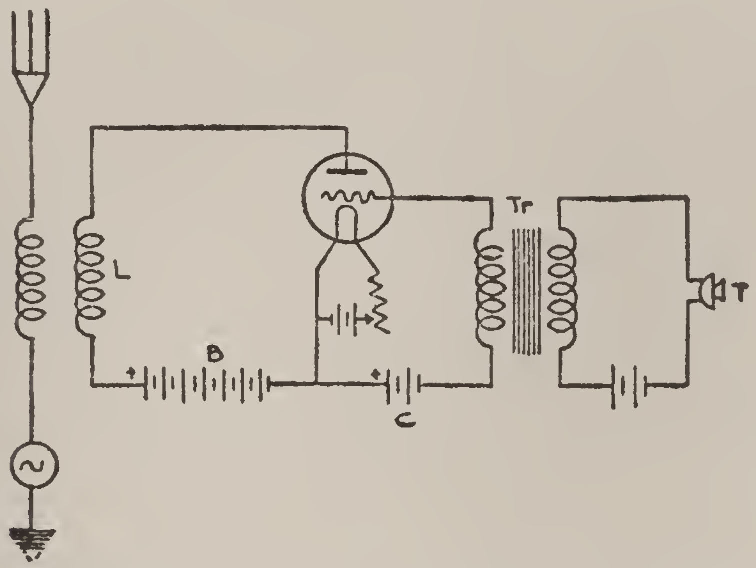


FIG. 45. Control of antenna current in radio telephony by vacuum tube modulator.

placed in series with the antenna, as in Fig. 44. Various types of arc, quenched spark, timed spark, high frequency alternators, and vacuum tube oscillators have all been used as sources with more or less success. The controlling device is usually the combination of a telephone transmitter with an arrangement of vacuum tube circuits, as shown in Fig. 45. The plate circuit of the vacuum tube is inductively coupled to the antenna by the coil L. The grid of the tube is kept at a negative voltage by battery C. The current through the antenna coil induces potential differences between filament and plate, but this produces only very slight changes in plate current on account of the large negative voltage of the grid. Now suppose voltage variations of audio frequency are impressed on the grid by means of the telephone transmitter T and the transformer Tr. As the grid becomes less negative, or even somewhat positive, the rectified plate current increases, absorbing power from the antenna and diminishing the amplitude of the antenna oscillations. The high frequency oscillations in the antenna therefore show variations in amplitude which keep time with the audio frequency variations of voltage in the grid circuit, diminution of antenna current corresponding with increasing positive potential of grid. These variations are illustrated in Fig. 43. In the upper part of the figure the fluctuations of grid voltage due to the telephone transmitter appear; in the lower part of the figure are shown the resulting variations in the amplitude of the high frequency oscillations in the radiating antenna.

The audio frequency variations of amplitude in the radio frequency wave will be reproduced in the antenna of the receiving station, and these will be rectified in the receiving circuit, giving in the telephone receivers audio frequency variations of current, corresponding in frequency and wave form to the boundary of the curve in the lower part of Fig. 43 (as shown on dotted line).

CHAPTER IX

ANTENNAE

THE antenna is used in radio communication for two purposes: (1) to radiate electric waves, and (2) to absorb or detect the electric waves which come to it. An antenna consists essentially of one or more wires, suspended at some elevation above the earth. When electric waves reach an antenna, they set up an alternating emf. between the wires and the ground. As a result of this electromotive force (emf.), an alternating current will flow in the antenna wires. The energy of the current is absorbed from the passing wave, just as some of the energy of a water wave, is used up in causing vibrations in a slender reed which stands in its way.

A receiving antenna needs to be large, in order to gather in enough energy from the passing waves to effect the receiving apparatus. Likewise a transmitting antenna should be as large as practicable in order to send waves to a greater distance. However, several conditions govern the size of the transmitting aerial, just, for instance, as the size of the heat radiators in an apartment are governed by the amount of heat available to be radiated. The same antenna may be used for both receiving and transmitting, in such cases a change-over or antenna switch is provided in the set to change from reception to transmission, and *vice versa.* An antenna used for receiving only, may, however, be made simpler than one which is also required for sending purposes, as it is obvious, with the absence of the high potential emitted by a transmitter, that the insulation need not be so heavy.

In practice, stranded wire is used for an antenna. High frequency currents with a high potential travel over the surface of a wire, therefore, a stranded wire offers a large surface. It has another advantage, in the event of a strain being placed upon the antenna, one or more of the strands may part, but the remainder will keep the antenna in commission.

As discussed in the chapter dealing with conductors, copper is the best conductor, but for several reasons, it has been discovered that pure copper is not as practicable as some alloys, therefore, in almost universal radio practice, silicon bronze or phospher-bronze are used. The standard gauges are usually 7-22 or 7-19. In other words seven strands of number 22 or number 19 wire.

All joints in an antenna must be soldered, or a suitable patent joint used, such as that called a "MacIntyre" splice. If joints are soldered, care must be taken that too much heat is not employed, otherwise the wiring at the joint becomes tempered and very brittle and is liable to break when any strain or jar is met with.

The insulation of an antenna is of the utmost importance, especially in damp foggy climates. For damped apparatus using moderate power, an insulator known as "Electrose" is very suitable and is manufactured in a very large variety which meets all demands. For undamped or continuous wave radio, and for high potentials, porcelain is possibly the best insulator; these are also made in a great variety and can be readily obtained for any purpose. Not only should the actual antenna receive great care in its insulation, but the guy wires of masts or towers should also be insulated with strain insulators. If they are lengthy several strain insulators should be employed, inserted in series with the guy at suitable intervals.

Types of Antennae.—Early in the history of radio, Marconi demonstrated that radiation from an antenna was directional in its effect, according to the shape of the aerial employed. It was this discovery which led in later years to the wonderful success of the direction finder or radio compass.

It is well known, that a single vertical wire is, for its size the best radiator, but it has to be made so extremely long in order to obtain sufficient capacity that it is not a practical antenna for long wave or long distance work. Antenna of different numbers of horizontal or inclined wires are therefore used, and are very practicable and radiate very well. It must be remembered that an antenna is merely a large condenser and may have various shapes consistent with this condition, although some forms will radiate much better than others.

Antennæ that radiate more energy in one direction than in the opposite, are termed ''directional,'' while an antenna radiating equally in all directions, is called ''uni-directional.''

The following types of antennae are the most common in practical use, and are easier to erect under conditions that confront the average experimenter. They are shown in Fig. 46.

What may be considered as the standard form of antenna for ship stations, and also for low powered land stations, is known as the T or inverted L type of aerial. This is an antenna of horizontal wires, usually two or four in number,

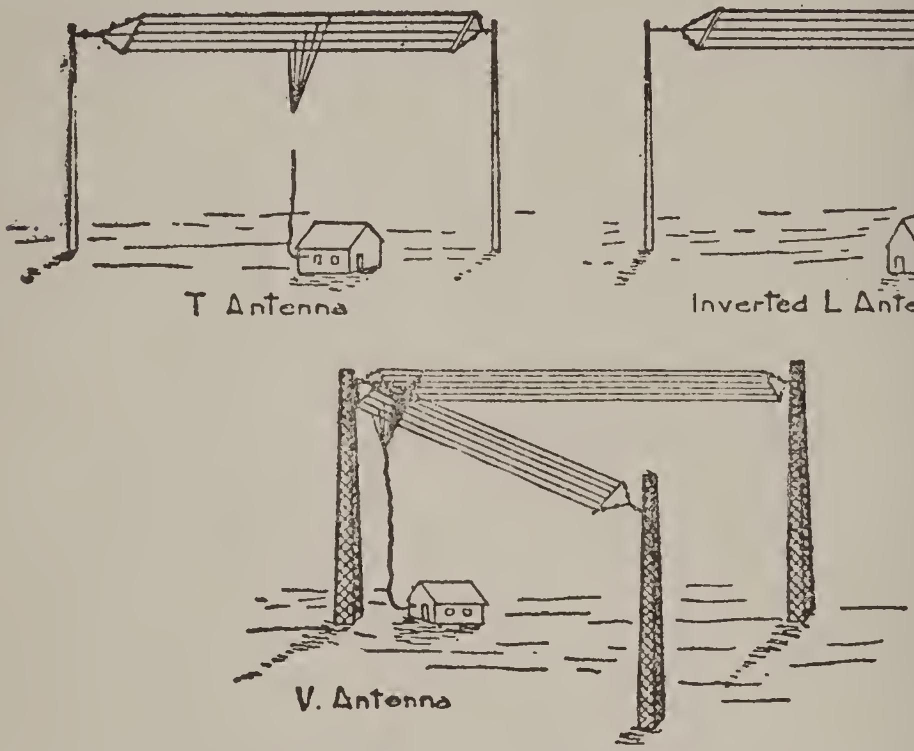


Fig. 46. Typical antennæ.

separated at equal distance on what is termed a spreader, and supported between two masts or towers.

Whether the down leading-in wires are taken from the center or at the end of the horizontal portion determines whether the antenna is of the T or inverted L type.

Another very practicable type for certain work is the V antenna, consisting of two sets of horizontal wires supported by three masts or towers, so that the horizontal portions form an angle or V.

The directional effect of an inverted L or V type, is greater than a T. There is a greater amount of energy sent in the direction in which the angle of the L points than in the opposite. With the T type the effect is more unidirectional, although more energy is sent in the parallel direction of the horizontal wires, than at right angles. The resultant wave would be oval in shape.

A more recent development in this field is what is known as the loop antenna. This consists of a coil frame constructed by fastening four wooden struts together in the form of a triangle, the apex of which fits into a wide slot in a center fastening, usually in the form of a casting. Four of these are provided and converge into the center casting, where they are held by bolts. This provides a square frame over which many coils of wire are wound. The two ends of the wire are brought in as leads. This loop is mounted on a shaft enabling the loop to be rotated in all directions, and the antenna thus cuts any lines of force desired. This is the type used for radio compasses.

Current and Voltage Distribution.—When an electromotive force is introduced into an antenna, a charging current flows in the wires. If we attempt to form a picture of this process in the wire antenna, we must remember that every inch of the wire forms a little condenser, with the earth acting as the other plate. The antenna is said to have a distributed capacity. As electricity flows from the bottom of the antenna, some of it accumulates on each portion of the wire, causing a displacement current to earth through the dielectric. The current in the wire accordingly diminishes as the free end of the antenna is approached, and becomes zero at the end. The current is evidently different at different parts of the antenna, being zero at the free end and a maximum where the antenna is connected to the ground. This is in marked contrast to the case of direct current, which always has the same value at every point of the current. The difference here is brought about by the very high frequency of the currents.

The voltage of the antenna, on the contrary, is zero at the grounded end and has a maximum value at the free end. In fact, the latter is the point where the most intense sparks can be drawn off; therefore, the insulation of the antenna from nearby objects and the earth must be particularly good at this point.

A large capacity to earth, concentrated at any point of the antenna, causes a large change in the current at that part of the antenna. If this bunched capacitance is located at the top of the antenna, such as is the case with a flat topped antenna of long wires, with only a few vertical lead-in wires, the average current in the flat top portion will be large, and it increases slightly in strength as the charges pass down through the lead-in wire (picking up the changes there), hence, giving a large current through the receiving apparatus. It is a distinct advantage to have as large a part of the total capacity of the antenna as possible at the top.

Grounds and Counterpoises. — The ground connections of some stations are often very elaborate affairs, a considerable number of copper plates or heavy wires, arranged radially from the foot of the antenna, being buried in moist earth. In general, the endeavor is made to insure a considerable area of conducting material in contact with the moist earth.

As the average experimenter probably is established in a house or apartment house, such an arrangement is not always feasible; therefore, he must cast about for the most convenient means of ground. If the building is of steel frame construction a connection to the steel makes a desirable ground, care being taken to see that a good solid connection is made. Otherwise a connection to the water supply piping is the best method of grounding. Gas and radiator piping should be avoided.

Too much emphasis cannot be laid upon the necessity of making the leads from the apparatus to the ground as short as possible, care being taken to have the lead with as large a surface as possible. For this purpose stranded flexible wire, or a broad strip of copper is desirable. A long thin wire offers high resistance, decreasing the received signals and decreasing the radiation of a transmitter.

CHAPTER X

DEFINITIONS

The following are brief definitions of electrical terms and explanations of various instruments used in radio telegraphy and telephony.

Many of these definitions are from the result of the work of the standardization committee of the Institute of Radio Engineers.

Absorbtion—That portion of the total loss of radiated energy due to atmospheric conductivity.

Ammeter—An instrument for measuring the current of electricity flowing in a circuit (See ampere).

Ammeter, Hot Wire—An ammeter dependent for its indications upon the change in dimensions of an element which is heated by a current through it.

Ammeter, Thermo—An instrument for measuring current, depending for its indications on the voltage generated at the terminals of a thermo junction heated either directly or indirectly by the current to be measured.

Amplifier or Amplifying Relay—An instrument which modifies the effect of a local source of energy in accordance with variations of received energy; and, in general produces a larger indication than could be had from the incoming energy alone.

Amplification, Coefficient of—The ratio of the useful effect obtained by the employment of the amplifier to the useful effect obtained without that instrument.

Antenna—A system of conductors designed for radiating or absorbing the energy of electromagnetic waves.

Antenna, Directive—An antenna having the property of radiating a maximum of energy in one (or more) directions.

Antenna, Flat Top—An antenna having horizontal wires at the top covering a large area.

Antenna, Harp—An antenna having approximately vertical sections of large area and considerable width (This description may also be applied to a fan antenna).

Antenna, Inverted L—A flat top antenna in which the leading down wires are taken from one end of the long narrow horizontal section.

Antenna, Loop—An antenna in which the wires form a closed circuit, part of which may be the ground.

Antenna, Plain—An approximately vertical single wire.

Antenna, T—A flat top antenna in which the horizontal section is long and narrow, the leading down wires being taken from the center.

Antenna, Umbrella—One whose conductors form the elements of a cone from the elevated apex of which the leading down wires are brought.

Antenna Resistance—An effective resistance which is numerically equal to the ratio of the power in the entire antenna circuit to the square of the R. M. S. current at a potential node (generally the ground).

Note—Antenna resistance includes:

Radiation resistance.

Ground resistance.

Radiation frequency ohmic resistance of antenna and loading coil and shortening condensers.

Equivalent resistance due to corona, eddy currents, and insulator leakage.

Arc—The passage of an electric current of relatively high density through a gas or vapor, the conductivity of which is mainly due to the electron emission from the self-heated cathode. Under present practical conditions the phenomena takes place near atmospheric pressure.

Arc Oscillator—An arc used with an oscillating circuit for the conversion of direct to alternating or pulsating current. The oscillations generated are classified as follows:

Class 1. Those in which the amplitude of the oscillation circuit current produced is less than the direct current through the arc.

Class 2. Those in which the amplitude of the oscillation circuit current is at least equal to the direct current, but in which the direction of the current through the arc is never reversed.

Class 3. Those in which the amplitude of the initial portion of the oscillation circuit current is greater than the direct current passing through the arc, and in which the direction of the current through the arc is periodically reversed.

Attenuation (*Radio*)—This is the decrease, with distance from the radiating source, of the amplitude of the electric and magnetic forces accompanying (and constituting) an electromagnetic wave.

Attenuation, Coefficient of (*Radio*)—The coefficient which, when multiplied by the distance of transmission through a uniform medium, gives the natural logarithm of the ratio of the amplitude of the electric or magnetic forces at that distance to the initial value of the corresponding quantities.

Audiblity—The ratio of the telephone current variation producing the received signal, to that producing an audible signal (An audible signal is one which permits the mere differentiation of dots and dashes).

The measurement of audibility is an arbitrary method for determining the relative loudness of telephone response in radio receivers, in which it is stated that a signal has an audibility of given value. The determination of the above ratio may be made by the non-inductive shunt-to-telephone method, except that a series resistance should be inserted to keep the main current constant, and that the shunt resistance should therefore be connected as a potentiometer.

Brush or Corona Losses—Those due to leakage convection electric currents through a gaseous medium.

Cage Conductor—A group of parallel wires arranged as the elements of a long cylinder.

Changer, Frequency—A device delivering alternating current at a frequency which is some multiple of the frequency of the supply current.

Changer, Wave—A transmitting device for rapidly and positively changing the wave length.

Characteristic, Dynamic, of a Conductor—(For a given frequency and between given extremes of impressed emf. and resultant current through a conductor): This is the relation given by the curve obtained when the impresed electromotive forces are plotted as ordinates against the resultant currents as abscissas, both electromotive forces and currents varying at the given frequency and between the given extremes.

Characteristic, Static of a Conductor—This is the relation given by the curve plotted between the impressed electromotive force as ordinates and the resultant current through the conductor as abscissas, for substantially stationary conditions.

Coefficient of Coupling, Inductive—The ratio of the effective mutual inductance of two circuits to the square root of the product of the effective self-inductances of each of these circuits.

Coherer—A device sensitive to radio frequency energy, and characterized by (1) a normally high resistance to currents at low voltages. (2) A reduction in resistance on the application of an increasing electromotive force, and (3) the substantial absence of thermo-electric or rectifying action.

Communication, Radio—The transmission of signals by means of electro-magnetic waves originating in a constructed circuit.

Compass, Radio—A radio receiving device for determining the direction (or the direction and its opposite) of maximum radiation.

Condenser, Air—A condenser having air as its dielectric.

Condenser, Compressed Gas—A condenser having compressed gas as its dielectric.

Corona—See Brush and Corona losses.

Counterpoise—A system of electrical conductors forming one portion of a radiating oscillator, the other portion of which is the antenna. In land stations, a counterpoise forms a capacitive connection to ground.

Coupler—An apparatus which is used to transfer radio frequency energy from one circuit to another by associating portions of these circuits.

Coupler, Capacitive—An apparatus which, by electric fields, joins portions of two radio-frequency circuits; and which is used to transfer electrical energy between these circuits through the action of electric forces.

Coupler, Direct—A coupler which magnetically joins two circuits having a common conductive portion.

Coupler, Inductive—An apparatus which by magnetic forces joins portions of two radio frequency circuits and is used to transfer electrical energy between these circuits through the action of these magnetic forces.

Coupling—See coefficient of coupling (Inductive).

Current, Damped Alternating—An alternating current whose amplitude progressively diminishes (also called oscillating current).

Current, Forced Alternating—A current, the frequency and damping of which are equal to the frequency and damping of the exciting electromotive force. See further Current, Free Alternating.

Note—During the initial stages of excitation, both free and forced current co-exist.

Current, Free Alternating—The current following any transient electromagnetic disturbance in a circuit having capacity, inductance and *less* than the critical resistance. See further. Resistance, Critical.

Curve, Distribution, of a Radio Transmitting Station for a Given Distance—This is a polar curve the radii vectors of which are proportional to the field intensity of the radiation at that distance in corresponding directions. See also Compass, Radio.

Note 1—The distribution curve depends, in general, not only on the form of the antenna, but also on the nature of the ground surrounding the station.

Note 2—The distribution curve generally varies with the distance from the station.

Curve, Resonance, Standard—A curve the ordinates of which are the ratios of the square of the current at any frequency to the square of the resonant current, and the abscissas are the ratio of the corresponding wave length to the resonant wave length; the abscissas and ordinates having the same scale.

Cyclogram—See Characteristic, Dynamic.

Cyclograph—An instrument for the production of cyclograms.

Decrement—See Decrement, Linear, and Logarithmic.

Decrement of a Linearly Damped Alternating Current—This is the difference of successive current amplitudes in the same direction, divided by the larger of these amplitudes.

Decrement, Logarithmic, of an Exponentially Damped Alternating Current—This is the logarithm of the ratio of successive current amplitudes in the same direction.

Decremeter—An instrument for measurnig the logarithmic decrement of a circuit or a train of electromagnetic waves.

Detector—That portion of the receiving apparatus which, connected to a circuit carrying currents of radio frequency, and in conjunction with a self-contained or separate indicator, translates the radio frequency energy into a form suitable for the operation of the indicator, such for instance, as a pair of telephone receivers. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received.

Device, Acoustic Resonance—A device which utilizes in its operation resonance to the radio frequency of the received signals.

Diplex Reception—The simultaneous reception of two signals by a single operating station.

Diplex Transmission—The simultaneous transmission of two signals by a single operating station.

Duplex Signaling—The simultaneous reception and transmission of signals.

Excitation, Impulse—A method of producing free alternating currents in an excited circuit in which the duration of the exciting current is short compared with the duration of the excited current.

Note—The condition of short duration implies that there can be no appreciable reaction between the circuits.

Factor, Damping—The product of the logarithmic decrement and the frequency of an expotentially damped alternating current.

Factor, Form—The form factor of a symmetrical antenna for a given wave length is the ratio of the algebraic average value of the R. M. S. currents measured at all heights to the greatest of these R. M. S. currents.

Note 1—For a given R. M. S. current at the base of the antenna, the field intensity at distant points is proportional to the form factor times the height of the antenna.

Note—The effective height(height of center of capacity) is equal to the form factor times the actual height of the antenna.

Note 3—The form factor varies in a given antenna at various wave lengths due to variation of the current distribution.

Frequencies, Audio (abbreviated a. f.)—The frequencies corresponding to the normally audible vibrations. These are assumed to lie below 10,000 cycles per second.

Frequencies, Radio (abbreviated r. f.)—The frequencies higher than those corresponding to the normally audible vibrations, which are generally taken as 10,000 cycles per second. See Frequencies, Audio.

Note—It is not implied that radiation cannot be secured at lower frequencies, and the distinction from audio frequencies is merely one of definition based on convenience.

Frequency, Changer—See Changer Frequency.

Frequency, Group—The number per second of periodic changes of amplitude or frequency of an alternating current.

Note 1—Where there is more than one periodically recurrent change of amplitude, or frequency, there is more than one group frequency present.

Note 2—The term "group frequency" is often called by the term "spark" frequency."

Frequency Transformer—See Changer, Frequency.

Fundamental of an Antenna—This is the lowest frequency of free oscillations of the unloaded antenna (No series inductance or capacity).

Fundamental Wave Length—The wave length corresponding to the lowest free period of any oscillator.

Gap Micrometer—A device for protecting any apparatus from excessive potentials, and consisting of a short gap designed for very fine adjustment.

Ground—A conductive connection to the earth.

Impulse Excitation—See Excitation, Impulse.

Interference, Wave (In Radio Communication)—The reinforcement or neutralization of waves, arriving at a receiving point along different paths from a given sending station; (to be distinguished from ordinary or station interference, which is simultaneous reception of signals from two or more stations).

Key—A switch arranged for rapidity of manual operation and normally used to form the code signals of a radiogram.

Key, Relay—See Relay Key.

Length, Wave—See Wave Length.

Losses, Brush or Corona—See Brush and Corona Losses.

Meter, Wave—See Wave Meter.

Oscillations (In Radio Work)—See Current, Damped Alternating.

Oscillator, Arc—See Arc Oscillator.

Potentiometer—As commonly used for radio receiving apparatus, a device for securing a variable potential by utilizing the voltage drop across the variable portion of a current carrying resistance.

Radiation, Sustained—See Waves, Sustained.

Radiogram—A telegram sent by radio.

Radio Telephone—An apparatus for the transmission of speech by radio.

Rectifier, Electron—A device for rectifying an alternating current by utilizing the approximately unilateral conductivity of a hot cathode and a relatively cold anode in so high a vacuum that a pure electron current flows between the electrodes.

Rectifier, Gas—An electron rectifier containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

Relay, Electron—A device provided with means for modifying the pure electron current flowing between a hot cathode and a relatively cold anode placed in as nearly as possible a perfect vacuum. These means may be, for example, an electric control of the pure electron current by variation of the potential of a grid interposed between the cathode and the anode.

Relay, Gas—An electron relay containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

Relay Key—An electrically operated key. See further, Key.

Resistance, Antenna—See Antenna Resistance.

Resistance, Critical, of a Circuit—That resistance which determines the limiting condition at which the oscillatory discharge of a circuit passes into an aperiodic discharge.

Resistance, Effective, of a Spark—The ratio of power dissipated by the spark to the mean square current.

Resistance, Radiation—This is the ratio of the total energy radiated (per second) by the antenna to the square of the R. M. S. current at a potential node (generally the ground connection). See further, Antenna Resistance.

Resistance, Radio Frequency—This is the ratio of the heat produced per second in watts to the square of the R. M. S. current (r. f.) in amperes in a conductor.

Resonance—Resonance of a circuit to a given exciting alternating electromotive force is that condition due to variation of the inductance or capacity in which the resulting effective current (or voltage) in that circuit is maximum.

Note 1—Instead of varying the inductance and capacity of a circuit the frequency of the exciting field may be varied. The condition of resonance is determined by the frequency at which the current (or voltage) is a maximum.

Note 2—The resonance frequency corresponds the more accurately to the frequency of the free oscillations of a circuit, the lower the damping of the exciting alternating field and of the excited circuit.

Resonance, Acoustic Device—See Device Acoustic Resonance.

Resonance, Sharpness of—See Tuning, Sharpness of.

Sharpness of Tuning—The measure of the rate of diminuation of current in transmitters and receivers with detuning of the circuit which is varied.

Spark—An arc of short duration.

Static—Disturbances caused by atmospheric charging of the antenna.

Note—When it is definitely known that disturbances are due to atmospheric charging of the antenna, the word "Static" is used. In general disturbances are called "Strays."

Strays—Electromagnetic disturbances set up by distant discharges. See Static.

Train, Wave—The waves emitted which correspond to a group of oscillations in the transmitter. See also, Frequency Group.

Transformer—A device for transferring electrical energy from one state to another. In radio we have a variety of transformers for various purposes. There are power transformers, oscillation transformers, amplifying transformers, telephone transformers, etc.

Tuning—The process of securing the maximum indication by adjusting the same time period of a driven element. See Resonance.

Tuning, Sharpness of—See Sharpness of Tuning.

Vacuum Tube, Three Electrode—See Relays, Electron and Gas. This tube is also known as an "Audion."

Vacuum Tube, Two Electrode—See Rectifiers, Electron and Gas. This tube is also known as a "Fleming Valve."

Waves, Electromagnetic—A periodic electromagnetic disturbance through space.

Wave Length (of an Electromagnetic Wave)—The distance in meters between two consecutive maxima, of the same sign, of electric and magnetic forces. In other words, the distance from crest to crest of two waves.

Wave Length, Fundamental—See Fundamental Wave Length.

Wave Length, Natural—In a loaded antenna (that is, with series inductance or capacity) the natural wave length corresponds to the lowest free oscillation.

Wave Changer—See Changer, Wave.

Wave Meter—A radio frequency measuring instrument, calibrated to read wave lengths.

Alternator—Is a device for converting mechanical energy into alternating current.

Alternator, High Frequency—Is an alternating current generator for radio frequency having a rotor of solid steel shaped as a disc for maximum strength and provided with inductor poles, and having stationary armatures with radial faces on both sides of the rotating disc.

Audion—The audion is a relay, operated by electrostatic control of currents flowing across a gaseous medium. In its present commercial form, it consists of three electrodes in an evacuated bulb, one of these electrodes being a heated metal filament, the second a grid-like electrode, and the third a metal plate; an input circuit connected to the filament and the grid; and an output circuit connected to the filament and the plate, including a local source of energy and a telephone receiver.

Chopper—A transmitting device for repeatedly changing circuit connections at a uniform high rate of speed. The object of the above operation is to cause a continuous variation at audio frequency of the energy radiated at a fixed wave length from an antenna.

Gap, Quenched—A spark gap provided for minimizing arcing and generally used under conditions which prevent the re-transfer of energy between the primary and secondary oscillation circuits.

Gap, Synchronous, Rotary—A rotary spark gap which produces discharges in synchronism with the supply of alternating electromotive force.

Gap, Rotary Non-Synchronous—A rotating gap for increasing low frequency spark discharges to a higher spark frequency.

Heterdyne—A receiver for radio frequencies which operates by the production of interference beats between two radio frequency currents or voltages, the source of one of these radio frequencies being located at the receiving station.

Kenotron—Kenotron is a name applied to a general class of apparatus having an incandescent cathode and operating with a pure electron discharge in a vacuum so high that gas ionization plays no essential role. One of the uses of the kenotron is the rectification of alternating current, particularly of high voltages.

Pliotron—A pliotron is a kenetron provided with a member for electrostatically controlling the electron discharge.

Tikker—A receiving device for changing circuit connections in such a manner as to render the sustained radio frequency electrical energy stored in an oscillating circuit, available for operating a telephone receiver.

Wave, Damped—Damped oscillations are those consisting of a series of alternating currents of gradually decreasing amplitude.

Wave, Undamped—Is a continuous wave which has a constant amplitude.

Wave, Continuous—See Wave, Undamped.

Wave, Sustained—See Wave, Undamped.

Capacity—A term chiefly employed in connection with condensers. A condenser stores electricity, the amount stored depending upon the capacity of the condenser. Capacity is measured in "farads." Capacities used in radio are so small that the farad is too large for practical use, therefore the unit employed is the microfarad (abbreviated m. f. d.) or one millionth of a farad.

Condenser—Refer to capacity. The condenser stores electricity. It consists generally of alternate layers of conductor and non-conductor, the latter being termed the dielectric.

Alternation—An alternation of current is one-half cycle or the rise and fall of an alternating current in one direction. There are two alternations to a cycle.

Cycle—A complete reversal of current. A cycle consists of two alternations. Further, see Alternation.

Alternating Current (abbreviated A. C.)—An alternating current is electromotive force that gradually flows from a zero to a maximum value in one direction, then decreases again to zero, rises in maximum value in the opposite direction and again decreases to zero. This is repeated over and over again. The number of repetitions per second determining the frequency of the alternating current.

Aerial—See Antenna.

Inductance—Is that property of a circuit by which electrical energy may be stored in electromagnetic form.

Self-Induction—Phenomena arising from the rise and fall of a magnetic field about a coil of wire, through which an electrical current is passing. It is the property of an electrical circuit which tends to prevent a change of the electric current established in it.

Mutual Induction—Is induction due to two independent circuits reacting on each other. In other words, the electromotive force induced in one of the circuits when the current in the other is changing at its unit rate per second.

Period—A period is the time required for a cycle of alternating current to pass through all its values. The period of a cycle determines the frequency of the current per second.

Frequency—Is the number of cycles taking place in an alternating current in a second of time.

Frequency, High—An alternating current where frequencies counted in thousands take place in a second of time.

Frequency, Low—An alternating current where frequencies counted in tens or hundreds take place in a second of time. These are generally from 60 to 500 cycles per second.

Oscillatory Currents (*Audio Frequency*)—Vibrations within the range of audibility of the human ear. Generally considered those of a frequency less than 10,000 per second.

Oscillatory Currents (*Radio Frequency*)—Vibrations above the range of audibility of the human ear, generally considered frequencies beyond 10,000 per second.

Frequency Spark—The number of spark discharges per second across a spark gap.

Frequency, Tone—See Frequency, Spark and Frequency, Group.

Oscillatory Circuit—A circuit permitting a free flow of oscillations, generally consisting of a wire coil in series with a condenser.

Syntonic Circuits—Are several circuits having the same natural period of oscillation.

Flux—A term designating the lines of magnetic or static force in any given space.

Flux Density—The number of electrostatic or electromagnetic lines per force per square centimeter.

Electromagnetic Lines of Force—Lines of strain about the poles of a permanent or electromagnet, or in a wire in which an electric current is flowing.

Electrostatic Lines of Force—Lines of strain about a body containing an electrostatic charge.

Reactance—A term used to express the resistance of a conductor to any changes of current in it.

Impedance—A term to express the opposition of a circuit to a varying current, due to the resistance and reactance of a circuit.

Volt—The unit of electromotive force.

Ampere—The unit of current.

Ohm—The unit of resistance.

Watt—The unit of power.

Coulomb—The unit of quantity.

Farad—The unit of capacity.

Henry—The unit of inductance.

Ampere-Hour—The unit expressing the quantity of current passing through a circuit when one ampere flows therein for one hour of time.

Rheostat—A device for regulating the resistance used for governing the flow of current in electrical circuits. They may be of a fixed or a variable standard.

Reactance Coil—A coil with a variable "choking" effect used for a double purpose. It regulates the current flowing in the primary or secondary windings of a transformer, also to place the circuit consisting of the alternator and primary winding of the transformer in resonance with the circuit containing the secondary windings of the transformer and the condensers.

Oscillation Transformer—A device to transfer oscillations of radio frequency from the closed oscillatory circuit, to the open or antenna circuit of a radio transmitter.

Antenna Tuning Inductance—A wire coil used to increase the inductance in the antenna circuit and regulating the radiated energy.

Change Over Switch—A device for the convenient and rapid shifting of the antenna from the receiving to the transmitting apparatus. This is also called an antenna or transfer switch.

Tuner—A receiving device for transforming energy absorbed by a receiving antenna and transferred to a detector circuit. It also permits an operator to conveniently tune in electromagnetic waves of varying wave lengths.

Condenser, Stopping—Used in receiving apparatus to prevent the flow of battery current through the tuning coil of the closed oscillatory circuit instead of through the crystal detector, as intended. It is also used in shunt to the receiving head phones to assist in the intensification of signals.

Direct Current—An electrical current flowing constantly in one direction.

Kilowatt—One thousand watts of power.

Selectivity—The term used to express the ability to select any wave length to the exclusion of other wave lengths.

CHAPTER XI

QUESTIONS AND ANSWERS

THE following are questions the writer anticipates may occur to the mind of the reader. Many are taken from the questions put to a commercial operator when he is examined by the Federal Radio Inspector for his license. Others are dictated by the trend of questions asked by experimenters in the question columns of radio publications. These in conjunction with the definitions contained in the preceding chapter, may be useful in explanation of some point not clarified in the other pages of this volume.

Q. 1. Describe the construction of some form of standard wavemeter

A. The following briefly described a simple wavemeter manufactured and used by the Marconi Company of America. It consists of a variable condenser to which is connected an inductance coil of a fixed given value. The inductance is attached to the condenser by means of a flexible cord so it can be placed in any position desired, while the variable condenser is placed at some distance from the circuit to be measured. A carborandum crystal is connected in series with the head telephones, both are then connected in shunt to the variable condenser. A small glow lamp is included in series with the coil, and may be cut out of the circuit by means of the switch indicated.

A scale is placed directly on the variable condenser, which in turn moves under a stationary pointer. The scale reading of the condenser may be graduated directly in wave lengths or the data may be plotted in the form of a curve in the terms of an empirical scale on the condenser. These calibrations are obtained by comparing the wavemeter to a standard oscillatory circuit or by calculation of the constants in the wavemeter itself.

The point of resonance on the wavemeter may be located either by a lamp in series with the circuit, by a crystal detector and head telephones in shunt to the condenser, a hot wire milli-ammeter in series with the wavemeter, a Neon gas tube in shunt to the variable condenser, or a crystal detector and head 'phones connected unilaterally to a binding post of the variable condenser.

Certain types of wavemeters have a variable inductance and a fixed capacity, while others may have a variable inductance and a variable capacity.

In using a wavemeter care must be taken that the coil of the wavemeter bears a certain relation to the circuit under measurement, otherwise it will not be cut by the lines of force.

Q. 2. If your hot-wire ammeter broke, or such an instrument was not available, what simple device can be substituted to show when a point of resonance is reached, or to show a maximum of radiation?

A. Several arrangements may be made. The best is a method using a small four-volt incandescent electric lamp, connected in series in the lead to ground of the open or antenna circuit. With this arrangement the lamp, for protection, is shunted by a loop of wire, preferably having a sliding contact. When the correct point of resonance is obtained with the open and closed oscillatory circuits, the lamp will light with a maximum glow.

Another method is to place a very short gap in the same lead described above. When resonance is reached, there will be a maximum amount of discharge across the gap. This method is not considered a good one to maintain permanently in the circuit, as it increases the resistance of the antenna circuit.

Q. 3. What are the advantages of a high frequency spark discharger?

A. There are several excellent advantages.

1. The signals emitted from such a spark are more readily detected above atmospheric disturbances or static.

2. The telephone receivers used in modern radio practice is more sensitive to such a frequency than to the lower frequencies.

3. A better manipulation of the characters of the Morse Code can be obtained by means of the telegraph key when high frequency is used than when low frequencies are employed. Thus a faster rate of signalling can be obtained.

An additional advantage is that higher frequencies permit the use of a smaller condenser, with a resultant decrease in the strain upon insulators.

Q. 4. What are the advantages of a quenched gap?

A. The quenched gap possesses numerous advantages, principally as follows:

1. The oscillations in the closed oscillatory circuit are quickly damped out, thus permitting the antenna circuit to vibrate in its own natural period without any reaction upon the closed circuit.

2. It is comparatively noiseless in use.

3. Permits of the use of low voltage transformers. An economy in both space and expense.

Q. 5. Why is alternating current desirous as a source of electromotive force in radio-telegraphy?

A. By using alternating current the necessity of using devices for making and breaking direct current is obviated. Mechanical or electrolytic vibrators are limited to the practical use of power less than one kilowatt, whereas the use of power utilizing alternating current is practically unlimited.

Q. 6. If your spark suddenly stopped while sending, give the order in which you would look for the trouble and the method of repair for each possibility.

A. The search should be in the following order:

1. Make or find a circuit diagram, unless thoroughly familiar with the connections and positive they are right.

In drawing diagram follow each branch of the circuit from the source (+ terminal of battery or generator armature) completely around (through the − terminal) to the place of beginning. Remember that no current will flow in a circuit or any part of a circuit unless there is a difference of potential in it.

2. Trace the wiring according to the diagram.
3. While tracing, see that—
    (A) Fuses are good, if any are in the circuit.
    (B) Connections are clean and good.
    (C) Contact is not prevented by insulating caps of binding screws or insulation of wire.
    (D) Wires do not touch, making short circuits.
    (E) There are no extra wires or connections.
    (F) There are no breaks in the wire inside of insulation. This occasionally happens with old lamp cord. The broken place is very limber, and can be pulled in two more readily than a sound place.
4. Look for defects in the apparatus itself.

In a generator, besides loose connections, electrical troubles easily remedied are, for direct current.

5. Failures to generate electromotive force, caused by—
    - (A) Brushes not in the right place. On nearly all direct current machines of reasonably modern construction, the proper position for brushes on the commutator is nearly opposite the middle of the field poles, or slightly forward (in the direction of rotation) of that point. The exact location, found by trial, is that which gives sparkless commutation, Brushes are set right at the factory, and should be left as they are, unless there is a good reason to believe that they have since been shifted.
    - (B) Brushes not making good contact because of bad fit or too little pressure. Test by lifting them slightly, one by one, to detect loose springs, also try pressing brushes to commutator with a dry stick. Remedy by working fine sandpaper back and forth, sharp side out, between the commu-

tator and brush (holding it in such a way that the toe of the brush is not ground off) or by tightening the brush springs, as needed.

Brushes are designed, either to press against the commutator squarely, pointing toward the center of the shaft, or, more commonly to trail somewhat as an ordinary paint brush might trail if held against the commutator. However, there is also in very satisfactory use a form of holder by which the brushes are held pointing against the direction of rotation. Instead of sliding up or down in a box they are pressed against a smooth face of brass by springs.

(C) Field connections reversed.

6. Sparking, when caused by—

(A) Roughened commutator, cured by holding fine paper (*not* emory) against it while running.

(B) Brushes shifted, for remedy see 5 above. It is very important that all the brushes be at the proper points. This means, for example, that if the brushes are supposed to touch at four points, spaced a quarter way round the commutator, they shall actually be a quarter of a circumference apart, as tested by fine marks on a strip of paper held against the commutator.

7. Heatings of commutator due to brush friction. Reduce tension of springs.

In alternating current generators look for—

8. Loose connections and bad contacts at brushes. Position of brushes on collector rings is immaterial, as there is no commutation on an a.c. machine.

In d.c. shunt motors, motor generators, or dynamotors, the simple troubles are:

9. Failure to start, or starting too suddenly with speed quickly becoming excessive, due to wrong connections.
10. Sparking, caused by excessive lead or wrong brush position. See 5 or 6 above.

The proper position for motor brushes is slightly backward (against the direction of rotation) of the center of the field poles.

Having thus traced the motor-generator circuits, the fault may lie in transformer or the radio circuits. These should be traced successively as follows:

The primary winding of the power transformer may be burnt out. If the voltage is 110 volts, this can be tested with an ordinary test lamp. As a rule the primary, consisting of a few turns of heavy wire, can be easily repaired. If the test indicates it is in the secondary winding of this transformer, the trouble may be more difficult to remedy. Most radio power transformers have a secondary built in sections, in this case it may be possible to remove the burnt out section. Unless another is available and substituted, it would be necessary to reduce the primary voltage, if the transformer is operated short of one or more sections.

If the fault is a punctured condenser, and no spares available, the punctured unit can be removed and the remaining units placed in a parallel connection, affording the same capacity as formerly employed, but again the primary potential must be reduced, as supplied to the transformer.

If a plain gap is used, it may be found that the electrodes have either fallen together, shorting the circuit, or becoming too far apart, the spark will not discharge across the gap.

If a quenched gap is in use, there may be a short circuit caused by the contact of the sparking surfaces with each other, or by the destruction of the insulation between the sparking surfaces.

Q. 7. What is the effect of opening a spark gap too wide?

A. It imposes an additional strain on the condensers which may result in a puncture. The spark also becomes rough or "stringy," with a resultant poor tone. It also imposes an extra strain on the windings of the secondary of the transformer.

Q. 8. What is the effect of connecting two equal banks of transmitting condensers in series?

A. The total capacity of the condenser is reduced to one-half of one bank, but the strain of the potential on the dielectric is divided equally between the two units, thereby protecting the condensers from possible puncture.

Q. 9. What is the effect on the adjustment of a transmitter if the coupling is considerably increased?

A. Oscillations of two different frequencies will be radiated from the antenna. If the coupling is too close, the energy will be distributed over several of wave lengths, causing considerable interference over a wider range of wave lengths.

Q. 10. How are the very high voltages produced for radio telegraphic purposes?

A. By means of step-up alternating current transformers.

Q. 11. Name some of the commercial frequencies which are employed in radio telegraphic work?

A. 60, 120, 240, 480 and 500 cycles per second.

Q. 12. What is the most common cause for the breakdown of high potential condensers?

A. A spark gap which is too wide. Also if the dielectric is of glass, a flaw in the glass may cause a puncture.

Q. 13. What is meant by a pure wave in radio telegraphy?

A. If there are two waves emitted by a transmitter, a wave is considered "pure" when the amplitude of the lesser wave is less than two-tenths of that in the greater wave.

Q. 14. Describe a method for protecting high potential condensers from puncture.

A. By placing a spark discharge safety gap across the terminals. This may be adjusted so that an excessive potential would discharge across the safety gap, if for some reason the spark gap of the transmitter failed to function. Also the condenser units may consist of two or three banks in series or in series parallel, this dividing the voltage between them.

Q. 15. What is the effect of placing a condenser in series with an antenna?

A. The total capacity of the antenna is reduced, sometimes by nearly 50 per cent, thus reducing the wave length.

Q. 16. What is the advantage in having more than one wire in the antenna for transmitting purposes?

A. A slight advantage in increased radiation, hence increased transmitting range. This is caused by the additional wires increasing the capacity, decreasing the effective inductance and decreasing the frequency resistance.

Q. 17. How can you tell if your antenna is radiating? Describe the apparatus used.

A. By attempting communication with a distant station. Although instruments may indicate a strong current flow in the antenna, sometimes there is poor radiation. When the set is first placed in resonance, a note should be made of the original results obtained. Should these values later fall off, it would be a good indication that something is wrong and that the radiation is not normal.

Q. 18. What are the uses of a lightning switch, and also, a protective air gap?

A. Such a switch is used to disconnect, when not in use or during a heavy storm, all transmitting and receiving apparatus from the antenna. The latter is then grounded by means of the switch. The use of such a switch is made arbitrary in some cities by the Boards of Fire Underwriters.

An air gap is a small gap which permits any heavy excessive current, such as lightning, to jump the gap, one side of which is grounded. The use of this gap has recently been made mandatory in New York City by the Board of Fire Underwriters.

Q. 19. Does a wave of high decrement refer to a "broad" or a "sharp" wave?

A. If the emitted wave of a station possesses a high decrement, it will be broad as received and difficult to eliminate interference, but if of low decrement, sharp tuning at the receiving station will result.

Q. 20. Why should all the joints in antenna wires be soldered?

A. To eliminate resistance, for one thing, and to prevent losses of energy by corrosion. It is particularly important in receiving aerials. Care must be taken, however, that not too much heat is applied when soldering, or the wire will be weakened. There is a device called a MacIntyre sleeve that answers even better than soldering in making joints.

Q. 21. What is the effect on radiation and range if the insulation of the antenna is poor?

A. It will reduce the range very considerably. Leaky insulators cause so much energy to be lost and therefore the range of the station is very greatly reduced.

Q. 22. What effect has the height of the antenna upon the range of the station?

A. Generally speaking, authorities appear to agree that the higher the aerial, the greater will be the displacement current established about the antenne. Experiments, especially recently, have upset many of the theories regarding this subject. Experience broadly shows that a high antenna and a good ground provide a station with a greater range.

Q. 23 What is the effect of tightening the coupling of the receiving tuner?

A. It has the effect of increasing the damping of the receiving set, thus allowing a response to several wave lengths. When the coupling is increased, it increases the mutual inductance between the primary and secondary windings, thus more energy is transferred than when a lesser coupling is employed.

Q. 24. If your head telephone circuit is found open, where is the trouble most likely to be and how would you remedy it?

A. Probably the fault may be found in the cords, a disconnection at the metal tips, or at the binding posts on the ear pieces of the phones. If the cord is worn out, ordinary wire may be substituted, preferably flexible lamp cord, untwisted. If the fault is in the magnets, the job will be more difficult and will necessitate sending it to the manufacturer for repair, or some other expert.

Q. 25. If the natural period or the fundamental wave length of an antenna is too long to receive short wave lengths, how would you proceed to adopt it for short wave lengths without shortening the antenna?

A. Insert a variable condenser in series with antenna. The effective capacity of the antenna will thereby be reduced and consequently the wave length also.

Q. 26. What precaution do you take to protect your receiving detector from being injured by nearby strong signals?

A. The coupling between the primary and secondary may be opened or the two circuits thrown out of resonance.

Q. 27. What tests may be made to ascertain whether a vacuum tube is oscillating?

A. A clicking sound will be heard in the telephones when the system is oscillating under the following conditions:

1. When the tickler is short circuited.
2. When the grid binding post is touched.
3. When secondary inductance switch on receiver is moved from one contact to another.

If the buzzer is started when audion is oscillating, a soft hissing noise will be heard in the telephones instead of the true note of the buzzer.

Periodic clicks will be heard in the telephones if the tickler coupling is too tight and the grid leak not great enough.

Q. 28. To what cause may failure to obtain oscillations in a vacuum tube be due?

A. Failure to obtain oscillations may be due to the following causes:

1. Reversed filament battery.
2. Reversed plate battery.
3. Reversed tickler leads.
4. Reversed leads from the "audion" binding posts on the receiver to the RA and RE terminals on the vacuum tube control apparatus.
5. Value of bridging condenser too small.
6. Improper value of stopping condenser.
7. Tickler too loosely coupled to the secondary.
8. Value of plate current not sufficient.
9. Bad cells in plate battery.
10. Defective vacuum tube.

CHAPTER XII

HOW TO BUILD A SIMPLE RECEIVER

The limited scope of this work precludes the possibility of entering into matters of design of all radio apparatus. However, it is thought that the beginner will obtain useful results from the set below described. This can be put together for less than thirty dollars. If the new experimenter later feels inclined to go in for a more elaborate equipment, the parts contained therein can be utilized to good advantage.

This set was designed by the Bureau of Standards to meet the public demand. With a suitable antenna and a reliable crystal for a detector, it should enable the user to read radio telegraph signals or music and voice over a range approximating 50 miles, probably more, especially at night.

The experience gained by a beginner in the construction and use of this simple receiver will be invaluable when he, or she, wishes to go further in the study of the art. The following described set will receive signals between wave lengths of 200 and 600 meters.

Parts of Set.—The two-circuit or inductively coupled receiving set consists essentially of a coupler, a variable condenser, crystal detector and accessories.

The assembled receiving set is shown in Fig. 47; and Fig. 48 shows how to wire the set.

The coupler, shown in left half of Fig. 47, is composed of a fixed section made up of the coil tube P, the upright J, the contact panel K, and the base B, and a movable section composed of coil tube S, the supporting contact panel M, and the base L.

The following parts will be required:

List of Parts Required:

6 ounces No. 24 double cotton covered copper wire;
2 round cardboard boxes;
3 switch knobs and blades, complete;
24 switch contacts and nuts;
3 binding posts, set screw type;
4 binding posts, any type;
1 crystal, tested;
3 wood screws for fastening panel to base;
wood for panels;

2 pounds paraffin;
lamp cords;
telephone receivers;
1 battery clip for crystal;
miscellaneous screws;
1 variable condenser (capacity 0.0004 to 0.005 microfarads).

Instructions for Construction

Instructions for making the movable coil of the coupler are as follows:

The coil tube S, Fig. 47, is a piece of cardboard tubing 3⅝ inches in diameter and 4 inches long. A round cardboard table salt box which can be obtained at a grocery store is about 3⅝ inches in

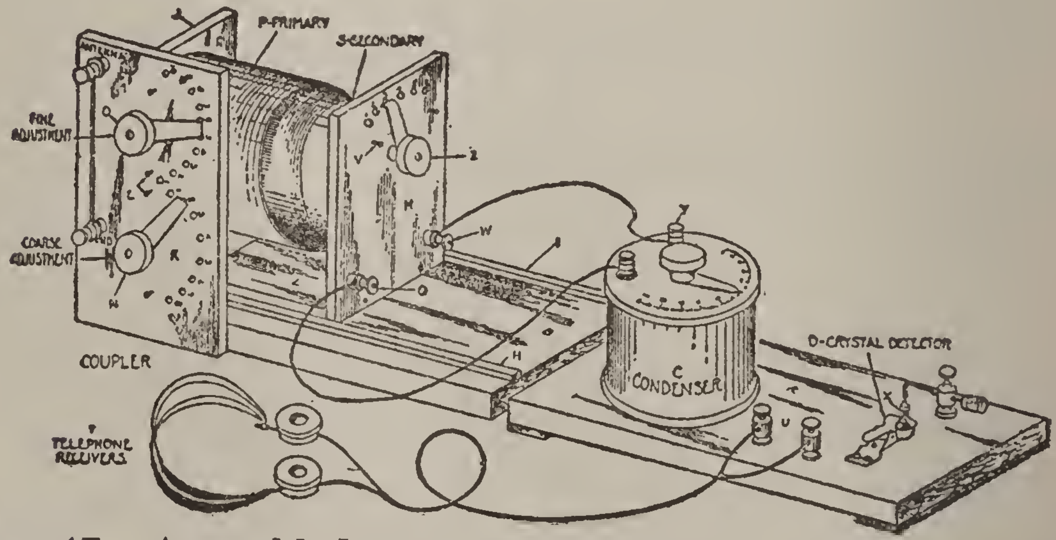


Fig. 47. Assembled two circuit receiving set with crystal detector.

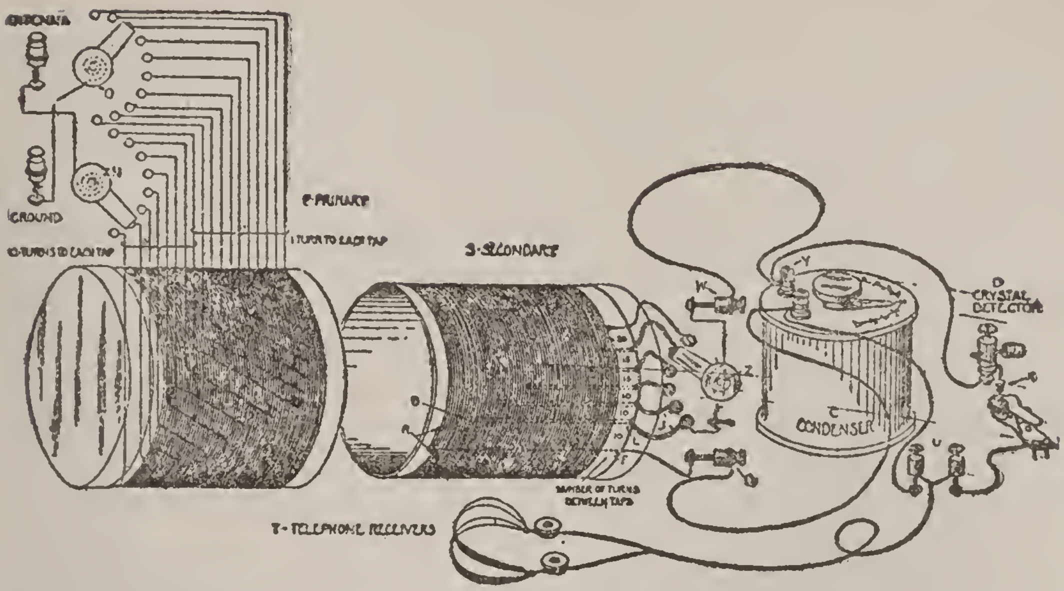


Fig. 48. Wiring diagram and details of two circuit receiving set with crystal detector

diameter and can be used for this purpose. One of the cardboard ends or caps should be securely glued to the box.

This tube is wound with No. 24 (or No. 26) double cotton covered wire.

To wind this wire punch two holes in the tube ⅜ inch from the open end, as shown at R, Fig. 48. Weave the end of the wire through these holes so that it is firmly anchored and has one end extending about 10 inches inside the tube. Punch a hole, F, Fig. 48, about ⅝ inch from the other end (which has the cardboard cover secured to it) in line with the holes punched at R. Draw the free end of the wire through the inside of the tube, and thread it out through the hole at F. Now wind on ten turns of wire and take off a 6-inch twisted tap made by twisting a 6-inch loop of wire together at such a place that it will be slightly staggered from the first connection. Hold the turns tight and punch a hole, B, directly underneath the tap. Insert the end of the tap in the hole and pull it through the inside of the tube so that the turns are held in place. The hole for this tap should be slightly staggered from the first two holes which were punched. Punch another hole, L, ⅝ of an inch from the other end of the tube and in line with the hole B. Thread the twisted tap out through this hole and pull it tight. Wind on 10 more turns and bring out another twisted tap; 15 turns and another tap; 15 more turns and another tap. Finally wind on 20 more turns and bring out the free end of the wire in the same manner as the taps were brought out. The tube now has 80 turns of wire wound on it and there are five twisted taps and two single wires projecting through the row of holes at the closed end of the tube. The position of the wires inside the coil tube is shown by the dotted lines.

Base and Support for Coil.—The contact panel M, Fig. 47, which supports the coil tube, is a piece of dry wood 5½ inches long, 4 inches wide and ½ inch thick. The end of the switch arm should be wide enough so that it will not drop between the contact points, but not so wide that it cannot be set to touch only a single contact. Having located the hole for the switch arm bolt, the switch arm should be placed in position and the knob rotated in such a manner that the end of the contact arm will describe an arc upon which the contact points are to be placed. The holes for the contacts should next be drilled, the spacing depending upon the kind of contacts that are to be used.

The movable base L is a square piece of dry wood 4 inches long, 4 inches wide, ¾ inch thick. Care should be taken to have the edges of this block cut square with respect to the sides. Now screw panel M to the movable base L, as shown in Fig. 47. Care should be taken to have the edges of the blocks M and L evenly lined up so that the two edges of the block L, Fig. 47, which slide along the inside edges of the stripe H and I, will be smooth, continuous surfaces.

Fixed or Primary Coil.—The cardboard tubing for coil tube P is 4½ inches in diameter by 4 inches long. About two ounces of No. 24 (or No. 26) double cotton covered copper wire is used for winding the coil. Punch two holes in the tube about one-half inch from the end. Weave the wire through these holes in such a way that the end of the wire will be firmly anchored, leaving about 12 inches of the wire free for connecting. Start with the remainder of the wire to wind turns in a single layer about the tube, tightly and closely together. After one complete turn has been wound on the tube hold it tight and take off a tap. This tap is made as above described, by twisting a six-inch loop of wire together, tap at such a place that it will be slightly staggered from the first connection. Proceed in this manner until ten twisted taps have been taken off, one at every turn. After these first ten turns have been wound on the tube, and tapped, take off a six-inch twisted tap for every succeeding ten turns until seventy taps are taken off or seventy additional turns wound on the tube. After winding the last turn of wire anchor the end by weaving it through two holes punched in the tube as at the start, leaving about twelve inches of wire free for connecting. It is to be understood that each of the eighteen taps is slightly staggered to the right from the one just above, so that the taps will not be bunched along one line on the cardboard tube. See Fig. 48. It might be advisable after winding the tuning coil to dip the tuner in hot paraffin. In both primary and secondary, where each tap is taken off a very slight solder connection should be made to make perfect contact with the tap and wire of the coil. Glue a cardboard cover to the end of the tube where the single turn taps are taken off.

The Panel.—Panel K should be made from a board 7½ inches long by 4½ inches wide and about ½ inch thick. The position of the contacts can best be determined by inserting the switch arms in their respective holes and turning the knobs so that the ends of the switch arms will describe arcs. The position of the several holes for the binding posts, switch arms and switch contacts may first be laid out and drilled.

The "antenna" and "ground" binding posts may be ordinary 8-32 brass bolts about 1½ inches long with three nuts and two washers. The first nut binds the bolt to the panel, the second nut holds one of the short pieces of stiff wire, while the third nut holds the antenna or ground wire as the case may be. The switch arm with knob may be purchased in the assembled form or may be constructed from ⅜-inch slice cut from a broom handle and a bolt of sufficient length equipped with four nuts and two washers, together with a strip of thin brass. The end of the switch arm should be wide enough so that it will not drop between the contact points, but not so wide that it cannot be set to touch only a single contact. The switch contacts may be of the regular type furnished for this purpose, or they may be 6.32 brass bolts with one nut and one washer each.

The fixed base B is a piece of dry wood 5½ inches wide, 11 inches long and between ¾ and ⅞ inch thick. The support J, for fixed coil tube, is 5½ inches wide (the width of the base), 6 inches long and about ½ inch thick. This board should be screwed to one end of the base, so that it is held securely in a vertical position. It will then project about five inches above the base G.

A strip of wood, I, 11 inches long, 5-16 inch wide and about ¼ inch thick, is now fastened to the base by cigar-box nails or small brads, so that it is even with the rear edge, as shown in Fig. 47. The upright panel M, having been fastened to the movable base L, as previously explained, is placed in position as shown. The next step is to locate the strip H in such a position that the block L will slide easily back and forth the entire length of the fixed base B. Having found this position, this strip is secured in the same manner as the strip I. It is, of course, understood that neither the movable coil tube S, nor the switch contacts and binding posts have, up to the present time, been mounted on the upright panel M. The wooden parts for the loose coupler are now finished and should be covered with paraffin.

It might be advisable after winding the coil tubes P and S to dip them in hot paraffin, this will help to exclude moisture. Have the paraffin heated until it just begins to smoke, so that when the coils are removed they will have a very thin coating of paraffin.

Variable Condenser.—The variable air condenser, C, should have a maximum capacity of between 0.0004 and 0.0005 microfarads (400 to 500 micromicrofarads).

The type pictured in Fig. 47 is enclosed in a round metal case, but the unmounted type may also be used. The variable condenser is mounted on a board, R, Fig. 47, about 10 inches long, 5½ inches wide and ¾ inch thick. The strips of wood are fastened under the ends so that wires may be run underneath for the connections. After the holes for the detector binding post and also the holes for the telephone binding posts U, have been drilled, the board should be coated with paraffin.

Crystal Detector.—The galena crystal D may be mounted as pictured in Fig. 47 and Fig.

48. The holder for the crystal is a metallic pinch clip such as the ordinary battery test clip or small paper clip. This clip should be bent into a convenient shape so that it may be fastened to the base.

The wire X which makes contact with the crystal is a piece of fine wire (about No. 30) which is wound into the form of a spring and attached (preferably soldered contact) to a heavy piece of copper wire (about No. 14). This heavy wire is bent twice at right angles, passes through the binding post and has a wood knob or cork fixed to its end as shown. It is desirable to have the fine wire of springy material, such as German silver, but copper wire may be used if necessary.

The importance of securing a tested galena crystal cannot be emphasized too strongly, and it should be understood that good results cannot be obtained by using an insensitive crystal.

Assembling Coupler.—The movable portion of the coupler should be assembled first. As shown in Fig. 47 the fittings making up this part of the set are the movable base L, the coil tube support M, the six switch contacts, the switch arm, and the binding posts, in the proper holes, which have been drilled. Adjust the switch arm until it presses firmly on the contact points (both heads) and fasten the bare end of a No. 24 copper wire between the nuts on the end of the switch arm bolt 2, Fig. 47 and Fig. 48, which projects through the panel M. Wind this wire into a spiral of two or three turns like a clock spring, leaving a few inches of the wire for connection. Insert two small screws V, Fig. 47, in the panel M, so that the switch arms will not drop off the row of contact points when the knob is turned too far.

The coil tube S is now ready to be fastened in position on the panel M. Cut a one-inch hole in the cardboard end of the coil tube and place it with the closed end next to the panel M, in such a position that it will be just below the row of nuts and washers of the switch contacts, and in the center of the panel M, with respect to the sides. Fasten it to the panel with short wood screws. The switch arm bolt with the spiral wire connected to it should project through the hole cut in the end of the coil tube. Thread the end of this wire through the hole punched near the end of the coil tube next to the panel and connect this wire to the back of the binding post W, Fig. 47 and Fig. 48. The wire F, Fig. 48, is now connected to the back of the binding post Q. There now remain five twisted taps and one wire to be connected to the six switch contacts. The taps should be cut off about 1½ inches from the coil tube, and the insulation removed from the pairs of wires thus formed. Each pair of wires should be twisted together, as shown at J, Fig. 48. The connections are now made by clamping the five taps, and also the end of the single wire between the nuts and washers on the contact bolts. The connections are clearly shown in the diagram.

We are now ready to assemble and wire the fixed portion of the coupler, composed of the base B, coil support J, panel K, and coil tube P.

Screw the panel to the base and to the support J, and insert the binding posts, switch arms and bolts and contact bolts in the proper holes. The switch arms should now be adjusted so that they make firm contact on the heads of the contact bolts. Now insert four small screws E, Fig. 47, in the front of the panel, so that the switch arms will not drop off the row of contact points when the knobs are turned too far. Insert a wire between the nuts on the end of the lower switch arm bolt N, where it projects through the back of the panel K, Fig. 47. Wind the wire into a spiral of one or two turns like a clock spring and connect the end to the upper binding post which is marked "antenna." These connections will be understood by referring to the upper left-hand corner of Fig. 48.

In the same manner connect another wire from the upper switch arm bolt to the lower binding post which is marked "ground." See Fig. 48. The connecting wires should be insulated except where a connection is needed and should not touch each other. Two short pieces of wire are now fastened to the binding posts in the front of the panel, as previously explained.

The coil tube P should now be laid on the base in about the same position as it is shown in Fig. 47. The sixteen twisted taps and also the two single wires from the ends of the winding are now to be connected to the back of the eighteen contacts on the panel K. Scrape the cotton insulation from the loop ends of the sixteen twisted taps as well as from the ends of the two single wire taps coming from the first and last turns. Fasten the bare ends of these wires to the proper switch contacts. Be careful not to cut or break any of the looped taps. The connecting wires may be fastened to the switch contacts by binding them between the washer and the nut. The order of connecting the taps may be understood by referring to Fig. 48.

Carefully raise the coil tube P against the support J, to such a position that when the coil S, of the movable section of the tuner, is pushed in the coil tube P, the space between the two tubes will be the same all around. Mark this position on the coil tube P on J and fasten it to J, with short wood screws.

Wiring Condenser and Detector.—The mounting of the condenser C, and the crystal detector D, on the base R, is clearly shown in Fig. 47. A wire is run from the binding post Y, on the variable condenser C, through a small hole in the base R, and is then connected to the under side of the detector binding post. Another wire is now run from the clip which holds the galena crystal through a small hole in the base, and is then connected to the under side of the right hand binding post U. The left hand binding post U is next connected to the binding post on the variable condenser, which has no wire attached to it, by running a wire under the base and up through a small hole. The wiring will be understood by referring to the right hand portion of Fig. 48. The wires may be the same size as were used for winding the tubes and should be insulated. Two pieces of wire should now be connected from the binding posts W and Q, Fig. 47 and Fig. 48, to binding posts on the variable condenser. The telephone receivers T are now connected to the binding posts U and receiving set is complete, except for connecting to the antenna and ground.

Connect the antenna lead and ground wire to the binding posts marked "antenna" and "ground," with proper connections to antenna and ground. You are ready to operate your apparatus. Too much importance cannot be paid to a good ground connection. The lead should be as short as possible between the receiver and ground.

Directions for Operating.—Push the coils S (secondary) about half way into the coil tube P (primary) and set the switch 2 on contact point 4. The primary switch 4 may be left in any position. The wire spring which rests on the crystal detector must be placed lightly at different points on the crystal until the transmitting station is heard. Then the set is adjusted as described below. During this operation contact switch should be placed on contact point 8.

Having adjusted the crystal detector to a sensitive point, the next thing is to adjust the switches on the coil tube P (primary), the switch on the coil tube S (secondary) and also the variable condenser C, so that the apparatus will be in resonance with the transmitting station. Set the primary switch N on contact point 1, and while keeping it in this position move the other primary switch O over all of its contacts, stopping a moment at each one. Care must be taken to see that the ends of the switch arms are not allowed to rest so that they will touch more than one contact point at a time. If no signals are heard, set the switch arm N on contact point No. 2 and again move the switch arm O over all of its contacts. Proceed in this manner until the transmitting station is heard. This is called "tuning" the primary circuit.

The tuning of the secondary circuit is the next operation. Set the secondary switch Z on contact 1, and turn the knob of the variable condenser C so that the pointer moves over the entire scale. If no signals are heard set the switch on contact 2 and again turn the knob of the variable condenser so that the pointer moves over the entire scale. Proceed in this manner until the signals are loudest, being careful to see that the ends of the switch arms touch only one contact point at one time. Next slide the tube coil S (secondary) in and out of the coil tube P (primary) until the signals are made as loud as possible. This operation is called changing the "coupling." When the coupling which gives the loudest signal has been secured, it may be necessary to readjust slightly the position of the switch arm O, the position of the movable coil tube S and the "setting" of the variable condenser C.

The receiving set is now in resonance with the transmitting station. It is possible to change the position of one or more of the switch arms, the position of the movable coil tube and the setting of the variable condenser in such a manner that the set will be in resonance with the same transmitting station. In other words, there are different combinations of adjustments which will respond to signals from the same transmitting station. The best adjustment is that which reduces the signals from undesired stations to a minimum and still permits the desired transmitting station to be heard. This is accomplished by decreasing the coupling (drawing coil tube S further out of coil tube P) and again tuning with the switch arm O and the variable condenser C. This may also weaken the signals from the desired transmitting station, but it will weaken the signals from the undesired stations to a greater extent, provided that the transmitting station it is desired to hear has a wave frequency which is not exactly the same as that of the other stations. This feature is called "selectivity."

APPENDIX I

FIRE PROTECTION REGULATIONS

Below will be found the latest regulations adopted by the National Board of Fire Underwriters. Readers installing radio equipments would do well to follow these regulations carefully as any delinquency would cause an increase in the fire insurance rates, or a cancellation of existing policy. In some cities these regulations are made compulsory by the city regulations covering fire protection.

The entire list follows:

All radio installations for Transmitting stations and all Receiving installations having outside exposed aerial lines (antenna) for receiving, or having connection with a light or power circuit should be approved by certificate from the Board of Fire Underwriters.

In setting up radio equipment all wiring pertaining thereto must conform to the general requirements of the National Electrical Code for the class of work installed and the following additional specifications.

For Receiving Stations Only

Antenna:

(a) Antenna outside of buildings shall not cross over or under electric light or power wires of any circuit of more than 600 volts, or railway or trolley or feeder wires, nor shall they be so located that a failure of either antenna or of the above mentioned electric light or power wires can result in a contact between the antenna and such electric light or power wires. Antennæ shall be so constructed and installed in a strong and durable manner and shall be so located as to prevent accidental contact with light and power wires by sagging or swinging. Splices and joints in the antenna span, unless made with proved clamps or splicing devices, shall be soldered. Antennae installed inside of buildings are not covered by the above specifications.

Lead-in Wires:

(b) Lead-in wires shall be of copper, approved copper-clad steel or other approved metal which will not corrode excessively and in no case shall they be smaller than No. 14 B. & S. gauge, except that approved copper-clad steel not less than No. 17 B. & S. gauge may be used.

Lead-in wires on the outside of buildings shall not come nearer than four (4) inches to electric light and power wires, unless separated therefrom by a continuous and firmly fixed non-conductor that will maintain permanent separation. The non-conductor shall be in addition to any insulation on the wire.

Lead-in wires shal enter the building through a non-combustible, non-absorptive insulating bushing.

Protective Device:

(c) Each lead-in wire shall be provided with an approved protective device properly connected and located (inside or outside the building) as near as practicable to the point where the wire enters the building. The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust, or flyings of combustible materials. The protective device shall be an approved lightning arrester which will operate at a potential of five hundred (500) volts or less.

The use of an antenna ground switch is desirable, but does not obviate the necessity for the approved protective device required in this section. The antenna grounding switch, if installed, shall, in its closed position, form a shunt around the protective device.

Protective Ground Wire:

(d) The ground wire may be bare or insulated and shall be of copper or approved copper-clad steel. If of copper the ground wire shall be not smaller than No. 14 B. & S. gauge; if of approved copper-clad steel, it shall be not smaller than No. 17 B. & S. gauge. The ground wire shall be run in as straight a line as possible to a good, permanent ground. Preference shall be given to water piping. Gas piping shall not be used for grounding protective devices. Other permissible grounds are grounded steel frames of buildings or other grounded metallic work in the building and artificial grounds such as driven pipes, plates, cones, etc. The ground wire shall be protected against mechanical injury, and an approved ground clamp shall be used wherever the ground wire is connected to pipes or piping.

Wires Inside Building:

(e) Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than two (2) inches to any electric light or power wire unless separated therefrom by some continuous and firmly fixed non-conductor making a permanent separation. This non-conductor shall be in addition to any regular insulation on the wire. Porcelain tubing or approved flexible tubing may be used for encasing wires to comply with this rule.

Receiving Equipment Ground Wire:

(f) The ground conductor may be bare or insulated and shall be of copper, approved copper-clad steel, or other approved metal which will not corrode excessively under existing conditions, and in no case shall the ground wire be less than No. 14 B. & S. gauge, except that approved copper-clad steel, not less than No. 17 B. & S. gauge may be used. The ground wire may be run inside or outside the building, when receiving equipment ground wire is run in compliance with rules for protective ground wire; in Section (d) it may be used as the ground conductor for protective device.

For Transmitting Stations

Transmitting stations are regarded as involving more hazard than stations used for only receiving, and require additional safeguard. All wiring and apparatus supplying power for sending, should be installed in accordance with the

National Electrical Code. Plans and specifications for proposed transmitting stations should be submitted for approval in advance of installation.

APPENDIX II

UNITED STATES AND INTERNATIONAL RADIO REGULATIONS

Below are given extracts from the laws and regulations governing radio communications, as they apply to the experimenter and amateur.

As will be seen, both an operator's license and a station license is required to operate a transmitting station of any kind. However, no license is required to operate a receiving station only, except that the regulation regarding the secrecy of messages must be complied with.

The regulations quoted apply to experimental and amateur stations and operators only. For regulations for commercial stations and operators, application should be made to the Superintendent of Documents, Government Printing Office, Washington, D. C., for a book entitled "Radio Communication Laws of the United States," which covers the entire field of radio.

Amateur and Experimental Station.—No private or commercial station not engaged in the transaction of bona fide commercial business by radio communication or in experimentation in connection with the development and manufacture of radio apparatus for commercial purposes shall use a transmitting wave length exceeding two hundred meters, or a transformer input exceeding one kilowatt.

The Secretary of Commerce may grant special temporary licenses to stations actually engaged in conducting experiments for the development of the science of radio communication, or the apparatus pertaining thereto, to carry on special tests, using any amount of power or any wave lengths, at such hours and under such conditions as will insure the least interference with the sending or receipt of commercial or Government radiograms, of distress signals and radiograms, or with the work of other stations.

Station licenses for the use and operation of apparatus for radio communication under the act may be issued only to citizens of the United States or Porto Rico or to a company incorporated under the laws of some State or Territory or of the United States or Porto Rico.

Licenses can be issued to clubs if they are incorporated or if a member will accept the responsibility for the operation of the apparatus, carrying with it the possibility of being penalized for infraction of the laws.

Applications for station licenses of all classes should be addressed to the United States Radio Inspector for the district in which the station is located, who will forward the necessary blank forms and information. The limits of the districts and addresses of radio inspectors are given below.

Upon receipt of the forms, properly completed, the radio inspector will make a thorough inspection of the station if practicable.

When applications and forms have been properly submitted, the stations may be operated in accordance with the laws and regulations governing the class of station for which application for license has been made, until such time as the application can be acted upon unless the applicant is otherwise instructed and provided temporary official call letters are assigned.

General and restricted amateur-station licenses are issued directly by radio inspectors. Station licenses of all other classes are issued from the office of the Commissioner of Navigation, Department of Commerce. Applications and form are forwarded by radio inspectors with recommendations by them.

The owner of an amateur station may operate his station in accordance with the laws if his application for a license has been properly filed but has not been acted upon. An application for an operator's license must also have been filed and every effort made to obtain the license before the station may be operated.

"Provisional" station licenses are issued to amateurs remote from the headquarters of the radio inspector of the district in which the station is located. These licenses are issued as a matter of convenience and record. If, upon inspection, the station is found to comply with the law, the inspector will strike out the word "Provisional" and insert the date of inspection and his signature at the bottom of the license.

If such a station is found not to comply with the law the provisional license may be canceled until such time as the apparatus is readjusted to meet the requirements of the law: *Provided, however,* That consideration will be given to any reports of interference filed against such a station.

All persons are warned that it is unlawful to operate stations after licenses have expired unless application for renewal has been properly made.

Hereafter expired station licenses of all classes, commercial and amateur, need not be returned to the radio inspectors with applications for renewals. Owners desiring a renewal license must complete new forms, as prescribed for original applications. New licenses will be issued in every case of renewal.

Any person applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed will be required to submit an affidavit to the Bureau of Navigation through the radio inspector of the district, attesting the facts regarding the manner in which the original was lost. The Commissioner of Navigation will consider the facts in the case and advise the radio inspector in regard to the issue of a duplicate license, or a duplicate will be forwarded through the inspector's office.

A duplicate license will be issued under the same serial number as the original and will be marked "Duplicate" in red across the face.

Decrement of Stations.—At all stations if the sending apparatus, to be referred to hereinafter as the "transmitter," is of such a character that the energy is radiated in two or more wave lengths, more or less sharply defined, as indicated by a sensitive wavemeter, the energy in no one of the lesser waves shall exceed ten per centum of that in the greatest.

At all stations the logarithmic decrement per complete oscillation in the wave trains emitted by the transmitter shall not exceed two-tenths, except when sending distress signals or signals and messages relating thereto.

Interferences and Fraudulent Signals.—That every license granted under the provisions of this Act for the operation or use of apparatus for radio communication shall prescribe that the operator thereof shall not willfully or maliciously interfere with any other radio communication. Such interference shall be deemed a misdemeanor, and upon conviction thereof the owner or operator, or both, shall be punishable by a fine of not to exceed five hundred dollars or imprisonment for not to exceed one year, or both.

That the expression "radio communication" as used in this Act means any system of electrical communication by telegraphy or telephony without the aid of any wire connecting the points from and at which the radiograms, signals, or other communications are sent or received.

That a person, company, or corporation within the jurisdiction of the United States shall not knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent distress signal or call or false or fraudulent signal, call, or other radiogram of any kind. For sending out such fraudulent signals the penalty is a fine not exceeding $2,500 or five years' imprisonment, or both.

Secrecy of Signals.—No person or persons engaged in or having knowledge of the operation of any station or stations, shall divulge or publish the contents of any messages transmitted or received by such station, except to the person or persons to whom the same may be directed, or their authorized agent, or to another station employed to forward such message to its destination, unless legally required so to do by the court of competent jurisdiction or other competent authority. Any person guilty of divulging or publishing any message, except as herein provided, shall, on conviction thereof, be punished by a fine of not more than two hundred and fifty dollars or imprisonment for a period of not exceeding three months, or both fine and imprisonment, in the discretion of the court.

Requirements for Operators, Licenses

Experiment and Instruction Grade.—Experimenters and instructors of scientific attainments in the art of radio communication whose knowledge of the radio laws satisfies the radio inspector or the examining officer may obtain this grade license, provided they are able to transmit and receive in the Continental Morse Code at a speed sufficient to enable them to recognize distress calls or the "keep-out" signals.

The operator's license for this grade is a commercial license, indorsed by the Secretary of Commerce with a statement of the special purpose for which it is valid.

If the applicant qualifies, the radio inspector or examining officer will forward a blank commercial license, with the papers, to the Commissioner of Navigation, with his recommendation. If approved, the license will be properly indorsed by the Secretary of Commerce and delivered to the licensee through the recommending officer.

This license has no reference to the instruction of radio operators as such, but is required by those operating apparatus licensed as experimental stations but who are unable to obtain commercial grade operators' licenses.

Amateurs before applying for licenses should read and understand the essential parts of the International Radiotelegraphic Convention in force and sections 3, 4, 5, and 7 of the act of August 13, 1912. The Department recognizes that radio communication offers a wholesome form of instructive recreation for amateurs. At the same time its use for this purpose must observe strictly the rights of others to the uninterrupted use of apparatus for important public and commercial purposes. The Department will not knowingly issue a license to an amateur who does not recognize and will not obey this principle. To this end the intelligent reading of the International Convention and the act of Congress is prescribed as the first step to be taken by amateurs. A copy of the radio laws and regulations may be procured for this purpose from the radio inspectors or from the Commissioner of Navigation, Department of Commerce, Washington, D. C., but they are not for public distribution. Additional copies may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a nominal price.

Amateur First Grade.—The applicant must have a sufficient knowledge of the adjustment and operation of the apparatus which he wishes to operate and of the regulations of the International Convention and acts of Congress in so far as they relate to interference with other radio communication and impose certain duties on all grades of operators. The applicant must be able to transmit and receive in Continental Morse at a speed sufficient to enable him to recognize distress calls or the official ‘‘keep-out’’ signals. A speed of at least 10 words per minute (five letters to the word) must be attained.

Amateur second grade.—The requirements for the second grade will be the same as for the first grade. The second-grade license will be issued only where an applicant can not be personally examined or until he can be examined. An examining officer or radio inspector is authorized in his discretion to waive an actual examination of an applicant for an amateur license, if the amateur for adequate reasons can not present himself for examination but in writing can satisfy the examining officer or radio inspector that he is qualified to hold a license and will conform to its obligations.

Amateurs should write to the nearest examining officer in their vicinity for Form 756 ‘‘Application for operator’s license,’’ and to the radio inspector in their vicinity for Form 762 ‘‘Amateur applicant’s description of apparatus.’’

Foreign-born applicants for station licenses must submit satisfactory evidence of their citizenship.

Amateur operators at points remote from

examining officers and radio inspectors may be issued second-grade amateur licenses without personal examination. Examinations for first-grade licenses will be given by the radio inspector when he is in that vicinity, but special trips can not be made for this purpose. (See par. 123.)

Persons holding radio operators' licenses, amateur second grade, should make every effort to appear at one of the examination points to take the examination for amateur first-grade license or higher.

Persons holding radio operators' licenses of any grade should, before their licenses expire, apply to the nearest radio inspector or examining officer for renewal and submit Form 756 in duplicate.

Operators' licenses are not valid until the oath for the preservation of the secrecy of messages is properly executed before a notary public or other officer duly authorized to administer oaths. Licenses must indicate on their faces that the oath has been taken and the officer administering the oath on the back of the license should sign also in the blank provided on the face.

Licenses will not be signed by examining officers until the oath of secrecy has been properly executed.

Administration and Administrative Districts:

The Department has established, for the purpose of enforcing, through radio inspectors and others, the acts relating to radio communication and the International Convention, the following districts, with the principal office for each district at the customhouse of the port named.

All information regarding operators and station licenses may be obtained from Radio Inspectors at the addresses below.

Communications for radio inspectors should be addressed as follows, and not to individuals: Radio Inspector, Customhouse, —— (city) —— (State).

Communications for the Bureau of Navigation should be addressed as follows, and not to individuals: Commissioner of Navigation, Department of Commerce, Washington, D. C.

1. BOSTON, MASS.: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
2. NEW YORK, N. Y.: New York (county of New York, Staten Island, Long Island, and counties on the Hudson River to and including Schenectady, Albany, and Rensselaer) and

New Jersey (counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson, and Ocean).

3. Baltimore, Md.: New Jersey (all counties not included in second district), Pennsylvania (counties of Philadelphia, Delaware, all counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, District of Columbia.
4. Savannah, Ga.: North Carolina, South Carolina, Georgia, Florida, Porto Rico.
5. New Orleans, La.: Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, Oklahoma, New Mexico.
6. San Francisco, Calif.: California, Hawaii, Nevada, Utah, Arizona.
7. Seattle, Wash.: Oregon, Washington, Alaska, Idaho, Montana, Wyoming.
8. Cleveland, Ohio: New York (all counties not included in second district). Pennsylvania (all counties not included in third district), West Virginia, Ohio, Michigan (Lower Peninsula).
9. Chicago, Ill.: Indiana, Illinois, Wisconsin, Michigan (Upper Peninsula), Minnesota, Kentucky, Missouri, Kansas, Colorado, Iowa, Nebraska, South Dakota, North Dakota.

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION.	QUESTION.	ANSWER OR NOTICE.
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	Have you anything for me?	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.
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	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.

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

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

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be used for all general public service radio communication

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or 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)	• • • — • —

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APPENDIX B

Bibliography

The following list of publications relating to the art of radio was prepared by the United States Bureau of Standards. While it is by no means comprehensive, a few of the most important references are given for each of the subjects mentioned.

The reader may also obtain from the Superintendent of Public Documents, Government Printing Office, Washington, D. C., a list of books bearing upon radio, together with their prices. Many excellent works upon the subject are available from this source, at exceedingly moderate prices.

From the same office may be obtained laws and regulations relating to radio, also a complete list of stations, both ship and shore, including broadcasting telephone stations:—

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RADIO—GOD'S WONDERFUL GIFT TO HUMANITY

By C. B. Cooper

VICE-PRES. SHIP OWNERS' RADIO SERVICE

APPENDIX C

RADIO—GOD'S WONDERFUL GIFT TO HUMANITY

What it Means to America

"Life's lesson is here with its fascination,
In this wireless thing that since creation
Has been laid away in nature's store,
Awaiting for some one to open the door.

"And when we hear our big spark thunder
Sending our signals away off yonder,
With the speed of the wings of light,
Through rain or shine or darkest night,

"Or when we hear our ear 'phones rapping
And answering signal comes clear and snapping,
We can't comprehend the wonder—the why,
Of this thing harnessed 'twixt earth and sky.

"And whys breed answers and whys again
Till we lose ourselves in the endless chain,
And where it leads or where the end,
Is beyond our powers to comprehend.

"The wizards—the men in the lab., you know,
First added plus X to y or O,
And nature revealed to him who sought,
And wireless telegraph to man was brought.

"And though this was added to that, until
Man conquered and harnessed it to his will,
There still remains the same old cry—
What is the thing, where from, and why?

"This selfsame question fills the pages
Of all the books of all the ages.
Question breeds question and question again,
Creating more riddles for man's weak brain.

"And that's what keeps alive the flame
And makes us play life's little game.
Uncertainties are the zest of life,
Knowledge of the finish stops the strife.

"And we who delve in our little part
Of nature's laws in this new-found art,
Must realize there's a power and plan,
And a God—a ruler of nature and man.

"This 'Everything' didn't just happen to be;
It must have been planned, created, and He
Who planned and created must rule by right
King of all nature—all man and all might."

Recently, in going through some old personal papers, I ran across the above—will I say poem? No, I think we had better call it simply rhyme because I am neither a poet nor a writer—but in reading it over I got to wondering if the thousands of people who are to-day thinking and talking Radio, and who are nightly listening-in to the concerts being broadcasted by radio telephone, are thinking of the subject purely from a commercial standpoint, or from an amusement standpoint, or whether they really get the wonder of it all. The above rhyme was written a number of years ago after I had just finished the construction of a radio telegraph station in Alaska. I had sat in that station, surrounded by rocks and wilderness, listening to the pound of the waves on the shore, yet talking through space to the ships at sea.

The apparatus that we were then using was of what is called the old "open spark type" that caused a noise like a gatling-gun. To-day the equipments have been perfected so that they are practically noiseless.

At the time this verse was written there was no such thing as a radio law. Wireless telephone had not been thought of. We who were engaged in the business had not much in the way of apparatus, but we had ideals and vision.

When we think of an ordinary telegraph message or a telephone message, we think of it as a man-made something. We know that the message has been transmitted over man-made wires and man-made telegraph or telephone lines. The message itself has been received on man-made instruments, and our thought is of the cleverness and ability of the engineers who made it possible. But in thinking of a radio telephone or telegraph message, I, for one, always think of it not as man-made, but as God-given.

It is true we have the man-made transmitting and the man-made receiving instruments, and we think of the wonderful cleverness of those who designed and built them, but the impulse transmitted and received travels through God's air—through that life sustaining, almost unexplainable thing that we breathe, and I think of radio as a something that is not meant for man-made commercialism, but a God-given gift put into the world to accomplish the things that man-made equipments cannot accomplish.

No other medium has yet been heard of that will communicate between ship and ship, or between ship and shore. Therefore the Almighty undoubtedly meant the radio telegraph for this particular purpose. It is for the saving of lives, for the furtherance of the commercial handling of ships, and for the many benefits and comforts that it gives to those who travel the seas.

Likewise, we now have the radio telephone. No other medium known will broadcast as it does, therefore is it not something that was given us primarily for that specific purpose? This must be seriously considered because there are only a limited number of wave bands in the air, and these bands must be conserved and allotted by proper Governmental regulations for specific purposes. If the radio telegraph were promiscuously used for point to point service ashore the air would become clogged with messages to the extent that it would react against efficient ship communication. Likewise, if the radio telephone is promiscuously used for point to point, or ship and ship telephone communication, the air will become so clogged that it will react against the usefulness of broadcasting.

For communication with ships we have the radio telegraph. For broadcasting we have the radio telephone. For point to point service on land we have the wire telegraph and telephone. Some day the radio art may be developed to a point where interference can be positively controlled, but until such time as this can be accomplished the Government will do well to guide the use of radio to the end of protecting the two specific purposes mentioned as much as possible against interference by other radio uses.

Radio broadcasting should be protected, extended by our Government and the commercial radio companies, and all engaged in the business should work harmoniously to the end of making radio broadcasting what God intended it to be.

The picture I see shows thousands and thousands of young men and boys studying, working, experimenting and enjoying their nightly occupation, of "listening-in,"—boys and young men that would probably be on the streets or otherwise occupied away from their homes. Time after time I have had fathers and mothers speak to me of the fact that their boys were now spending their evenings at home where formerly their evenings were spent outside. This in itself, will undoubtedly prove something that will be of untold benefit to the manhood of our country.

I can also picture the day when every farmhouse in the country will be equipped with radio receiving sets, and either the Government or commercial organizations will be transmitting concerts, educational matter, together with weather reports or other information. To my mind this should mean a wonderful thing for the family situated miles from the railroad station, miles from the town, way off from those things that we of the city can enjoy, but which through the medium of radio broadcasting can be taken to the entire country, farmer and city dweller alike.

Take the educational feature alone—is it not going to mean a broadening of the entire educational system of the country? And when I say education I not only mean school and college information, but I mean the discussion by prominent men of topics of the day, and as the rhyme says—

> "And where it leads or where the end
> Is beyond our powers to comprehend."

Recently I sat in Washington and listened to the representative of a large corporation talk as though he thought the Government should turn the entire broadcasting control to his company, but I cannot imagine any Government doing anything that will permit a monopoly of this God-given something that can carry itself eventually into practically every home in the country. Our Government must at all times keep itself in full control,—should open the art to competition so that the best possible equipments will, by competition, be put at the disposal of the public, and Government regulations should go still farther and create control of the subject matter that is broadcasted, because the same medium that can be made so wonderfully useful can, at the same time, be put to equally harmful use.

Supposing unrestricted broadcasting had existed during or previous to the war. Suppose right now Bolshevists, Anarchists, or any individual or individuals were permitted to freely broadcast uncensored ideas, our whole country could have been or could now be turned into turmoil overnight.

The ideal that should be striven for in the handling of both radio telegraph and radio telephone by Government, commercial, and general public alike, should be that

"We who delve in our little part
Of nature's laws in this new-found art,
Must realize there's a power and plan
And a God—a ruler of nature and man.

"This 'Everything' didn't just happen to be;
It must have been planned, created, and he
Who planned and created must rule by right
King of all nature—all man and all might."

Then let us endeavor to so draft our laws and so handle our business that this thing called Radio can be used for its God-given purpose of creating harmony, knowledge and brotherly love throughout the nation and throughout the oceans.

INDEX

INDEX