MANUAL

OF

WIRELESS TELEGRAPHY

FOR THE USE OF

NAVAL ELECTRICIANS

BY

COMMANDER S. S. ROBISON, U. S. NAVY

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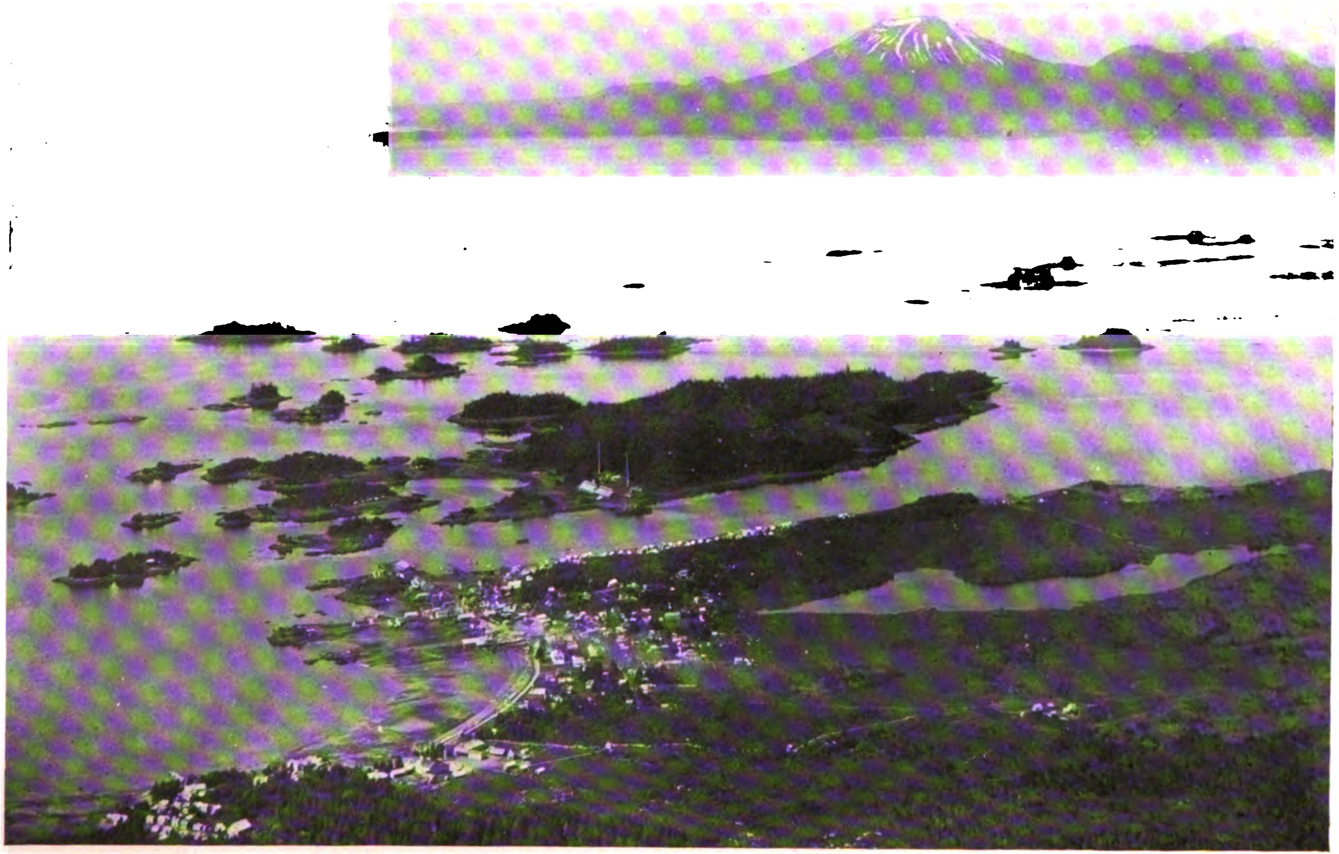

U. S. NAVAL WIRELESS TELEGRAPH STATION, SITKA, ALASKA.

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PREFACE

This manual, first published in January, 1907, was revised in 1909 by L. W. Austin, Ph. D. The present (2d) revision contains the results of some of Dr. Austin's later researches as well as more detailed instructions relative to installation, care and operation, also additional appendices, containing extracts from Service Regulations adopted at the International Wireless Telegraph Convention in Berlin, October, 1906, and the U. S. Statute of 1910, relative to wireless telegraph apparatus on merchant vessels.

The author is also indebted to Mr. J. Martin, of the Navy Yard, New York; Mr. Geo. F. Hanscom, of the Navy Yard, Mare Island; Mr. Geo. R. Clark and others for figures, illustrations and suggestions.

July, 1911.

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MANUAL OF WIRELESS TELEGRAPHY.

Chapter I.

GENERAL REVIEW OF FACTS RELATING TO HIGH FREQUENCY CURRENTS.

ELECTRICITY.

1. If amber is rubbed with silk a change in the condition of the amber and of the silk is produced which can be detected in various ways.

This change in condition is described by saying that the amber and the silk are *electrified* or charged with *electricity* by friction. Both of these terms are derived from the Greek word "elektron," meaning amber.

The silk and amber thus electrified attract each other and bodies in their vicinity, but the silk will repel another piece of silk similarly electrified and the amber will repel another piece of amber similarly electrified. Since amber and silk have no effect on each other when not electrified, the qualities of attraction and repulsion are said to reside in the electric charges, and the fact is expressed by the statement that like charges repel, unlike charges attract each other. The silk is said to be *positively,* the amber *negatively,* electrified or charged. Positive and negative charges are indicated by plus (+) and minus (—) signs.

The charges are said to consist of *static* or frictional electricity.

Bodies thus charged when not brought into contact with each other or with what are called conductors remain in an electrified condition for some time.

Bringing oppositely charged bodies in contact generally removes all evidences of electrification. The charges are said to unite and, being of opposite signs, to neutralize each other, and the bodies are said to be *discharged.*

Sparks accompanied by a sharp crackling sound are produced between highly electrified bodies when brought very near each other. After the spark has passed the bodies are found to be discharged.

Charged bodies which can be discharged by sparking at greater distances than others are said to be charged to a higher *potential.*

All bodies, whatever their nature, are capable of being electrified.

The presence of static charges of electricity can be shown by what are called electroscopes. One of the most sensitive, the gold-leaf electroscope, consists of two small pieces of gold leaf, which, becoming charged in the same sense (i. e., positively or negatively), by touching a charged body, repel each other, and diverge, and show by their divergence the presence of electric charges.

2. Certain bodies, notably metals, have the quality of transmitting or carrying electric charges through themselves and are called *conductors.* Bodies lacking in this quality, or possessing it to a very limited degree, are called *nonconductors,* or *insulators,* or *dielectrics,* according to the purpose for which they are used.

3. When pieces of zinc and carbon are immersed in a conducting liquid (fig. 1) the combination is called a *primary cell.* If a wire is connected to the zinc and one to the carbon and the free ends of the two wires brought near each other, these ends are found to be electrified; the end of the wire connected to the carbon electrified like the silk (+) and the end of that connected to the zinc like the amber (—). The carbon is called the *negative* element or *positive pole* of the cell and the zinc the *positive* element or *negative pole.* A number of cells together is called a *battery.* The liquid in which the elements are immersed is called the *battery solution.* If the free ends of the wires are brought together an *electric current* is established, of which the *positive* direction is said to be from the carbon to the zinc, through the wires; from the zinc to the carbon, through the liquid. (See fig. 2, and note 1, appendix.)

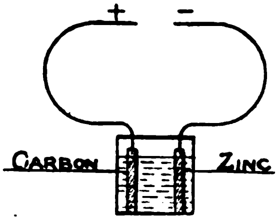

Fig. 1.

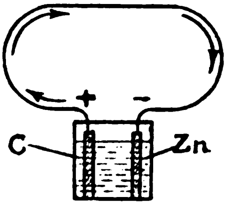

Fig. 2.

The current is said to be caused by a difference of *potential* between the carbon and the zinc. It is supposed to be made up of small electric charges transmitted through the wire in quick succession, the charges being produced by chemical or electric action between the carbon and the zinc in the liquid.

The force which causes the movement of the electric charges which make up the current is called the electro-motive force and is usually written E. M. F.

If the free ends of the wire in fig. 2 instead of being directly connected are immersed in another conducting liquid, as in fig. 3, the current will flow through this liquid. The immersed ends are called *electrodes.* The one at which the current enters is called the *positive* and the one at which it emerges the *negative* electrode. These are also called the *anode* and the *cathode,* respectively. The conducting liquid in this cell is called the *electrolyte.*

4. If the anode and cathode in fig. 3 are made of lead (or preparations of lead) plates, and the electrolyte is a solution of sulphuric acid in water, the combination is called a *secondary* or *storage cell* or *accumulator* and a number of such cells is called a *storage battery.* The anode is called the *positive plate* and the cathode the *negative plate.* If, after a current has been forced through such a cell for a time, the wires from the primary cells are disconnected and the positive and negative plates connected by a wire (fig. 4) outside of the electrolyte, a current will flow, the positive direction of which will be from the *positive* to the negative plate in the wire, and from the *negative* to the positive plate in the electrolyte.

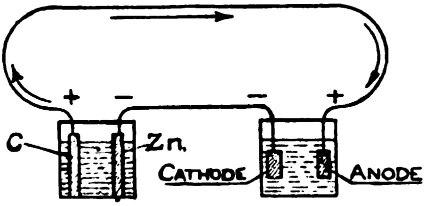

FIG. 3.

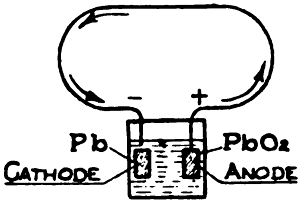

FIG. 4.

5. For convenience, a battery of primary or secondary (storage) cells is indicated as in fig. 5, the elements forming positive poles by the light lines and the elements forming negative poles by the shorter, heavy lines. Cells connected as in fig. 5 are said to be in *series;* connected as in fig. 5a, in *parallel.*

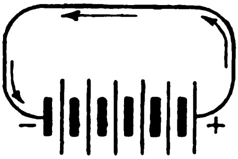

FIG. 5.—Cells in Series.

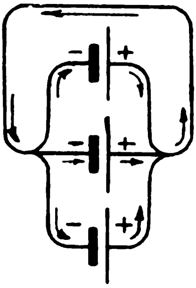

FIG. 5A.—Cells in Parallel.

MAGNETISM.

6. A magnet situated at a distance from other magnets and pivoted so that it is free to move, will point toward the north magnetic pole of the earth, which in some localities coincides with the north star in direction. That end of the magnet which points in the direction of the north star is called the north-seeking pole, or simply the *north pole* of the magnet. The other end is called the *south pole.*

Similar magnetic poles, like similarly charged bodies, repel each other. Dissimilar magnetic poles, like oppositely charged bodies, attract each other—i. e., two north poles or two south poles repel each other: a north and a south pole attract each other. The north pole is sometimes called the *positive* pole and the south pole the *negative* pole of the magnet.

Wrought or *soft* iron can be magnetized but only retains its magnetism while under the influence of the magnetizing force; *steel* or *hard* iron once magnetized retains its magnetization permanently, and special means to demagnetize it are required.

All bodies can be electrified, but all bodies can not be magnetized.

7. If a sheet of paper is held over a powerful magnet and iron filings sprinkled on the sheet, the filings will assume positions approximately as shown in fig. 6. Some force connected with the magnet must make the filings assume these positions, which are different from what they would be if the magnet was not under the paper; and from the way the filings are arranged, this force must act in the space surrounding the magnet. This space is called the field of magnetic force, or simply the *field of force,* and the lines in which the filings tend to arrange themselves are called the *lines of force,* and we shall see in chapter II that this conception is used as a basis for electric measurements. The direction of the lines of force at any point indicates the direction of the magnetic force at that point, and their number in any area, the strength of the field in that area.

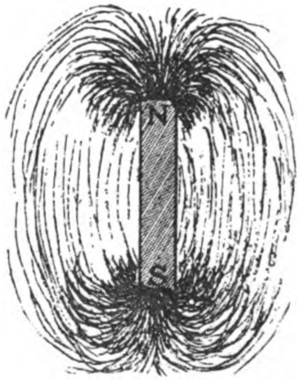

FIG. 6.

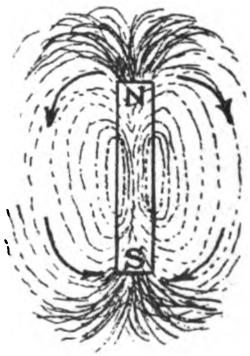

FIG. 7.

It is found that a small magnetic needle, pivoted so that it is free to move and brought near the large magnet, will lie parallel to the direction of the lines of force at any point at which it may be placed in the field, and that the north pole of the needle always points along the lines of force in the direction leading to the south pole of the magnet.

The direction in which the north pole of the needle points is called the *positive* direction of the lines of magnetic force, and the direction in which the south pole points, the *negative* direction of the lines of magnetic force.

Lines of magnetic force are said to run from the north pole of the magnet to the south pole through the air, and back to the north pole through the steel (fig. 7).

ELECTRO-MAGNETISM.

8. If the wire in fig. 1 is coiled into a spiral, as in fig. 8, with the positive direction of the electric current as shown by the arrows and the battery connections, a field of magnetic force which can be explored by a small magnetic needle, or outlined by iron filings, as in fig. 6, will be found to exist around the spiral, and the direction of the lines of force will be found the same as those around the magnet in fig. 7. If the current is reversed, the lines of force are reversed in direction.

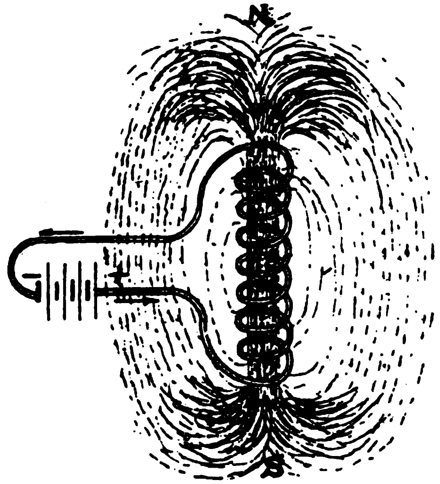

FIG. 8.

Such a spiral, when traversed by a current, is found to have all the properties of a magnet, and is called an *electro-magnet* or *solenoid.*

The strength of the magnetic field around an electro-magnet rises and falls with the rise and fall of the current, and its polarity depends on the direction of the current.

The *positive* direction of the lines of magnetic force which surround a solenoid is from the north to the south pole outside of the spiral, and from the south to the north pole inside of it, just as the *positive* direction of an electric current is from the *positive* pole to the *negative* pole outside of a battery and from the *negative* to the *positive* pole inside of it.

If the number of turns of the spiral is reduced to one it does not lose its magnetic character. The lines of force then form circles around the wire, their *positive* direction being shown in fig. 9, the upper side being a north pole and the under side a south pole. If the turn is straightened out, as in fig. 10, the lines of force still form circles around the wire, and the north pole of the exploring needle points in the positive direction of those lines. This direction is found to be always at right angles to the wire.

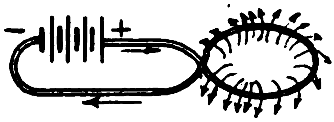

FIG. 9.

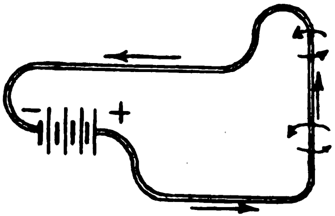

FIG. 10.

9. It appears from the foregoing that what is called the *positive* direction of motion of electric currents, or charges, is related to what is called the *positive* direction of the lines of magnetic force, in the manner shown by the arrows in figs. 8, 9, and 10, and, further, that the terms *positive* and *negative* as applied to electric and magnetic effects, and so largely used in connection with them, are purely conventional. (See note 2, appendix.)

10. Returning now to the statement in article 8 that the strength of the magnetic field around a solenoid rises and falls with the strength of the current, and its polarity (i. e., the direction of the lines of magnetic force produced) depends on the direction of the current, it can be further stated that a magnetic field exists around every wire carrying an electric current (fig. 10). The direction of the lines of force in this field depends on the direction of the current. These lines of force always enclose circles in planes at right angles to the wire.

11. Since a current is conceived to be made up of a quick succession of moving electric charges (art. 3), the above facts may be stated in another way, viz., that moving electric charges produce magnetic fields in which the lines of magnetic force enclose circles in planes at right angles to the direction of motion of the moving charges. This has been proved to be true for single static charges.*

ELECTRO-MAGNETIC INDUCTION.

12. Fig. 11 represents a primary battery, with the two poles of the battery connected by a conducting wire, broken at K. A straight portion

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* By Professor Rowland, Johns Hopkins University.

A B of this wire is parallel to, and at a distance from another conducting wire C D. When the break at K is closed, a current flows in the circuit, and a field of force is created around the wire. Let us consider the straight portion A B in which the direction of the current is shown by the arrows, and the direction of the lines of force by the circles (shown as ellipses), at right angles to A B. Several of these lines of force are shown embracing the parallel wire C D.

If gold-leaf electroscopes (art. 1) are attached to the ends C and D of the wire C D, and if the current started in A B when the break is closed is sufficiently powerful, the gold leaves will be observed to diverge, momentarily, whenever the circuit is made or broken at K. The stronger the current in A B, and consequently the stronger the magnetic field produced, the more pronounced the indications of the electroscope will be.

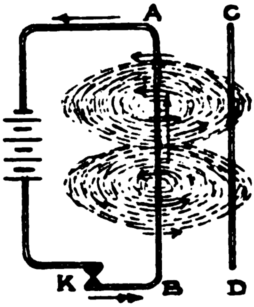

FIG. 11.

This shows that the ends C and D of the wire C D are electrified when the current is made or broken in A B. When the current is made, the end D is negatively charged like the amber and like the wire attached to the zinc element in fig. 1, the end C positively, like the silk and like the wire attached to the carbon element in fig. 1.

When the circuit is broken at K the electrification of C D is reversed, C becoming negatively and D positively electrified. A sudden increase or decrease of the current in A B produces the same effect as when the current is made or broken.

It is to be noted that the electrification of C D is only momentary. As soon as the causes producing it are removed, the electric charges unite and neutralize each other through the body of the conductor.

We know that when the current in A B is made, a magnetic field is created around A B which extends to and beyond C D, and that when the current in A B is broken, the magnetic field disappears, and that the only thing common to A B and C D is this magnetic field, the lines of force in which surround them both, and since we see that one kind of electrification is produced in C D when the lines of force are being created, and the opposite kind when they are being dissipated, we conclude that the movement or creation of these lines creates the electric charges that we observe in C D.

13. In art. 11 it is stated that moving electric charges create magnetic lines of force. Now, we see the truth of the converse, viz., that moving magnetic lines of force create electric charges.

These two facts are of general application and are the basis of all electro-magnetic calculations.

14. It is of great importance to keep clearly in mind the fact that electrification in C D only takes place when the current is made or broken or changed in A B. When there is no current in A B there are no magnetic lines of force, and consequently there is no electrification in C D. When there is a constant current in A B the magnetic field is constant and there is no electrification in C D.

It is while the current in A B is rising or falling, and the lines of force expanding from or contracting toward A B and cutting through C D as they pass, that C D is affected. A *movement* of the lines of force is required to electrify C D, and this movement is produced by changes in the current in A B.

If the ends C and D are joined to form a complete circuit, a momentary current will flow when changes in the magnetic field around C D take place.

We have just seen that a moving magnetic field in the vicinity of C D creates electric charges in C D. We would also find that moving C D in a magnetic field has the same effect. The change of current in A B is said to *induce* the current in C D, and the action is called *electro-magnetic induction.*

The preceding facts can be stated as follows: When magnetic lines of force cut or are cut by a conductor, electric charges (i. e., a tendency to current flow) are induced in the conductor, and currents flow if the conductor forms a closed circuit, the direction of the induced currents depending on the direction of cutting.

15. When the current in A B is rising, the magnetic lines of force are expanding, and cutting C D in the direction from left to right, the direction of the momentary current in C D being as shown in fig. 11a.

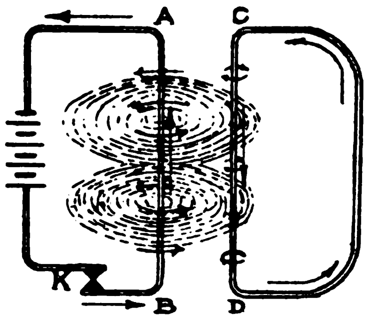

FIG. 11A.—Current in A-B Rising.

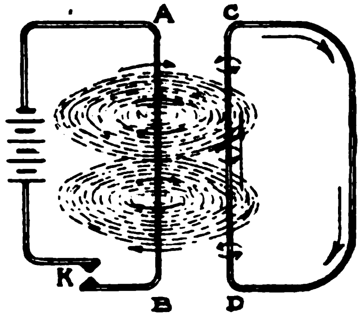

FIG. 11B.—Current in A-B Falling.

When the current in A B is falling, the magnetic lines of force are contracting, and cutting C D in the direction from right to left, the direction of momentary current in C D being shown in fig. 11b. These momentary currents or movements of electric charges in C D themselves produce momentary magnetic fields around C D, the direction of the lines of force of which are shown by the arrows in figs. 11a and 11b. It will be seen that these lines of force are opposite in direction to those which created the current in C D. The field of force created around C D reacts upon A B, tending to create in A B a current in the opposite direction to that already in A B, i. e., to stop it.

In other words, the change of primary current in A B induces a secondary current in C D. The latter current in turn induces a tertiary current, which is in A B. This influence of two currents on each other is called their *mutual induction.*

16. The electric charges produced by friction (art. 1), by chemical action (art. 3), and by the movement of lines of magnetic force are all identical in their properties, and the magnetic fields produced by the movement of these charges are also identical in their properties. It is therefore evident that a very close relation exists between electricity and magnetism.

17. We have seen that the field of magnetic force around a wire carrying a current or around a magnet can be mapped out by iron filings. In a similar manner the field of electric force around charged bodies can be shown by the use of various light powders.

Figs. 12 and 12b show the electric field between unlike and like charges, respectively. Figs. 12a and 12c show the magnetic field between

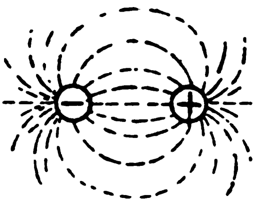

Fig. 12.

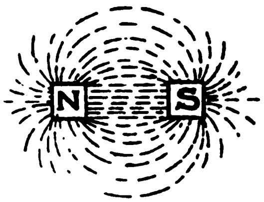

Fig. 12A.

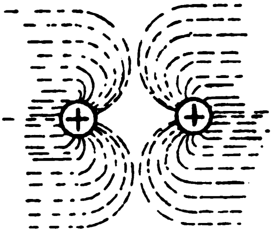

Fig. 12B.

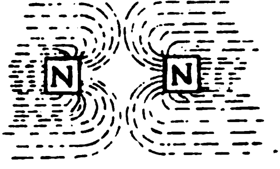

Fig. 12C.

Fig. 12.—Electric Field Charges of Opposite Sign.—Attraction.
Fig. 12A.—Magnetic Field between Unlike Poles.—Attraction.
Fig. 12B.—Electric Field Charges of Same Sign.—Repulsion.
Fig. 12C.—Magnetic Field between Like Poles.—Repulsion.

unlike and like poles, respectively. The electric field between two charged bodies is found to resemble very closely the magnetic field between magnet poles. In all figures it can be seen that in electric as well as magnetic fields each line of force appears to repel its neighbor, and that they have their ends on points of opposite electrification or magnetization. If these lines tend to shorten in the direction of their length this tendency will cause the attraction between the bodies from which they proceed.

18. It may be asked,—what are these lines of force which are not visible and which can not be physically grasped? The only reply is that we believe all electric and magnetic phenomena to be the results of the disintegration of the atoms of matter or the rearrangement of their constituent parts (see note 2, appendix), the movements of which produce stresses and consequent movement or strains in what is called the *ether,* an almost infinitely elastic, infinitely tenuous substance which surrounds and permeates all matter and all space.

The earth is immersed in an illimitable ocean of ether, just as fishes are in water.

We move about in a sea of it.

What we call electric and magnetic fields are places where ether movements and ether stresses can be detected by the phenomena which they produce, and which are being described.

An electric field is a state of strain (stretch or compression) in the ether; it can be removed between any two points by connecting them with a conductor. The release of the strain starts movements of electric charges in the conductor. Movements of these charges produces another state of strain in the ether at right angles to the first. We call this a magnetic field.

We have seen that movement of either field creates the other, and that the lines of force in the two fields when they are thus produced are in planes at right angles to each other. When equilibrium is restored one field or the other has disappeared, though they can coexist in a transitory state.

19. *It has been proved that light and heat are forms of ether motion also, and that all movements (electric and magnetic) in the ether are propagated with the velocity of light.*

It has also been proved that electric movements progress along straight wires at practically the same speed that magnetic movements progress at right angles to them—i. e., with the speed of light.

This velocity has been measured many times and found to be 186,000 miles, or approximately 300,000,000 meters per second.

We must learn therefore to think of light movements and of electric and magnetic actions not as being instantaneous, but as being restricted to a definite measurable speed.

It takes *time* for electric and magnetic effects to be propagated in the ether, time for them to be propagated along a wire. The wire guides or strikes out the line of maximum disturbance.

20. Let us now return to fig. 11. Before connection at K is made, the field of magnetic force does not exist, but the wires are electrified by means of action between the zinc and carbon in the battery solution. When the break at K is closed, a magnetic field is established; when the connection at K is broken, the magnetic field disappears. The question arises,—how is this magnetic field created? How is it dissipated? The reply is: It is created by movement of electric charges in A B which disturb the ether and this disturbance is propagated through the ether at right angles to A B, with the speed of light, i. e., at the rate of 186,000 miles or 300,000,000 meters per second. This disturbance is of such a nature as to produce a state of strain in the ether which may be compared to that produced in a piece of rubber by compression or tension. The strain is relaxed as soon as its cause (i. e., the movement of the electric charges) is removed.

The amount of strain (i. e., the strength of the magnetic field) decreases as the distance from the moving charges increases. It spreads in all directions, but except with very delicate instruments can not be detected at any great distance from A B.

The creation and dissipation of this state of unstable equilibrium in the ether, which must be brought about by some kind of movement in it, produces electrical movement in C D, or, as it is perhaps better to say, produces electric charges in C D. C D stands in the way of and is disturbed by an advancing or receding wave of movement in the ether, originated at A B. C D is, like all other conductors, an obstacle in the path which creates an eddy, so to speak, in the ether wave and reacts, however minutely, on A B, because the movement of the electric charges produced in C D also creates an ether movement, but in the opposite direction to that proceeding from A B.

21. We have now reached a point where the electric and magnetic actions under discussion are directly applicable to wireless telegraphy, but before proceeding with this subject it is desirable to consider more fully the action of A B on C D, because the creation of electric currents by moving or varying magnetic fields, and vice versa, is the basis of industrial electric power—of that used in wireless telegraphy as well as in other branches of electricity; and other facts or developments of this fundamental fact will appear which will lead to a clearer comprehension of it.

22. In fig. 11, C D is shown parallel to A B. If C D is slowly revolved around its own center as an axis the effect on it of making, breaking, or changing the current in A B will be found to decrease until C D is at right angles to A B, when it will disappear altogether. The lines of force are circles at right angles to A B; they do not cut C D when it is at right angles to A B because it is parallel to them, and consequently no effect is produced.

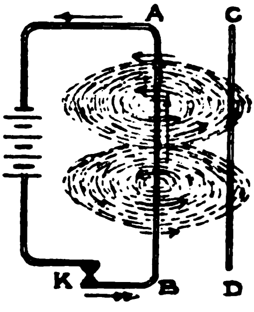

FIG. 11.

The induced effects in C D will be found to increase as it is brought nearer A B and to decrease as it is removed from A B. The field near A B is stronger, and more lines of force are created there or dissipated there than at a greater distance from A B—i. e., a greater disturbance in the ether takes place.

23. If the two ends of C D (fig. 11), are brought close together, but without touching, and if the current made or broken in A B is very strong, a spark will pass between the ends of C D at each make and break. If C D is separated from A B by an opaque, nonmetallic screen and the makes or breaks in A B are made to represent the characters of a code, messages sent in this code from A B can be received at C D when each is invisible from the other. By the addition of a battery to C D, similar to that producing current in A B, replies can be sent, and thus a crude wireless telegraphy produced.

24. If A B is coiled into a spiral or *helix* and C D into a similar spiral or *helix* (fig. 13), the effect of making, breaking, or changing the current in A B is much greater than where both wires are straight; for the disturbance created in the ether—that is, the number of lines of force produced by the moving charges in A B—is equal, for equal lengths of the wire, and since a greater length is concentrated in the same space, the number of lines of force in that space, assuming the current in the spiral to be the same as that in the straight wire, are correspondingly greater. This stronger field would produce an increased effect on a straight wire; but the length of C D is also concentrated. Therefore the effect is increased still more.

25. We know that A B when coiled as in fig. 13 and traversed by a current forms a solenoid (art. 8, fig. 8). The space inside the coil is called the *core,* and it has been assumed that the surrounding substance (excluding the ether, which is present both in the interior and on the exterior of all bodies) is air. It is found, however, that if the core of the solenoid is iron, as in fig. 14, instead of air, the effect on C D is very much more powerful—i. e., the numbers of lines of force created with the same current is very greatly increased.

This shows that it is easier to create lines of force in iron than in air; or, to state the fact differently, lines of force permeate iron more easily than they do air. The relative ease with which magnetic lines of force are created in a substance is expressed in figures and called its magnetic *permeability*. The permeability of air at atmospheric pressure is called unity, and on that basis the permeability of the purest wrought iron is 3,000. In other words, within limits the same current will produce 3,000 times as many lines of force in iron as in a body of air of the same length and area of cross section.

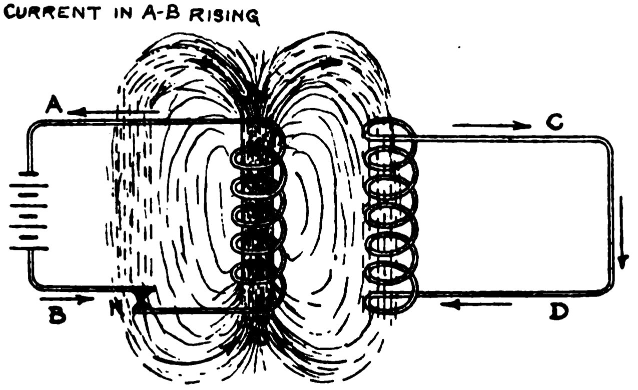

Fig. 13.

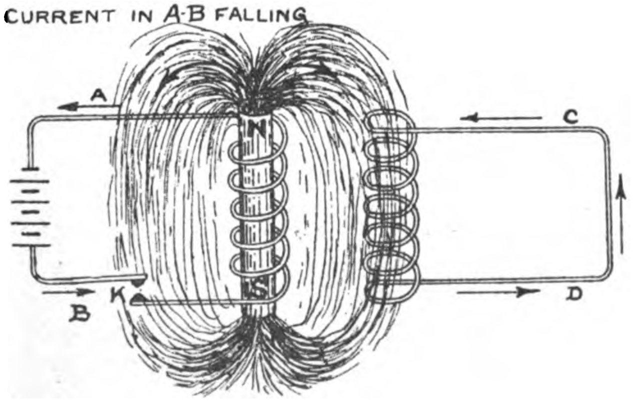

Fig. 14.

26. If the iron of fig. 14 is extended to include C D, as in fig. 14a, the effect of changes in A B is increased still more, because in fig. 14 the lines of force are partly in iron and partly in air, while in fig. 14a they have an iron path throughout, and are consequently much greater in number. C D can also be placed inside of A B or outside of it, with or without an iron core (figs. 14b and 14c).

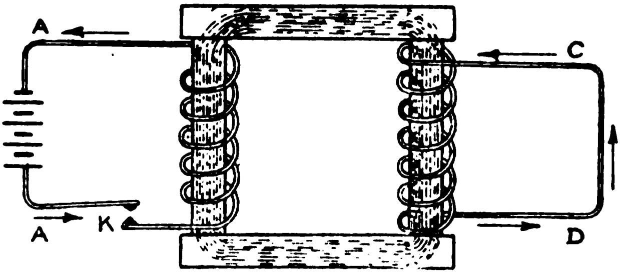

FIG. 14A.—Closed-Core Transformer (current in A B falling).

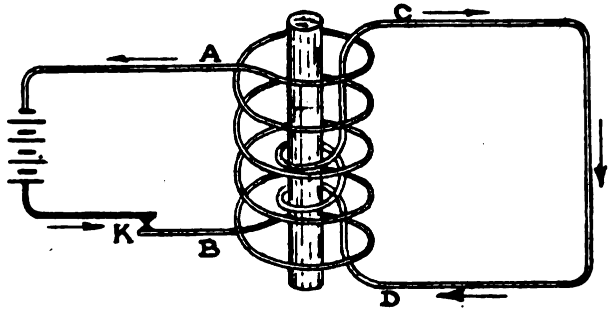

FIG. 14B.—Open-Core, Step-Down Transformer or Induction Coil (current in A B rising).

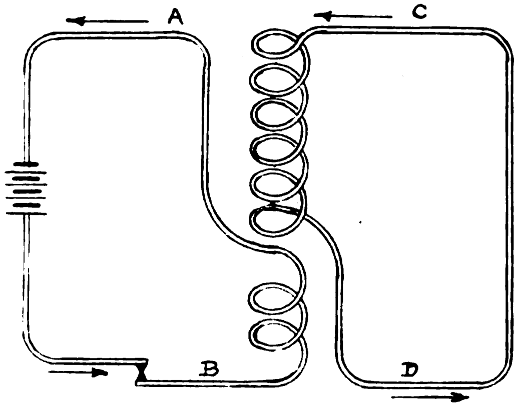

FIG. 14C.—Air-Core, Step-Up Transformer (current in A B rising).

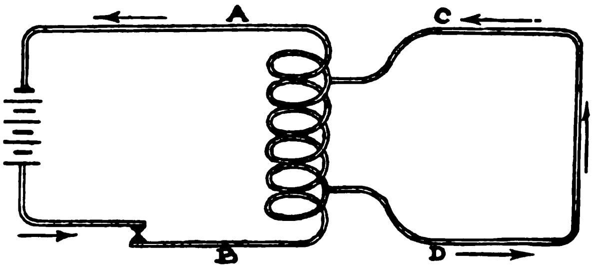

FIG. 14D.—Auto Step-Down Transformer (current in A B rising).

27. Since the tendency to current flow in C D is produced by lines of magnetic force cutting C D, and since on making or breaking current in A B each line of force cuts C D once, for each turn in C D, if the turns in C D are decreased or increased, as in figs. 14b and 14c, the tendency to current flow—i. e., the electro-motive force—is raised or lowered. From this fact, and from the fact that the current in C D is opposite in direction to that in A B, the arrangements in figs. 14a, 14b, and 14c are called transformers. Fig. 14a is called a *closed-core transformer;* fig. 14b an *open-core transformer* or *induction coil;* fig. 14c an *air-core transformer.*

Transformers are called *step-up* or *step-down* with reference to whether the number of turns in the coil C D is greater or less than those in A B. Fig. 14b is a step-down; fig. 14c a step-up transformer. The coil A B is called the *primary* and the coil C D the *secondary winding,* and where A B and C D have some turns common to both, as in fig. 14d, the arrangement is called an *auto-transformer.*

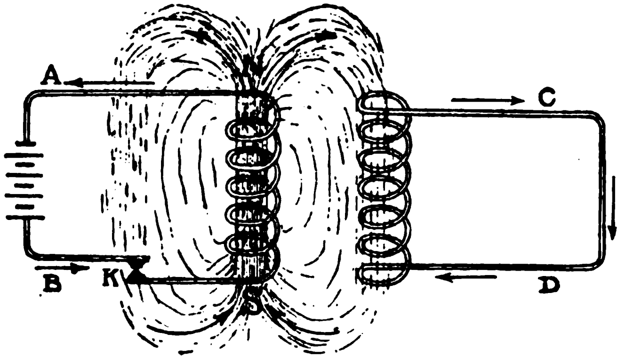

FIG. 13.

28. Referring again to fig. 13: When the break at K is closed, a current is started, which progresses upward through the coil, the moving charges composing it creating a magnetic field around the wire. The lines of force, as they expand from the current in the first turn of the spiral, cut the second turn of A B in the same way that they cut C D a little later. They induce a current in the second turn opposite in direction to that in the first turn—i. e., tending to stop it. The same effect is produced in the third and succeeding turns. In other words, the different parts of the coil A B react on each other just as the coil C D reacts on A B. This reactive effect of the turns on each other makes the rise in current slower than in a straight wire, and is greater when the core of the coil is of iron than when it is of air, because of the greater number of lines of force produced.

29. We find that a stronger current is produced by the same battery in a short wire than in a long wire of the same size and material, and in a thick wire than in a thin wire of the same length, and we say that this is is due to the greater *resistance* of the long wire and of the thin wire as compared with the short or with the thick wire. To establish the same current in the longer or the thinner wire as in the shorter or thicker wire requires a larger battery—that is, greater E. M. F.

30. Now, we find that when the wire is coiled into a spiral and a *change* in the current is taking place, the turns react on each other and resist the change of the current. This resistance does not depend on the size nor the material of the wire, but only on the amount and quickness of the *change* in the current, and is therefore of a different character from the resistance referred to above. The resistance of a wire to changes in current established in it, is called its *reactance,* and during the change the total effect of the true resistance and the reactance is called the *impedance* of the wire or circuit.

In circuits having reactance the production or progression of electrical effects is retarded. It takes longer to create a given current than in the same length of straight wire. It may be said, therefore, that coiling a wire increases its electrical length—i. e., increases the time it takes an electrical movement created at one end of it, to reach the other.

The currents in C D are said to be produced by the *induction* of A B on C D. The retarding effect of the coils in A B to the rise and fall of current in A B is said to be due to the *self-induction* of A B. It has been shown that the amount of both kinds of induction depends on the shape and arrangement of both circuits and the material (iron or air) in and around them.

METHODS OF PRODUCING CURRENTS BY ELECTRO-MAGNETIC INDUCTION.

31. The currents under discussion have been illustrated as being produced by batteries of primary cells, and for many purposes these are very valuable, but for the production of very powerful electrical effects advantage is taken of the fact, stated in art. 14, that when magnetic lines of force cut or are cut by a conductor, electric currents flow in the conductor, if the latter forms a closed circuit.

The direction of current flow can be determined by the following rule:* (a) An increase in the number of lines of force embraced by a circuit induces a current in the opposite direction to that in which the hands of a watch move, while a decrease in the number of lines of force induces a current in the same direction as that in which the hands of a watch move, the line of sight being in both cases along the positive direction of the lines of force. (Art. 7 and fig. 7.) Or rule (b) The *positive* direction

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* From Fiske's "Electricity and Electrical Engineering."

of the lines of force is with the hands of a watch when the current is flowing away from the observer. And rule (c) The currents induced by moving lines of force always tend to prevent change in the inducing current. Induced currents are, therefore, in the opposite direction when the inducing current is rising and in the same direction as the inducing current when the latter is falling. (Art. 15.)

Rule (a) is illustrated by fig. 15; rule (b) by fig. 15a.

From rules (b) and (c) can be deduced the following illustrated in fig. 15b, which represents a conducting wire C D below a line N S representing a field of force and its direction. When in the relative positions shown movement of either wire or line of force *toward* the other creates a current to the rear, moving either one *away* from the other creates a current to the front.

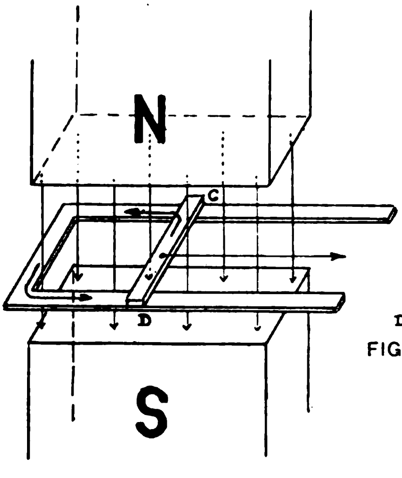

FIG. 15

FIG. 15a

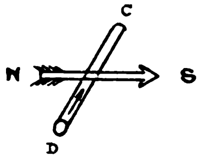

FIG. 15b

It will be seen that the field N S can be revolved through any angle around the wire C D as an axis so as to be to the right, left, or above or in any intermediate position without changing the truth of the above statement.

These three rules show the relation between what we call the *positive* direction of the lines of magnetic force and what we call the *positive* direction of electric current.

32. Now let the wire C D in fig. 11 be bent until it forms a rectangle, and let it be placed in the magnetic field between the north and south poles of a powerful electro-magnet having an iron core. By bending the core into the shape shown in fig. 16, the north and south poles are opposite each other and a greater number of lines of force are produced, because the distance they have to travel through the air is very much shortened as compared with fig. 14.

Exploration of the field in fig. 16 by means of iron filings or by means of a small magnetic needle will show that the lines of force extend directly from a point in the north pole to the opposite point in the south pole. In other words, that they are straight and parallel to each other, and they are so shown in fig. 16. The field is also found to be of uniform intensity, which indicates that the number of lines of force are equally distributed throughout its area.

Now, if C D is moved up or down in the magnetic field, no indication of a current can be perceived, and it appears that the statement in art. 14 (that when magnetic lines of force cut or are cut by a conductor electric currents flow in the conductor if the latter forms a closed circuit) is in error, but when we consider that when C D is moved upward (the field being of uniform intensity) as many lines of force are cut by the bottom half as by the top half of C D, the currents induced in the two halves must therefore be equal, and since both flow to the rear we see that they neutralize each other, and the result is zero. Another way to explain this is to consider that portion of the field inclosed by C D as containing a certain number of lines of force. Those coming in when C D is moved induce a current in one direction, those going out induce a current in the opposite direction, and if as many come in as go out no effect is produced.

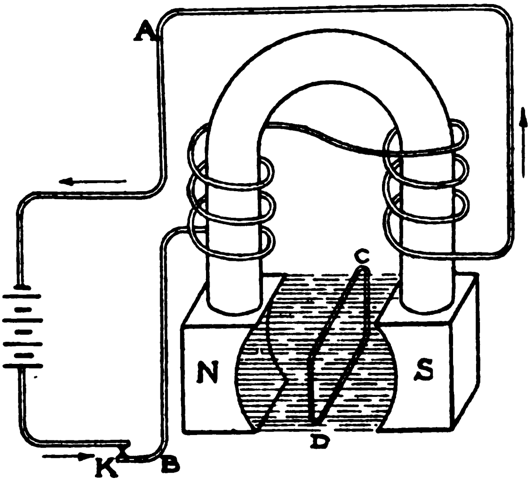

FIG. 16.

33. If C D were straight, electric charges would be produced on its ends and would be maintained there as long as the cutting of the lines of force continued, but bending it into a closed circuit changes conditions to the extent that cutting of lines is going on all around the circuit, some inducing charges in one direction, some in the other, and it is only when there is a preponderance of cutting in one direction that a current actually flows. This would occur if C D were moved from a point where the field is weak to where it is stronger, or vice versa, but the field under discussion is supposed to be uniform. (See rule a.)

If C D is rotated around one of its diameters as an axis (say the horizontal diameter at right angles to the lines of force) when it is horizontal, as in fig. 17, the lines of force included will be zero, and when vertical, as in fig. 17a, the lines of force included will be the maximum number possible in that field, so that a revolution of 90° will make an entire change in the number of lines of force passing through the rectangle.

For instance, if the revolution is in the direction of the hands of a clock—i. e., if the top of C D moves to the right (see fig. 17a)—the upper half of C D is cutting lines of force in the direction which induces movements of electric charges to the front, while the lower half is cutting lines of force in the direction which induces movements of electric charges to the rear, so that an electric current is established in C D in the direction shown, or the number of lines of force included in C D is decreasing, and looking from N to S, the current moves with the hands of a watch.

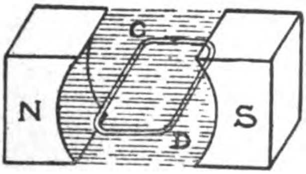

FIG. 17.

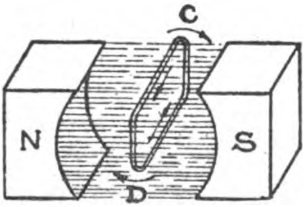

FIG. 17A.

If C D's rate of revolution is constant, a little consideration will show that when it has revolved through 90° and its plane is horizontal it is then moving at right angles to the lines of force, and consequently cutting them faster than when, its plane being vertical, it moves parallel to the lines of force for an instant and is not cutting any; also that the increase in the rate of cutting is progressive from one position to the other. It will therefore be seen that the electric current produced is a maximum when C D is horizontal, and that it is zero for an instant when C D is vertical because during that instant it moves parallel to the lines of force and therefore there are none being cut. (No change in number included.) It is also evident that the increase of the current from zero to a maximum is progressive during the first 90° of revolution, that it then progressively decreases until C D has revolved through 180°, and is again moving parallel to the lines of force when it falls to zero.

As the revolution continues, that half of C D which during the first half revolution was cutting lines of force in such a manner as to induce a current to the front now cuts them in such a manner as to induce a current to the rear, its former place being taken by what was originally the lower half, so that the direction of current in C D is reversed. (Rule c.)

Another maximum rate of cutting lines of force and consequent maximum of current is produced when C D has revolved through 270°. The current progressively increases from 180° to 270° and then decreases until when the original conditions are restored by the completion of one revolution the current has again fallen to zero.

From the above and from an inspection of fig. 17a it will be seen that current is always flowing to the front in that half of C D which is going down to the right and to the rear in the half going up on the left, and that each half revolution the current changes in direction. Such a current is called an *alternating current.*

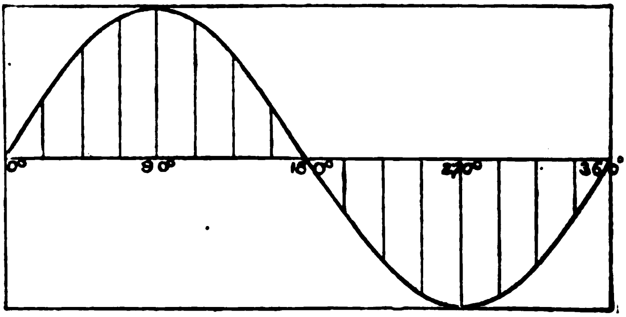

FIG. 18.

34. This can be shown graphically in fig. 18, where the rate of cutting and therefore the rate of change of number of lines included in the circuit at different equidistant points in one revolution is represented by equidistant vertical lines proportional to the cutting rate, and consequently to the current strength. Vertical lines above the horizontal line represent current strength in one direction and below it current strength in the opposite direction. A regular curve is produced by joining the tops of these lines. This curve is the curve of sines, because the rate of cutting and the strength of the induced current are proportional to the sine of the angle of revolution.*

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* Since the lines of force are horizontal, the number cut during the revolution of C D through any angle is proportional to the vertical movement of the extremity of the radius of C D which generates the angles. The amount of this vertical movement is the sine of the angle, and therefore the induced current is proportional to the sine of the angle.

35. If C D instead of forming a closed circuit entirely in the magnetic field has its ends connected to two rings which revolve with it and touching these rings are the ends of a coiled wire (E F, fig. 19), the currents induced in C D also flow through E F and make of it a solenoid whose strength varies with the strength of the current and whose polarity reverses with the reversal of the current. If a small magnetic needle were pivoted in E F, its direction would tend to change with each reversal of the current, and it can thus be made to indicate both the direction and the amount of current flowing through the coil E F. Such an instrument is called a galvanometer.

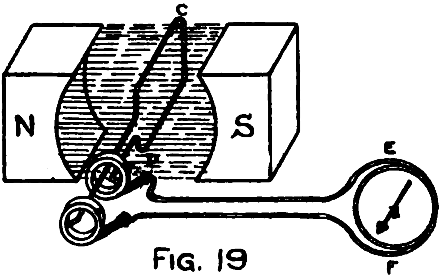


FIG. 19

The currents in the coil E F are supplied from C D, and they are induced in C D by its movements in a magnetic field. C D has become a *source* of electricity like the battery in A B. E F corresponds to the coil A B in fig. 13, and the rise and fall of current in E F will produce a rise and fall of current in another coil near it, just as the make and break at K in fig. 13 induces momentary currents in C D.

The currents in C D, fig. 13, were induced by *interrupted current.* Those induced by E F in coils near it are induced by *alternate current.* Interrupted current was used almost entirely in wireless telegraphy in its earlier development. It has now been replaced by alternate current.

36. It only remains now to make C D produce the magnetic field in which it revolves, and we can dispense entirely with the primary battery in A B. This can be done as follows:

In fig. 20 instead of having each end of C D connected to a ring of conducting material, as in fig. 19, one ring is removed and the other split into two equal parts and an end of C D connected to each part, the ends of E F being adjusted so that as the split ring revolves with C D one end of E F is always connected through the split ring with

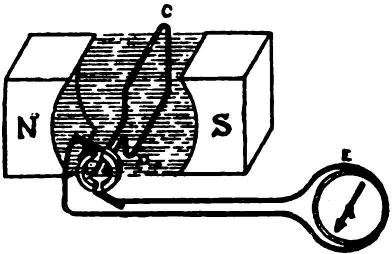


FIG. 20.

that half of C D in which the current is flowing to the front and the other end to that half in which the current is flowing to the rear. This arrangement makes the current in E F always flow in the same direction. It rises and falls with the current in C D, but does not reverse, because just as the current reverses in C D, E F changes ends, so to speak, by breaking connection with one half of the split ring and making connection with the other. The current in E F is now said to be a *pulsating* instead of an *alternating* current, and the change can be graphically represented by transferring the part of the curve below the line in fig. 18 to a corresponding position above it, as in fig. 18a.

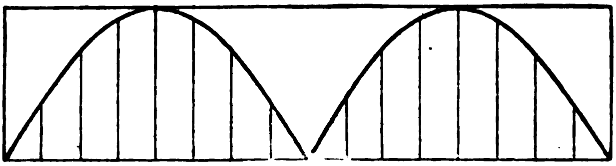


FIG. 18A.

The *alternating current* in C D is said to be *rectified* into a *direct current* in E F. The split ring by means of which it is rectified is called a *commutator,* and the entire apparatus (either with or without a commutator), a *dynamo.*

37. With a single coil, C D, rotating in the magnetic field the current in E F can be made to flow always in the same direction, but in order to make it constant a large number of coils, equally spaced, must be used, so that one of them is passing through the position (horizontal) in which maximum current is produced practically all the time. If there were 10 such coils, each connected to its own split ring (fig. 21), and all connected to E F, the currents in each would overlap, so that the resultant current in E F to another scale might be indicated by a line joining the highest point of each (fig. 18b). In other words the current in E F is practically constant.

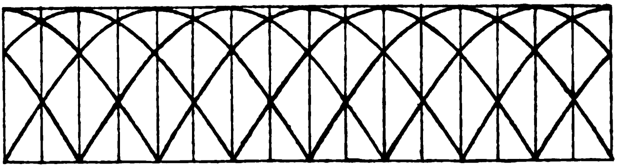


FIG. 18B.

The revolving coils are held in place on a cylindrical drum or ring and the whole is called an *armature.* If this ring is made of iron the strength of the magnetic field is much increased, because the iron affords a path for the lines of force from one pole to the other and thereby lessens the distance through which they have to pass in the air. (See art. 25.)

The tendency to current flow in C D created by cutting lines of force is called the *electro-motive force* in C D (see art. 3), and is found to depend on the number of lines cut in a given time, so that the faster C D revolves, and the stronger the magnetic field, the greater the electromotive force and the greater the current produced in any given circuit. Now, if the current induced in C D, instead of all flowing through E F, is divided, so that part of it flows around the core of the electro-magnet (fig. 21), this current can take the place of that produced by the battery in A B and the battery can be dispensed with.

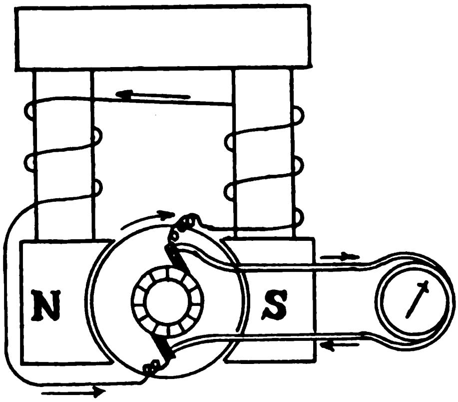


FIG. 21.

38. In art. 6 it is stated that wrought or soft iron can be magnetized, but only retains its magnetism while under the influence of the magnetizing force. *Steel* or *hard iron,* once magnetized retains its magnetization permanently and special means to demagnetize it are required. It is found that electro-magnets with soft-iron cores can be made more powerful (i. e., will give a stronger field) than if the cores are of steel, and that electro-magnets with either kind of core can be made to give much stronger fields than any permanent magnet. Also, that soft-iron cores retain a very small part of their magnetism and polarity when the current is broken, so that, if the magnet poles between which C D revolves are made of the most efficient material (wrought iron or mild steel containing no phosphorus), when C D stops they still retain their polarity in a slight degree.

When C D starts to revolve again the weak field generates a small current in C D, which sends this current through the wire around the poles; this current increases the strength of the poles and consequently of the field which increases the current in C D and so on. This is called *generating* or *building up,* and continues until the limit of the power moving C D in the continually strengthening field is reached, or until the iron core is *saturated,* in which condition no increase of current will increase the field.

39. When alternating current is desired, a dynamo, in order to be self-exciting, i. e., to produce its own field, must have part of its current rectified by means of a commutator. It is more usual, however, to drive a small direct-current dynamo by means of the same power which drives the larger one, the current from the small dynamo being used to create the magnetic field in the larger one. Such a machine is called an *exciter.*

40. The fact that magnet poles of unlike polarity attract each other (art. 6) applies to electro-magnets, with or without iron cores, as well as to permanent magnets. Hence two electro-magnets placed as in fig. 13 will attract or repel each other according to their polarity. Each line of force apparently tends to contract in the direction of its length, and by so doing exerts a mechanical pull on the conductors which it surrounds.

The same effect is observed between a magnet and a wire carrying a current (which, as we know, has a magnetic field around it) and between two wires, each carrying a current. They actually pull or push each other according to the quality of their magnetism, which is determined by the direction of the current.

41. If in fig. 21 the armature instead of being revolved to the right by some outside agency, is supplied with a current flowing through it in the same direction as the current it generates, it will revolve to the left.

The current flowing to the front in the winding of the right half of the armature and to the rear in the winding of the left half makes of it an electro-magnet with a north pole at the bottom and a south pole at the top. The revolution is caused by the attraction of the north pole of the armature by the south pole of the field magnet, and its repulsion by the north pole of the field magnet. This action is reversed in the south pole of the armature.

The movement will be continuous, because, as the top of the armature moves toward the north pole of the field magnet, the commutator acts to maintain the flow of current as before, and the consequent armature poles are always at the top and bottom halfway between the field magnets.

The armature thus creates a current when made to revolve, and revolves when supplied with current.

In the first instance we have seen that the entire machine is called a *dynamo;* in the second it is called a *motor.* Every dynamo will run as a motor if supplied with current. Every motor will act as a *generator* or dynamo if made to revolve in its own field.

The motor can be made to drive another armature in another field. Such a machine is called a *motor-generator.* It can be run with direct or alternating currents and made to generate direct or alternating currents of a higher or lower E. M. F. For this reason it is sometimes called a *rotary transformer,* as distinguished from the *stationary transformers* already described.

ELECTRIC AND MAGNETIC FIELDS.

42. Electricity produced by friction (art. 1) is sometimes called *frictional electricity;* by primary batteries, *voltaic electricity;* by electromagnetic induction, *dynamic electricity.* But however produced and transformed, all kinds of electricity are *identical,* and the same is true of all kinds of magnetism. Wherever there is an electric charge, stationary or moving, emanating from the charge are electric lines of force which end at other electric charges. Wherever there are moving electric charges (currents) there are magnetic lines of force also, and these magnetic lines of force are always at right angles to the direction of the motion of the charges and to the electric lines of force proceeding from them.

And, finally, motion, or state of strain in the ether, which these lines of force represent, travels with the speed of light, and the fields of force, while more pronounced and therefore more easily detected near the moving charges, are really all pervasive. They have no limits.

43. Imagine a disturbance—say an expansion of a gas—to take place in the center of an immense rubber ball. A wave of tension, which becomes less as its distance from the center increases, progresses outward to the *farthest* confines of the ball. When the gas contracts, a wave of contraction, also starting from the center, and decreasing with its distance from the center, progresses outward to the *farthest* confines of the ball. If expansion and contraction are equal the ball's former state of equilibrium is restored.

In this way it can be imagined that starting a current produces a state of strain in the ether or stretches it in one direction; stopping it releases the strain. Action in both cases starts at the point where the current is produced and progresses outward with the speed of light, and a little consideration will show that it can have no limit, though it soon ceases to be perceptible except under certain conditions, to be later described.

The function of wireless telegraphy is to produce these ether movements at will.

ELECTRIC CAPACITY.

44. We can produce momentary currents in conductors, whether open or closed, by the cutting of lines of force, and the evidences of electrification are most pronounced at the ends of an open conductor, but these disappear as soon as the cutting of lines of force ceases. We find, however, that electrification of amber, glass, silk, and other bodies remains after the rubbing ceases, and if glass plates or other nonconductors be connected to the ends of a conductor in which an E. M. F. is being generated, so that connection is made all over the surface of the glass (as it is when rubbed), the glass when separated from the conductor will be found to be electrically charged the same as when electrified by rubbing. When two plates oppositely charged (art. 1) are connected through wires leading to a galvanometer, the amount of deflection of the galvanometer needle (caused by the magnetic field of the momentary current created as the charges unite and neutralize each other) is a measure of the quantity of electricity on each plate.

In testing plates of different sizes, shapes, and materials, charged to the *same potential* by being connected to the poles of the same source of electricity, it is found that different values of the throw of the galvanometer needle are produced. Other conditions being equal, plates having the greatest amount of surface are found to have the largest *capacity.* Plates of the same capacity will give a larger throw of the galvanometer when charged from a source of high than a source of low potential, so that the amount of electricity stored in an electrified body depends on its *potential* as well as on its *capacity.*

45. If two plates, oppositely charged by being connected to the poles of a battery, as in fig. 22, or to the terminals of a dynamo or transformer are discharged by being connected through a galvanometer, the throw of the galvanometer will not be as great as if the same plates, charged to the same potential by the same battery as in fig. 22a, are discharged through the same galvanometer. By being brought closer together the plates seem to have their capacity increased. It takes a greater amount of electricity to bring them to the same potential than when farther apart. If two plates charged at a distance from each other, as in fig. 22, and then disconnected from the battery are brought to the position shown in fig. 22a, their potential, as measured by an electroscope, is found to be lowered. The electricity is said to be condensed by the approach of the plates, and such an arrangement is termed a *condenser,* a somewhat misleading term, but one generally used.

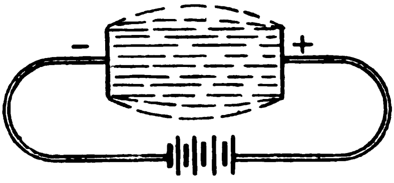


FIG. 22.

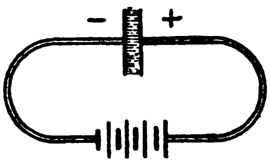


FIG. 22A.

This is analogous to the increased strength of magnetic field produced by shortening the magnetic circuit while retaining the same magnetizing force. In both cases the field of force represents stored energy which can be made to reappear in the discharge of the condenser or the dissipation of the field.

The two plates can be reduced to one if of nonconducting material, but since a nonconductor can not transmit electric charges, in order to utilize the two surfaces of the plate, each must be covered with a conductor which will permit the charges to distribute themselves over its area.

ELECTRIC INDUCTION.

46. Electric lines of force permeate a nonconductor—i. e., electric induction takes place through it,—in a way analogous to that in which magnetic induction takes place through iron or air.

The permeability of air for magnetic induction is taken as a standard and called unity. (See art. 25.)

Its permeability for electric induction is also taken as a standard and called unity, and as we find that iron, nickel, cobalt, and oxygen have a greater magnetic permeability than air, so we find that glass, beeswax, paraffin, nearly all kinds of oil, and indeed most bodies we call insulators, have a greater electric permeability than air. The quality of a body as compared with air in this respect is called its *specific inductive capacity,* and bodies when considered with reference to electric induction through them are called *dielectrics.* (Art. 2.)

It is found that the best quality of glass has nine times the specific inductive capacity of air. This means that when subjected to the same potential, the electric field, when this glass is the dielectric, is nine times as strong as that created when the medium intervening between the charges is air, it requires nine times as much work to create it, and its discharge can do nine times as much work.

47. Bodies such as iron or nickel through which magnetic induction is taking place are found to change slightly in shape, and sudden changes in the induction or lines of force permeating them produce slight sounds. The action is also accompanied by the production of heat, but as the magnetizing force (magneto-motive force) increases, the lines of force tend to reach a maximum which no increase of magnetizing force will increase. When in this condition the magnetized body is said to be *saturated.* There is, however, apparently no limit to the magnetization of air.

In the same way bodies (dielectrics) through which electric induction is taking place are found to change (enlarge) slightly in shape, but increase of electro-motive force (in this case potential) does not appear to tend to a maximum of electric induction. The physical strain on the dielectric, however, continues to increase and finally reaches a point where it pierces or ruptures the dielectric, the action being accompanied by a sharp crackling sound and by the production of light and heat, which we call an electric spark. If the dielectric is air or a liquid, the rupture is immediately repaired by the action of the surrounding substance on that heated by the passage of the spark; but if the dielectric is a solid the rupture is permanent. Magnetization is limited by saturation. The limit of electrification is marked by rupture. The electric charges are found to have been dissipated after the spark has passed. The condenser is said to be discharged. If the oppositely charged plates are discharged without sparking, a slight sound is produced if the dielectric is glass. This is analogous to the minute sounds given out by magnets when magnetized or demagnetized suddenly.

Magnetization or electrification seems to consist of forcing to point in the same direction the magnetic or electric polarities of the molecules of a substance.

We have seen that the *capacity* of an electrified body depends on the area of its electrified surface, on the nearness of its charge to charges of opposite sign, and on the material of the dielectric—i. e., the substance intervening between the charges.

ELECTRIC CONDENSERS.

48. Bodies capable of being electrified and arranged so as to present a large capacity in a small space are frequently called simply *capacities,* but this term is misleading, and though the term *condenser* is not entirely satisfactory it will be used. The total charge in a condenser depends on its potential as well as its capacity. Its potential depends on the potential of the source of electricity only, but its capacity, as stated above, depends on its size, material, and arrangement.

Condenser capacities may be said to be related to each other in the same way as rubber bags inflated by gas. A large bag charged to a given pressure contains more gas than a small bag charged to the same pressure. The gas in the large bag is making no greater effort to escape per square inch (i. e., has no higher potential) than the gas in the small bag; but it requires a longer time and more gas to charge the large bag than the small one.

So when connected to the same source of electricity it requires a longer time to charge a condenser of large capacity to a given potential than it does to charge a small one to the same potential, and its power to do work is correspondingly greater.

In the same way it requires a longer time to create the magnetic field of a large electro-magnet than that of a small one, and a stronger magnetic field (within limits) is created by a large current than by a small one under the same conditions, and the energy stored in the strong field and its power to do work is correspondingly greater.

49. It is evident that a close analogy can be drawn between the electric field in a condenser and the magnetic field around an electro-magnet. We have seen that any movement of either field creates the other; that they can exist independently only in a static condition; that, though they have no limits, the center of effort, the point of greatest activity in each, is at the body which we consider electrified or magnetized; that bodies differ in their qualities in these respects; that an actual physical change takes place in the dielectric when electrified and in the iron or nickel when magnetized, and, finally, that both electric and magnetic fields represent stored energy in an infinitely elastic medium, and we shall see that this medium, on account of its elasticity, vibrates and oscillates when either an electric or a magnetic field is suddenly created or destroyed in it.

50. The most common and best known form of condenser is the Leyden jar, which consists of an inner and outer coating or film of tin foil or copper on a glass jar, the glass being the dielectric. Electric induction takes place through the glass and the energy is stored in the electric field, the tin foil merely serving to increase the area over which electric induction takes place, and hence the *capacity* of the condenser.

Condensers are often made up of a large number of interlaced plates or films of conducting material, having between them for a dielectric larger pieces of glass, mica, or oiled paper, alternate plates being similarly charged. Condensers are represented either as in fig. 23 or fig. 23a. They will be represented in this book as in fig. 23. Condensers are also made in which the relative position of the plates, and therefore the capacity, can be varied at will. These are called *variable condensers,* and will be represented as in fig. 23b. In variable condensers the dielectric may be glass, air, oil, mica, or paper.

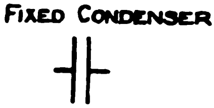


FIG. 23.

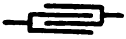


FIG. 23A.

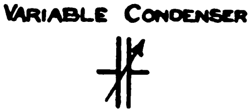


FIG. 23B.

DISCHARGE OF CONDENSERS.

51. If, after being charged by connecting the inner coating to one pole of a source of electricity and the outer coating to the other, the two coatings are connected by means of a conducting wire the charges neutralize each other and the condenser is said to be discharged. The discharge of a condenser being a movement of electricity creates a current and consequently a magnetic field around the wire through which the discharge takes place.

If the potential is high enough the condenser can be discharged without actually connecting the two coatings, for when the opposite ends of wires connected to them are brought within a certain distance of each other sparks will pass, and the condenser will be found to be discharged, the same as if the wires were actually connected. The charges unite by rupturing the air dielectric. The energy stored in the electric field appears as sound, light, heat, and other invisible ether vibrations.

This spark discharge is found when analyzed to consist usually of several sparks, passing first in one direction, then in the other. Each condenser coating is charged positively and negatively in rapid succession, each charge being somewhat less than the preceding until the entire energy of the original charge is dissipated. This form of condenser discharge is oscillating. The released charge acts like a released musical string which vibrates until its energy is dissipated, and as the same string gives out the same note, whether stretched strongly or only a little, so a condenser when discharged through the same wire always vibrates or oscillates in the same period, regardless of its potential. Just as the note given out by the string depends on its material and length, so the rate of vibration of a condenser depends on its *capacity,* which, as we have seen, depends on its material and arrangement.

52. Another illustration of oscillatory condenser action can be given: Let fig. 24 represent two glass vessels connected by a U tube with a stopcock at the bottom of the tube. One vessel is filled with water and the other empty. If the U tube is large enough to permit free passage of the water, when the stopcock is opened quickly the pressure in the filled vessel will cause a sudden rush of water up the other side of the tube into the empty vessel, which will continue until it has reached nearly the same height as before (fig. 24a). It will then rush back into the first vessel, and so on, reaching a little lower level each time until equilibrium is reached at the same level in both vessels (fig. 24b).

The only action which prevents the oscillation from being continuous is friction of the water on the walls of the tube and internal friction between its molecules.

Released condenser charges would also continue to oscillate indefinitely if it were not for the resistance in the discharging wires and in the dielectric and the sound and light produced by the spark. These absorb the energy of the charge, and, being relatively large, a position of equilibrium is reached after a few oscillations.

If the U tube in fig. 24 is very small or the stopcock only slightly opened the water will gradually rise on the other side and will finally reach a position of equilibrium without any oscillation, and it is found that if the condenser discharge takes place through a long thin wire instead of a thick one the condenser is slowly discharged through it without any oscillation.

53. The oscillation of the water in fig. 24 is due to its *inertia*. Inertia is a property of all bodies and is in amount proportional to their weight. It is represented by their resistance to change of condition, either of motion or of rest.

The water in the first vessel falls by the action of *gravity*. Once in motion its inertia (resistance to change of condition) causes it to rise on the opposite side against the action of gravity. When gravity has overcome its inertia it falls again by gravity and is carried on by inertia.

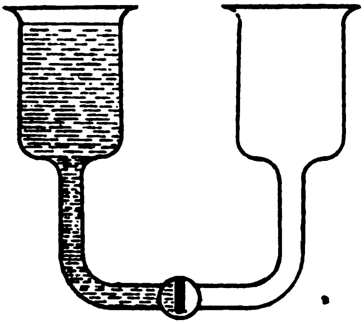


Fig. 24.

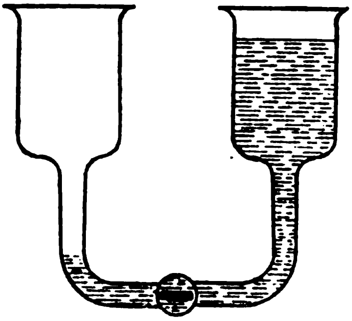


Fig. 24A.

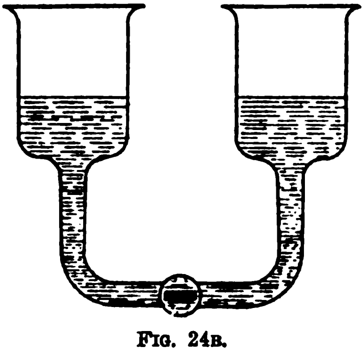
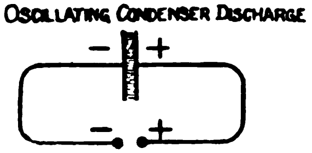


Fig. 24B.

It continues to overshoot the mark, so to speak, until friction, internal and external, brings it to rest.

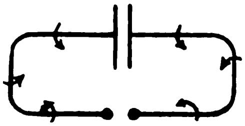
Though the electric charges on condenser coatings appear to be independent of gravity, they do possess *inertia,* as is shown by their resistance to change of direction and by their oscillatory movements.

54. Let us consider a charged condenser (fig. 25) discharged through a thick wire connecting the coatings. A break in the wire prevents the discharge until the potential is high enough to cause sparks to cross the break. One condenser coating before discharge is at a certain positive potential, the other at an equal negative potential. Both discharge through the wire in the same time, and when they have reached zero potential the electric field has been dissipated, but the moving charges in the wires have induced a magnetic field around the wire. The strength of this magnetic field depends on the amount of the moving charges, i. e., the strength of the current, and on the *self-induction* (art. 30) of the wire which, as we know, depends on its shape and the material (air or iron) in which the magnetic field is created. All the energy (except that lost by friction) which was stored in the electric field is now in the magnetic field (fig. 25a). The magnetic field, having no continuous source of magneto-motive force (current) to maintain it, collapses on the wire, producing movements of the electric charges into the condenser coatings, which now become charged in the opposite sense (fig. 25b). The electric field is again set up, containing all the remaining energy, and the magnetic field disappears until the charges again move toward each other.



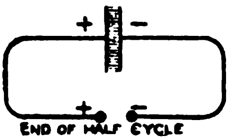
AT START ENERGY ALL ELECTRIC.

FIG. 25.



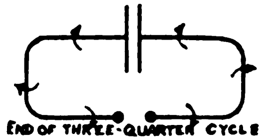
END OF QUARTER CYCLE ENERGY ALL MAGNETIC.

FIG. 25A.



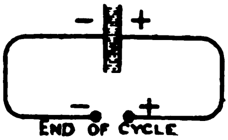
ENERGY ALL ELECTRIC REVERSED.

FIG. 25B.



ENERGY ALL MAGNETIC REVERSED.

FIG. 25C.



ENERGY ALL ELECTRIC LESS IN AMOUNT.

FIG. 25D.

The attraction of the unlike charges for each other is analogous to the attraction of gravity for the water in fig. 24, and the magnetic field caused by the self-induction of the moving charges is analogous to the inertia of the water, which makes it rise in the second vessel, because the collapse of this magnetic field charges the condenser in the opposite sense, and for this reason self-induction is sometimes called *electro-magnetic inertia.*

From the foregoing illustration of what appears to take place during the oscillating discharge of a condenser we see that the energy before an oscillation begins is all electric. At the end of the first quarter of a cycle it is all magnetic. At the end of a half cycle it is all electric, but in the opposite sense. At the end of three-quarters of a cycle it is all magnetic, but with the direction of the lines of force reversed. At the end of a complete cycle or oscillation the energy is all electric again (figs. 25a, 25b, 25c, 25d) and in the original sense, but less in amount on account of the losses which have taken place during the transformations and which are shown by the heating of the condenser and the wires (and the sound and light produced by the spark if the oscillations take place through a spark gap). At all intermediate points of a cycle the energy is partly electric and partly magnetic.

55. A complete *oscillation* or *cycle* is made up of two *alternations.* The highest potential reached during an oscillation is called the *amplitude* of the oscillation. The difference between the amplitude of two successive oscillations is called the *damping* and is a measure of the losses. The interval in time between two successive oscillations is called the *period.*

56. Since every body has electric capacity in proportion to its surface (art. 44), and since movements of electric charges, without which a body can not be electrified, always produce magnetic fields, every body must have self-induction, and therefore electro-magnetic oscillations can take place in it.

We know that every body vibrates in its own period mechanically, and we find that every body vibrates in its own period electrically, and further that the number of vibrations or oscillations per second depends entirely on the capacity and self-induction of the body.

It will be seen that while a closed circuit is necessary for the flow of a continuous or direct current, for oscillating currents a straight wire is sufficient. A circuit containing a condenser which would completely obstruct a direct current has no effect on an alternating current other than to change its sign.

57. We must be careful to distinguish between the capacity of a condenser and the total charge in it, and between the self-induction of a wire and the total induction caused by the current in it. The *capacity,* it may be repeated again, depends on the material and arrangement of the charged body. The *total charge*—that is, the *total electric induction*—depends on the *capacity* and the *potential.* In like manner the *self-induction* depends on the arrangement of the conductor and the surrounding material (whether iron or air). The *total magnetic induction* depends on the *self-induction* and the *current.*

58. We can see in a general way that the period of an oscillating circuit depends on the capacity and self-induction of the circuit, and not on the total electric or total magnetic induction, because the capacity and self-induction are determined by the material and arrangement of the circuit, which qualities determine the mechanical period of a body. It takes longer to discharge a condenser of large capacity than one of small capacity, and it takes longer to create a given current in a circuit of large than in one of small self-induction. Increasing the potential gives more work to be done during a discharge, but also gives power to do it in the same ratio, so that increase of potential does not change the period, though it may change the amplitude of the oscillations.

59. It was stated (art. 29) that coiling a wire increases its self-induction and enables a strong magnetic field to be created around it, and that this increases the *electrical length* of the wire—i. e., it takes an electrical disturbance started at one end of it longer to reach the other end when the wire is coiled than when the same wire is straight.

Now we see that the electrical length of a wire depends on its capacity and self-induction and that its period in seconds—i. e., the time of one complete oscillation (the time required for an electrical impulse started at one end to reach the other and be reflected back)—must be twice its electrical length divided by the distance electricity travels in a second, which we know to be the same as light (300,000,000 meters).

The capacity and inductance of a straight wire long in proportion to its thickness are so related that its electrical length is equal to its natural length.

From the above the period or time of one complete electrical oscillation of a straight wire one meter long is $\frac{2}{300000000}$ second, and it therefore oscillates 150,000,000 times per second.

The number of oscillations or cycles made by an alternating current per second is called its *frequency*.

60. We know that by coiling a wire its self-induction can be greatly increased, and its period thereby lengthened. By adding capacity to the wire in the shape of condensers its period can be lengthened still more, so that by suitable arrangements a circuit having small mechanical length, but comparatively great electrical length, can be made up in a small space.*

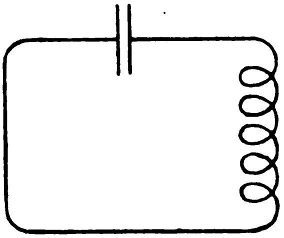


FIG. 26.

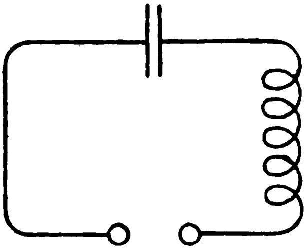


FIG. 26A.

Such a circuit is shown in fig. 26. It is made up of a condenser connected to a coiled wire, and will be called in this book an *oscillating circuit.*

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* It must not be forgotten that every wire possesses capacity by virtue of its surface, and self-induction by virtue of the fact that an electric current can flow in it. Even condensers have a certain amount of self-induction.

The oscillating circuit in fig. 26 may have a break or gap in it, as in fig. 26a. If the potential of the condenser is sufficient to rupture the air or other dielectric in the gap, the circuit does not lose its oscillating character. The presence of the gap does, however, decrease the number of oscillations for one charge and prevents the complete discharge of the condenser, because the oscillations cease as soon as the potential falls below a certain value. The greater the loss or *damping* in each oscillation the smaller the number of oscillations that will take place before the potential falls so low that the spark ceases.

61. As stated in art. 48, the term condenser is not satisfactory, and the word *capacity* is often used to mean *condenser,* especially in connection with such an oscillating circuit, the condenser being spoken of as a *capacity* and the coiled wire as an *inductance,* which means a conducting wire arranged so as to have large self-induction.

FIG. 27.

FIG. 27A.

FIG. 27.—Inductive Resistance.
FIG. 27A.—Noninductive Resistance.

Fig. 27 represents an *inductive resistance,* or simply an inductance, since it is assumed that all wires have resistance.

Fig. 27a represents a *noninductive resistance,* or simply a resistance—it represents a coil so wound that the currents in adjacent turns are in opposite directions and the coil has therefore no self-induction.

62. An oscillating circuit whose electrical length can be varied at will is represented in fig. 28. It consists of a variable condenser in connection with a fixed inductance (fig. 28), or it may consist of a fixed condenser and a variable inductance (fig. 28a), or both capacity and inductance may be variable, the arrow in fig. 28a being meant to show that any number of turns of the coil can be included at will.

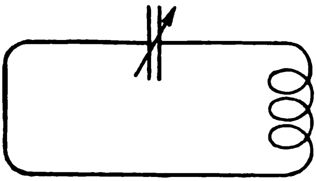

FIG. 28.

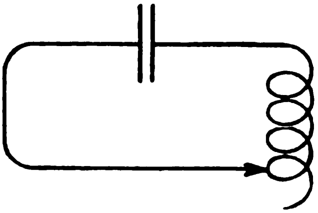

FIG. 28A.

63. Two circuits having the same electrical length are said to oscillate in *resonance;* their periods are equal, though the inductance and capacity may not be the same in each.

4

For instance, suppose the oscillating circuit (28a) is adjacent to a wire, as in fig. 28b, having the same electrical length, we know that for oscillating currents (see art. 56) a closed circuit is not necessary. We also know that by reason of their mutual induction (art. 15) the closed oscillating circuit, which we can call A B, will induce currents in the wire, which we can call C D. Since their *periods* are *equal* the induced oscillating current in C D will be suitably timed to the natural period of C D and the two circuits will oscillate in resonance. C D can be called the *open circuit* as distinguished from A B, the *closed circuit.*

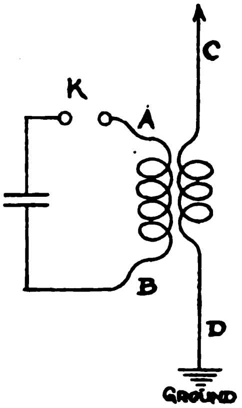

FIG. 28B.

Oscillating circuits now used in wireless telegraphy have electrical lengths varying from 100 to 5000 meters, giving from 1,500,000 to 30,000 oscillations per second. Those first used by Marconi had electrical lengths of about 6 centimeters and oscillated approximately 2,500,000,000 times per second.

ETHER WAVES.

64. As stated in art. 55, a cycle is made up of two alternations or movements in opposite directions and is represented in fig. 18. Such a curve also represents the crest, hollow, and slope of regular waves on the surface of the ocean or other body of water. The distance from crest to crest or from hollow to hollow of a water wave is called a *wave length,* and this distance is equal to that of two alternations. Since electromagnetic (ether) disturbances spread in all directions with the speed of light, and when sent out by an oscillating current succeed each other at equal intervals of time, and since the magnetic and electric forces produced by oscillating currents change direction during each alternation, just as the particles of water rise to the crest or fall to the hollow of a wave, their positive and negative amplitudes may represent the crests and hollows of waves separated by half periods or half wave lengths, an oscillating current may be called a wave producer, and the oscillations considered as movements of the ether may be called ether waves.

65. Hertz (in 1886 at Carlsruhe, Germany) was the first to show that oscillating electric currents really do produce ether waves—like those of light only longer and subject to all the laws governing light waves. For this reason, wireless is sometimes called Hertzian wave telegraphy.

66. The vibrations of particles producing sound waves, as in air, consists of to-and-fro movements parallel to the direction of the waves, the latter consisting of alternating conditions of compression and rarefaction of the air.

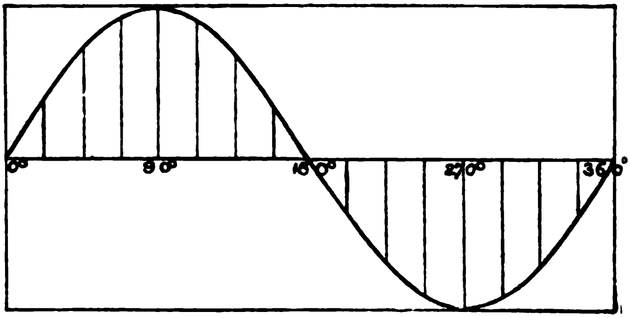

FIG. 18.

The movement of the particles in ether waves is at right angles to the direction of propagation of the wave, and the electric and magnetic movements are also at right angles to each other at any point in the wave front. This is called transversal vibration, as distinguished from the longitudinal vibration of the particles in sound waves.

When one particle of a substance is displaced or made to vibrate, it induces its neighbors to follow it, and starts them to vibrating in the same periods but in different phases, each particle starting to vibrate (passing the word, so to speak) at a definite interval of time after the one next to it has started. The vibrations may be longitudinal or transverse, as described above, or they may be circular or elliptical, but if they are regular the waves produced are regular.

The *amplitude* of the wave (art. 55) depends on the extreme limits from its normal position of the vibration of each individual particle. The *wave length* depends on the time of one complete vibration of each particle and the velocity with which the displacement or vibration is propagated from one particle to another of the substance. It is found that this velocity is equal to the square root of the elasticity of the body divided by its density.

We know that this velocity in the ether is 300,000,000 meters per second, and we conclude that the ether must have very great elasticity combined with very small density.

It has been stated that electric charges or electrons are the only things which have a grip on the ether, and that when they are vibrating the ether vibrates with them.

When a particle is subject to several forces at the same time, its resultant movement depends on the resultant of the forces and will vary as the forces vary, so that a body can, in effect, vibrate in more than one way at the same time, and can produce complex waves where vibrations are superimposed on each other. This is shown every day at sea by the small waves or ripples on the slopes of large ones, or the short waves from local winds superimposed and propagated in the same or different directions from the long swells due to distant storms.

67. The vibrations producing ether waves, and consequently the wave lengths and frequencies, are of an almost infinite range, for instance:

Ether vibrations from 430 to 740 trillions per second (a little less than one octave) are visible to the eye and are called *light.*

Between 870 to 1500 trillions of vibrations per second we have the ultraviolet and X-rays, and from 430 down to 300 trillions of vibrations per second what are called infrarouge rays.

Below 300 and down to 20 trillions of vibrations per second we detect ether vibrations by our sense of feeling or by the thermometer, and they are called *heat.*

Forty-five octaves lower on the same scale are the ether vibrations which we call electric waves and which are used in wireless telegraphy. The shortest of these yet measured is 0.2 of an inch in length; the longest, over 1,000,000 miles.

Marconi, in his first experiments, used a pair of small spark balls which gave out waves about 12 centimeters in length.

68. Ether waves of all lengths are subject to reflexion, refraction, diffraction, and absorption, and bodies, such as insulators of certain kinds, which are opaque to the short waves we call light, are transparent to the long electric waves used in wireless telegraphy. Practically all conductors are opaque to electric waves. Generally speaking, insulators are transparent to electric waves, but in transmitting the wave they *absorb* some of its energy.

Conductors, being opaque to electric waves, partially reflect and partially absorb the wave energy.

A simple case of wave reflexion is seen when a rope hanging vertically is given a quick jerk and then held taut in the hand. A wave can be seen traveling up the rope till it reaches the top, where it is reflected, travels down the rope to the hand, is reflected there and starts up again to the top, and so continues until its energy is damped out.

If a number of equally timed jerks are given, a succession of waves at equal intervals is sent up the rope. When reflected back they meet others coming up whose lengths are equal to those coming down. At some points the rope tends to move a certain distance in one direction with the direct wave, and the same distance in the opposite direction with the reflected wave; the result is that it does not move at all. These points are found along the rope one-half wave length apart; at all other points the rope moves or vibrates in the resultant direction of the direct and reflected wave impulse, and what are called *stationary* waves are set up.

The points at which there is no movement are called *nodes,* and points at which there is maximum movement are called *loops.* This is shown graphically in fig. 18c.

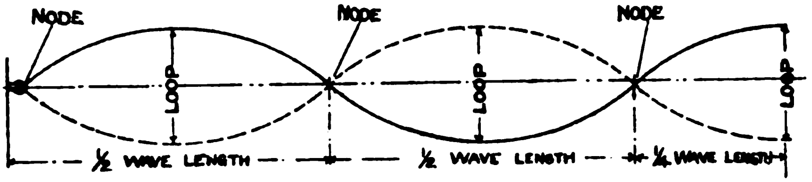

FIG. 18C.

Stationary ether waves can be set up around conducting wires by suitably timed electrical impulses applied to the ends of the wires.

69. It will be observed that the point of support of the rope where it can not move must, in every case, be a node. So in a conducting wire, the *end* of the wire away from that receiving the impulses must be a *current node,* because no current can flow there. It can, however, and a little consideration will show that it must, be a *potential loop,* for while there is no movement at the point of support, the greatest pressure or tendency to move is there.

Since the electrical impulses consist of variations of current and potential, which succeed each other regularly, and since at a given point we find a loop of potential and a node of current, we must, at a quarter-wave length distant, find a node of potential and a loop of current.

This is shown graphically in fig. 18d, which represents the relative positions of current and potential nodes and loops in stationary electric

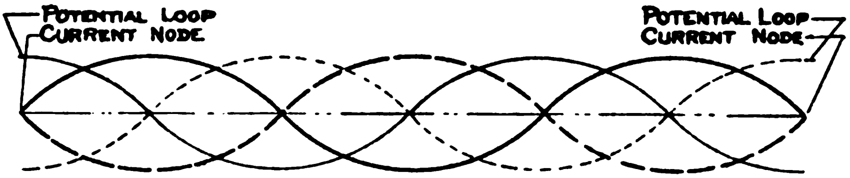

FIG. 18D.

waves, and illustrates the statements made in art. 54 (figs. 25a, etc.), relative to the alternations of electric and magnetic fields in oscillating condenser discharges.

70. If an oscillating current be set up in a free wire (fig. 18e) by a neighboring discharging circuit in resonance with it, the free wire will be found by measurement with a micrometer spark gap to have an alternating potential in it, varying from nothing at the middle point, C, to a maximum at either end somewhat similar to the full curve E C F.

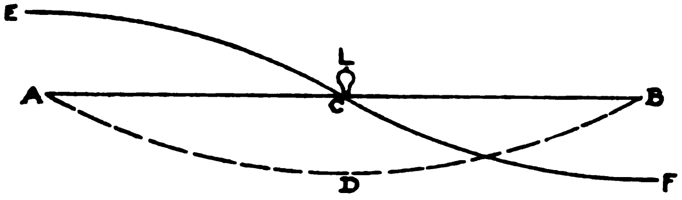

FIG. 18E.

If at the same time the current in the free wire could be measured, it would be found to have a maximum value at C and a minimum at the ends similar to the dotted curve A D B. If the wire A C B is not too far from the discharging resonant circuit and the wire be cut at C and an incandescent lamp L be connected to the two halves as shown in the figure, the lamp will glow.

REFLECTION OF ETHER WAVES.

71. If ether waves impinge on a reflecting surface not normal to their direction, they are reflected at an angle equal to that which the reflecting surface makes with their original direction (the angle of incidence is equal to the angle of reflection), so that directed waves may be detected at points not in the line of direction by the interposition of a reflector.

Air at atmospheric pressure (about 760 millimeters of mercury) is an insulator. Its density decreases with distance above the earth's surface, and its insulating qualities decrease with the decrease of density. At a height of approximately 45 miles above the earth's surface its pressure is about 1 millimeter of mercury. At the density corresponding to this pressure it is a good conductor, and though still transparent to short ether waves like those of light, it partly reflects and partly absorbs long ether waves. In the intermediate distance it is at first transparent, then partially transparent, absorbent, and reflecting, simultaneously.

It is known that ether waves are guided by conducting surfaces to a certain extent (for instance, by wires), as well as reflected by them, and that otherwise they travel in straight lines. Fig. 18f shows the approximate path of an ether wave started from the earth's surface and reflected from the upper atmosphere. It will be seen that even if the earth's surface did not guide the waves they might be detected at points below the horizon.

Other causes of reflection may exist, such as large bodies of electrified air, or heavily charged clouds, which would cause interference between direct and reflected waves and make electrical shadows at certain places, i. e., points at which, owing to conditions outlined above, either the waves are so attenuated that they can not be detected or they are completely neutralized.

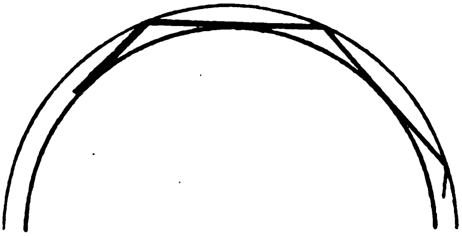

FIG. 18F.

REFRACTION OF ETHER WAVES.

72. When ether waves impinge on transparent bodies at any angle other than the normal, if their velocity in the transparent body, on account of its elasticity or density, is different from that at which they were previously moving, that part of the wave first entering the body will move either faster or slower than it did before. The part outside will therefore either fall behind or gain on the first part. This action will affect each portion of the wave front as it enters the body, and the result will be that its direction of movement will be changed. The effect is to bend the wave out of its original path, and the action is called *refraction.*

Ether waves passing through the atmosphere, whose density varies at different points, are subject to this bending action.

DIFFRACTION OF ETHER WAVES.

73. When waves meet a body in their path (for instance, when the comparatively long waves used in wireless telegraphy impinge on a high island or mountain range) at the points where the wave front cuts the extreme width of the island and along the crest or summit new centers of disturbance are created, which radiate some of the wave energy to points behind the island. It has the effect of bending the waves around the object. This action of waves is called *diffraction.* In amount it depends on the wave length. From the new centers of disturbance waves are sent out, which interfere with each other, not being propagated in the same directions. The result is that for a distance, depending on the width and height of the obstacle and on the wave length, a shadow exists beyond it.

Partial reflexion of the waves toward their source takes place on the side of the obstacle nearest the source. An attempt to show this graphically is made in fig. 18g, but the best illustration is given by the motion of water around a rock on a windy day. The small back waves on the windward side are reflected to windward. The waves circling or bending around the rock are *diffracted.* The still water in the lee of the rock is the shadow, in which no action exists. At a distance depending on the size of the rock and the wave length the zones of interference disappear, the regular waves from the two sides of the rock unite, and there is no evidence of its existence at points beyond, though it has decreased the total strength of the waves.

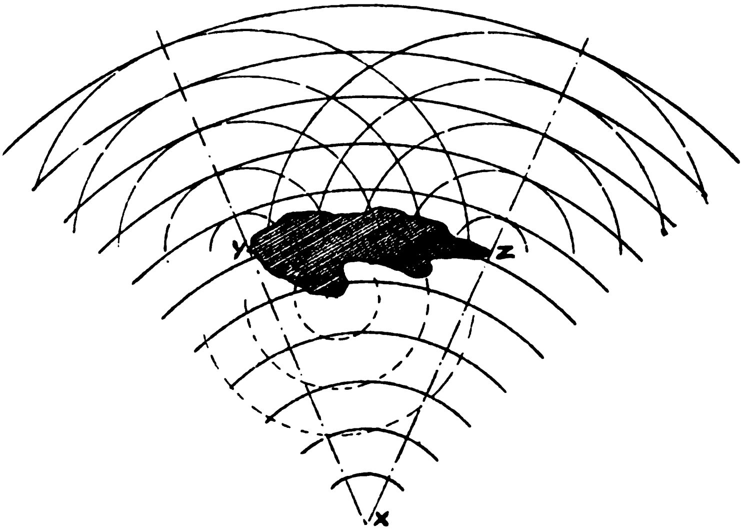

FIG. 18G.

For the above reasons high land between two wireless telegraph stations has the effect of decreasing the strength of signals at each station, and if close to either station may entirely prevent that station from receiving. (It may be in the shadow or be subject to interference from reflexion.)

The effects of reflexion and diffraction on waves passing over irregular country are very pronounced. The effects of reflexion, refraction, and absorption in the atmosphere are equally pronounced, the qualities of the atmosphere in all *three* respects varying greatly from day to day and between day and night.

An ether wave traveling from one wireless-telegraph station to another over rough country and through an atmosphere of varying density, working its way around and over mountains, being balloted from thunder clouds at one point and absorbed by semiconducting gases at another, may be said to pursue an adventurous journey.

PRODUCTION OF ETHER WAVES.

74. We have now seen how to produce electric and magnetic fields, how to utilize magnetic fields for the production of electric currents in dynamos, how to increase the potential of these currents by means of step-up transformers, and how by means of this high potential current to force large charges into electric accumulators or condensers and by discharging these condensers in oscillating circuits to produce what we call *electric* or *ether waves*. These operations can be represented graphically or diagrammatically, as in fig. 29, which shows a separately excited A. C. *dynamo* in circuit with the *primary winding* of a *step-up transformer,* whose *secondary* charges the *condenser* of an *oscillating circuit* containing a *spark gap.*

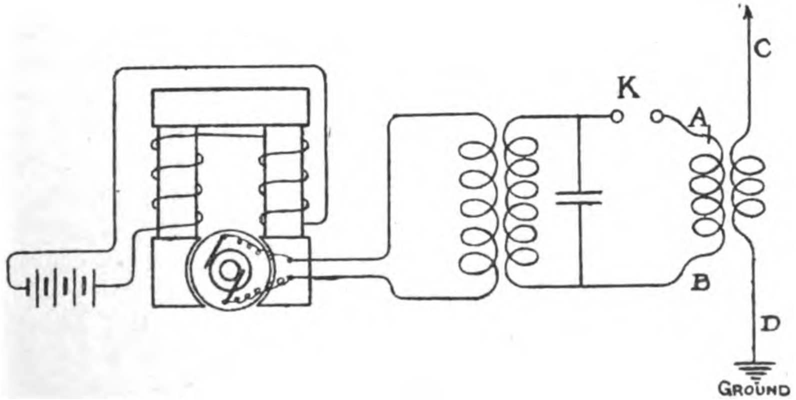

FIG. 29.

The secondary winding of the transformer is of many turns, in order to give a high potential. The transformer also has an iron core. The great number of turns of the secondary winding, added to the effect produced by the iron core, gives the circuit containing the secondary winding and the condenser a very large self-induction, and consequently a very long period. The circuit composed of the condenser, self-induction, and spark gap has a very much shorter period, and when the spark gap is ruptured this circuit oscillates as if it were entirely disconnected from the secondary, usually completing its oscillations and coming to rest in a fraction of the *period* of the circuit formed by the secondary winding and condenser.

The oscillating circuit (condenser, spark gap, and inductance) is shown in fig. 29 near a conducting wire, having a few turns of inductance close to those of the oscillating circuit. In this circuit we can consider the condenser as representing the source of current, like the battery in fig. 11, art. 12; the spark gap as the break K, the turns of inductance in the oscillating circuit as A B, and the open circuit with one end grounded as C D. The oscillating currents in A B produce like currents, but in the opposite direction in C D (art. 12), and C D becomes a source of *ether waves.*

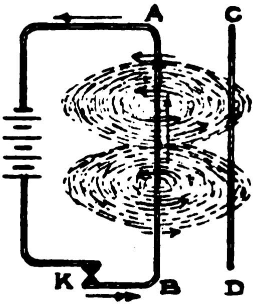

Fig. 11.

75. The production of ether waves and their detection at a distance from the source constitutes wireless telegraphy.

C D is usually called the *open* or *radiating circuit.*

A B the *closed* or *oscillating circuit.*

The two inductances in A B and C D form the primary and secondary, respectively, of an air-core oscillation transformer (art. 27). When arranged as in fig. 29, A B and C D are said to be *inductively* connected.

C D may have part of its inductance common to A B. The arrangement in this case acts as an auto-transformer, and the circuits are said to be *direct* connected (fig. 29a).

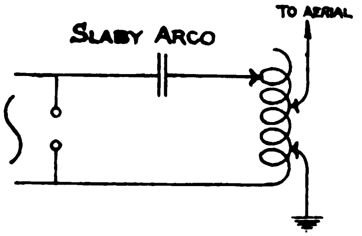

Fig. 29a.

If the oscillating and radiating circuits have the same *period,* they oscillate or vibrate in resonance. The radiating circuit in such a case receives the inductive impulses from the oscillating circuit at the proper time, and the amplitude of its oscillations is thereby increased.

The adjustment of A B and C D to any given period and their adjustment to each other's periods is called *tuning.*

It will be noted that the oscillating circuit has concentrated *capacity,* while the capacity of the radiating circuit is distributed.

76. The fundamental principle of wireless telegraphy is that all bodies vibrate electrically as well as mechanically that their periods of electrical vibration depend solely on the *capacity and self-induction of the vibrating body;* that these electrical vibrations produce ether waves which are propagated with the speed of light, and which can be detected at great distances from their source by means of instruments specially designed for the purpose.

Chapter II.

QUANTITATIVE CONSIDERATION OF HIGH FREQUENCY PHENOMENA.

UNITS.

77. Attention has thus far been concentrated on the *quality* rather than the quantity of the electro-magnetic actions under discussion. Before proceeding further it is necessary to consider the standards of measurement adopted and *their relation to each other.*

78. Electric and magnetic actions being forms of energy, and being mutually convertible, as we have seen, are subject to all the laws governing transformations of energy.

Work is done when conductors are moved in magnetic fields, the resistance to movement and the amount of movement determining the amount of work done.

The unit of mechanical *work* is a *foot-pound,* by which name we designate the work done in lifting 1 pound 1 foot against the action or *force* of gravity.

Force, by which we mean the cause of action or movement (pulling or pushing ability), is measured in pounds, and *force* multiplied by the distance through which it acts is *work.* Lifting 10 pounds 10 feet = 100 foot-pounds.

The amount of work done in a given time—that is, the rate of doing work—is called *power.* The unit of mechanical power we call a horse-power, and it represents a rate of doing work equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second.

In the above definitions of work and power the *units* of *distance, weight* (or mass), and *time* used are the *foot, pound,* and *minute,* all of which are defined by law and are called *fundamental units.*

79. Another system of units, proposed by the British Association for the Advancement of Science and now generally used in electrical measurements, is based on the *centimeter, gram,* and *second,* and is usually called the c. g. s. system. The use of this system is authorized by law and is universal in scientific work.

The following relations exist between the two sets of units:

1 foot = 30.48 centimeters, approximately.
1 pound = 453.59 grams, approximately.
1 minute = 60 seconds.*

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* The unit of time is based on a fundamental unit, being a fraction of the

The units of length and weight in the United States are kept at the Bureau of Standards in Washington, and the unit of time is determined by the Naval Observatory in the same city.

The unit of *force* in the c. g. s. system is that force which, acting on a gram mass for 1 second gives it a velocity of 1 centimeter per second. This force is called a *dyne.*

The force of gravity acting on a gram mass for 1 second will give it a velocity of 32.2 feet per second = approximately 981 centimeters per second; therefore the force of gravity is equal to 981 dynes and the pull of a dyne represented as a weight is equal to $\frac{1}{981}$ of a gram.

The pull of a pound, which equals 453.59 grams, must be equal to that of 453.59 × 981 = approximately 445,000 dynes.

The unit of *work* in the c. g. s. system is the work done in overcoming the force of 1 dyne through 1 centimeter, and is called an *erg.* In other words an *erg* is the work done in lifting $\frac{1}{981}$ of a gram 1 *centimeter.*

An *erg* by definition is a dyne overcome through a centimeter, and we see that a *foot-pound* is 445,000 dynes overcome through 30.48 centimeters; therefore a *foot-pound* equals 445,000 × 30.48 = approximately 13,570,000 ergs, and a horse-power, which equals 550 foot-pounds, per second = 13,570,000 × 550 = approximately 7,460,000,000 ergs per second.

80. The c. g. s. units of distance (centimeter) time (second), force (dyne), and work (erg) are employed to define the *absolute* units used in electrical measurements. These are *electro-motive force, current,* and *resistance.* (Art. 3, art. 26.) From these are derived the so-called *practical* units in daily use—*volt, ampere,* or *ohm.*

On account of the fact that the names adopted for the practical electromagnetic units are all names of noted scientists and not related to nor in any way descriptive of the qualities they are used to designate, their acquirement must be entirely a feat of memory. They can be more easily remembered by associating them with the names of the theoretical or absolute units.

By agreement among electricians, electro-motive force is represented by the letter *E;* electric current by the letter *I;* resistance to the flow of electricity by the letter *R;* time by the letter *T;* work by the letter *W;* power by the letter *P.*

81. We know that it requires work to move conductors in magnetic fields, or one magnet in the vicinity of another, and the movement generates an E. M. F. in the conductor.

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time of a revolution of the earth, and this unit is common to both systems. The foot and the pound are really arbitrary units. The centimeter is a fraction of a fundamental unit, namely, of the distance from the equator to the north pole on a certain meridian. The gram is the weight of a cubic centimeter of distilled water. It is an arbitrary unit.

Magnetic fields are represented in strength by the number of lines of force per square centimeter that they contain.

Unit magnetic field is said to contain one line of force per square centimeter (the field, of course, being uniform throughout), and is such a field as will act on unit magnetic pole with a force of 1 dyne. Unit pole being such a pole as will, when placed a distance of 1 centimeter in air from a similar pole of equal strength, be repelled by a force of 1 dyne.

Moving a conductor across unit field so that it cuts 1 square centimeter of the field per second generates unit E. M. F.

If the conductor forms part of a closed circuit and the current generated in it is such that when cutting 1 square centimeter of unit field per second its movement is opposed by a force of 1 dyne, the circuit is said to have unit resistance, unit current is said to flow, and the work done is 1 erg per second (the force of a dyne overcome through a centimeter).

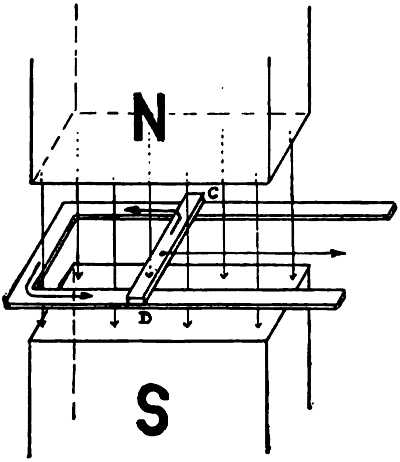

FIG. 15.

82. Let fig. 15 represent unit magnetic field between two magnet poles N and S. Let C D represent a conductor one centimeter in length moving at right angles to this field at the rate of one centimeter per second, and making sliding connections at its ends with a very heavy conductor whose resistance as compared with C D is so small that it can be neglected and the resistance of the circuit considered as concentrated in C D.

Then, if it requires a pull of 1 dyne (1/981 gram) to keep C D moving at the rate of one centimeter per second, C D has unit resistance, unit current flows, and by definition unit E. M. F. is generated.

If the speed of C D is doubled, the E. M. F. is doubled and the current (as shown by the effects) is doubled, we can express this by saying:

(a) Current varies directly as E. M. F. If the size of C D is doubled (the speed remaining the same) the *resistance* is reduced to one-half, but it requires a pull of 2 dynes to keep up the same speed, and we find that the current is doubled as before; we say: (b) Current varies inversely as resistance. Combining (a) and (b) we can say current $= \frac{\text{E. M. F.}}{\text{resistance}} - I = \frac{E}{R}$ (1).

Equation (1) is the fundamental electrical equation and states in mathematical form what is known as Ohm's law, viz.: "The current in any circuit varies directly as the electro-motive force, and inversely as the resistance in the circuit."

83. Doubling the current doubles the opposition to movement and other things remaining the same doubles the work per second, or the power. Power, therefore, varies directly as the current.

Doubling the speed of movement doubles the electro-motive force and also the current, but it quadruples the power of work done per second since it represents a pull of two dynes through 2 centimeters in one second. Power, therefore, varies directly as the E. M. F., as well as directly with the current, and we can say that it varies as their product, or $P = I E$ (2).

84. Since magnetic fields containing 20,000 lines of force per square centimeter can be obtained, a rate of cutting of one line per second gives too small a unit of E. M. F. for practical use.

On the other hand, the current necessary to produce a resistance of 1 dyne to this slow movement in unit field is somewhat large, therefore to replace the *theoretical* or *absolute units* the so-called *practical* units have been adopted.

VOLT.

The practical unit of E. M. F. is the *volt* and is the E. M. F. generated when lines of force are cut at the rate of 100,000,000 per second.

AMPERE.

The practical unit of current is the *ampere* and is one-tenth of the theoretical unit.

OHM.

In order to maintain the truth of the equation $I = \frac{E}{R}$ (1), the practical unit of resistance, which is the ohm, is taken as 1,000,000,000 times the theoretical or absolute unit.

Ohm's law then still remains true. $I = \frac{E}{R}$ or amperes $= \frac{\text{volts}}{\text{ohms}}$, because this equation in terms of the absolute units is $\frac{I}{10}$ (amperes) $=$ $\frac{E \times 100,000,000 \text{ (volts)}}{R \times 1,000,000,000 \text{ (ohms)}}$, which is the same as $I = \frac{E}{R}$. The *size* of the *units* has been changed, but the proportion between them is the same as before.

WATT.

The practical unit of power is the *watt,* which is the ergs of work done per second when 1 ampere is flowing with an E. M. F. of 1 volt.

This in ergs (see equation (2)) equals unit E. M. F. × 100,000,000 × $\frac{\text{unit current}}{10}$, or 10,000,000 ergs per second. Therefore 1 watt equals 10,000,000 ergs per second. The power expended in any circuit in watts equals the product of the volts and amperes in the circuit, or $P = IE$ (2).

Ten million ergs of work is called a *joule.* Therefore a watt = 1 joule per second.

We have seen that 1 H. P. = 7,460,000,000 ergs per second. Therefore 1 H. P. = 746 watts. 1 watt = approximately 0.737 foot-pounds per second.

85. After having selected the practical units, it became necessary, for the purpose of comparison and for everyday use, to represent them in practical form, because the accurate measurement of dynes and ergs is a very difficult matter practically.

But it can be done in accordance with definitions given in art. 78. Also art. 81 indicates how to measure the strength of magnetic fields and how to determine and compare E. M. Fs. and currents by the ergs of work done in creating them. A volt or an ampere can thus be definitely created.

The current from certain primary batteries is found to be constant when their terminals are connected by the same wire:

Since current and resistance are constant, the voltage of such cells must be constant, and this voltage once determined by comparison with absolute volts as determined above, we have at once a practical concrete standard of E. M. F.

It is found that the decomposition of an electrolyte (art. 1), by an electric current, always results in the separation or deposit of exactly equal quantities of the constituents of the electrolyte for equal quantities of current. The deposit in a certain time, being weighed, serves as a very accurate measurement of the amount of electricity which passes in that time, and consequently affords a very accurate means of comparing electric currents. When 1 ampere determined as above is passed through a given electrolyte, the weight of material deposited gives us at once a practical standard of current.

86. On account of the relation $I = \frac{E}{R}$ (1) between amperes, volts, and ohms in a circuit, if any two of them are known the other is also known, so that only two measurements of concrete units are required. The question of which two should be selected and the exact form that each should take has been the subject for discussion at a number of international conferences, the latest of which has recommended that only two electrical units shall be chosen as fundamental units, viz., the international *ohm* defined by the resistance of a column of mercury, and the international *ampere* defined by the deposition of silver.

The *volt* to be defined as the E. M. F. which produces an electric current of 1 ampere in a conductor whose resistance is 1 ohm.

Different methods of measurements produce slight differences in the values of the standards, but the values recognized by law in the United States are as follows:

The *standard* (international) *ohm* is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice—14.4521 grams in mass—of a constant cross-sectional area, and of a length of 106.3 centimeters.

The *standard* (international) *ampere* is the unvarying current which, when passed through a solution of nitrate of silver in water in accordance with certain specifications, deposits silver at the rate of 0.001118 of a gram per second.

As previously stated, a volt is the E. M. F. which if steadily applied to a conductor whose resistance is 1 ohm will produce a current of 1 ampere; but a concrete standard for the volt is also recognized by law, it being specified:

That the electrical pressure at a temperature of 15° centigrade between the poles or electrodes of the voltaic cell known as Clark's cell, prepared in accordance with certain specifications, may be taken as not differing from a pressure of 1.434 volts by more than 1 part in 1000.

The latest international conference has recommended the adoption of the Weston cadmium cell as preferable to the Clark for a standard cell. The Weston cell has an E. M. F. of 1.018 volts at 20° C.

Standard resistance wires having a known ratio to the legal ohm are made, and these, with standard cells, are used for calibrating *volt meters* and *ammeters,* which are the names given to the galvanometers for indicating automatically the E. M. F. and current in any circuit. In this way electrical values are made uniform throughout the country.

87. In addition to the *volt,* the *ampere,* the *ohm,* the *watt,* and the *joule* other practical units have been adopted, the most important of which, for our purposes, are:

COULOMB.

The unit of *quantity,* the *coulomb,* which is the amount of electricity passing any point in a second when 1 ampere is flowing in the circuit.

FARAD.

The unit of *capacity,* the *farad.* A condenser is said to have a capacity of 1 farad when 1 coulomb of electricity will charge it to a potential of 1 volt.

(Potential and E. M. F. are in some senses identical, one being the passive and the other the active state. An E. M. F. is the result of difference of potential.)

If this definition were in terms of the absolute units, that for capacity would read:

A condenser is said to have unit capacity when one unit of electricity will charge it to unit potential. Since by definition a condenser has a capacity of one *farad* when one-tenth of the absolute unit of electricity charges it to a potential of 100,000,000, a farad must equal $\frac{1}{10} \times \frac{1}{100,000,000} = 10^{-9}$ absolute units of capacity.*

HENRY.

88. The unit of *self-induction,* the *henry.* A circuit is said to have a self-induction of 1 henry when, if the current in it is varied at the rate of 1 ampere per second, the induced E. M. F.—that is, the counter or reacting E. M. F.—tending to oppose the change is 1 volt.

The definition of self-induction in terms of the absolute units would be:

A circuit is said to have unit self-induction when, if the current in it is varied at the rate of one unit per second, the E. M. F. of self-induction is unity. Since by definition a circuit has a self-induction of one henry, when, if the current is varied at the rate of one tenth of unit current per second, the E. M. F. of self-induction is 100,000,000, such a circuit would have an E. M. F. of self-induction 10 times as great, or 1,000,000,000, if the current instead of being varied at the rate of one-tenth unit per second were varied at the rate of one unit per second. Therefore the unit of self-induction, the henry, is equal to $1,000,000,000 = 10^9$ absolute units of self-induction.

By agreement among electricians self-induction is represented by the letter *L;* capacity, by the letter *C.*

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* When quantities are dealt with having a large number of ciphers either before or following the significant figures it is convenient to express them as multiplied by some power of ten, i. e., $10 = 10^1$, $100 = 10^2$, $\frac{1}{10} = 10^{-1}$, $\frac{1}{100} = 10^{-2}$, etc.

Self-induction, when expressed in terms of the fundamental units of length, mass, and time, has the *dimensions* of a length, and the practical unit of self-induction was formerly called a quadrant on account of the fact that in the metric system, an earth quadrant—i. e., the distance from the equator to the north pole = 1,000,000,000 centimeters, and since the henry = 1,000,000,000 absolute units of self-inductance, it was said to = 1,000,000,000 centimeters.

In this notation a millihenry = 1,000,000 centimeters. (See art. 91.)

89. The *units* which have been considered in this chapter have been derived from the relations between electric currents and magnetic fields and are called *electro-magnetic units.* Another system of units, also based on the centimeter, gram, and second, called *electro-static units,* is in use. The relation between the absolute units of quantity in the two systems is the velocity of light in centimeters per second. This velocity is 30,000,000,000, or 3×10^{10} centimeters per second, and the electro-magnetic unit of quantity = 3×10^{10} electro-static units.

The coulomb, being one-tenth of the absolute unit, = 3×10^9 electro-static units.

The electro-magnetic unit of potential is $\frac{1}{300}$ of the electro-static unit.

In both systems a condenser is said to have unit capacity when unit quantity of electricity charges it to unit potential.

From the definition of a *farad,* given in art. 87, we see that the quantity of electricity in a condenser equals in coulombs the potential in volts multiplied by the capacity in farads, or $Q = EC, \therefore C = \frac{Q}{E}$. Substituting for Q and E their unit values in electro-static units given above, $C = \frac{3 \times 10^9}{\frac{1}{300}} = 9 \times 10^{11}$, or the practical electro-magnetic unit of capacity is 9×10^{11} times as large as the electro-static unit.

The capacity of spherical bodies is found to vary as their radii, and in the electro-static system a sphere of 1 centimeter radius has unit capacity; therefore the capacity of a sphere may be expressed by its radius in centimeters, and capacities are still expressed by some writers and manufacturers by the radius in centimeters of the equivalent sphere.

A condenser having a capacity of 1 farad has a capacity equal to that of a sphere having a radius of 9×10^{11} centimeters.

A microfarad (see art. 91), = 10^{-6} farads, is equal to a capacity $9 \times 10^{11} \times 10^{-6} = 9 \times 10^5$, or 900,000 centimeters in electro-static units.

The earth's radius is approximately 65×10^7 centimeters; its capacity should be approximately 7000 microfarads.

90. This difference in units is very confusing, but it exists particularly with reference to the two qualities of self-induction and capacity with which wireless telegraphy is intimately concerned. Microfarads and millihenrys will be used in this book, and where centimeters are found as in some catalogues and some books on electricity, the relations here given—1 millihenry = 1,000,000 centimeters; 1 microfarad = 900,000 centimeters—will enable one set of units to be converted into the other.

The entire system of units used in electrical measurements is a monument to the ingenuity of scientists, but productive of many difficulties to students.

91. While the volt, the ampere, and the ohm are really practical units, the farad and henry are too large for practical use.

It would take a very large condenser to have a capacity of 1 farad and a coil of many turns to have a self-induction of 1 henry. Subdivisions of the farad and henry are in practical use.

Multiples and subdivisions of the other units are also frequently used, and for this purpose the prefixes kilo, meaning 1000; mega, meaning 1,000,000; milli, meaning $\frac{1}{1000}$, and micro, meaning $\frac{1}{1,000,000}$, are added to the units, and such terms as—

kilowatt $= 1{,}000$ watts,
megohm $= 1{,}000{,}000$ ohms,
millivolt $= \frac{1}{1{,}000}$ volt,
milliampere $= \frac{1}{1{,}000}$ ampere,
millihenry $= \frac{1}{1{,}000}$ henry,
microfarad $= \frac{1}{1{,}000{,}000}$ farad,
microsecond $= \frac{1}{1{,}000{,}000}$ second,

are in common use. The most common practical units of capacity and self-induction (the qualities of electric circuits with which wireless telegraphy is principally concerned, because they determine the period of vibration) are the microfarad and the millihenry, but even these are too large for convenience.

The terms mil, meaning $\frac{1}{1000}$ inch; micron, meaning $\frac{1}{1,000,000}$ meter; circular mil, meaning area of a wire having a diameter of $\frac{1}{1000}$ inch, are also in general use among electricians.

92. The E. M. F. (volts) in any circuit connected with a dynamo depends only on the rate of cutting of lines of force (strength of field and rate of revolution).

The *resistance* (ohms) in any circuit depends only on the material, cross section, and length of the conductor forming the circuit.

The *current* (amperes) in any circuit depends only on the E. M. F. and the resistance in the circuit.

The *power* (watts) in any circuit depends only on the E. M. F. and current in the circuit.

The *self-induction* (henries) in any circuit depends only on the shape and length of the circuit, on the magnetic permeability (art. 25) of the material surrounding and inclosed by the circuit, and on the amount of this material.

The *capacity* (farads) in any circuit depends only on the shape and area of its surface, on the electric permeability (art. 46) of the material surrounding the circuit, on the amount and location of this material (the dielectric), and on the position of the circuit relative to other conductors.

(Straight wires are said to have distributed inductance and capacity, coiled wires have concentrated inductance, and condensers have concentrated capacity.)

The *coulombs* in a charged condenser or circuit depend only on the capacity and potential of the condenser or circuit.

93. From the foregoing we can make up a table of values as follows:—

A volt $= 100{,}000{,}000 = 10^8$ absolute units of E. M. F.

An ohm $= 1{,}000{,}000{,}000 = 10^9$ absolute units of resistance.

An ampere $= \frac{1}{10} = 10^{-1}$ absolute units of current.

A watt = a volt × an amp. $= 10^8 \times 10^{-1} = 10^7$ absolute units of work per second = 1 joule per second $= \frac{1}{746}$ H. P. = 0.737 foot-pounds per second.

A horse power = 746 watts.

A kilowatt = 1000 watts.

A farad $= \frac{1}{1{,}000{,}000{,}000} = 10^{-9}$ absolute units of capacity.

A farad in electro-static units $= 9 \times 10^{11}$ centimeters.

A microfarad $= \frac{1}{1{,}000{,}000}$ farad $= 10^{-15}$ absolute units of capacity.

A microfarad in electro-static units = 900,000 centimeters.

A henry $= 1{,}000{,}000{,}000 = 10^9$ absolute units of self-induction.

A millihenry $= \frac{1}{1000}$ henry $= 10^6$ absolute units of self-induction.

A millihenry in electro-static units = 1,000,000 centimeters.

A standard Leyden jar or plate having a capacity of .002 microfarad has been adopted for naval use. In electro-static notation 1 standard jar has a capacity of 1800 centimeters.

Chapter III.

CAPACITY, SELF-INDUCTION AND MUTUAL INDUCTION IN WIRELESS TELEGRAPH CIRCUITS.

FUNDAMENTAL EQUATION OF WIRELESS TELEGRAPHY.

94. It was stated in art. 56 that the period of electrical vibration of any circuit depends only on the capacity and self-induction of the circuit.

When the ratio of the resistance to the self-induction of a circuit is small, and the circuit vibrates in its own period, the period is found to be equal in seconds to $2\pi\sqrt{LC}$ (3) when L is measured in henries C is measured in farads $\pi = 3.1416$. This is called the fundamental equation of wireless telegraphy. (See table 7, appendix A.)

If R is greater than $2\sqrt{\frac{L}{C}}$ the circuit will not vibrate at all. For instance, when a condenser is discharged through a wire of great resistance the charge leaks out slowly without any oscillation.

A nonoscillatory condenser discharge, as compared with an oscillatory discharge, is like the flow of molasses into a jar as compared with a large and sudden flow of water into a similar jar. One takes up a position of equilibrium slowly but surely, while the other vibrates and splashes and only settles down after a considerable period.

Equation (3) shows that a circuit having a self-induction of 1 henry and a capacity of 1 farad would have a period of $2\pi = 6.2832$ seconds. Its wave length would be 1,168,000 miles.

The standard wave length originally adopted for naval wireless telegraph circuits was 320 meters; the period was approximately $\frac{1}{900000}$ second. That is, they made approximately 900,000 complete vibrations per second. The usual capacity in these circuits was 0.014 microfarad (seven 0.002 microfarad jars in parallel). Therefore the self-induction must have been 0.0022 millihenry.

It will be noted that the period of a circuit varies as the square root of the product of the inductance and capacity, so that doubling either of these increases the period by $\sqrt{2}$, i. e., to 1.432 times its former value. Doubling both inductance and capacity doubles the period.

SELF-INDUCTION.

95. We see that all *conductors* must have self-induction, because we know that all currents are surrounded by magnetic fields produced by the currents. The production of the field creates an E. M. F. in the circuit opposite in direction to the E. M. F. causing the current and tending to stop it, so that self-induction has been defined in a *qualitative* manner as the inherent quality of electric currents which tends to impede the introduction, variation, or extinction of an electric current passing through an electric circuit.

It has also been expressed in quantity as the number of lines of force induced in a circuit by the establishment of unit current in it. It bears the same relation to electricity as inertia does to matter; it represents its resistance to change of condition, and it might be defined as the work necessary to create unit current in a circuit.

Suppose we wish to determine the work done in creating a current of value I in a circuit of self-induction L in a time T.

Since $L =$ the counter E. M. F. of self-induction when the current is varied at the rate of 1 ampere per second, the counter E. M. F. when it is varied at the rate of $\frac{I}{T}$ amperes per second $= \frac{LI}{T}$. If the rise in current is uniform, the counter E. M. F. is uniform and the total work done (which equals the product of the E. M. F., current, and time) would be equal to $\frac{LI}{T} \times I \times T = L\,I^2$, were it not for the fact that the current rises uniformly from zero to I and its mean value is $\frac{I}{2}$ and therefore the work done $= \frac{LI^2}{2}$ (4). Since the factor of time does not appear in the result it shows that it requires the same amount of work to create a given current in a circuit of given self-induction whether it is created slowly or quickly, and that this work is equal in joules to one-half the product of the self-induction in henries by the square of the current in amperes. Therefore in a circuit whose self-induction is 2 henries the work done in creating a steady current of 10 amperes is equal to $\frac{2 \times 10^2}{2} = 100$ joules $= 73.7$ foot-pounds.

This 73.3 foot-pounds represents the energy stored in the magnetic field; it is the work done by the circuit in creating its own field. If it is in the neighborhood of other circuits the momentary current created in them during the rise of current reacts on the field and makes the amount of work required still greater.

When the current is broken the collapse of the field restores this energy to the circuit, thus tending to prolong the current.

In alternating currents, where the rise and fall is continuous, the magnetic field is continually absorbing or giving out energy. In oscillating circuits the energy is constantly changing from magnetic to electric and vice versa.

CAPACITY.

96. Now suppose we wish to determine the work done in charging a condenser of capacity C to a voltage or potential E in a time T. The potential of the condenser is zero before charging begins and increases as the charge increases, so that the resistance to charging also increases with the charge; therefore it must take more work to add a coulomb of electricity to a condenser of high than to one of lower potential.

The total quantity of electricity in coulombs in the condenser is $Q = E\ C$, and assuming that the condenser is charged at a uniform rate, the coulombs per second flowing into it $= \frac{CE}{T}$, and this must equal the amperes in the charging circuit. The condenser being charged at a uniform rate, its potential will rise uniformly from zero to E and the total work done during the time T must equal the average potential $\frac{E}{2} \times$ rate of charge $\times$ time $= \frac{E}{2} \times \frac{CE}{T} \times T = \frac{CE^2}{2}$ (5).

Since the factor of time disappears, this shows that it requires the same amount of work to charge a given condenser to a given potential whether it is charged slowly or quickly, and that this work is equal in joules to one-half of the product of the capacity in farads by the square of the potential in volts.

Therefore, in a circuit whose capacity is 2 farads, the work done in charging it to a potential of 10 volts $= \frac{2 \times 10^2}{2} = 100$ joules $= 73.7$ foot-pounds. We see that it takes the same amount of work to charge a condenser whose capacity is 2 farads to a potential of 10 volts as it does to create a current of 10 amperes in a circuit whose self-induction is 2 henries.

If the capacity of the condenser is 2 microfarads instead of 2 farads, the required work is one-millionth of 73.7 foot-pounds $= 0.0000737$ foot-pounds.

This 73.7 foot-pounds represents the energy stored in the electric field, just as the 73.7 foot-pounds in art. 95 represented the energy stored in the magnetic field.

Disregarding losses it is the amount of work the condenser can do on discharge.

COMBINATION OF SELF-INDUCTION AND CAPACITY IN OSCILLATING CIRCUITS.

97. In an oscillating circuit, when the condenser is discharged—i. e., when the coatings are at zero potential—the electric energy has been transformed into magnetic energy. If there were no losses in the condenser due to heating, radiation, etc., the conversion would be perfect, the work in the magnetic field of the circuit referred to in art. 95 would equal 73.7 foot-pounds, and this, in turn, would be again transformed into electric energy when the condenser recharges. (See art. 54.)

A magnetic field can not be maintained steadily except by a current, but a condenser can be charged and kept in that condition for some time. However, condensers used in wireless telegraphy are always discharged immediately, and the energy stored in them before discharge is the stock in trade, so to speak, of the *sending apparatus;* it represents the work it can do on the ether.

98. Keeping in mind our five equations—$I = \frac{E}{R}$ (1); $P = IE$ (2); wave length $(\lambda) = 2\pi\sqrt{LC}$ (3); $W = \frac{LI^2}{2}$ (4); and $W = \frac{CE^2}{2}$ (5).

Let us consider a condenser having a capacity of 0.02 microfarad (10 standard jars in parallel), charged to a potential of 30,000 volts.

Such a condenser would contain $\frac{2 \times 30{,}000}{100{,}000{,}000} = 0.0006$ coulomb, and would be capable of doing work equal to $\frac{2 \times 10^8 \times 9 \times 10^{-8}}{2} = 9$ joules $= 6.64$ foot-pounds.

If this condenser is discharged through a circuit having a self-induction of such value (0.00125 millihenry) as will give a wave length of 300 meters, the frequency of the circuit is 1,000,000, the alternations 2,000,000 per second, and 0.0006 coulomb will create in such a circuit an average current of $2{,}000{,}000 \times 0.0006 = 1200$ amperes. (This shows the necessity for ample surface in condenser leads.)

If this energy is radiated in five complete oscillations, the rate of doing work, if the efficiency of conversion is unity, is 9 joules in $\frac{5}{1000000}$ second $= 1{,}800{,}000$ per second $= 1800$ kilowatts.

This shows that though the available energy is very small, the rate of doing work, that is, the power of a wireless telegraph sender, may be very great for an exceedingly short period of time.

EFFICIENCY OF SENDING APPARATUS.

99. We can not, however, utilize the whole of the energy stored in the condenser on account of unavoidable losses which will appear later. With a certain wireless telegraph set on which experimental measurements were made, Fleming found the actual power radiated to be about 10% of that supplied to the transformer and 20% of that supplied to the condenser.*

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* Journal Institution of Electrical Engineers, vol. 44, London, April, 1910.

Professor Fessenden and Dr. L. W. Austin in the Brant Rock experiments found that with the set on which measurements were made about 75% of the power delivered to the spark gap was radiated.

Very few complete investigations of this kind have been made.

EFFICIENCY OF RECEIVING APPARATUS.

100. Fessenden in his published account of his experiments on the sensitiveness of wireless telegraph detectors states that in the most sensitive detectors the least amount of work which will render a signal readable is .007 erg per dot.

If a dot lasts $\frac{1}{15}$ of a second this represents approximately .01 erg per second, or $\frac{1}{10^9}$ watts.

Dr. L. W. Austin's tests of telephones in 1908, several years subsequent to Fessenden's experiment, indicate that to produce audible sound in a telephone required not less than $\frac{3}{10^{11}}$ watts. With telephones of the sensitiveness previously available it required not less than $\frac{3}{10^9}$ watts.

The 6.64 foot-pounds of work which the condensers under consideration can release equals 90,000,000 ergs. With a radiation efficiency of 20%, if about one billionth part of this can be concentrated on the receiving apparatus, the signals sent out can be read.

DIFFERENCE BETWEEN DIRECT AND ALTERNATING CURRENTS DUE TO SELF-INDUCTION AND CAPACITY.

101. The fundamental electric equation $I = \frac{E}{R}$ is derived from measurements of the relations existing between electric current and a constant E. M. F. in a circuit of constant resistance.

Self-induction only affects a current when it is being started or stopped. It increases the time it takes for the current to rise to its steady value and the time it takes to fall to zero. For continually changing currents both in strength and direction it impedes both rise and fall, and therefore acts as a resistance, so that the resistance of a circuit for alternating currents is not the same as for steady or direct currents, but is a combination of the ohmic resistance and the inductive resistance or reactance (art. 30). Reactance is not a true ohmic resistance, which appears as heat, but is rather a counter or opposing E. M. F.

The action is still further complicated in circuits having capacity, as wireless telegraph circuits have, since capacity is found to assist both the rise and fall of current, and therefore to act in an opposite direction to the self-induction and to decrease the total resistance or impedance.

In alternating circuits we have $I = \frac{E}{Z}$ where $Z =$ the impedance $= \sqrt{R^2 + \left[2\pi NL - \frac{1}{2\pi NC}\right]^2}$ N being the frequency of the alternating current.

Since capacity and inductance produce opposite effects, they can be used to neutralize each other, if $2\pi NL = \frac{1}{2\pi NC}$ the equation becomes $I = \frac{E}{R}$ as for direct currents, E being the instantaneous value of the E. M. F.

In circuits where the resistance and capacity are very small, and the self-induction comparatively large, as in primary sending circuits, $Z =$ approximately $2\pi NL$, or the current depends almost entirely on the reactance of self-induction. The current in wireless telegraph sending circuits is sometimes governed by *reactance regulators* placed in the primary circuit. (See art. 30.)

TIME CONSTANTS OF CONDENSERS AND INDUCTIVE CIRCUITS.

102. Every capacity and inductance has what is called its *time constant.*

The time constant of a condenser is equal to $C\ R$—i. e., the product of its capacity and the resistance through which it is charged. If C is measured in microfarads, R must be measured in megohms, and their product will then be in seconds. The greater the time constant of a condenser the longer time it will take for it to arrive at a given fraction of the charging potential.

For any usual transformer charging frequency this effect is inappreciable.

The time constant of an inductive circuit $= \frac{L}{R}$. The greater the time constant of a circuit the longer it takes to establish a current of a given strength in it.

SKIN EFFECT IN HIGH-FREQUENCY ALTERNATING CURRENTS.

103. Another effect of alternating currents on the apparent resistance of circuits is seen when the frequencies are above 100. It is called by Fleming the phenomenon of skin or surface resistance. The current seems to begin at the surface of a conductor and soak in, and to penetrate to the center it must have *time.* This is another instance of the *time effect* that must be kept in mind when dealing with alternating and oscillating currents. Lord Rayleigh has investigated this effect and finds that for wires made of nonmagnetic material of diameter *d* the ratio between the resistance for frequencies of a million to the steady resistance is $\frac{R^1}{R} = \frac{\pi d}{2}\sqrt{\frac{1,000,000}{P}}$ where $P =$ the specific resistance of the wire.

If the wire is of iron its resistance for high-frequency currents is still greater.

The resistance of No. 16 wire for frequencies of a million is 6.5 times greater than its steady resistance. The larger the diameter of the wire the greater the proportional increase in resistance. Stranded wire, having proportionally greater surface than solid wire of the same area of cross section, offers less resistance to high-frequency currents.

Flat ribbons, having larger surface, offer less resistance than circular wire of the same area of cross section.

In the Stone receiving circuits, the inductance coils were wound with wire of such size that for the frequency intended the current penetrated to the center and there was no wasted material. Resistance is decreased by using a number of strands in parallel.

Currents in wireless telegraph circuits having a wave length of 300 meters penetrate about $\frac{1}{15}$ millimeter, or approximately $\frac{1}{400}$ inch, inside the surface of the conductor. If the wires are of iron the current penetrates about $\frac{1}{2000}$ inch.

We see, therefore, that oscillating currents used in wireless telegraphy, especially those in the closed circuit, not only may be very large for a very short period of time, but that they remain practically on the surface of the conductor, and it is evident that the latter should have much greater area than would be necessary to prevent heating by the same steady current.

CAPACITY AND SELF-INDUCTION OF STRAIGHT WIRES.

104. The capacity and self-induction of all but very simple forms of circuits are very difficult to calculate, and in general they are determined by comparison with known values.

The capacity of a straight, vertical wire of length *l* and diameter *d*, well above the earth and away from other conductors, is in micro-

$$\text{micro-farads } C = \frac{l}{4.1454 \, log\left(\frac{2l}{d}\right)}.$$

Fleming states that a wire 111 feet long and diameter 0.085 inch, suspended vertically, was found to have a capacity of 0.000205 microfarad, or approximately one-tenth of one standard Leyden jar. Four wires of the above size and length, being 6 feet apart, were found to have a capacity of 0.000583 microfarad, or about three times as much as one wire.

One hundred and sixty such wires in the shape of an inverted cone, 2 feet apart at the top and in contact at the bottom, had a capacity of only about thirteen times that of a single wire.

It will be seen that doubling the wire in an aerial does not double its capacity. For wires about 2 feet apart the capacity increases approximately as the square root of the number of wires—that is, 16 wires would give four times the capacity of 1 wire.

The self-induction of a straight wire of length l and diameter d and circular cross section at a distance from other conductors is $2\,l\,(2.3026 \log. \frac{4l}{d} - 1)$, values being given in centimeters. The self-induction of two parallel wires varies as the distance between them, decreasing with the distance, so that adding straight wire to an aerial does not add to its self-induction in the same proportion.

The relation between the inductance and capacity of a straight wire of circular section and diameter small in comparison with its length is such that its electrical length is equal to its natural length, and its wave length is therefore twice its natural length.

A vertical straight wire, well grounded and of small diameter has an apparent electrical length equal to twice its natural length, its wave length is four times its natural length.

Pierce states that a single wire 100 feet long and $\frac{1}{8}$ inch diameter, when alone in space has as much capacity as an isolated flat metallic disc 16 feet in diameter.[*]

CONDENSERS IN SERIES AND IN PARALLEL.

105. When two or more condensers are placed in parallel (fig. 28c), their total capacity C is equal to the sum of their capacities taken singly; i. e., $C = C_1 + C_2 + \text{etc.}$ When two equal condensers are placed in series (fig. 28d), the resulting capacity is one-half of that of each taken singly, or in general

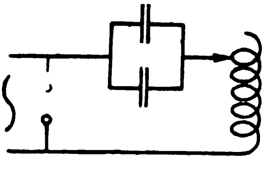

FIG. 28C.

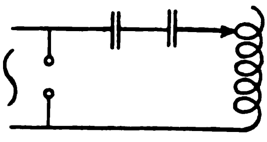

FIG. 28D.

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

[*] Principles of Wireless Telegraphy, by G. W. Pierce, A. M., Ph. D. (1910).

A condenser is often placed in large aerials to shorten the natural wave length for receiving. The aerial in this case being considered as one plate of a condenser and the earth the other, when a condenser is placed between the aerial and the earth we have two condensers in series.

Condensers which will be ruptured if used alone can be used in series, dividing the voltage between them.

For instance, take a transformer giving 30,000 volts to be used in connection with condensers that will stand but 20,000, by placing 2 in series each condenser would have to stand but 15,000 volts.

It will be seen that 32 jars made up into 2 condensers of 16 jars, in parallel, in each and the two condensers placed in series would only have the capacity of a single condenser of 8 jars in parallel, but the work on each jar would be four times lighter.

106. If a straight wire is broken in the middle the oscillation period of each half would be half the original period were it not for the fact that the adjacent ends of the wire and the air between them form a small condenser which has the effect of slightly increasing the capacity of each half, thus giving it a period slightly longer than half of the original period.

From the above it appears that we can shorten the electrical length of an aerial (radiating circuit, art. 75, fig. 29) by putting a condenser in series with it, but we can not shorten it to less than one half its original period.

We know that by *coiling* the wire we can increase its self-induction and, therefore, its electrical length and wave length with very little increase in its physical length. In practice wave lengths of the closed circuit (art. 75) are altered by changing their self-induction as above. The wave lengths of the open circuit (aerial) are increased by adding inductance. They are decreased by adding condensers in series (for receiving only).

MEASUREMENT OF INDUCTANCE AND CAPACITY IN OSCILLATING CIRCUITS.

107. By comparison with standard inductances and capacities, the capacity and self-induction of circuits can be measured and their periods calculated.

Measured inductances and capacities connected together so as to form an oscillating circuit are made so that the capacity or inductance (usually the capacity) or both are variable. They can be calibrated so as to show directly either the period or wave length of the circuit for any position of the variable elements.

If brought near another circuit in which electrical oscillations are taking place and adjusted so as to have a maximum of current induced the two circuits are said to be in *tune* or *resonance.* (They have the same electrical length.) When used as above, calibrated oscillating circuits are called *wave meters, ondameters* or *cymometers.*

Wave meters can be so arranged as to measure separately the inductance or capacity of oscillating circuits as well as their periods. If a spark gap forms part of the oscillating circuit, its period can also be directly measured by measuring the time between the successive surgings of the spark. This is done by photographing the sparks by reflection from the surface of a rapidly revolving mirror. The movement of the mirror between sparks separates their images on the photographic film, and knowing the number of revolutions of the mirror per second, the elapsed time between sparks can be calculated and hence the period of the circuit.

INDUCTANCES.

108. In sending circuits the capacities (condensers) are usually fixed and the wave lengths are varied by varying the inductance (self-induction). This usually consists of a bare copper wire, tube, or ribbon coiled so as to form a helix. Of course the self-induction of such a coil could be very greatly increased by providing it with an *iron core* but the magnetic hysteresis loss (art. 148) would be too great. The magnetic hysteresis loss in air, like the dielectric hysteresis loss, is practically zero; therefore, these inductances have air cores and as much of their length is included in the circuit as will, in connection with the fixed capacity (condensers), give the wave length desired. (See Fig. 73 for photograph of sending helix.)

MUTUAL INDUCTION AND ITS EFFECT ON OSCILLATING CIRCUITS.

109. Mutual induction between two circuits is explained in art. 15. It is represented by the letter M and is defined as the E. M. F. generated in one circuit when the current in the other circuit is varied at the rate of one ampere per second. The two circuits are *coupled* together by virtue of their mutual induction and the induced current represents a transfer of energy from one circuit to the other.

If their mutual induction is large, they are said to have *close* or tight *coupling;* if small, the coupling is said to be *loose.* It is evident that the mutual induction between two circuits depends on the self-induction of each. That is, the strength of the *magnetic fields* produced by varying the current. Also that it depends on the distance apart of the two circuits and the material (iron or air) intervening. It is a maximum when all the lines of force created by the current in either circuit cut the other. In this case the coupling is said to be perfect. If the two circuits in the case of perfect coupling have the same self-induction their mutual induction is equal to the self-induction of each; if different the mutual induction in such a case is equal to $\sqrt{L_1 L_2}$. L_1 being the self-induction of one circuit, L_2 that of the other.

If the two circuits are moved in relation to each other so that only part of the magnetic field created by each cuts the other, their mutual induction is decreased.

The ratio of the mutual induction (for any position of the circuits) to its maximum value is called the coefficient of coupling for that position, or

coefficient of coupling $= \frac{M}{\sqrt{L_1 L_2}}$.

The mutual induction between two oscillating circuits alters the effective self-induction of each (art. 92), making it apparently larger or smaller as one circuit is receiving energy from or transferring energy to the other.

110. Since the natural period of a circuit in seconds $= 2\pi\sqrt{LC}$ (3), if L, the effective self-induction is varied, the period of the circuit is varied.

Coupled circuits having the same or nearly the same natural periods are found to have two periods of oscillation, one faster and the other slower than the natural period of each. Therefore the *open radiating* circuit sends out electric waves of two lengths, one longer and one shorter than the natural wave length of the circuit. The closer the coupling the greater the difference in length of these two waves. This difference divided by the natural wave length of the circuit is called the percentage of coupling. This can be more easily ascertained than the coefficient of coupling. For instance, if an open circuit, having a natural wave length (as determined by a wave meter) of 400 meters sends when coupled to a closed circuit of the same natural length two waves, one of 445, the other 365 meters, the percentage of coupling $= \frac{445-365}{400} = 20\%$.

111. If the circuits have loose coupling, i e., are moved farther apart, the mutual induction is less and the difference in the wave length radiated is less. This distance can be increased until the two waves practically coincide with the natural wave length of the circuit. This is very loose coupling but since without mutual induction, no energy can be transferred, the two can never be the same.

Most of the energy is found to be in the longer wave and until recently that in the short wave was practically wasted. The method now used of generating but one wave length will be described under sending apparatus.

Chapter IV.

ELECTRIC OSCILLATIONS AND RADIATION OF ELECTRIC WAVES.

112. It has been stated that every oscillating circuit must contain inductance and capacity. This is true even though the circuit consists of straight wires, for these have distributed inductance and capacity. If the circuit is formed as in fig. 26a with a coil of wire and a condenser, the inductance and capacity are said to be concentrated or lumped. There is also a certain amount of distributed inductance and capacity, but in general this will be small compared with the concentrated portions.

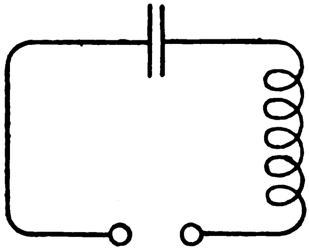

FIG. 26A.

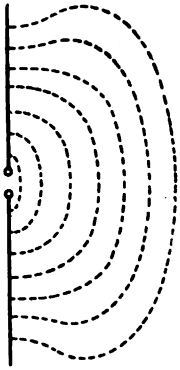

FIG. 30.

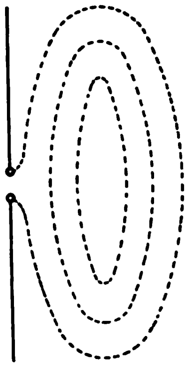

FIG. 31.

FIG. 26A.—Non-radiating Circuit.
FIG. 30.—Radiating Circuit.
FIG. 31.—Electric Wave Leaving Oscillator.

In the case of a linear oscillator (fig. 30), when the oscillations are taking place and the charges are most widely separated, we may imagine lines of electric force to be connecting each unit of positive electricity on one end to a unit of negative electricity on the other. For clearness of conception we may picture these lines of force as having a real existence and exerting an elastic pull between the positive and negative units, tending to draw them together, while at the same time, provided they are running in the same direction, they tend to repel each other. These lines of force in the case of a linear oscillator, on account of their repulsion away from the oscillator, form wide loops which tend to snap off and travel away into space when the charges again rush back through the spark gap, thus forming electrical waves or radiation as shown in fig. 31. In the case of the circuit shown in fig. 26a, where the principal capacity lies in the condenser, the lines of force are concentrated between the condenser plates. They do not loop out to any extent, and hence such a circuit radiates very feebly. On account of these differences an open circuit oscillator (fig. 30) is often called a radiating circuit, while a closed circuit (fig. 26a) is called non-radiating, although all high frequency circuits radiate in some degree.

113. Let fig. 32 represent a closed circuit inductively connected to a vertical grounded open circuit or aerial, and suppose the spark gap to break down at the point of maximum potential of the charging current. At this instant there is no current in the closed circuit and, therefore, no current in the open circuit. The energy is all electro-static, all in the closed circuit and practically all in the electro-static field between the condenser plates, the capacity of the spark points and other parts of the circuit being very small.

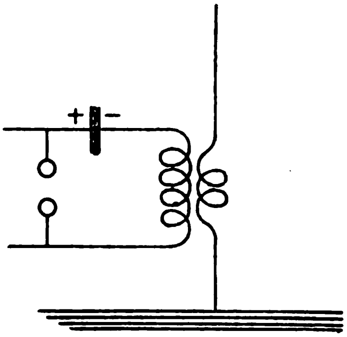

FIG. 32.

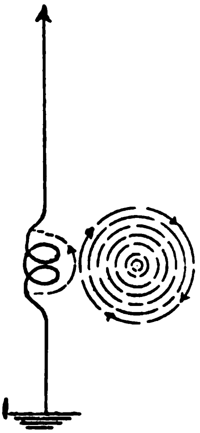

FIG. 32A.

As soon as discharge through the spark gap commences the field of the current in the closed circuit inductance induces movements of electric charges in the open circuit, the starting point of the disturbance being the open circuit inductance. As the charges in the open circuit separate they are connected by electro-static lines of force and surrounded by magnetic lines of force, both moving outward at the same rate that the charges move in a straight wire.

The electro-static field becomes a maximum when the charge reaches the top of the wire. At this time the magnetic field is a minimum. At the expiration of a half period, when the charges meet again, the magnetic field is a maximum, but reversed in direction. The electro-static field reverses as the charges separate again. If they can be represented as meeting in the open circuit inductance, the electro-static field just after the end of a half period can be represented as in fig. 32a, where the mutual repulsion of the electro-static lines of force outside the wire has kept them from returning as fast as the charges travel towards each other. As the charges meet, the ends of the lines of electric force unite and become closed circuits, or electric whorls shaped like smoke rings which, owing to the mutual repulsion of all their parts, expand outward, upward, and downward.

It is in some such manner that we can conceive energy to be detached and sent out into space from wires forming oscillating circuits.

The expanding rings touch the earth and are guided by it as by any other conductor, thus resembling near the earth expanding hemispherical shells.

These may be called earthed waves to distinguish them from the free waves which exist momentarily in the vicinity of an ungrounded oscillator.

114. If the point of connection with the closed circuit is considered as at the earth, earthed waves only are generated and detached from the aerial and no free waves exist at any time. The production of earthed electric waves under these conditions is illustrated in fig. 33.

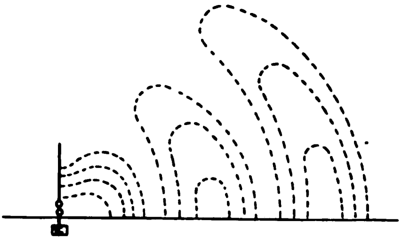

FIG. 33.—Earthed Electric Waves.

We know that earthed waves are guided by conducting *surfaces;* we know that light waves are not; we do not know where the dividing line is between waves that are radiated in straight lines and those that are guided by conductors.

115. For simplicity we have described the process of radiation in terms of electro-static lines of force, but it must not be forgotten that a moving electro-static field always produces a magnetic field at right angles to itself and at right angles to the direction of movement, so that we have electro-static lines perpendicular to the surface of the earth (at least near the aerial), and magnetic lines in circles surrounding the aerial.

Both the electro-static and the electro-magnetic fields reverse their directions every half wave length.

The process of radiation withdraws energy from the circuit just as is the case when a resistance is placed in the circuit; hence the radiation resistance is an expression often used, meaning the resistance which under the given conditions would use up the same amount of energy as that removed from the circuit by radiation. This radiation resistance depends only on the form and dimensions of the aerial and on the frequency of the oscillations, increasing rapidly as the frequency increases. It is independent of the intensity of the oscillations and of other sources of lost energy in the circuit.

Radiation resistance might be called the *radiation coefficient.* Accurate means of measuring it are not yet in general use.

DAMPED OSCILLATIONS.

116. It has been explained (art. 54) that when a circuit consisting of a condenser, inductance, and spark gap is charged by a transformer to a potential so great that a spark passes across the gap, the electricity stored up in the condenser discharges itself through the spark gap, and by its inertia charges the condenser in the opposite sense, only at the next instant to again discharge itself, and so on. All this takes place during the time of one spark, and in fact this surging of electricity is what keeps the spark in existence after the first discharge. This surging back and forth would continue indefinitely were it not for the energy used up in the heat of the spark and in the resistance and other losses in the rest of the circuit. But as no new energy can be introduced into the circuit until the condenser is recharged, the electrical surgings decrease in intensity and finally cease.

If we represent time by the horizontal axis and the amplitude of the oscillations by the vertical axis, fig. 34 will show graphically the course of the phenomenon. It is exactly analogous to a light pendulum which is set swinging and which is brought to rest after a limited number of swings by the friction of the air.

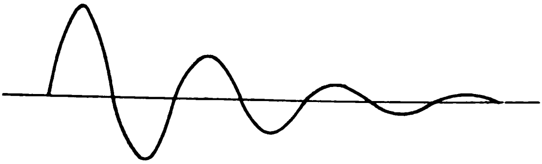

FIG. 34.—Damped Oscillations. Energy Supplied at Beginning of Wave-train.

Gradually decreasing oscillations of this kind are called damped oscillations and obey the law that each succeeding amplitude is a given fraction of the one before it, that is, the amplitudes form a geometric series.

117. For purposes of calculation it is sometimes convenient to make use of a system of logarithms which instead of using 10 for its base, as is the case with common logarithms, uses the number 2.7183. These natural logarithms can always be obtained from the common logarithms by multiplying the latter by the factor 2.3026. If the natural logarithms of the successive amplitudes of our oscillations be taken, it will be found that the successive logarithms differ from each other by a constant number. This number in the present case is known as the logarithmic decrement of the oscillations. Its chief interest to us lies in the fact that it is a measure of the energy losses in the circuit.

Wave amplitudes in the ratio. $\frac{10}{8}$	Natural logarithms of the amplitudes (constant difference) $\delta=0.223\pm$	Wave amplitudes in the ratio $\frac{10}{8}$	Natural logarithms of the amplitudes (constant difference) $\delta=0.223\pm$
1000	6.908	410	6.016
800	6.685	328	5.793
640	6.462	262	5.569
512	6.238	210	5.347

It is often expressed by the symbol δ (delta). If we express all the losses in the circuit in terms of a resistance R which would give us the equivalent loss, $\delta = \frac{R}{2nL}$, where n is the frequency and L the inductance of the circuit, R and L being expressed in corresponding units, for instance, absolute units. This formula enables us at once to determine the equivalent resistance of the circuit when the damping has been measured. For the derivation of this formula and for the general mathematics of the damping theory, the reader must be referred to mathematical works on the subject. Some authors define δ as the logarithmic decrement per half oscillation, but following the more general usage we have defined it as the decrement per whole oscillation, that is, between two oscillations in the same direction.

UNDAMPED OSCILLATIONS.

118. It has been seen in the last article that the cause of the dying out of a train of oscillations in a spark circuit is the using up of energy in the circuit together with the fact that no energy can be brought in from outside to conpensate this loss. If means can be found for keeping up a constant supply of energy, our oscillations can be made to continue indefinitely and with equal amplitude (fig. 35).

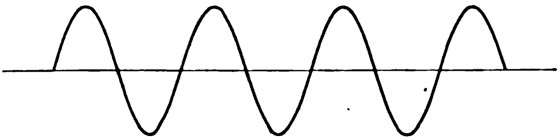

FIG. 35.—Undamped Oscillations. Energy Constantly Supplied.

119. The electric waves produced during one set of oscillations are called a *wave train.* If more than one, the wave trains produced during one-half cycle of the charging current are called a *group of wave trains.*

The duration of a wave train is the time of one oscillation multiplied by the number of oscillations in the train.

It is found that the duration of a wave train is much less when the oscillating circuit (A. B. K., fig. 29) is connected to an aerial with one end free and the other earthed, like C D, than when it oscillates without any other electrical connection. The energy is radiated more rapidly, the vibrations more quickly damped. For this reason the circuit formed by the condenser, spark gap, and inductance is called the *closed* or *oscillating* circuit; that formed by the aerial, inductance and ground, the *open* or *radiating circuit.* (See art. 75.)

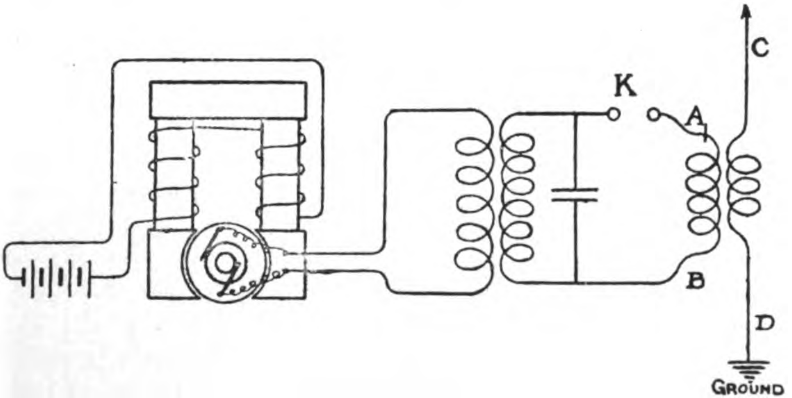

FIG. 29.

120. Considering the series of expanding hemispherical shells referred to in art. 113, and shown in fig. 33, if there is but one wave train per alternation of the condenser charging current, the thickness of one of these series is equal to the wave length multiplied by the number of oscillations per train. Suppose this to be 10 and the wave lengths 500 meters, then the depth of a wave train is 5000 meters, or a little more than three miles. If the frequency of the alternating current is 60 cycles, or 120 alternations per second, we have 120 wave trains per second, and since they travel at the rate of 186,000 miles per second the wave trains have intervals of 1550 miles between them, so that working at ordinary distances and this frequency, each wave train has passed the receiving station before its successor has left the sending station.

If the alternator frequency is 500, the wave trains are only 186 miles apart, or about the distance of ordinary daylight communication between ships.

121. Professor G. W. Pierce, of Harvard University, has measured the period of some types of oscillating circuits used in wireless telegraphy, and it is from his published account of his experiments that the following description is derived.

Suppose a spark gap set to break down at a potential of 10,000 volts, to be used in a circuit where the maximum potential reached in the condenser is 30,000 volts.

Let the curve of sines in fig. 18 represent the condenser potentials of the oscillating circuit during 2 alternations, each lasting $\frac{1}{120}$ of a second.

The resistance of the spark gap is practically infinite before the potential reaches 10,000 volts, and therefore no current passes. When the potential has risen to 10,000 volts the spark gap is ruptured. Its resistance decreases instantly to a fraction of an ohm, and during the first half of the oscillation the condenser is discharged to zero potential. During the last half of the oscillation it is charged again in the opposite sense. The sparks pass first in one direction and then in the other, and the spark gap not regaining its resisting qualities, the oscillations or surgings continue until the potential (owing to losses due to the radiation of energy in the shape of electric waves, to heating the circuit, and the light and heat at the spark gap) does not rise high enough to disrupt the gap.

The transformer immediately recharges the condenser, which, as soon as it again reaches a potential of 10,000 volts, breaks down the spark gap again, and a second series of oscillations begins.

In the circuit under consideration the maximum charging potential is 30,000 volts, so that a condenser with a spark gap breaking down at 10,000 volts may be charged and discharged several times during one-half cycle of the charging current.

The spark acts like a trigger which suddenly releases the stored energy in the condenser, and as soon as this energy has been radiated, the trigger automatically resets itself and does not release again until the condenser is recharged.

It is evident that if the spark gap in the circuit under consideration is adjusted to 30,000 volts, but one discharge of the condenser per alternation will take place and but one train of waves will be sent out. Shortening the gap will increase the number of discharges per alternation.

The exact number for any spark-gap length will depend on the time of an alternation—i. e., the frequency, and on the length of time it takes the available power to charge the condenser to the voltage required to break down the gap. Less energy per wave train will be radiated on a short gap than on a long one, because the work done varies as the square of the voltage (see art. 96); but the total work done may be equal, on account of the greater number of discharges.

If the spark gap is too short, an arc is formed and no oscillations take place except those due to the frequency of the charging current.

Professor Pierce has shown that the interval between wave trains may vary on account of the residual charge left in the condenser. When the spark gap's original resistance is restored, the potential of the residual charge may be opposed to the potential of the transformer and delay the charging. He has shown also that the gap sometimes partly retains its conducting character and breaks down at a lower potential than its length would indicate. This makes the sparks and oscillations irregular in strength and number and produces ragged and poor signals.

In certain cases Professor Pierce notes an increase of received energy of 400 per cent when using a Cooper-Hewitt mercury interrupter in place of an ordinary spark gap.

122. With a given power the *work* that can be done per second is fixed. In charging a condenser $W = \frac{E^2C}{2}$. The number of times this is done per second gives the work per second, or the *power* expended. By increasing the frequency we can for a given power either reduce the voltage (length of gap) or the capacity of the condenser. For instance, at a frequency of 500 cycles, for the same power, the condenser need only be 1/10 the size as for a frequency of 50 cycles. Or, keeping the capacity the same, the voltage can be reduced to $1/\sqrt{10}$ = approximately 1/3 of that necessary for the same power at 50 cycles. A table showing the capacities necessary for given powers at different frequencies and voltages is given in table 2, appendix A.

123. When the spark gap is set to break down at the maximum charging potential the condenser absorbs and stores all the energy that can be transferred by the charging transformer in one-half of an alternation. When it discharges it transfers part of the energy to the open circuit to be radiated as electric waves. Since its period of discharge is very short as compared with that of the charging current the latter current does not appreciably change during the time the condenser is discharging. This current immediately begins to again charge the condenser but the voltage of the latter does not rise high enough to cross the gap so that the condenser soon begins to return energy to the charging circuit. It does this until its potential and the charging potential (and current if they are in phase) falls to zero. It then begins to absorb energy again with the reverse potential, and on reaching the maximum voltage again discharges across the gap.

Fig. 36 is an attempt to illustrate this action graphically. The area included by the curve on the left of the zig-zag line indicates the work done on the condenser during the first half of an alternation; the zig-zag line indicates the number and amplitude of vibrations made by the closed circuit in transferring the energy to the radiating circuit. The area included by the curve on the right of the zig-zag line represents the work done during the second half of the alternation in recharging the condenser. This work is all returned to the charging circuit. From the above it will be seen that a *condenser* only makes use of one-half of the *available* power, *returning* the other half to the circuit.

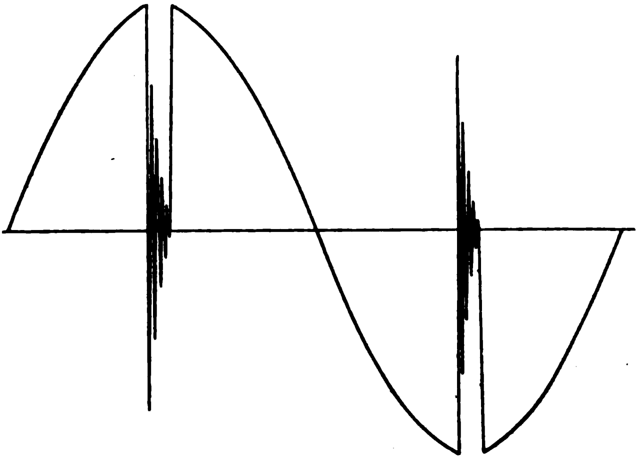

FIG. 36.

MECHANICAL WORK DONE IN MAKING DOTS AND DASHES OF THE TELEGRAPH CODE.

124. We are now in position to speak in more specific terms of the work done in sending wireless telegrams.

Let us suppose that we are delivering 2 kilowatts at 60 cycles and 110 volts to a transformer, which delivers it to a condenser at a maximum potential of 30,000 volts.

Two kilowatts = 2000 watts = 2000 joules per second = 1474 foot-pounds per second.

Since 60 cycles = 120 alternations per second, the work equals approximately 12.3 foot-pounds per alternation.

If the work done on the condenser is in phase with the charging E. M. F., and if the spark gap is set to break down at a potential of 30,000 volts, the condenser will be discharged at the peak of the charging curve, or when one half of the work that can be done in an alternation (6.15 foot-pounds) has been done on the condenser. The capacity of a condenser which takes 6.15 pounds of work to charge it to 30,000 volts = .0186 microfarad, or approximately nine 0.002 microfarad jars in parallel.

Suppose we are sending at the rate of 20 words per minute, that the words average 5 letters each, and that each letter is made up of 3 characters equal in length to 9 dots, then a minute can be represented as equal to $20 \times 5 \times 9 = 900$ dots = 15 dots per second. In other words, the length of a dot is one-fifteenth of a second. Now we have 120 alternations per second, so that we have about 8 alternations per dot when sending at the rate of 20 words per minute; therefore a dot is made up of 8 distinct sets of discharges of the condenser and a dash of three times that number. The condenser is doing work in producing ether waves at the rate of 6.15 foot-pounds per alternation, equaling, approximately, 50 foot-pounds per dot and 150 foot-pounds per dash.

It will be noted from the text that at this sending rate the frequency necessary to give 1 alternation per dot and 2 alternations per dash is only 7½ cycles per second.

It will be noted further that we can not utilize 2 kilowatts continuously. We can only use it in charging the condenser during the first half of each alternation. As soon as the discharge begins the condenser circuit oscillates in its own period as if entirely disconnected from the transformer.

In this respect the charge and discharge of a condenser resembles the loading and firing of a gun. We must bear in mind, however, that though the charging may be done at any rate we desire, the discharge is very much more sudden than that of any gun.

It is not necessary, therefore, except when considering methods of regulation, to devote attention to the charging of the condenser, and our minds can be concentrated on what happens during its *discharge*, when it forms part of an oscillating circuit.

From the foregoing discussion we see that the real source of power in wireless telegraphy is the condenser, and that we can only use it intermittently, not more than one-fiftieth of the time, in fact, but that while working it works very energetically.

DECREASE OF AMPLITUDE WITH DISTANCE FROM SOURCE

125. From the discussion in art. 120 on the thickness of the hemispherical shell enclosing a train of ether waves, if we assume this thickness to remain constant and that part of the shell near the earth to be represented by an expanding cylinder, it is increasing in size by one dimension only, viz., circumference, and therefore the energy in any part of this shell will vary inversely as the distance, instead of inversely as the square or cube of the distance from the source as would be the case if expansion were taking place in two or in three directions.

Messrs. W. Duddell and J. W. Taylor in experiments made for the English Navy in 1905 proved that at least for distances up to 60 miles the received energy as stated above varies inversely as the distance from the sending station. But additional experiments by Dr. L. W. Austin show that this law does not hold except for very short distances, and that the amplitude is lessened from other causes than those due to distance alone. We know that the energy is absorbed in the atmosphere more by daylight than by night—more at high (summer) than at low (winter) temperatures. The amount of absorption as between one day and another probably depends also on the electric condition of the atmosphere. Long waves suffer less absorption than short ones. Irregular country produces interference. The absorption over some soils is for comparatively long distances, 30 times as great as over sea water. Transmission over salt water is the best.

126. As illustrating the difference in absorption between short and long waves, and (a) the greater efficiency of short waves for short distances, (b) the rapid falling off at distances above 100 miles. Dr. Austin finds:

(a) Strength of received signals at 20 miles, using 300 meter waves, 5 times as great as with 1500 meter waves; at 100 miles, 300 meter waves, 4 times as great as 1500 meter waves; at 400 miles, 300 meter waves, 3 times as great as 1500 meter waves; at 800 miles, signals from 300 meter waves weaker than from 1500 meter waves.

(b) using 300 meter waves, strength of signals at 200 miles, .03 of that at 100 miles; at 400 miles, .07 of that at 100 miles; at 800 miles, .007 of that at 100 miles. (See table 8, appendix A.)

DETECTION OF ELECTRIC WAVES.

127. The direction of the magnetic lines of force at any point in a wave near the earth is parallel to the earth's surface and at right angles to a line joining the point with the source of radiation. The direction of the electro-static lines of force at any point near the earth is perpendicular to the earth's surface.

An iron wire placed horizontally and parallel to the lines of magnetic force will be magnetized by a passing electric wave just as iron wires held in the magnetic meridian become magnetized; pointed in the direction of the station the effect would be zero. It has been proposed to utilize this fact, both as a detector of electric waves and of their direction.

Any conducting wire held perpendicular to the earth will be cut at right angles by the magnetic lines of force and will have electric charges induced in it which will create currents, and it is by means of the currents induced in vertical conductors that electric waves are usually detected. A vertical wire thus situated also has a difference of potential created in its ends since it joints two points of the advancing wave whose electric potential differs. (This may also be the case in a horizontal wire if in the line joining its position with the source of radiation.)

The total electric is equal to the total magnetic energy in an advancing wave.

If two horizontal conducting plates, forming a condenser are in the path of the wave, they will have electro-static charges of different potentials induced in them. This potential difference will vary with their vertical distance apart. If these plates are joined by a conductor, electric currents will be produced in it.

We see, therefore, that there should be at least four ways of detecting electric waves: (a) By placing conductors at right angles to the magnetic field; (b) Magnetizable and conducting bodies parallel to it; (c) By placing conductors parallel to the electric field; (d) By adding to conductors at right angles to the magnetic field conducting planes forming condensers at right angles to the electric field.

It would seem that by the last method we should be able to abstract the greatest amount of energy from an electric wave and, therefore be able to detect it at the greatest distance from its source.

128. It will readily be seen that the induction of currents in another aerial, however great the distance from the inducing aerial, is not greatly different from the inductive actions of the wires A B and C D on each other, which was discussed in the early part of this book.

It was there pointed out that inductive actions caused by ether movements could have no limits, however small they might be at great distances. In other words, every change of current sends out some non-returnable energy. Oscillating circuits of high frequency send out more non-returnable energy and radiate better than those of low frequency. *Open* oscillating circuits radiate faster than closed oscillating circuits.

Chapter V.

SENDING CIRCUITS AND APPARATUS.

129. We shall now proceed to consider wireless telegraph sets in detail:

GENERATORS.

Induction coils (fig. 14b) with hammer breaks operated by direct current have been used to a very limited extent for naval purposes. The vibrations of the hammer were difficult to regulate and the large size necessary to handle large currents made the frequency too low for successful work. Hammer breaks were soon discarded and make and break regulated by some form of rotary motion. The most successful form was the mercury turbine interrupter. This interrupter was installed in the circuit containing the sending key and the primary winding of the induction coil. The interrupter consisted of a direct-current motor driving a centrifugal pump revolving in a chamber of mercury. The mercury was connected to one side of a break in one leg of the primary circuit. It was drawn up by the pump and delivered as a jet through a revolving nozzle. The mercury jet during a portion of each revolution struck a metallic segment connected to the other side of the break in the circuit, and, if the sending key was closed, thereby completed the circuit and built up a current in the induction coil which charged the sending condensers. When the jet passed the segments the circuit was broken. (The jet passed through grain alcohol which absorbed the spark at break.) This make and break occurred once in each revolution. The motor made approximately 1800 revolutions per minute. Assuming that the condenser was discharged only on the break, this gave but 30 discharges per second, or a note two octaves * lower, as compared with 120 discharges from a 60-cycle alternator. The operation of these sets was much improved by increasing the number of segments and therefore the number of makes and breaks per second, as many as six being used, thus giving a spark note slightly higher than that of a 60-cycle alternator.

The spark in the interrupter at break always carbonized some alcohol and the latter also became mixed with mercury and formed a more or less

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* The octave of a note is that differing from it by 8 notes of the scale —do-re-mi-fa-sol-la-si-do—the octave above having twice as many vibrations per second and the octave below having one-half as many vibrations as the note referred to. Standard tuning forks vibrate 256 times per second. The pitch of a note is the number of vibrations per second producing that note.

conducting carbon-mercury-alcohol emulsion, so that the interrupter and contents required frequent cleaning, washing, and filling.

For small powers these sets, with care, gave good results, and being generally used with mechanical recording apparatus the spark note was not of marked importance.

CONSIDERATIONS GOVERNING FREQUENCY OF GENERATORS.

130. Turbine interrupters were practically entirely replaced by 60-cycle alternating current generators operated by motors (on ships and at navy yards) or oil engines (isolated shore stations and light ships). These in turn are being replaced by 500-cycle sets operated by motors or engines as above. No special description of generators will be given.

Sixty-cycle current was first selected because alternators of this frequency were commercial articles. When the use of telephones with receiving sets became general it was realized that a sound of a higher note was desirable and that for the very best results the frequency (pitch) of this note should be that to which the telephone diaphragm or the operator's ear, or both, were most sensitive. A pure spark note is produced when the spark gap is so adjusted that the condenser discharges but once per alternation, thus sending out but one *wave train* per alternation.

THE ADVANTAGES OF A HIGH SPARK FREQUENCY.

131. If two alternating currents of the same intensity but of different frequencies be sent through a telephone, it is found that the sound in the telephone produced by the current of higher frequency is much louder than that produced by the lower. This fact is due in part to the peculiarities of the human ear, which is more sensitive to high-pitched sounds than to low, also in part to the diaphragm of the telephone, which is usually of such a weight and size as to vibrate most readily to a sound of rather high pitch. This fact has an important bearing on wireless telegraphy, for the pitch of the sound produced in the telephone connected to the detector at the receiving station depends simply on the number of wave trains per second at the sending station. In order to determine exactly what is the relation between the strength of current required to produce an audible sound in the telephone and the frequency, a series of experiments was carried out on a pair of head telephones of the type ordinarily used in wireless telegraphy, the results of which are shown in the table.

Frequency per second.	Volts to produce audible sound.	Frequency per second.	Volts to produce audible sound.
60	6200×10^{-7}	540	80×10^{-7}
120	2900 "	660	30 "
180	1700 "	780	11 "
300	600 "	900	6 "
420	170 "		

In the first column are given the frequencies or the number of wave trains per second, and in the second the number of volts of alternating current which it would be necessary to apply to the terminals of the telephone to produce an audible sound. From this it is seen that it requires about a thousand times as much voltage at a frequency of 60 to produce a sound as is required at a frequency of 900. We may assume therefore that if the number of wave trains at the sending station be increased from 60 to 900 per second, and the spark length be kept the same, the effect at the receiving station would be increased one thousand times. If the number of sparks be increased in this way without reducing the spark length, it is evident that the energy made use of at the sending station must be greatly increased. It will be more interesting therefore to calculate what the increase in sending efficiency of the station will be with increasing spark frequency if the total energy be kept constant. So if we assume that the energy is proportional to the number of wave trains, and divide the relative increase in loudness of sound in the telephone at the receiving station for any frequency by the relative increase in the number of wave trains per second, we will have a fair comparison of the efficiencies at the two frequencies.

Frequency.	Strength of signal.	Frequency.	Strength of signal.
120	1	540	13
240	1.5	900	64

The results of such calculations are seen in the table, which shows that there would be very slight advantage in replacing a 60-cycle alternator giving 120 wave trains per second with a 120-cycle giving 240 wave trains, but that the advantage increases rapidly as the frequency is increased. The maximum sensitiveness of the telephone appears to lie in the neighborhood of 900.

132. In addition to the increase of sensitiveness of the telephone at high frequencies, there are other quite independent advantages in the use of a high-pitched spark. First, it is found in practice that a high-pitched musical signal is much more readily distinguished at the receiving station in the midst of ordinary interference and atmospheric disturbances; and second, at the sending station a shorter spark gap, which would generally be used with a high frequency spark, puts less strain on the insulation of the condensers and other parts of the circuit, and reduces the losses due to brush discharges, which in many stations amount to a considerable share of the total amount of power employed.

A third advantage is that with a high-spark frequency larger amounts of energy can be radiated from a moderate-sized aerial without subjecting it to excessively high potentials.

Experiments have been recently carried out in which it has been shown that in moderate frequencies with stationary spark gaps there are nearly always secondary discharges, irregular, but giving very high tones, so that the real advantage of the high-spark frequency, from the standpoint of telephone sensitiveness, is usually less than that indicated in the table. The advantages of ease of reading, the lessening of the strain on the condensers and insulators, and the increase in effective energy capacity of the antenna, especially when the latter is small, are very marked, so that it has been found possible to use small wireless sets of 2 K. W. capacity where formerly 5 to 10 K. W. were employed.

The only difficulty involved in using very high spark frequencies lies in the cooling of the spark gap. For this purpose a rotary gap or some special refrigerating device must be used.

133. For the reasons stated above 500 cycles has been adopted as a standard frequency for the present.

An examination of table 2, appendix A, will show how capacity for the same power decreases directly as the frequency increases, or keeping power and capacity the same, how *voltage* can be decreased with increase of frequency. Condensers are more efficient when worked at a voltage below that which will give brush discharges.

134. To ensure a perfectly regular condenser discharge and thus obtain but one wave train per alternation, some generators have a disk mounted on an extension of the main shaft and revolving with it. This disk carries projecting electrodes, one for each pole of the alternator, equally spaced like the spokes of a wheel and connected to one side of the closed circuit. (See fig. 52.) In revolving they pass very close to a fixed electrode, or spark point, connected to the other side of the circuit, sparking taking place as the points pass—one series of oscillations for each alternation. Generators carrying rotary spark points must of necessity be placed in or near the operating room and are to that extent objectionable on account of the noise of the spark, the additional space required, and the noise of revolution which intereferes with receiving.

Motor generators, or generators driven by engines, except as stated above, are usually arranged for being started or stopped from a distance. The controlling apparatus is mounted on a switchboard which carries voltmeters and ammeters, one each for the supply current and one each for the generator current. A frequency meter is also part of the switchboard equipment. This with the field rheostat of the motor enables the operator to adjust the speed of revolution so as to give the required frequency.

TRANSFORMERS.

135. A generator designed for a certain frequency works best in connection with a transformer designed for the same frequency. If the size of the condenser to be used in the closed circuit is fixed, and known to the designer of the transformer, the latter can be built so that the secondary winding and condenser form a circuit whose natural period is that of the generator frequency; a few such transformers have been supplied and are preferred to those requiring *reactance regulators.* Neither generator nor transformer will work without overheating at a frequency much greater than that for which they are designed on account of the increase of heating in the *iron cores* and *frames,* with increase of cycles of magnetization per second.

An examination of fig. 29 will show that the generator armature winding and the primary winding of the transformer form one circuit, and the secondary winding and condenser another. The reactances of these circuits should be such as to maintain the charging E. M. F. and current in phase with each other.

When 60-cycle current was the standard, transformer windings were designed to give a potential of from 25,000 to 30,000 volts in the secondary when the primary was supplied with 110-volt current.

With the reduction in voltage made practicable by the use of higher frequency, standard transformers now have a maximum voltage of 12,500 when supplied with 220-volt current.

For small sets both induction coils and closed core transformers are satisfactory; for large sets closed core transformers are preferred. Transformers are fitted with safety spark gaps set at the maximum safe sparking potential.

REGULATION OF A. C. SENDING APPARATUS.

136. Sending sets work most efficiently when the interruptions or alternations of current are in resonance with the circuit formed by the secondary of the transformer and the sending condenser.

When running on open circuit practically no work is being done by the motor or generator except that necessary to overcome friction.

When the primary circuit is closed by the sending key, with the spark gap opened, so that no sparking takes place, the secondary of the transformer charges the condenser during the first half of each alternation and receives current from the condenser during the second half of each alternation.

The load thrown on the motor-generator by pressing the key depends on the period in a cycle at which contact is made, but, generally speaking, it may be considered as instantaneous "full load."

If the spark gap is set so that the condenser potential breaks it down, the oscillations of the closed sending circuit practically cut out the secondary of the transformer, so that a condition of instantaneous "no load" exists as soon as the spark passes. As soon as these oscillations cease, the secondary again begins to charge the condenser and a condition of almost instantaneous full load is established. This interval is so short that the inertia of the moving parts of the motor generator prevents any change of speed or voltage, so that the instantaneous full load thrown on when the key is closed is the one affecting operation. Again, the inertia of the moving parts of the motor generator is often sufficient to keep up the voltage during the length of a dot, but not during the length of a dash.

When the key is closed the momentary current starting at that instant depends only on the reactance of the primary of the transformer and of the generator armature, since the resistance is very low.

To control this sudden rush of current an adjustable choke coil, called a reactance regulator, may be placed in the primary circuit. This coil, on account of its inertia, acts as a buffer against sudden changes of current, and by means of its adjustability enables the phase relation of the E. M. F. and current in the circuit to be varied and thus the power expended to be controlled.

Since the reactance regulator controls the power expended, it controls the secondary voltage and the maximum spark gap that can be used.

By placing the sending key in shunt around it and having an inductive resistance in series with the key, the reactance regulator can be adjusted so that no sparking will take place, but by closing the key the current added through the shunt circuit is sufficient to cause sparking to take place. By means of this method the sudden changes from full to no load are avoided and the regulation improved, and since only a small portion of the total sending current is broken at the sending key, it is much easier to keep the contacts in good condition.

A safety switch is placed in the primary lead when the method of control described above is installed. This switch should only be closed when sending and should be opened at all other times when the motor generator is running.

A better method of control now being introduced is to have the sending key, by working auxiliary contacts, strengthen the fields of the motor and alternator by cutting out resistance just before the primary circuit is closed.

The charge and discharge of the condenser when not sparking is indicated by a rustling sound, which signifies *danger*. This warning applies equally to induction coils and transformers, both terminals of which are dangerous when using alternating current.

On account of the small penetrating effect of high-frequency currents (art. 103), it is believed that high voltages when associated with frequencies of above 100,000 per second are not dangerous to human life, but low frequency, high-voltage currents are very dangerous, and it must be borne in mind that a condenser being charged and discharged at the alternator frequency is very much more dangerous than when it is discharging across the spark gap.

Other methods of generating high frequency currents are in use than by charging condensers through transformers and discharging them through spark gaps. But since other methods have not yet been practically applied in the United States to any great extent, they will not be discussed in this chapter.

SENDING KEYS.

137. The sending key, or the auxiliary key operated by it, is placed in one leg of the primary circuit.

When placed directly in the primary circuit, sending keys in some cases, have condensers shunted around them to absorb the spark at break. Their contacts when used to break the primary current direct, are larger than in the ordinary telegraph key on account of the larger currents handled. In other respects they resemble the telegraph key. When used to operate a relay the ordinary telegraph key fills all requirements. The relay consists of a solenoid energized by the sending key, its armature making and breaking the primary current in air or oil.

Figs. 37, 38, 38a and 39 illustrate types of sending keys. The Slaby Arco keys shown in fig. 37 were of massive construction and very rugged. Fig. 38 shows a solenoid break the connections for which are illustrated by fig. 38a. It will be noted that this is a *positive break* as well as *make*. Fig. 39 is practically the same as the ordinary telegraph key with large contacts.

Sending keys should be adjusted to have just sufficient movement to prevent arcing and permit well defined making and breaking.

For direct breaking, though platinum contacts are largely used, comparatively large brass or silver contacts are satisfactory. All contacts must be kept smooth and clean and their faces parallel.

What is known as a "break key" is preferred. It was first used on the Stone sets, and is an ingenious and useful device for "listening in" while sending. An attachment to the sending key breaks the detector circuit just before the sending key makes contact. When the sending key is released the receiving circuit is automatically cut in, so that the receiver can "break" the sender by a call, which the latter can hear in the interval between his letters or words.

For sending time signals, a Western Union relay closes a local battery having in circuit a solenoid, whose armature carries a lever which presses and releases the sending key in unison with the current impulses sent from the standard clock at the *Naval Observatory.*

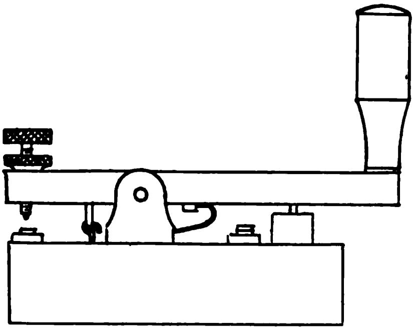


FIG. 37.—Slaby Arco Key.

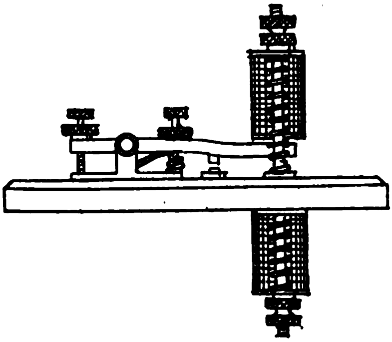


FIG. 38.

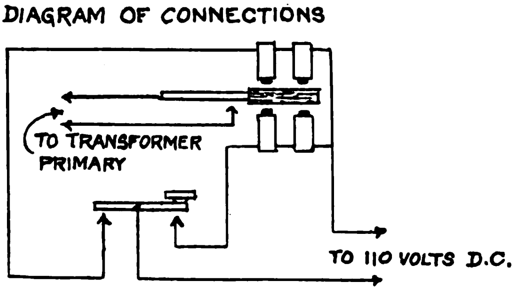


FIG. 38A.—Solenoid Key.

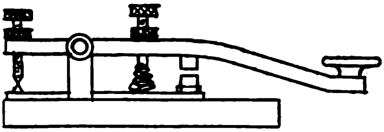


FIG. 39.—Wireless Specialty Apparatus Co.

CLOSED CIRCUITS (INDUCTANCE, CAPACITY, SPARK GAP).

138. Sending circuits are illustrated by elementary diagrams in figs. 29a and 40 to 48 inclusive. The names under these figures are the names of the engineers proposing or designing sets with the connections shown.

To render them capable of adjustment all wireless telegraph oscillating circuits have either variable inductances or condensers or both. These condensers and inductances vary greatly in design. Those for sending circuits especially on account of the high potentials to which they are subjected, are very different in construction and mounting from those used in receiving circuits.

Fixed condensers and variable inductances are used in sending circuits. The condensers may be *single,* two or more in series, or in parallel. Series parallel installations may be made also, just as in primary batteries. (See figs. 28c and 28d.)

The variable inductance usually consists of a helix of comparatively large bare wire (round or flat) mounted on an insulating frame a foot or more in diameter, the turns of wire varying from about ¾" to 2" apart. (See fig. 73.)

A large number of the sending circuits in use at present are direct connected, but inductively connected sets are equally efficient and have this advantage that the *coupling* can be varied by a movement of either the closed or the open circuit inductance as a whole without varying the wave length of either circuit. (Figs. 42, 43, and 45.)

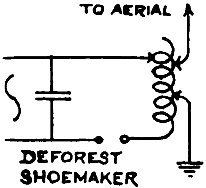
139. In *direct connected* sets, three movable clips or sliders are usually provided, one for the closed and two for the open circuit (fig. 40). The closed circuit is permanently connected to one end of the helix and the circuit completed by means of the wire from the movable clip, which can be connected to any desired point.

The open circuit has the ground and the aerial wire, respectively, attached to the other two clips and these are attached to such points of the helix as will give the open circuit the same natural period as the closed circuit and at the same time give the two circuits the number of turns in common necessary for the desired coupling.

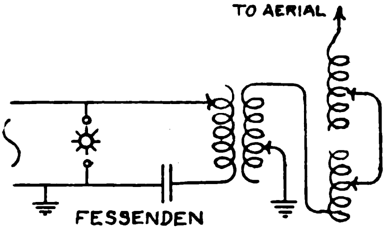
140. In *inductively connected* sets, the closed circuit helix is the same as before, the open circuit helix is permanently attached to the ground lead and the aerial lead attached to whatever point is necessary. The mutual induction and coupling are varied by moving the open circuit helix as a whole. (Figs. 42 and 43.)

Making the adjustments to particular wave lengths and couplings is called *tuning* and is discussed in Chapter VII.

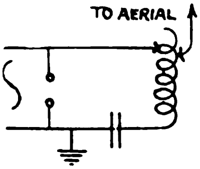
141. In the latest Telefunken sets (fig. 46) the sending inductance in both closed and open circuits consists of flat spirally wound coils, mounted



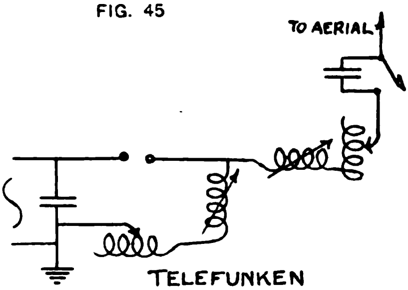
DEFOREST
SHOEMAKER
FIG. 40



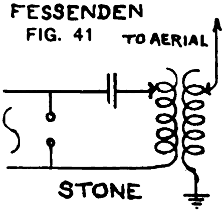
FESSENDEN
FIG. 45



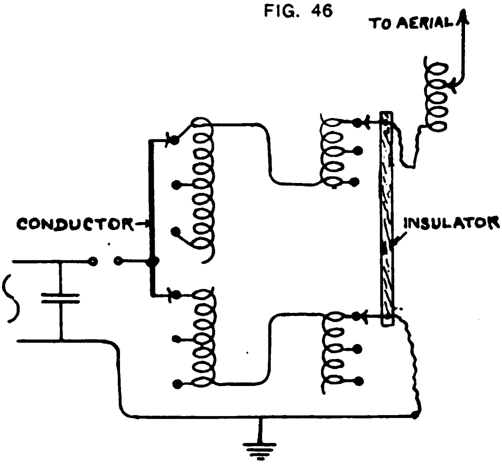
FESSENDEN
FIG. 41



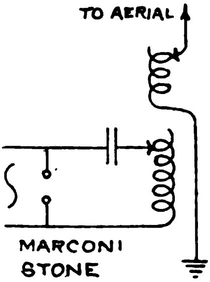
TELEFUNKEN
FIG. 46



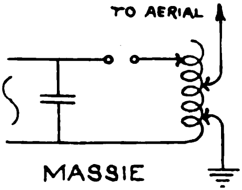
STONE
FIG. 42



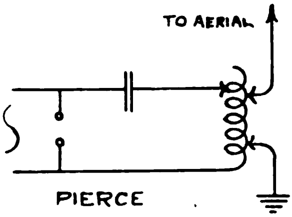
LOWENSTEIN
FIG. 47



MARCONI
STONE
FIG. 43



MASSIE
FIG. 44



PIERCE
SLABY ARCO
FIG 48

parallel and close to each other in a frame. Alternate coils being connected to a lever by which their position relative to the others can be varied. The coils are connected so that currents in adjacent coils oppose each other and decrease the self induction of the whole, called by the manufacturers a variometer. By means of the lever the coils can be separated and the self-induction and consequently the period of the circuit regulated. This is illustrated in fig. 46 by an arrow drawn diagonally across the inductances in which it is used. Fig. 74 shows the apparatus as manufactured.

142. For older direct connected sets connections shown in figs. 40 and 44 are preferred. The S symbol indicates alternating current. In the figures referred to, the condenser is directly across the secondary terminals of the transformer, and the spark gap in one leg of the closed oscillating circuit, as contrasted with the spark gap being placed directly across the transformer terminals. (Fig. 48.) The former is considered to be a more symmetrical arrangement.

143. Attention is invited to fig. 41, which shows one leg of the transformer directly grounded and the other leg connected direct to the aërial. All other methods of connection afford *direct* path to ground and path through condenser *and* spark gap. This method of installation affords path to ground through condenser *or* spark gap only and affects *tuning.* If the aerial is touched when current is on the transformer, the latter, having one leg grounded, is short-circuited through the body and a severe shock may be experienced.

Though this method of connection is no longer used, it is referred to here to show the necessity of giving careful consideration to the relative positions of *ground,* spark gap, and condenser. Errors in connections are sometimes made so that the most direct path to ground is through the spark gap. This induces potentials at the gap or condenser approximately equal to those at the upper end of the aërial and produces disagreeable inductive effects in the operating room.

144. Fig. 43 shows the preferred form of inductive connection or coupling, that is, one inductance above the other. This takes up less floor space and the coupling is varied by vertical instead of horizontal movement, as is necessary when the coils are side by side as illustrated in fig. 42.

Fig. 47. indicates a method of connecting up sending sets so that the operator by moving a hand wheel or lever can change the wave length of the open and closed circuits the same amount without changing the coupling. This apparatus is just being introduced and should greatly facilitate the operator's control over his sending wave length.

CAPACITY.

145. The condenser capacity necessary to absorb 2 K. W. at 60 cycles and a maximum potential of 30,000 volts (.4" gap) is .0186 M. F. or approximately nine standard jars. (Table 2, appendix A.)

At 500 cycles and 30,000 volts it is .00223 M. F., a little more than one jar.

At 500 cycles and 12,500 volts (.015 gap) it is .0127 M. F., approximately six jars.

Older 2 K. W. sets had capacities given below and required maximum volts as indicated to absorb 2 K. W.

Slaby Arco,	60	cycle,	capacity	.014	M. F.,	max.	volt,	app.	35,000,	gap	.5 in.	app.
Fessenden	"	"	"	.004	"	"	"	"	65,000	"	1.6 in.	"
DeForest Shoemaker	"	"	"	.02	"	"	"	"	30,000	"	.5 in.	"
Stone	"	"	"	.0105	"	"	"	"	40,000	"	.6 in.	"

Sets now supplied have capacities based on 500 cycles at 12,500 volts, condenser racks or tanks being arranged to hold a number of jars somewhat greater than that necessary for the rated output.

146. For 2 K. W. sets standard coppered jars in air or oil are preferred. Tinfoil covered jars are no longer supplied.

Inside connections to Leyden jars are best made by soldering one end of a strip of copper or brass gauze to the inner copper coating and clamping the other end to the charging bus bar.

Outside connections are made either by supporting all jars on a conducting plate connected to the other charging bus bar or connecting this bar to a strap of sheet brass or copper clamped around the jar.

The important point about condenser connections is that they should make a good electrical contact of comparatively large area, with the charging wire or bus bars and with the condenser jars or plates. A symmetrical arrangement of material giving as nearly as possible equal lengths of discharge paths should be made.

Many kinds of springs and clips for condenser connections have been devised and are in use, but none are better than those just described. Less difficulty is experienced with connections on copper coated jars or plates than was the case when tinfoil was used exclusively for distributing the charge over the glass dielectric.

147. The condensers now in use are *standard Leyden jars* in air or oil. (Fig. 49.) *Glass plates* in air or oil (glass dielectric). *Metal plates* in compressed air (air dielectric) (fig. 50) and tinfoil (paper dielectric). For large powers, glass plates in oil or metal plates in compressed air are preferred. For small sets the most convenient for use—installation and

FIG. 49.—Leyden Jar Battery.

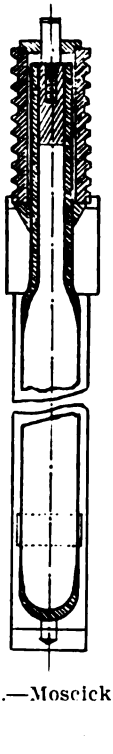


FIG. 49A.—Moscicki Tube.

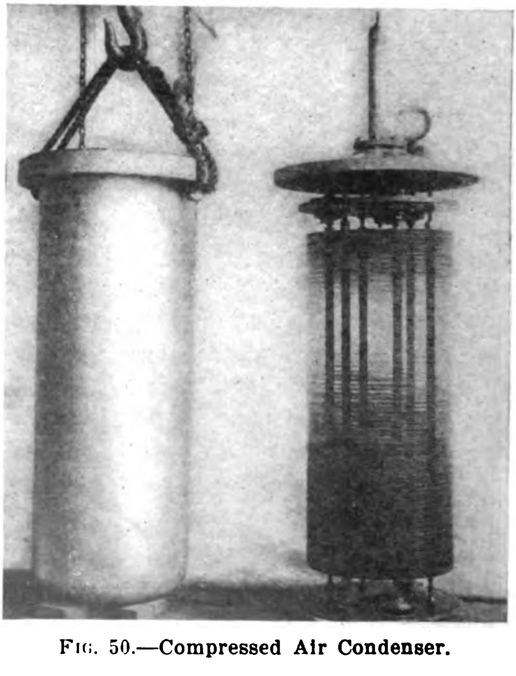


FIG. 50.—Compressed Air Condenser.

inspection—are the standard jars, in air or oil, or glass plates set vertically in oil. Fig. 49a is a special form of Leyden jar which is convenient for some purposes. The low voltages associated with 500 cycle sending sets have made practicable the use of paper condensers as noted above for small powers.

CONDENSERS AND CONDENSER MATERIAL.

148. When a piece of iron is magnetized and demagnetized—i. e., goes through a cycle of magnetization—a certain amount of energy is expended, which appears in the shape of *heat* in the iron. It is supposed to be due to internal friction in the molecules of the iron and is called magnetic hysteresis.

In the same way, to put a condenser through a cycle of charge and discharge requires the expenditure of a certain amount of energy, which appears as heat in the dielectric and is called dielectric hysteresis. The loss of energy due to this quality varies in different dielectrics and is a function of the frequency.

In choosing condensers for the closed sending circuit, it is of great importance to find those which will absorb a minimum of energy and at the same time show no tendency to break down under the large differences of potential impressed upon them.

The losses of energy in condensers are of two kinds; internal losses produced by dielectric hysteresis, and external losses produced by the brush discharges at the edges of the conducting surfaces. The ideal dielectric in respect to the internal losses is air, as it is entirely free from internal energy absorption. When used at ordinary pressures, however, it is unable to bear any considerable difference of potential. It has been discovered that when the air pressure is increased to the neighborhood of 250 pounds, the dielectric strength becomes so great that it is suitable for use at any of the potentials ordinarily used in wireless telegraphy. Compressed air condensers are ordinarily made up in the form of a series of plates so connected that the alternate plates may be charged positively and negatively, and the whole set is enclosed in an air-tight steel tank which can be pumped up to the desired pressure. Such a condenser, while ideal in its electrical properties, is somewhat bulky, and difficulties are sometimes found in preventing leakage of the air. It is therefore common in stations where the last degree of efficiency is not demanded to make use of glass condensers, either in the form of flat plates or jars. The conducting surfaces of condensers are now generally formed of electrolytically deposited copper. It is generally stated that flint glass is the glass best suited to form the dielectric. Experiments which have been made show that the internal losses of glass condensers in ordinary use amount to from 2 to 8 per cent of the total energy flowing through them.

The losses due to the brush discharges from the edges of the conducting surfaces, which sometimes amount to 30 per cent of the total energy, may be much reduced by immersing the condensers in oil or by placing several condensers in series, which reduces the individual potential difference on each condenser, or by covering edges of foil (or copper) and plates with an insulating compound.

149. Practically all other insulators have a greater specific inductive capacity than air at ordinary pressure, and nearly all of them have a greater dielectric strength than air (art. 150). The Leyden jar, having long been used as a high-potential condenser, its method of manufacture being well known, and the best glass having not less than nine times the capacity of air, hàs been very generally used in wireless telegraph sending circuits Air and oil, while requiring much larger volume to give the same capacity as glass, have the excellent property of mending themselves after puncture by a spark, while all kinds of solid or semisolid dielectrics require renewal after rupture.

Mica has very great dielectric strength, as much as *5000 volts per mil,* and has been used to some extent in condensers in the form of *micanite.*

The semisolid dielectrics, such as beeswax and paraffin, have to be made up with considerable attention to the temperatures in which they are to be used, since they may melt in summer and crack in winter, but they are cheap and easily obtained.

Dielectric strength of insulators per millimeter increases with decrease of thickness, except in oils, where it seems to decrease.

Dielectric strength of air increases with increase of pressure.

Dielectric strength of air decreases with decrease of pressure until the pressure is in the neighborhood of 1 millimeter of mercury, when it increases.

Dielectric strength of a vacuum should be infinitely great.

Fleming states that with the best flint glass it is possible to store about 45 foot-pounds of energy per cubic foot of glass. The limit is set by the *dielectric strength* of glass. He has shown that the lengths of discharge paths of all condenser elements should be equal.

Capacity varies *inversely* and dielectric strength *directly,* as the thickness of the dielectric, but they do not vary in the same ratio.

The dielectric strength of glass condensers decreases, that of oil condensers increases, with the frequency.

150. Tables showing the specific inductive capacity of a number of dielectrics and their dielectric strengths are given below. This data is incomplete. Data relative to the hysteresis losses of various dielectrics is almost lacking, and want of agreement is noted among different authorities.

Material.	Specific inductive capacity.	Dielectric strength. Volts.
Air	1	[1] 4,500 [2] 3,000
Hard rubber	2.29	[3] 40,000
India rubber	2.10	[3] 30,000
Mica	6.64	[3] 60,000
Micanite	...	[3] 40,000
Typewriter linen paper	...	[3] 45,000
Paraffin oil	2.71	[3] 7,000
Glass (crown)	6.96	[3] [4] 20,000
Glass (plate)	8.45	
Glass (light flint)	6.72	
Glass (extra dense flint)	9.86	

[1] Per millimeter for thicknesses up to 1 millimeter.

[2] Per centimeter.

[3] Per millimeter.

[4] Approximate.

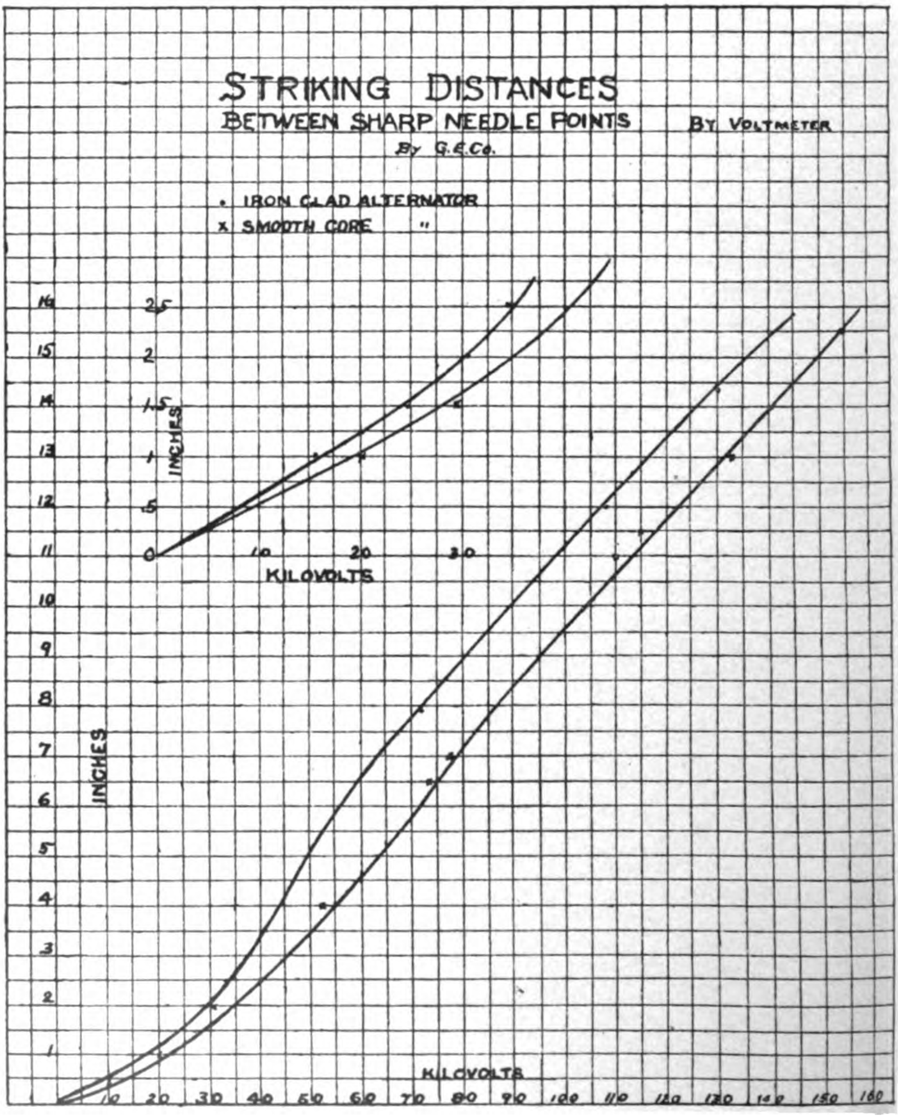

STRIKING DISTANCES
BETWEEN SHARP NEEDLE POINTS
By G.E.Co.
BY VOLTMETER
• IRON CLAD ALTERNATOR
x SMOOTH CORE "
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
INCHES
2.5
2
1.5
1
.5
0
INCHES
10
20
30
KILOVOLTS
KILOVOLTS
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

FIG. 51.

DIELECTRIC STRENGTH OF AIR.

151. The dielectric strength of air is considered to be about 4500 volts per millimeter for gaps of about 1 millimeter in length, and about 3000 volts per millimeter for gaps of the length of a centimeter or more. Fig. 51 shows sparking distances in air between needle points, as determined by experiment. These distances are usually greater than those obtained from equal voltage between the blunt spark points used in wireless telegraphy. The latter probably correspond more closely to table 1, appendix A. On the other hand, this table of spark distances was determined by raising the voltage very gradually and exactly alike for each gap, while in oscillating circuits there is a convulsive rush which may produce very high potentials. This has been shown by introducing a minute spark gap elsewhere in the circuit, the effect being to greatly increase the gap, which can be ruptured by a given transformer potential. The inertia of the charge carries it forward, and just as the inertia of water in a pipe produces a great pressure if its flow is suddenly checked, so the potentials in the sending circuits may, and usually do, rise much higher than is indicated by the transformer ratio.

SPARK GAPS.

152. A great deal of thought and ingenuity has been expended on improving the action of spark gaps. For instance, the use of magnetic blowouts, induced and forced air drafts across the gap; dividing them into a series of short gaps; placing gaps in parallel; enclosing them in compressed air and in nitrogen gas; making the points hollow and cooling them with air or water.

Until recently, no method of construction for small powers was markedly better than the ordinary gap in air between two zinc rods, ¼ to ½ inch in diameter, and these are still largely used. There are two points in common for all good working gaps—(a) The sparking surfaces must be clean and fairly smooth; (b) They must be kept from heating.

The increased radiation from cooled spark electrodes as compared with heated ones is very evident.

Heated surfaces give off more metallic vapor and tend to the formation of a low frequency arc.

There is no doubt that much of the irregularity noted in sending is due to an improperly adjusted spark gap and the effect known as "soaring" or "swinging" is probably due to the inequalities in the action of the spark gap and condensers.

An open spark must be kept white and crackling and have considerable volume. If too long, it will be stringy; if too short, an arc will be formed.

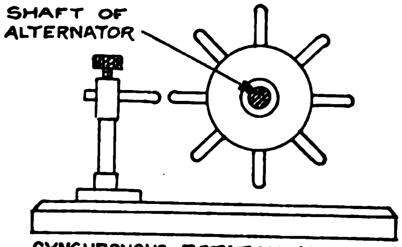
All spark gaps are adjustable—either in length or in number. All should be well muffled for obvious reasons.

The types of spark gaps now in use are shown in figs. 52-61. The only types now supplied are fig. 52, the synchronous rotating gap, and fig. 57, quenched gap.

153. The function of the spark gap in an oscillatory circuit is to allow the condenser to charge to the required potential, and then to break down and permit the charge to surge back and forth until its energy is dissipated. The ideal spark gap would be one which would insulate perfectly while the condenser was charging and conduct perfectly while it was discharging, and the nearer these conditions can be fulfilled the more efficiently will the spark gap perform its duty. Either condition can be fulfilled alone, but the combination is somewhat difficult to obtain.

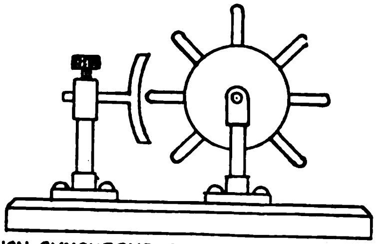
The resistance of the spark gap when the discharge is passing depends upon two factors; it increases rapidly with the spark length, and decreases rapidly with the oscillatory current, amounting with a half-inch gap to several hundred ohms when a fraction of an ampere passes, and a small fraction of an ohm when 50 or 60 amperes are flowing. With the spark length above half an inch, the resistance with the same oscillatory current flowing may be taken as roughly proportional to the spark length. But in a condenser circuit the amount of electricity stored up in the

SPARK GAPS



SYNCHRONOUS ROTATING SPARK GAP

FIG. 52



NON-SYNCHRONOUS ROTATING SPARK GAP

FIG. 53

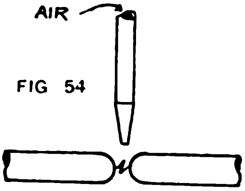


FIG 54

AIR BLAST GAP

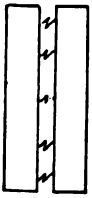
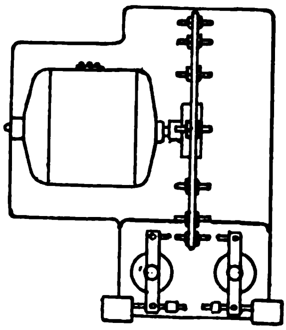


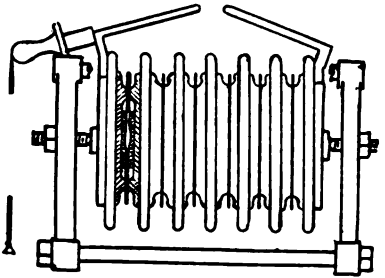
FIG. 55

PARALLEL GAP



MARCONI DISC DISCHARGER

FIG. 56



QUENCHED SPARK GAP

FIG. 57

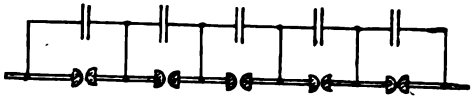


FIG. 58 TELEFUNKEN

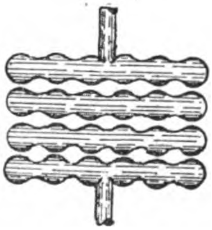
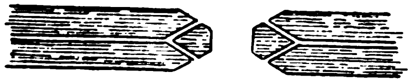
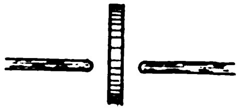


FIG. 59 STONE



MASSIE GAP FOR COMPRESSED AIR

FIG. 60



FESSENDEN-DE FOREST

FIG. 61

condenser, and hence the amount of oscillatory current, increases with the spark length. Thus we have two conditions working against each other as regards the influence of the spark length on the spark resistance; but we can increase the amount of current flowing without increasing the spark length by increasing the size of the condenser, and the most efficient form of circuit for a given power is that in which a moderate spark length and large condensers are used.

When, after the condenser is charged, the spark gap breaks down, the gap becomes filled with metallic vapor and for the time being forms a high-frequency alternating current arc. It is the presence of the metallic vapor which produces the conductivity of the spark. After the discharge ceases, however, if this metallic vapor is not removed from the gap, the insulation will evidently be poor at the time that the condenser is next being charged, hence the first condition of spark efficiency would be wanting. It is therefore necessary to remove this vapor completely as soon as possible after the surgings of the condenser charge cease. This is done partly by cooling the electrodes of the spark gap, thus stopping the vaporization, and in some cases by blowing the vapors out of the gap.

154. In the simple gap, such as is found in sets of small power, the vapor is usually sufficiently dissipated by the natural cooling of the electrodes and by ordinary air currents. Such a gap, however, not provided with an air blast should not be enclosed. For somewhat larger powers, an air blast is ordinarily considered necessary. This carries away the metallic vapors and at the same time cools the electrodes. Such an arrangement is shown in fig. 54.

Another form of gap for small powers which gives good satisfaction is the parallel gap (see fig. 55), in which two cylinders of zinc or brass are placed parallel to each other, and the spark runs from point to point, never jumping twice consecutively in the same place. This wandering of the spark is facilitated by a slight roughening of the electrodes with a file. The explanation of this phenomenon of the running spark is probably as follows: The spark jumps from a slight projection on the electrode which in the course of the oscillations is burned away, so that at the next discharge an easier path is found from some other projecting point.

155. For high powers a good form of spark gap is the rotating synchronous gap shown in fig. 52. This consists of one or more stationary members and a rotating member made up like a wheel with projecting spokes. This in its best form is attached directly to the shaft of the alternator, and is so adjusted that a spoke comes opposite a stationary member at the exact moment that the maximum of potential is obtained in the condenser. This insures one discharge for each alternation of the current, the complete absence of conducting vapors, and gives a satisfactory insulation for each spark. The regularity of discharge from this form of gap produces a pure musical note, which is of great importance in the telephonic reception of signals. (See art. 132.)

156. Another form of rotating gap, called the non-synchronous rotating gap, is shown in fig. 55. In this the wheel is rotated rapidly by an independent motor without regard to synchronism with the alternator. The face of the stationary member of the gap forms an arc of a circle long enough to a little more than cover the distance between two spokes, thus always insuring the proper sparking distance. The rotating wheel itself forms an efficient fan.

157. What is called a "quenched gap" * (shown in fig. 57) is made up of a number of copper discs accurately turned and separated by annular rings of mica about .01 inch thick. The spark is confined to the air tight space inside the mica-rings.

This type of gap, if a proper number of discs are in series, also gives one discharge for each alternation of the current and produces the same pure musical note as the synchronous gap.

It is almost noiseless and has the further advantage of (probably on account of its large cooling surface) quickly stopping the oscillations of the closed circuit, so that the open circuit is left free to vibrate in its own period, and it therefore radiates waves of but one length. This fact has an important bearing on the *tuning* of wireless telegraph sets and also on the coupling, which can without change of wave length be made that which will transfer energy from the closed circuit to the open circuit with the least loss.

158. The quenched gap can not be depended upon to operate without artificial cooling of the discs when any but very small powers are used. Like all other gaps, its action is improved by an air blast.

In the case of the rotating gap the equivalent air velocity in a case of large power was about 20,000 feet per minute. Mr. J. Martin finds a very distinct gain in radiation from an air cooled gap with air pressures up to 15 pounds per square inch, which corresponds to a velocity of 82,000 feet per minute, or about 1400 feet per second.

Take a single gap operating on a 1000-meter wave on the peak of the charging E. M. F.: If the coupling between the open and closed circuits is such that the closed circuit transfers all its energy to the open circuit in five complete vibrations the first group of sparks will last 1/30000 second. To remove the conducting vapor from the gap in that time would require a minimum air velocity across the gap of 1000 feet per second if the electrodes were .4 inch (1 cm.) in diameter. From this point of view it would seem, therefore, that any gap will act as a quenched gap if the

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* Discovered by M. Wien, in the course of an investigation on electrical discharges between metal surfaces placed very close to each other, and published by him in October, 1906.

air velocity across the gap is sufficiently great, and that the required air velocity varies directly as the diameter of the spark electrodes—inversely as the wave length, directly as the damping—and (since it is known that close coupling increases the damping) directly as the percentage of coupling.

Loose coupled circuits would require a lower air velocity than close coupled ones.

Fig. 56 illustrates the Marconi disc discharger, which is practically the same in principle as fig. 53—the non-synchronous rotating gap. A special motor is required to operate the discharger. It has also the disadvantage of being as noisy as the synchronous gap. The disc discharger, like the synchronous rotating gap, is suitable for large powers. It is fitted with an auxiliary stationary gap for use in case of motor breakdown.

TRANSFER OF ENERGY BETWEEN COUPLED CIRCUITS.

159. The transfer of energy between coupled circuits having the same natural period is well illustrated by the mutual action of two similar pendulums connected by a *flexible* support. If, one being at rest, the other is pulled aside and released, the swinging pendulum gives properly timed impulses to the other through the flexible connection and starts it to swinging also, gradually decreasing its own swings while the other increases, until the first one stops; at which time the second has reached an amplitude nearly as great as that of the first swing of the one pulled aside. In other words, all of the energy has been transferred to the second pendulum. The first one then starts again and increases its swings while the second gradually slows down and comes to rest at which time the first is again at its maximum. All the energy has been returned by the second pendulum to the first. The swings are slowly damped by air friction until the system comes to rest. If the periods of the two pendulums are not equal, or nearly so, the impulses are out of step (resonance) and no transfer of energy takes place—the pendulum first started keeps on swinging and the second remains at rest.

160. If the points of support by the flexible connection are a foot or more apart (loose coupling) the second pendulum picks up the swing rather slowly and both pendulums make a large number of vibrations before the second has received all the energy from the first and the latter has come to rest.

If the points of support are close together (close coupling) the second pendulum reaches its maximum and the first comes to rest in a few vibrations, the transfer of energy is more rapid, and the damping greater. The ball of energy, so to speak, is tossed back and forth between them more rapidly than when they are farther apart—more loosely *coupled.*

Professor Pierce [*] has photographed the sparks in a short gap in the open circuit when oscillating in connection with the closed circuit and shows that they occur in groups. This particular circuit showed groups of four. In other words, four vibrations sufficed to transfer all the energy from one circuit to the other.

Two circuits may be alike in period, but have different dampings.

161. Returning now to the consideration of the quenched gap and the closed circuit, what we call the closed circuit is only closed when the spark gap is conducting and its period in that condition is the one measured either when we take the time interval between sparks or determine it by a wave meter. It has a different period when the spark gap is not conducting because its capacity with reference to being charged from the open circuit is less and it is therefore out of tune with the open circuit and the latter does not transfer any energy to it. The effect of the method of construction of the quenched gap seems to be to restore the nonconducting character of the gap the first time the closed circuit comes to rest, and thus leave the open circuit free to radiate. It would be interesting to take photographs in both circuits to determine whether this really is the case.

162. Referring to art. 109 on mutual induction: The open circuit is first set to oscillating in either the period longer or shorter than its natural period and has reached its *maximum* when the closed circuit has stopped and opened. Thereafter the open circuit is free to vibrate in its own period, and that it changes to that period is shown by the wave meter readings, but in building up it is sending out waves of a different period.

The first maximum reached in the open circuit is the highest maximum and, since no further loss by retransfer to the closed circuit takes place, the quenched gap is consequently the most *efficient*. It will also conduce to efficiency to make the building up period of the aerial (when it is radiating waves of a different length) as short as possible. In other words, close coupling, but close coupling increases the induced E. M. F. in the condenser circuit. Therefore, there is a possibility with very close coupling of retransfer of energy by breaking down the gap and again closing that circuit.

163. We can therefore conceive of a wave train from an ordinary open circuit as made up of a series of waves whose amplitude rises and falls during the transfer and retransfer of energy from one circuit to the other; the damping depending on the coupling and being partly natural (due to heating and radiated energy in the shape of electric waves), partly artificial (due to retransfer of energy to the closed circuit).

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[*] G. W. Pierce, Principles of Wireless Telegraphy, 1910, p. 248.

A wave train from the open circuit of a quenched gap can be represented as in fig. 62, by a building up at a certain frequency (depending on the coupling) to a maximum depending on the radiation or other losses per oscillation, and then oscillations in the natural period of the open circuit, with damping dependent on the radiation and resistance of the open circuit only. The closed circuit starting at a maximum and transferring all the energy to the open circuit in a few oscillations as shown in the upper part of fig. 62; there being no retransfer of energy from the open to the closed circuit and vice versa as occurs with the pendulums discussed in art. 159 and 160.

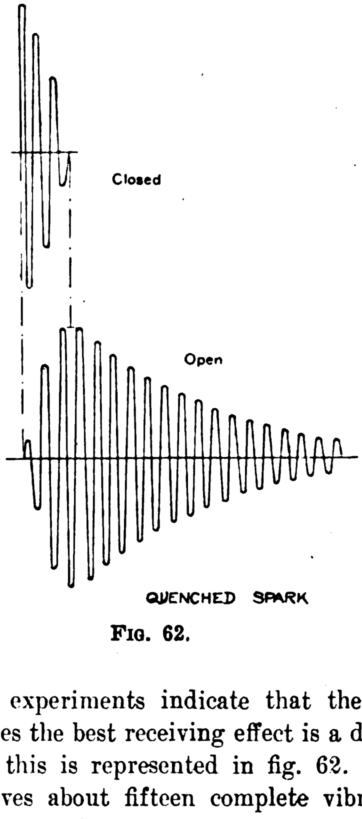


FIG. 62.

164. The results of experiments indicate that the damping of the closed circuit which gives the best receiving effect is a decrement of about .2 per oscillation, and this is represented in fig. 62. This rate of decrease of amplitude gives about fifteen complete vibrations before the amplitude falls to one tenth of the maximum.

The above gives as the most efficient depth of a 425-meter wave train from a 500-cycle generator about 3.3 sea miles, its duration 1/47000 second, the distance between wave trains 186 miles, the time interval 1/1000 second, so that even with a frequency of 500 cycles we only generate electric waves about 2% of the time.

LIMITATIONS ON WAVE LENGTHS.

165. A certain amount of inductance is necessary in the closed circuit in order to transfer energy to the open circuit, whether the circuits are direct or inductively coupled. Since condensers of any desired capacity can readily be obtained, it is easy to make the closed circuit any electrical length we desire.

There is, however, a lower limit to this, depending on the material and arrangement of the condenser and leads. Other things being equal, the larger the capacity, the longer the connecting leads; and the shortest wave length that can be obtained for a given capacity is that found when the leads from the condenser are connected in the most direct manner to those from the closed circuit and spark gap.

The standard wave length for ships and shore stations was first set at 320 meters. It is now 425 meters for ships, except at stations where the necessary condenser capacity is such that a wave length as short as 425 meters can not be obtained. It will be noted that the increase in frequency to 500 cycles will, though the standard voltage has been lowered, permit a decrease of capacity and thus permit the radiation of larger powers on shorter wave lengths than is now practicable.

Experience shows that aerials with short wave lengths radiate more efficiently than those with long ones, and that up to several hundred miles short waves travel over salt water with no greater absorption than long ones; when transmission over land is necessary and for long distances over water we gain more by the reduced absorption of long waves than we lose by decreased radiation efficiency.

166. The open circuit, while it has concentrated inductance like the closed circuit, has distributed capacity which is comparatively small, and though any electrical length we desire can be obtained by adding inductance, it is found that concentrated inductance beyond that necessary to receive energy from the closed circuit lessens the radiation, and on that account it is necessary to increase the period of the open circuit by adding capacity in the shape of additional wires to the aerial. We have seen that, unless they are quite a distance apart, two parallel wires do not have twice the capacity of one, so that it is practically difficult to get very long wave lengths in the open circuit, especially on shipboard.

The wave lengths that we can efficiently use in the open circuit are therefore limited by practical considerations.

Since the energy in any discharge varies as the square of the voltage, and since any desired voltage can readily be obtained, the work that can be stored in a condenser of given capacity depends only on the dielectric strength of the condenser material.

But in the case of the open circuit, when the first transfer of energy is completed, unless it is radiated nearly as fast as received, the maximum voltage in the open circuit, on account of its capacity being very much smaller, is much greater than that in the closed circuit. And we find that very high voltages, on account of difficulty of insulation, break out in sparks at all points of the circuit, that the aerial wire glows throughout its length, and the whole apparatus generally acts like a dry linen fire hose when subjected to a high water pressure—i. e., it spurts electricity at all points in all directions.

So practical considerations limit the wave lengths that can be efficiently used on board ship, and also limit the *power* that can be used with them.

167. Referring to the closed circuit, it is probable that the best results with any given sender are obtained when the work necessary to charge the condenser to the transformer voltage is equal to that supplied by the available power of one-half alternation. This gives but one wave train per alternation, and, if true, fixes at once the capacity of the closed sending circuits for any given power. Good results, however, have been obtained by producing a condition of resonance in the secondary circuit with the primary frequency and obtaining a wave train only every two or more alternations.

However, if the generator, sending circuits and aerial are properly designed, the greater power per wave train will be gained at the expense of efficiency on account of the high voltages in the aerial and the reduced spark frequency.

OPEN CIRCUIT—(AERIAL, INDUCTANCE, GROUND).

168. Aerials, with which the open circuit inductances of sending sets are connected, are shown diagrammatically in figs. 63 to 71 inclusive.

The main principles to be remembered in connection with aerials (or antennae, as they are sometimes called) are that the higher the aerial the more efficiently the energy will be radiated in the form of electric waves and the larger the currents induced in the vertical part of the aerial the greater the amount of energy radiated.

So what we need is *height* for efficiency; and capacity for amount (distance). The former is limited by the height of mast; capacity by the amount of wire that we can conveniently support at the mast heads. Experiment indicates that *distance* for the same *power* varies as the *square of the height.*

The total capacity of a ship aerial is usually less than one standard jar. To hold the same amount of energy as the condenser circuit the aerial is therefore while oscillating, charged to a higher maximum potential.

The form of aerial now generally used on ships and ashore is called the *flat-top* or inverted L (fig. 67).

The leads to the operating room are taken from one end; the other (free) end is subject to high potentials and must be well insulated.

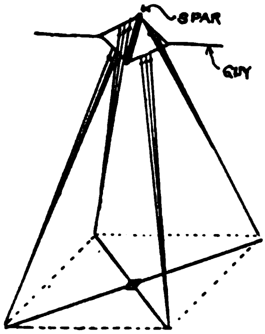


FIG. 63 BELLINI-TOSI

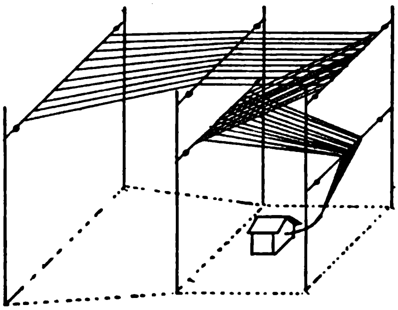


FIG. 64 MARCONI

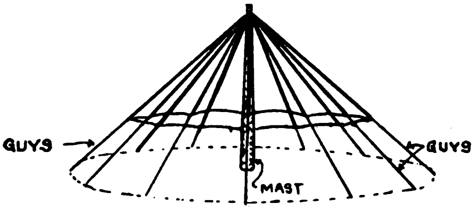


FIG. 65 UMBRELLA

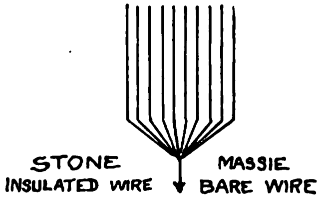


FIG. 66

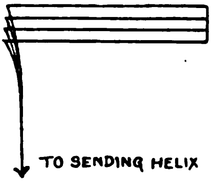


FIG. 67

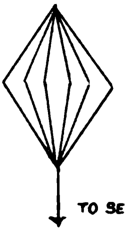


FIG. 68

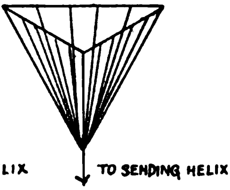


FIG. 69

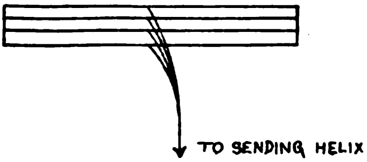


FIG. 70

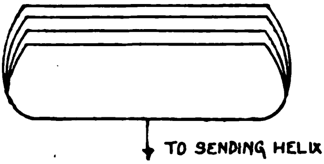


FIG. 71

Some T aerials are in use (fig. 70). They give greater relative capacity for the same amount of wire, but as we shall see presently, the natural period of the flat top is not too great. T aerials sag in the center, thus decreasing their effective height and they are subject to high potentials at both ends.

The other types shown are, or have been, used on shore stations, except the special receiving aerial shown in fig. 63, which is a direction aerial used on ships and which will be referred to in Chapter VIII.

The umbrella aerial shown in fig. 65 has been used at some large shore stations. It is probably the best form that can be supported by a single mast.

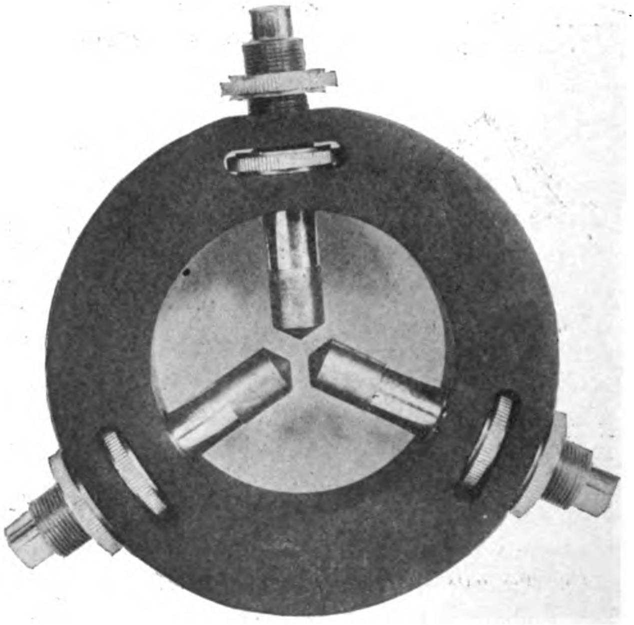


FIG. 72.—Wireless Telegraph Anchor Spark Gap.

LOOPED AERIALS.

169. It will be noted that the diagrams of receiving sets (figs. 82 and 83) show an aerial in the form of a loop, beyond three spark points arranged in the form of a triangle. The lower one of these points is connected to the sending circuit inductance so that as far as sending is concerned this aerial is the same as any other, since the high potentials used in sending easily jump the short gaps between the two sides of the loop; but for receiving it is different—the weak currents can not jump the gap, which is known as an anchor spark gap, so that the circuit is only *looped* for receiving and not sending.

The anchor spark gap (fig. 72) serves to cut out the sending circuit when receiving. When sending, the volume and color of the sparks in the anchor gap serve to indicate roughly whether the sending apparatus is working properly. For receiving sets not requiring a looped circuit the two sides of the loop are joined below the gap and *used as a single wire.* A little consideration will show that the wave length of a loop is the same as that of half the loop on open circuit. A loop is, however, a persistent oscillator.

170. Except where they pass near conducting objects or through decks, all parts of the aerial wire are left bare on account of the lighter weight and smaller surfaces exposed to the wind as compared with insulated wire. The size of wire generally used is made up of seven strands of No. 20 B. & S. phosphor or silicon bronze wire or monnot metal having fairly high elastic strength.

Stranded wire is more flexible, and the materials given above have fairly good conductivity and much greater elasticity than copper wire. The elasticity prevents permanent elongation and sagging after being hauled taut.

171. The natural wave lengths of certain aerials of the flat top type (inverted L and T aerials, figs. 67 and 70) are given in tabular form below. To the aerial is added the necessary turns on the open circuit helix to bring the natural wave length to 425 meters. It usually requires a number of turns of the helix to do this. When it is desired to greatly increase the sending wave length special loading coils are added to the open circuit. (See figs. 45, 46 and 47.) Since the closed circuit has large capacity and small *self-induction* a turn or more of inductance added to the closed circuit makes a large *percentage* addition to its self-induction and, therefore, to its wave length. But the open circuit has small capacity and relatively large self-induction, so that each additional turn does not make such a large percentage addition to its self-induction and, therefore, its increase of wave length per additional turn is much less than that of the closed circuit. (See *Adjustments, Chapter VII.*)

Ship.	Type.	No. wires.	Distance apart.	Length of flat top.	Vertical length of lead to operating room.	Total length.	Natural wave (meters).	Coupled wave (meters).	Per cent.	Maker.
Glacier............	T	10	2 ft.	170 ft.	82 ft.	252 ft.	330	360 478	28	Telefunken.
Mayflower..........	T	8	26 in.	124 "	132 "	256 "	360	385 455	15	DeForest.
Dolphin............	Γ	6	2 ft.	140 "	136 "	276 "	330	300 532	54	Fessenden.
Louisiana..........	Γ	6	3 "	150 "	129 "	279 "	425	410 436	6	Shoemaker.
Chester............	Γ	8	..	160 "	97 "	257 "	395	... 425	..	Shoemaker.
Birmingham.......	Γ	4	4 "	160 "	90 "	250 "	385	385 425	10	Shoemaker.
Connecticut.... ...	Γ	4	4 "	125 "	137 "	262 "	360	372 456	19.7	Shoemaker.
Maine...............	Γ	4	5 "	120 "	120 "	240 "	330	384 434	11.7	Telefunken.
Baltimore	Γ	4	4 "	130 "	132 "	262 "	870	415 460	10	DeForest.
Guantanamo.......	Inverted pyramid.	..	...	...	200 "	...	900	1120 1630	38	DeForest.

172. In all aerials referred to above, except the *Maine* and *Baltimore*, the long wave contained the greater amount of energy. In the case of these two aerials the greater amount of energy was radiated on the short wave.

These sets (except the Shoemaker, whose closed circuit was designed to give loose direct coupling at 425 meters, and which did not require the use of the aerial loading coil for 425 meters) had no direct provision for changing the wave length of the aerial except in the coupling coil, and, therefore, when coupled gave a wider variation from the standard wave length than the Shoemaker sets.

OPEN CIRCUIT INDUCTANCE.

173. With direct coupling the open circuit inductance forms part of the same *helix* as the closed circuit inductance, as has already been stated. (See fig. 40.) In inductively coupled sets the *open circuit helix* is movable, so that the coupling can be varied by moving the entire coil while keeping the same wave length. Provision is also made for a variable connection to the helix so that the wave length can be varied. (Figs. 42 and 43.)

174. It must not be forgotten that varying the wave length of either circuit by varying the inductance of the coupling coil or coils varies the mutual induction, as well as the self-induction, and also the *coupling* and damping, so that the most recent sets—Fessenden (fig. 45), Telefunken (fig. 46), Lowenstein (fig. 47)—make provision for varying the wave length at some other part of the circuit than at the *coupling coil,* or, as in the Lowenstein sets, for automatically moving the coils so as to maintain the same coupling when the wave length is varied. These outside coils are called *loading coils,* as distinguished from the coupling coils, by means of which energy is transferred from the closed to the open circuit (and vice versa in sets not having quenched or properly air cooled gaps).

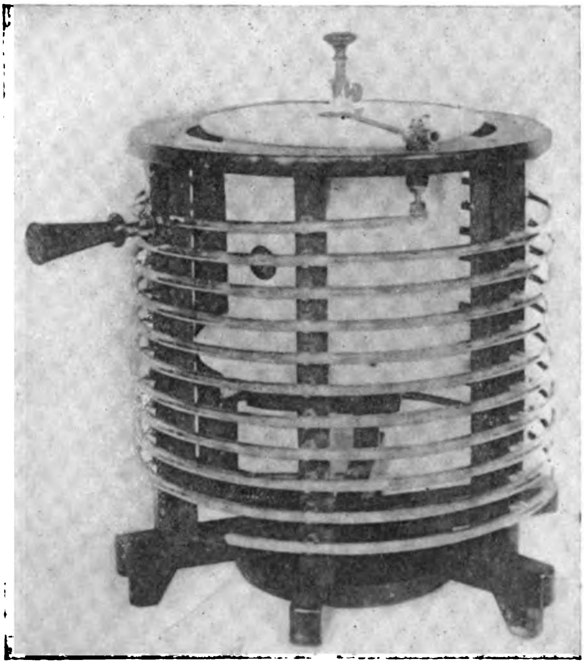


Fig. 73.—Helix and Spark Gap.

The method of building the Telefunken variometer coils, shown in fig. 46, is illustrated further in fig. 74. This method of varying the self-induction of a circuit has the advantage of not having any dead ends as in the old inductance helices, shown in fig. 73. However, the variometer shown in fig. 74 is not suitable for inductive coupling.

None of the sending sets now in use permit the wave length of both open and closed circuits to be changed without some effort and more than one movement of the operator.

Additional remarks on coupling will be found under "Adjustments," Chapter VII.

For those parts of the aerial which require insulation to protect it from grounding and to protect persons, a special heavily insulated wire called rat-tail wire, is used.

A lightning switch (fig. 75) is installed outside the station, or where the aerial enters, by means of which it is grounded during thunder storms.

The other aerial accessory—the hot wire ammeter (fig. 76—is installed in the ground lead; its uses are particularly referred to in Chapter VII.

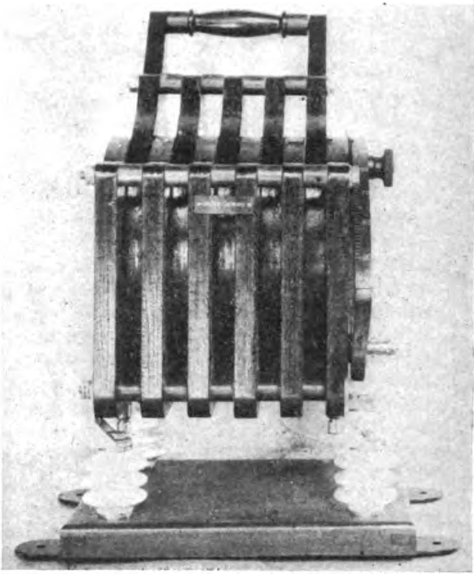


FIG. 74.

GROUNDS AND GROUND CONNECTIONS.

175. As has been previously explained, wireless telegraphy makes use of earthed electric waves, as compared with the free waves discovered by Hertz and used by Marconi in his first experiments. It was soon found by Marconi that good connection to earth or to a large conducting body is essential to good working. On board ship the end of the aerial below the open circuit inductance (called the *ground lead*) must be well soldered, bolted, or clamped to some portion of the hull.

A grounded vertical wire well earthed has a wave length not less than four times its natural length. At its free end there is a potential loop and a current node (maximum potential—no current). At its earthed end there is a current loop and potential node (maximum current—no potential). (See fig. 18d.) The same wire free at both ends has an electrical period equal to twice its length, and if oscillating, has high potentials at both ends. If the ground connection is not good, there is a tendency to choke the current passing in and out of the earth and thus to cause a rise of potential and consequent sparking and reflection of energy at the earth connections, making the period irregular and impairing the sending qualities of the station.

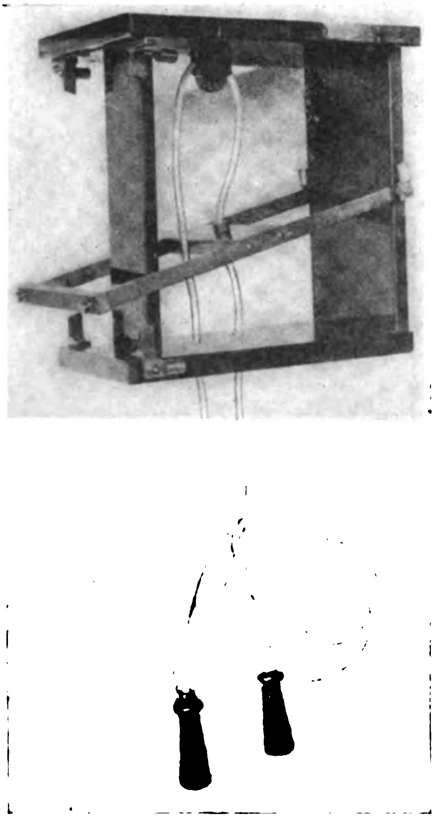


FIG. 75.—Lightning Switch.

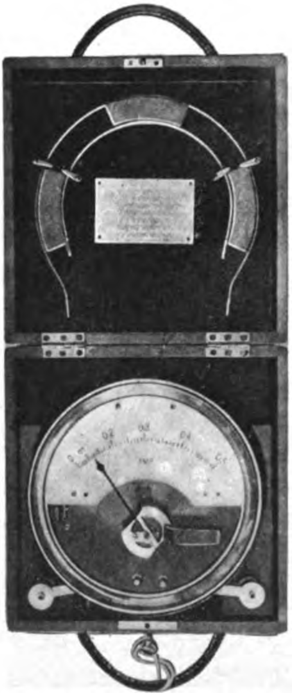


FIG. 76.—Hot Wire Ammeter.

It should be possible to grasp the ground lead where it is soldered to the ship without injury. Inability to draw a spark there is proof of good connection.

176. At shore stations it is found that the resistance of the earth between two earthed conductors a given distance apart varies widely in different localities and in the same locality with moisture and temperature, and low ground resistance at a station is usually accompanied by good radiating qualities. Where and when the soil is very dry it is necessary to pay much greater attention to the area of the ground connections, and where the resistance of the earth in the vicinity of the station is high the station is a poor radiator unless an artificial ground called a "*counterpoise*" is installed. This can consist of any large conducting area laid on the ground or wires connected between the mast guys. The natural period of the counterpoise should be the same as that of the aerial.

Generally a good ground is made by connecting the ground lead to copper plates of large area in good contact with moist earth, or to radiating lines of galvanized iron telegraph wire ending in pipes driven to moist earth, or to wire netting spread on the ground and covered with earth. At stations on tops of buildings grounds are made to the steel frames of the building and to water and gas pipes.

Chapter VI.

RECEIVING CIRCUITS AND APPARATUS.

177. Receiving circuits will be considered in the following order, viz.: Open circuit, closed circuit, condensers, inductances, detectors, telephones, batteries, ampliphones, recorders.

In practically all cases the same aerial wire is used for both sending and receiving.

The advancing waves of electric and magnetic force from the sending aerial cut the receiving aerial and induce in it oscillating currents. If the receiving circuit has the same period as that of the passing waves, the induced oscillating currents in the aerial will increase until the energy dissipated per oscillation, by re-radiation, resistance, and transfer to other parts of the receiving circuit, is equal to that received per wave.

If the receiving aerial circuit is directly or inductively connected to a closed oscillating circuit to which part of the energy received per wave is transferred during each oscillation instead of being re-radiated, this closed oscillating circuit will absorb energy, and if its period is equal to that of the arriving waves the oscillations will increase in amplitude with each half period since a closed circuit radiates slowly. If a detector is placed in either the open or closed circuit so that the oscillating currents produce differences of potential at its terminals and the maximum amplitude of the oscillation set up is sufficient to make it function, the passing of groups of wave trains separated into dots and dashes at the sending station can be detected at the receiving station.

At the sending station the closed circuit furnishes energy to the radiating circuit, which sends it out in the shape of electric waves.

At the receiving station this radiating circuit absorbs energy from the passing waves and transfers to the closed circuit part of what it absorbs.

It is evident that no spark gap is required in the closed receiving circuit and that, since no high potentials nor heavy currents need be provided for, it is not necessary that the receiving inductances and condensers should have the same dimensions or arrangement as those in the sending circuits. But in all other features receiving circuits are the exact analogue of sending circuits and the detector could occupy the place of the spark gap. However, all detectors consume energy, and placing them either directly in series with the aerial or in the closed receiving circuit is equivalent to placing a certain amount of resistance in *series* with these circuits, and therefore increases the resistance and

ELEMENTARY DIAGRAMS, RECEIVING, AND DETECTOR CIRCUITS.

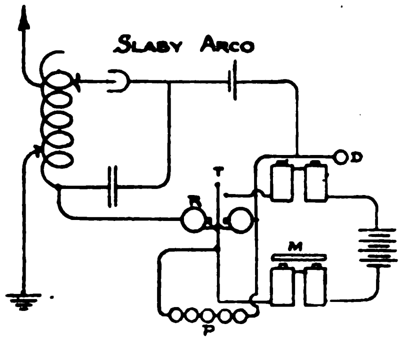


FIG. 77

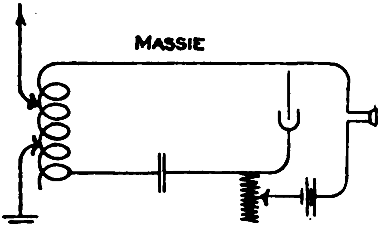


FIG. 78

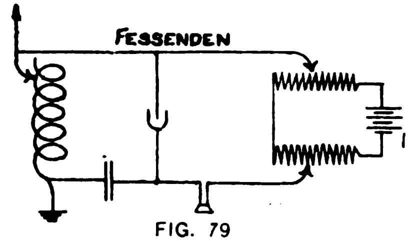


FIG. 79

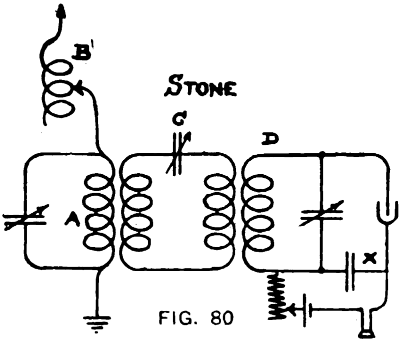


FIG. 80

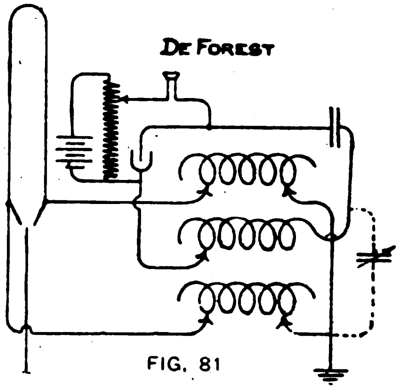


FIG. 81

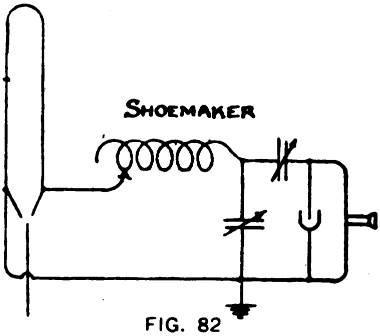


FIG. 82

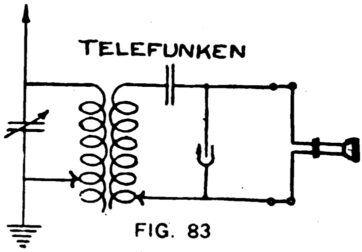


FIG. 83

hence the damping and interferes with the building up of the induced current and the tuning of the circuit.

It is found by experiment that the strongest signals are obtained when a certain fraction of the total energy is taken up by the detector. It is usually placed in the closed circuit or in shunt across the terminals of the closed circuit condenser. When placed directly in the aerial, it is only suitable for receiving a highly damped wave train—one in which nearly all the energy is contained in the first oscillation.

178. Receiving and detector circuits are illustrated in figs. 77 to 88 inclusive.

In all figures, the fixed condensers shown are for the purpose of preventing the direct current from the battery or detector from flowing through the inductance. Variable condensers, and variable inductances are used for changing the period (wave length) of the circuits.

Referring to fig. 79, the cup-shaped construction under the word *Fessenden* indicates a *detector.* The construction shown above the figures 79 indicates a telephone in all diagrams. The non-inductance resistance, with arrow-headed connection, is used to regulate the impressed voltage at the detector terminals. It is called a potentiometer. Other symbols used have been previously described.

Fig. 77 shows the detector (in this case a coherer—see Art. 188) in shunt in the open circuit, the open circuit having a variable tuning inductance. The remainder of the figure shows the coherer-tapper, call, and the relay for the Morse recorder.

Fig. 77, like figs. 78 and 79, illustrates *direct-connected* receiving sets. They are not now generally used. *Inductively connected* sets, shown in figs. 80, 83, 85 and 86, are preferred.

It will be noted that in fig. 83 provision is made for tuning the closed circuit with detector directly in circuit; while in the Fessenden interference preventer illustrated in fig. 85, no provision is made for tuning the detector circuit.

In figs. 80 and 86 the detector is in shunt around a closed tuned circuit.

In all inductively connected receiving sets provision is made for varying the mutual induction between the open and closed circuits. (See Art. 182.) This whether the closed circuit is tuned or untuned.

Dr. Austin states that the only advantage of tuning the detector circuit is a slight increase in selectivity and that no louder signals are produced. Professor Pierce's investigations of detector circuits, like those in fig. 83 (except that the closed circuit inductance was fixed and the condenser variable), indicate that, if the resistance of the detector is not too great, very much greater selectivity with equal loudness of signals is obtained by tuning the detector circuit, with the detector directly in the circuit as in fig. 83. No absolute figures are at hand as to the effect of

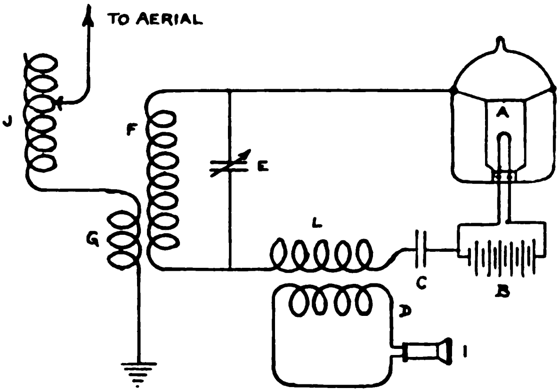


FIG. 84 VALVE RECEIVER - MARCONI -

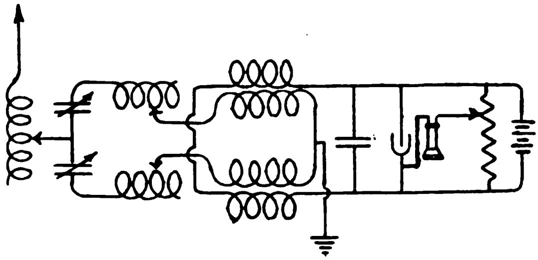


FIG. 85 FESSENDEN INTERFERENCE PREVENTER

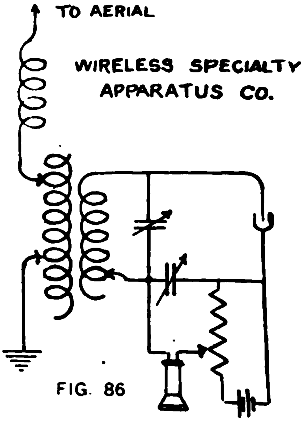


FIG. 86

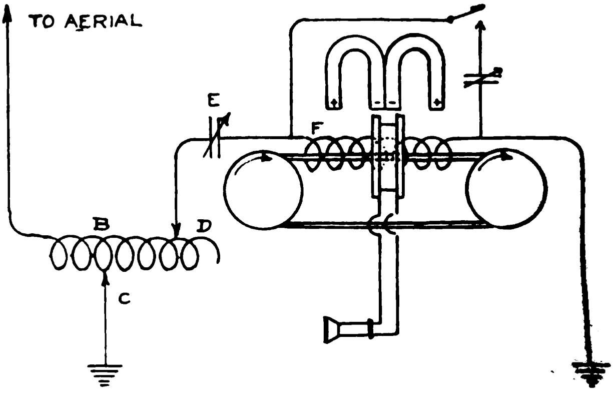


Fig. 87.—Magnetic Detector—Marconi.

shunting the detector around a closed tuned circuit as in figs. 80 and 86, but results obtained in distance of communication show this method equal if not superior to any other, and it would seem that, if the detector has a resistance such as would prevent sharp resonance from being obtained when placed directly in the closed circuit, shunting it will assist in producing sharp resonance and together with *tuning* the closed circuit make a more efficient arrangement.

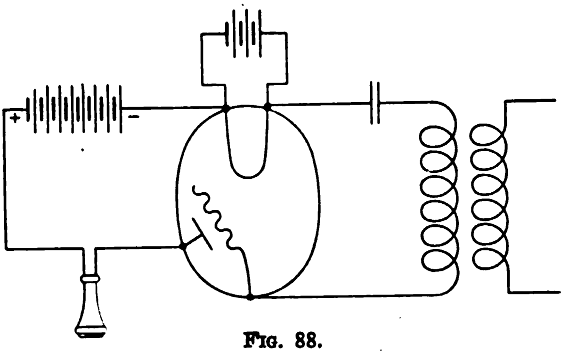


FIG. 88.

179. Receiving sets, such as shown in fig. 80, were first introduced by Stone and used later by Marconi. The intermediate tuned circuit in these sets is called the *weeding out* circuit. Provision is made for switching the detector to the weeding out circuit when very sharp tuning is unnecessary, since there is loss of range, due to loss of energy in so many transfers.

The Fessenden interference preventer, shown in fig. 86, attains selectivity in a different manner from that just described. The currents induced in the aerial, from whatever cause, have two possible paths to earth; one of these paths is tuned to the wave length it is desired to receive, while it is supposed that waves of other lengths, or static discharges, out of tune with either leg, will divide themselves equally between the two legs and produce no effect on the untuned detector circuit.

Attention is invited to figs. 81 and 82, showing the DeForest and Shoemaker *looped* receiving circuits. These differ from the other circuits illustrated in that the induced currents are in the same direction on the two sides of the loop and like a double-ended sending aerial induce a maximum potential at some point in the loop whose electrical distance from the point of origin of the disturbance is the same for each side. The wave length of a looped circuit ungrounded is therefore the same as that of one-half of it *ungrounded* and the wave length grounded is twice the electrical length of the loop. In other words, one-half the loop can be considered as a shunt of the same period as the other half. From this point of view the DeForest detector circuit is practically the same as fig. 83 and the Shoemaker circuit can be considered as one having a detector directly in the open circuit and shunted by a variable condenser.

Figs. 84 and 88 represent the valve and audion receiver circuits. In fig. 84 the valve is shunted around a tuned closed circuit; in fig. 88 it is in a closed untuned circuit. Fig. 87 shows the magnetic detector in a tuned open circuit, provision being made to shunt a variable condenser around it.

The above figures illustrate practically all methods of tuning receiving circuits and of connecting detectors to them. Detailed instructions for the use of each set are furnished with it.

180. We wish the sending aerial to be a good radiator, but not so good that it will give a whip crack discharge. We want its oscillations to be persistent enough to require for their best reception a receiving aerial tuned to the period of the sender, and as a present standard we have set for the sender a damping of .2, so that it makes fifteen complete oscillations before the oscillating current falls to .1 of its original value. We want the receiving aerial to radiate as little as possible; but to so combine the energy of the fifteen waves that the highest maximum is produced in the aerial, if the detector is in the open circuit, in the closed receiver circuit, if the detector is there or in shunt around it.

If the sending aerial is coupled so as to send out waves of two lengths, there appears to be no question that the coupling of the receiving circuits should be such that if they acted as senders they would send out waves of these lengths, or so loosely coupled that their natural period is that of the longer of the arriving waves. (The one containing the most energy.) If, in the case of very loosely coupled circuits or those supplied with quenched spark gaps, but one wave length is being generated, receiving circuits should also be loosely coupled or should be coupled so that the transfer of energy from the open to the closed circuit and the damping of the latter (with the detector, however connected) is at such a rate that a maximum current in the closed circuit is reached at the instant the open circuit has come to rest after being set into vibration by the passing wave train and has radiated or transferred all its induced energy. This is analogous to the statement relative to the quenching of the closed sending circuit (throwing it out of tune) when the open circuit has reached its first maximum. In the case of reception after the closed circuit has reached its first maximum the rectified current in the case of crystal detectors or the battery current in the case of electrolytic detectors has also reached its maximum.

However, further investigation is necessary before definite statements as to the best coupling of receiver circuits can be made, and until such time the apparent best obtained by trial in each set must be used.

TYPES OF RECEIVING INDUCTANCES AND CONDENSERS.

181. A variable receiving condenser usually consists of semi-circular metal plates separated by air dielectric, alternate plates being fixed. The others are movable on an axis, by turning which, any desired amount of the movable plates can be included between the fixed plates. The axis carries a pointer which moves over a scale graduated in degrees or directly in microfarads. If used in connection with a fixed inductance, the scale, like a wave meter, which in this case it becomes, may be graduated directly in wave lengths. Some of the Stone receiving sets had sliding glass plate condensers, and the Pierce sets, step-by-step variable condensers in the receiving circuits, but the revolving plate type described above is practically a *standard* and is illustrated in fig. 96. (Pierce wavemeter.)

Variable condensers now supplied have the limits of their capacity marked on the name plate in microfarads.

182. Variable inductances include the step-by-step and roller types. The former is sometimes made up of plug steps, giving a limited number of changes, one section of a coil being varied at a time, or it may be a cylindrical coil of insulated wire wound on hard rubber, glass or porcelain, one point in each turn being bare and connections being made by a slider giving as many adjustments as there are turns of wire in the coil.

In the DeForest *pancake tuners* the coil was a flat spiral of insulated wire on glass, one point in each turn being bared so as to form an arc of a circle, the end of an arm pivoted at the center of this circle making contact at any desired point. Shoemaker sets (fig. 82) have a single roller inductance, the bare wire being wound in a spiral groove on an ebonite cylinder. A sliding contact on a rod parallel to the cylinder works in the groove and is pressed against the wire by a spring. By revolving the cylinder an infinite number of adjustments can be obtained.

Fessenden sets (figs. 79 and 82), have double roller inductances, by turning which, the wire can be reeled from one roller to another as desired. On one roller the turns are insulated from each other and on the other they are short circuited so that any desired length can be retained in circuit. None of the above types of variable inductances can be readily mounted so as to vary the mutual induction between them by any definite amount. They are not entirely suitable for loose coupling. For this reason the preferred types of receiving circuits are made up of fixed inductances (or those varied by plug steps) mounted so that they can either be pulled apart or one coil revolved so as to change its plane and hence the mutual induction with reference to the other or others. Receiving inductances (variometers) mounted like variable condensers are now being manufactured. Their self-induction can be varied quickly and conveniently and close adjustment of period (tuning) made with them or with the variable condensers.

From the formula for damping $d = \frac{R}{2nL}$ it can readily be seen that a very pronounced natural period—a stiff circuit—can not be obtained unless the self-induction is large compared with the total resistance (including the radiation resistance).

Variometers have a constant D. C. resistance, since the entire length of wire is always in circuit. In order that this resistance should not be too high compared with the self-induction, it is specified that the D. C. resistance shall not exceed 4 ohms per millihenry.

Practically all inductances are wound on hard rubber or glass—a material like air, which is a good insulator, with no hysteresis loss is the ideal material for the purpose. In winding, dead ends, which are a source of loss, should be avoided.

One variable inductance of fig. 83 is hinged so that the coupling can be varied by a combined movement away and of rotation with reference to the inner coil. (See fig. 111.)

Fig. 86 illustrates the 1-P-76 receiving set, of which a great many are in use.

In these sets the coupling between the open and closed circuits is varied by sliding the closed circuit inductance on a graduated bar parallel to its axis instead of revolving it as in the Telefunken receiving set. (See fig. 111a).

The closed circuit of these sets has been calibrated and curves drawn showing the wave lengths for all settings from 150 up to 4450 meters. These curves are furnished with the sets and (with very loose couplings so that the two circuits have but one period) the wave length of received signals can be read directly. Similar curves have been made and supplied with some of the Telefunken receiving sets. Additional loading coils for very long waves are now being supplied.

Figs. 84 and 88 illustrate the valve and audion receiving sets. The detectors in these sets are alike except that the resistance of the audion is decreased as compared with the valve by an E. M. F. from a local battery connected as shown in fig. 88 (the negative terminal to the lamp). It will be noted that an inductively connected low resistance telephone is used with the Marconi (Fleming) valve in fig. 84.

DETECTORS.

183. There are but two types of detectors now in general use: *Crystal* or rectifying detectors, and the *electrolytic*. Coherers and microphones are practically obsolete, and comparatively few of the magnetic and audion, or valve detectors, have been installed. All types of detectors in use are self restoring. Generally speaking all require to be put on open circuit while sending to preserve them from injury due to induced potentials and currents.

THE ELECTROLYTIC DETECTOR.

184. It consists of a fine platinum wire just touching an electrolyte made either of a 20% solution of nitric or sulphuric acid or an alkali. Of these the nitric acid solution is preferred. The other electrode is also of platinum. The containing cup (fig. 79) is made quite small so that the cohesive power of the electrolyte will prevent splashing in a sea way. The electrolytic detector must have the fine wire terminal connected to the positive pole of the local battery (fig. 79), otherwise the device is not operative.

Dr. Austin states that the higher the frequency the finer the wire should be and that the depth of immersion does not matter if the detector is not directly in series in the closed circuit.

When a current flows through the electrolyte the latter is decomposed (the action being called electrolysis) liberating oxygen at the anode and hydrogen at the cathode. The accumulation of these non-conducting gases on the electrodes interferes with the passage of the current, which soon ceases to flow and the cell is then said to be *polarized.*

The fine wire anode is then insulated by the oxygen, which forms the dielectric of a small condenser, of which one conducting surface is the electrolyte and the other the wire point.

The critical potential of the detector is just below that necessary to break down this insulating layer of oxygen and is determined by increasing the potential at the detector terminals by means of the potentiometer until a bubbling or hissing sound is heard in the receiving telephone; then resistance is cut in until this sound just ceases.

When electric oscillations are impressed on this condenser the polarization layer breaks down and permits a pulse of direct current from the battery to pass through the cell and *telephone.* As soon as the oscillations cease the polarization is restored.

Except when they are very strong the loudness of the sounds produced in the telephone is an exact measure of the energy of the oscillations passing through the cell.

This constancy of action of the electrolytic cell is utilized as a means of comparing the sensitiveness of detectors, the standard being the sensitiveness of an unjacketed platinum wire electrode .0002 in diameter in a solution of 20% nitric acid.

Glass jacketed electrodes formed by sealing the wire in glass (the two having the same coefficient of heat expansion) have been used, but are less reliable and in general less sensitive and are no longer supplied.

Some of these glass points were made hook shaped, the hook pointing upward to facilitate depolarizing but no increase in sensitiveness was noted on this account.

With the Shoemaker receiving sets was furnished what was called a primary cell detector. The electrolyte used was a 20% solution of sulphuric acid and the other electrode was a zinc rod amalgamated with *mercury,* which in the acid solution gave a difference of about .7 volt between zinc and platinum. No local battery was required (fig. 82). At times this detector compared favorably with the one just described, but was in general more irregular and less sensitive in its action.

In all electrolytic detectors very strong signals or static discharges produce actual sparking or an explosive action in the electrolyte, which destroys the platinum point and an operator must be constantly on the lookout to protect his point from burning out. The best results in electrolytic detectors have been obtained with a distance between electrodes of approximately ¼ inch.

RECTIFYING DETECTORS.

185. There are certain substances which when brought together in not too close contact have the property of producing a direct current when an alternating current or electrical oscillations are sent through them. The cause of this action is not yet known. Among these substances are carbon in contact with steel, tellurium with aluminum or galena, silicon with any of the ordinary metals, and certain crystals.

The first of the crystal detectors to be supplied was General Dunwoody's carborundum crystal detector.

Since rectifying detectors permit the passage of current in but one direction, they produce pulses of direct current. These pulses, if strong enough, can be heard in a telephone so that local batteries are not required, although a slight increase of sensitiveness is noted in some detectors with an E. M. F. across the terminals of the detector of about 0.2 volt.

Rectifying detectors are connected in receiving circuits in the same manner as the electrolytic.

Their sensitiveness for general use is practically equal to the electrolytic and their simplicity makes them the most suitable. They are in general less sensitive to injury from static discharges, strong signals, or induced currents from sending, than the electrolytic, but, like coherers, different crystals of the same material vary widely in sensitiveness and sensitive spots in any crystal have to be found by trial and when found are not constant. They are thus not as capable of quick readjustment as the electrolytic, but their other advantages are such as to be conclusive as regards their use.

The carborundum detector when first introduced was simply held between two points or wrapped with copper wire for one connection, with a needle, knife edge, or more blunt piece of metal for the other. It was later found that embedding a large part of the crystal in a conductor such as solder or a mercury paste, and thus limiting the rectification to one contact only, produced much better results and carborundum crystals have been found equal in sensitiveness to some of those now generally utilized.

Pickard's silicon detector followed the carborundum and is still in use but it has been largely superseded by the Perikon & Pyron, supplied with the receiving set illustrated in fig. 86. The Perikon detector consists of two crystals, chalcopyrites and zincite. A number of zincite crystals are held in a conducting disc, a crystal of chalcopyrites is mounted so that it can be brought into contact with any part of any of the zincite crystals at will, and the pressure between the two *regulated.* In the adjustment for maximum intensity of signals, the exact degree of pressure and the most favorable points of contact are of importance. These can only be ascertained by trial and test with the testing buzzer.

The sensitiveness of the Perikon may be approximately doubled by connecting a battery across its terminals so as to give approximately 0.2 volt. The positive pole must be connected to the single crystal.

The Pyron consists of a crystal of iron pyrites in contact with a metal point like the silicon. This is very satisfactory for strong signals and constant in its action. The iron pyrites is more sensitive when the pressure of the metal point is adjustable. The *area* of contact is also a determining factor of sensitiveness; comparatively fine points will discover sensitive places on irregular crystals, which blunt points will not.

The Perikon is more sensitive and must be protected against strong signals. The *zincite* is the crystal injured by strong signals. It should not be subjected to heavy pressures or grinding from the chalcopyrite. When deadened the zincite crystals can be made operative by scrubbing them with a bristle brush wet with carbon bisulphide, then with soap and water and then rinsing with fresh water and drying. In damp weather or in tropical climates this detector is improved by spreading a drop of paraffin oil over the surface of the crystals. This comment applies to the silicon also.

VACUUM TUBE DETECTORS.

186. The two forms in use are Marconi valve detectors and the DeForest audion. This detector, invented by Fleming, is a rectifier permitting the passage of current in one direction only. It consists of a special incandescent lamp (see fig. 84), operated by a 12-volt storage battery and having a small sheet or cylinder of metal held in the bulb near the filament. Lamp filaments when glowing emit negative electricity, which carries away part of the filament and causes the darkening of the bulb seen on old carbon lamps. The vacuum thus becomes a conductor in one direction only. It is found to be a very sensitive one.

Referring to fig. 88, in the audion, a local battery with variable voltage is connected across the lead to the filament and the lead to the metal electrode, the positive pole of the battery being connected to the metal plate. A rheostat for regulating the voltage of the storage battery is also supplied. The battery voltage increases the fall of potential across the space between the filament and the plate, and this, in connection with the regulation of the voltage of the filament, renders the detector more sensitive than with the connections shown in fig. 84.

MAGNETIC DETECTORS.

187. The operation of magnetic detectors depends on the fact that when iron is being magnetized its magnetization is somewhat delayed in time behind the impressed magnetizing force, and when in this condition the iron is very sensitive to any change in the magnetizing force, a very small increase of which will produce a momentarily large increase in the strength of the magnetic field.

Many patents have been issued for various forms of magnetic detectors, the best known and the most largely used of which is Marconi's, patented in England in 1902.

In its present form it consists of a flexible band of silk-covered iron wires, moved by clockwork around two pulleys which support it. A glass tube, through which the band passes, has a primary winding of insulated wire in series with the aerial and a secondary winding forming a closed circuit through a telephone. Close to the secondary windings are placed similar poles of two horse-shoe magnets, which magnetize the iron band slowly moving under them. Electric oscillations in the primary winding, produced by passing electric waves, produce momentary changes in the magnetization of the iron band under the magnets, and these changes induce oscillating currents in the secondary winding which produce sounds in the telephone.

An elementary diagram of this magnetic detector is shown in fig. 87. It requires no local battery, and, not being subject to burn-outs except from very large currents, it is a very convenient instrument, but is not as sensitive as those previously described, especially for short wave lengths. There are other methods of connecting this detector than that shown in fig. 87, but since comparatively few magnetic detectors are in use they are not shown here.

COHERERS AND LODGE-MUIRHEAD DETECTOR.

188. Coherers being practically obsolete are not described. They are illustrated in fig. 89.

Of the many other kinds of detectors that have been used, the Lodge-Muirhead, which would work either with a telephone or recorder, was the most sensitive and reliable.

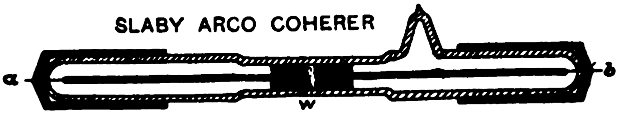
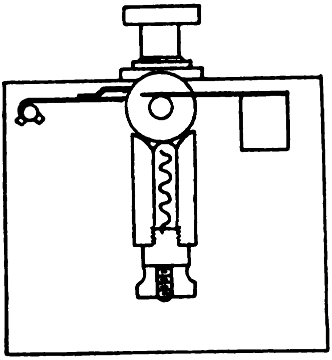


FIG. 89



LODGE-MUIRHEAD COHERER

FIG. 90

It is illustrated in fig. 90 and consists of a polished steel disc rotated by clockwork, its edge just touching the edge of a globule of mercury covered by a film of oil. A pad which rubs against the disc keeps it clean and bright. This coherer may be direct or inductively connected in or to the aerial. Its conductivity changes sufficiently to relay a current for working a siphon recorder so that it is suitable for use in connection with determining longitudes by wireless telegraphy.

It is also self-restoring and can therefore be used with a telephone.

TESTING BUZZERS.

189. A testing buzzer with its battery of one cell, its condenser and circuit, is a miniature sending set and an important auxiliary of every receiving set. The oscillations set up in its circuit induce currents in the receiving circuits, which serve by their effect to determine the sensitiveness and readiness for operaton of the detector. A testing buzzer outfit furnished with the Telefunken sets is shown in fig. 91. The connections of that supplied with the 1-P-76 receiving sets in fig. 92. The condenser is the Western Electric Co.'s 21-J.

RECEIVING TELEPHONES AND ACCESSORIES.

190. The low resistance telephones in ordinary use are not suitable for wireless work on account of the high resistance of the detectors, which may be several thousand ohms. Specially made telephones are required to produce the best effect. The magnet wire has very thin silk or enamel insulation. A length of wire whose resistance is approximately equal to that of the detector can be efficiently used. This is from 1000 to 2500 ohms in each of the double head telephones supplied.

For low frequencies, telephones with adjustable diaphragms are found to be about ten times as sensitive as the ordinary type with a fixed distance between diaphragms and magnets.

This advantage decreases as the frequency approaches the present standard of 500 cycles (1000 sets of sparks per second), but is still sufficient to warrant the retention of the adjustable diaphragm type.

At stations where it is necessary to listen on two wave lengths at the same time, one half of the head set is connected to one receiving set and the other half to the other receiving set.

In some Marconi sets low resistance receiving telephones are used, connected through a step-down transformer. (See fig. 84.)

Batteries and potentiometers are used with receiving telephones, their connections being as shown in figs. 77 to 89.

In order to produce sound, intermittent work must be done on a telephone diaphragm at a certain minimum rate. (See Arts. 100 and 131.) In other words we must apply a certain *power* to it—power being rate of doing work. The frequency must be within the limits of audibility. (Art. 218.)

It appears that with rectifying detectors we obtain this power directly from the aerial, while with the electrolytic, the power from the aerial only works the detector as a relay—the power used in making sound in the telephone coming from the local battery.

Difficulties surrounding accurate measurement of the very minute quantities involved make the above statement subject to modification. We do not yet know exactly how a detector acts.

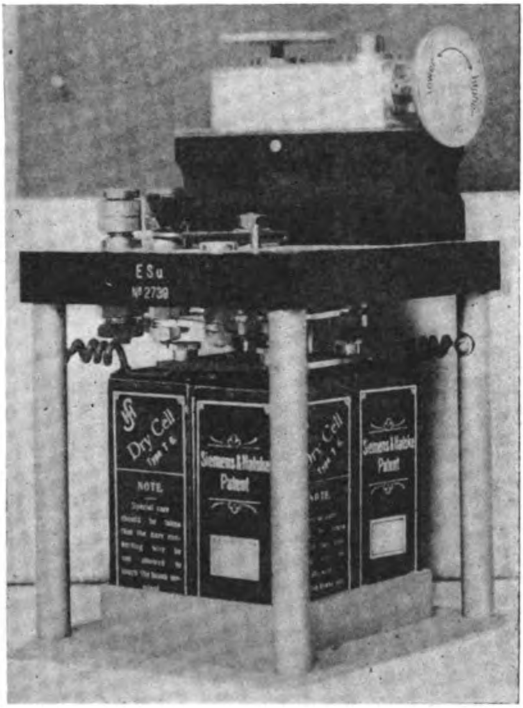


Fig. 91.—Wireless Telegraph Test Buzzer. For Ships.

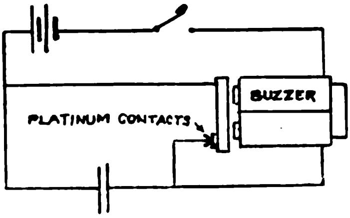


Fig. 92.

TELEPHONE RELAYS.

191. Those now in service are called ampliphones. If they prove to be constant and reliable they will be supplied for general use, (a) to enable ordinary messages to be read without the use of a head telephone, (b) as a call, (c) to increase the absolute difference between signals of different strengths thus enabling the message desired to be read through interference or static, (d) to step-up signals so weak that they could not otherwise be read and thus increase the range of communication, (e) as a resonance device responding within limits to a single spark frequency, thus cutting out interference, (f) for separating signals of different wave train frequencies so that several messages of different frequencies can be received at the same time on the same aerial, (g) to automatically record incoming signals.

Coherer detectors change their resistance sufficiently to work a relay which actuated a call, tapper and recording apparatus. The induced currents rectified by crystal and valve detectors are too weak to produce visible material movement and the same is true of the direct currents produced by the momentary depolarization of electrolytic detectors.

It has been found, however, that these currents will produce sufficient movement of the diaphragm of a receiving telephone to alter its pressure on a microphonic contact, this alteration being enough to change the conductivity, and thus increase or decrease the current in a circuit containing the contact, a battery and another telephone. This change in current moves the diaphragm of the second telephone and its movements can either be read directly as sound or made to change the current in another circuit by change of pressure on another microphonic contact. One or more of these microphonic relays produces sufficient action in a loud speaking telephone to be heard in the operating room.

When used as a resonance relay the relay diaphragms are mounted so as to have a pronounced mechanical period of vibration and act as wave filters or weeding out circuits, responding most efficiently only to wave trains of a frequency the same as their own. The sound produced by the last one in circuit (the loud speaking telephone) may be intensified by attaching to it an air pipe whose *note* is the same as that of the *diaphragm* in vibration.

RECORDING APPARATUS.

192. The use of recording apparatus was necessarily abandoned when coherers were no longer used. It is possible that microphonic relays referred to in the preceding article will again permit the use of recording and calling apparatus. Both tend directly to economy in the operation of wireless stations, by reducing the number of operators to a minimum.

Chapter VII.

INSTALLATION, ADJUSTMENTS, CARE, OPERATION.

INSTALLATION.

193. For installation ample room is available at all shore stations.

On board ship, a room having about 100 square feet of floor space, with no dimension less than 6 feet, should be provided for the installation and operation of a wireless telegraph set. The operating room should be well ventilated and lighted, as nearly sound-proof as practicable, and free from vibration. The exact location of the room is not of great importance, provided a good lead to it for the aerial can be obtained. The farther this lead is from large conducting bodies the better.

The room should have a well-insulated entrance for the aerial and should be fitted with an operating table about 2½ feet wide, not less than 7 feet long, and of convenient height for working the sending key while sitting down.

The table should be strongly built of dry, well-seasoned wood.

The instruments should be mounted on the table so that they are at safe sparking distance from each other and from any part of the operating room.

The receiving instruments should be as far away from the sending instruments as practicable. The induction coil or transformer may be mounted on the bulkhead or under the table. In any case it should be where its terminals are not likely to be touched accidentally. The motor generator is preferably installed near the operating room, but outside of it. It may be installed in the operating room or in the dynamo room.

The connections betweeen all parts of the sending and receiving instruments should be as direct as possible, and in the case of sending instruments they should be of large surface and well insulated by air or other nonconductors. Sharp turns in connecting wires should be avoided on account of brush discharges, which always start at corners. The effect is the same as if the electricity were traveling too fast to turn corners.

The necessity for bringing a number of leads to the combination switch for sending or receiving detracts considerably from the simplicity of the installation and to a slight extent from the efficiency of the set as a whole.

High-potential leads should be kept well away from low-potential leads, and where they cross it should be nearly at right angles.

The ground connections should be electrically good and of large area.

The receiver (and the transmitter when practicable) should be wired up before installation, requiring only securing in place and attachment to aerial and ground for receivers; to power, aerial and ground for transmitters.

The sending appliances should be so arranged that the leads connecting the condenser, inductance, and spark gap of the transmitter will be of minimum length.

At shore stations means should be provided outside the operating room for disconnecting the aerial from the operating circuit and connecting it direct to ground.

On board ship a lightning switch should be installed which when in use will safely and completely disconnect the aerial from all of the receiver and transmitter circuits and connect it direct to ground.

The aerial should be well insulated where it enters the operating room and where it passes through decks or bulkheads. Porcelain or glass insulators are best for this purpose.

When necessary to guy the aerial at any point an insulator should be used in the guy line. The suspending or hoisting halliards of the aerial should be insulated. Two types of suitable strain insulators for this purpose are shown in figs. 93 and 94.

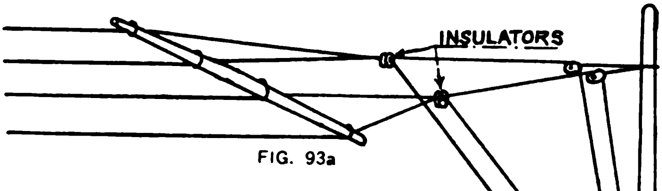


FIG. 93a

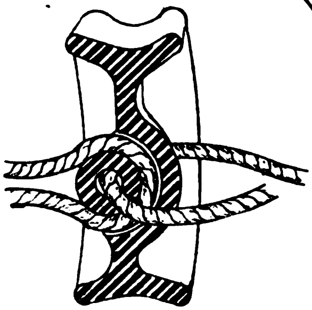


FIG. 93 AERIAL INSULATOR - BUCK LINK - STRAIN-10

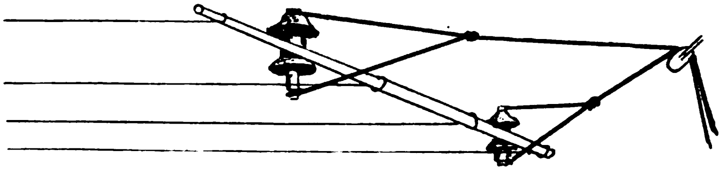


FIG. 94 AERIAL WITH LOCKE Nº 105 INSULATORS

194. The large momentary currents in aerials produce large inductive effects in conductors near and parallel to them. This is more noticeably the case in wire stays of masts, shrouds, braces, etc.

It should also be noted that an aerial wire parallel and near to a long lighting or power lead may induce sufficiently high potentials in the lead to puncture the insulation and cause sparking between it and the conductors in the vicinity of combustible material, thereby causing fires. Or it may puncture the insulation and cause a burn-out of an armature, field, or transformer. All of these effects have been experienced. They are especially frequent and dangerous in the wireless sending apparatus.

PROTECTIVE DEVICES.

195. Rigging of masts at shore stations is divided into short lengths by strain (usually locust) insulators. Wire braces are served near the middle with chokes made of No. 26 B. & S. soft iron wire for a length of about 10 feet.

Wire leads at shore stations are lead covered and the lead grounded. Leads in conduit on board ship are protected by the conduit being grounded.

Wires in the open should be protected by chokes of soft iron wire, as for braces, or have an armored cover well grounded.

To conduct to ground induced high potential at

(a) Terminals of primary of transformers.
(b) Terminals of armature of alternator.
(c) Terminals of shunt field of alternator.
(d) Terminals of shunt field of motor.
(e) Terminals of armature of blower motor.

The protective devices shown in fig. 95 are installed.

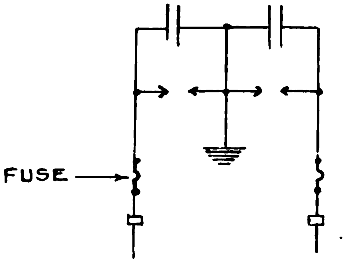


FIG. 95.—Protective Appliance.

The protective devices consist of two 1-microfarad condensers connected in series, the middle connection grounded and the two outer terminals connected by strip copper leads (as short as possible) to the apparatus to be protected. In parallel with each condenser is a permanently set spark gap about the width of thin tissue paper. Each leg of the device is fused with a 3-ampere cartridge fuse. Graphite resistance rods were formerly used for this purpose. Only the construction described above is now supplied.

In addition to the above, safety spark gaps are fitted to receiving telephones. Secondary terminals of transformers are protected by chokes made from the leads, and by safety spark gaps permanently set at the maximum safe sparking distance.

196. All wireless telegraph sets are fitted with a multiple switch which in the sending position disconnects the receiving circuits from the aerial and ground and breaks detector and telephone connections as may be necessary to protect them from induced high potentials.

When in the receiving position this switch opens the primary or secondary circuit of the transformer and, if the motor generator is in the operating room, operates a relay for opening the field of the motor, or in some cases short circuits the armature to bring it to a stop quickly. This switch should also stop the blower motor.

The necessity for the above detracts considerably from the simplicity of an installation.

ADJUSTMENTS.

197. This includes calibration and tuning. Since the periods of the open circuits of both sending and receiving sets depend on the aerial with which they are used and the constants of the latter can not usually be predetermined, the open circuit has to be calibrated after the set is installed. The closed circuit of receiving sets can readily be calibrated before installation. Also the closed circuit of sending sets, if wired up before installation.

All adjustable inductances now supplied have a scale indicating in millihenries the value of the amount in circuit at each point of variation. All fixed condensers have the value of their capacity in microfarads engraved on the name plate of the condensers, and all variable condensers have the range of their capacities marked on the name plate.

The wave length of a circuit made up of a calibrated inductance and a calibrated capacity as above can be calculated from the formula: Wave length in meters $= 1884.95\sqrt{CL}$. When C is in microfarads, L is in micro-henries, the formula being derived from the fundamental: $T = 2\pi\sqrt{LC}$.

For calibrating the aerial circuit and other circuits not already calibrated wave meters are supplied, which are used as receivers to calibrate sending circuits and as senders to calibrate receiving circuits. After calibration the adjustment of these circuits to the same wave length and to the desired coupling is called *tuning*.

198. To be completely in tune, a sending set should have the circuit made up of the A. C. armature winding, primary leads, and primary winding of transformer, in resonance (tune) with that formed by the sending condenser and secondary winding of the transformer. Both circuits should be in resonance with the alternator frequency.

The closed sending circuit should be in resonance with the open circuit and the coupling and decrement of the open circuit such as to afford the necessary selectivity to the receiving circuits with the best efficiency of radiation.

Receiving circuits to receive from such a sender should be in resonance with each other and with the sending circuits and should have the same coupling as the sending circuits. The telephone diaphragm should be in resonance with the wave train (alternator) frequency and with the operator's ear.

As was previously stated, instead of designing telephone diaphragms for resonance with alternators, we design the alternator for resonance with the telephone diaphragm.

Resonance is thus seen to be a vital quality in wireless telegraph circuits. (1) Resonance of alternator frequency with primary sending circuit. (2) Resonance of primary circuit with secondary sending circuit. (3) Resonance of closed oscillating circuit with open radiating circuit. (4) Resonance of coupled receiving circuits with each other and with coupled sending circuits. (5) Resonance of telephone diaphragm with primary frequency. (6) Resonance of human ear with telephone diaphragm.

Of these (1), (2) and (5) are elements of design and are not changeable at the will of the operator. (1) and (2) can be varied to a certain extent by reactance regulators which in the latest Telefunken sets are provided for both circuits; but it is preferable to cover this feature in the original design of the transformers. (3) and (4) are entirely under the operator's control and on them the efficiency of the set depends.

WAVE METERS AND THEIR USE.

199. Standard calibrated oscillating circuits called wave meters, which are adjustable at will to a great number of known wave lengths are used for calibrating and tuning.

When adjusted to resonance with the circuit to be measured the fact is indicated according to the tpye of wave meter by a maximum of sound in a telephone, a maximum glow in a vacuum tube, a maximum reading of a hot wire ammeter or the brightness of a glow lamp.

The Pierce wave meter uses a telephone exclusively. It is suitable for determining resonance only. The Donitz meter uses a hot wire ammeter or air thermometer, whose maximum reading indicates resonance and lower readings the relative amount of energy received when the wave length of the wave-meter is varied. These readings can be plotted as a curve. Wave meters now furnished can be used either with a detector and telephone or with a hot wire ammeter or galvanometer for determining resonance. Wave meters are also fitted with small spark gaps and spark coils so that they can be used as *senders* for *calibrating* receiving circuits. Instructions for the use of wave meters are supplied with the instruments.

200. In determining wave lengths three methods for fixing the condenser reading for maximum current may be used. 1. For a rough determination the apparent position of maximum reading may be fixed by a single observation. 2. For a more accurate determination the maximum reading of the hot-wire ammeter or galvanometer may be noted, and the condenser pointer be moved first to the right until the current reading falls by a certain amount, and then to the left of the maximum position until it falls to an equal amount. The position half way between these two condenser readings may be taken as the true maximum. 3. The values of the current reading corresponding to a large number of condenser readings on each side of the maximum may be taken, and a curve plotted having condenser readings as abscissas and current readings as ordinates. From this curve the most accurate possible position of the maximum can be obtained.

Where wave meters are to be used only for the determination of the position of maximum resonance, small vacuum tubes are sometimes placed in parallel with the inductance, and these light up when the potential across the inductance reaches a maximum.

For measuring the wave length of any sending set as it is being used it is only necessary to bring the wave meter into position near the sending helix, close the key for a long dash and ascertain, by moving the pointer over the graduated scale, the position of resonance as indicated above, i. e., by telephone H. W. A. (hot-wire ammeter) or galvanometer. This will generally be on the longer wave or *"upper hump"* since in stations sending out two waves the longer wave contains the most energy and is the most easily read. To locate the short wave (*"lower hump"*) it may be necessary to bring the wave meter inductance quite close to the sending helix. In sets having loose coupling and those supplied with quenched spark gaps, *but one position of resonance should be found.*

To ascertain the wave length of the closed circuit disconnect the aerial and proceed as before. But one wave length will be found. This, if the same as the first one measured, will show that there is but one length of wave being generated and radiated. The two operations above described can be performed in less than five minutes. To ascertain the wave length of the aerial is not so easy. To do so disconnect the closed circuit, place a temporary spark gap in the ground lead of the aerial, connect leads from the transformer to each side of the gap and, in ordinary ship sets where the capacity of the aerial is small, also put a Leyden jar across the gap. Place the wave meter near the aerial inductance and adjust to resonance. This reading should be the same as that found for the closed circuit.

201. If both open and closed circuits read 425 and the upper hump is found to be 450 and lower hump 390, the percentage of coupling is

$$\frac{450-390}{425} = 14\%.$$

If but one hump is found and that at 425, with an ordinary spark gap, the circuits are very loosely coupled. This fact can also be determined approximately by an inspection of the sending helix. If direct connected and but one wave length is found, it will also be found that the number of turns common to the two circuits is very small or *less than one turn.* If inductively connected, that the active parts of the two helices are not close together, in other words, the mutual induction is very small. The single wave found on loose coupled sets using an ordinary gap is not as sharp as that found on the closed circuit read separately. Some mutual induction is necessary to transfer energy so that the two waves *can not quite merge into one.*

The above measurements will show whether the open and closed circuits are in resonance and what wave length or lengths are being sent out as adjusted.

202. Tuning curves showing the wave length for any adjustment of each circuit should be made, plotting the wave meter readings as wave lengths horizontally on the bottom of a sheet of cross section paper (standard A sheet) and the number of turns of the helix for each reading on the side vertically.

Draw smooth curves (see figs. 98 and 101) through the points thus found for both the open and closed circuits. An inspection of these curves will show how many turns must be included in each circuit for any given wave length. When set by these tuning curves to the same wave length the accuracy of the curves can be checked by the reading of the H. W. A. If the setting is correct, any change in either circuit will decrease the reading of the H. W. A. It must be remembered as stated elsewhere that it generally takes a change of several turns of inductance to change the wave length of the open circuit appreciably, while a change of less than one turn will change the wave length of the closed circuit considerably, so that it is much easier to throw the two circuits out of resonance by changing the closed circuit turns than by changing the open circuit turns.

It must also be remembered that the tuning curve for a closed circuit is only correct for the capacity in the circuit at the time the measurements were made.

The removal of a jar from the condenser; change of shape or length of leads to helix; bad connections to jars—each and all change the wave length of the closed circuit and throw it out of resonance with the open circuit with marked decrease in radiation.

The H. W. A. can be used to adjust two circuits to the same wave length but it gives no indication of what that wave length is.

When a wave meter is available it is shown above that to take a reading of the closed circuit wave length requires but a minute's work.

The wave length of the open circuit with the same number of turns included varies little from any cause, and if the insulation and ground are good the causes of decreased radiation should be looked for in the spark gap or in bad connections, broken jars, etc., in other parts of the closed circuit.

It has been proposed where the coupling is such that two wave lengths are radiated to throw the two circuits slightly out of resonance to increase the proportion of the total energy in the long wave; but no distinct gain in efficiency has been noted.

It is better to loosen the coupling to the point where but one wave can be found, even if this is beyond, as it usually will be, the point where the highest hot wire ammeter reading is obtained.

It must be remembered, however, that efficiency varies directly as the H. W. A. reading and the latter must be maintained as high as possible consistent with sending out waves of but one length.

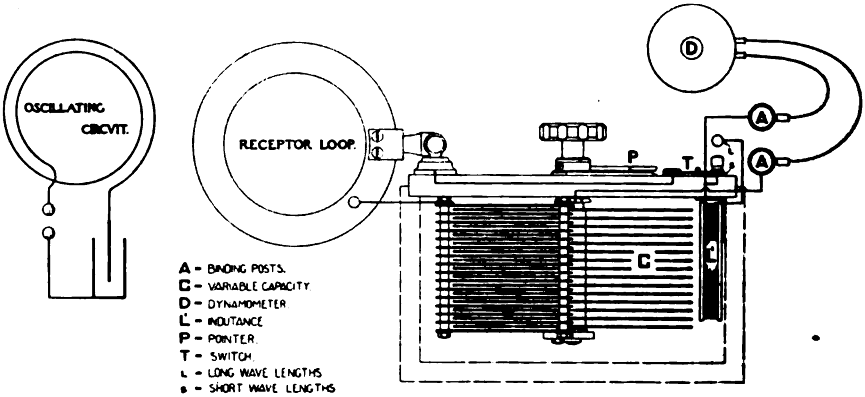


FIG. 96.

203. Fig. 96 shows the Pierce wave-meter referred to in Art. 181. This meter is used for calibrating and determination of resonance by means of sound only.

INSTRUCTIONS FOR USING THE PIERCE WAVE METER OF THE MASSACHUSETTS WIRELESS EQUIPMENT CO.

A.—CALIBRATION OF SENDING STATION.

1. *To make the Instrument ready for use.*—Take off the cover, fold back the hinged loop, and attach the leads of the telephone receiver (stowed in cover of box) to the two binding posts near together to the left of the metric scale.

2. *Placing the Instruments.*—Place the instrument near the circuit whose wave length is to be determined, and by turning the loop on its projecting horizontal axis bring it in such a position (parallel) that it will be linked by the magnetic lines from the oscillating circuit. The proper distance from the loop to the oscillating circuit depends on the intensity of the oscillations. When the observations are to be made directly on the Leyden jar circuit the wave-meter loop may be one or two meters from the discharge circuit, while if observations are to be made on parts of the circuit in which the currents are feebler, this distance may be reduced to a few centimeters.

In setting up a station the wave lengths of the various parts of the circuit may be determined separately in the usual manner.

When the station is already set up ready for use, the wave length or the two wave lengths it is radiating may be determined by placing the wave meter near the *wire to ground* or the *wire to antenna* with the loop of the instrument in the plane of the wire.

3. *Regulation of Spark.*—Make the spark of the station short and adjust the current in the discharge circuit so that the spark is clear and sharp.

4. *Taking Observations.*—Put the telephone receiver to the ear and with the hand holding the receiver, touch one of the metallic tips of the lead where it enters the receiver. This will shut out the general hum due to the alternating current in the transformer. If no such hum is present it is not necessary to touch the terminal in this manner.

Now with the free hand turn the handle in the center of the instrument and set for a maximum in the telephone.

In making these observations the switch to the right must be either on " L " or " S ." This switch should be on " L " for long waves and on " S " for short waves. With the switch on " S " read the position of the pointer or *red scale*. The position of the pointer for a maximum sound in the telephone is the wave length in *meters*. If the switch is on " L " the black scale should be read and gives the wave length in meters.

In case the sounds in the telephonic receiver are too loud for accurate settings, their intensity may be reduced either by moving the instrument farther away, or more conveniently, by turning the receptor loop so that the inductive action is diminished. In the final setting it is desirable to have the sound in the telephone just audible at resonance.

5. *Use of Geissler Tube for Demonstrations.*—If it is desired to use a Geissler tube with the instrument, leave the telephone connected in, connect one terminal of the tube to the nearer left-hand post along with the telephone lead and the other terminal of the tube to the idle binding post at the back of the instrument. The tube is then in parallel with the condenser of the wave meter and should glow at the proper setting.

B.—CALIBRATION OF RECEIVING STATION.

204. 6. *Use of Wave Meter as Sending Station.*—Take off the telephonic receiver of the wave meter and put in its place the spark-gap supplied with the apparatus. This attachment has a coil in its base of approximately the proper inductance to replace the telephone. Use the wave meter as a sending station and for any given wave length of the wave meter set the receiving station to resonance as in receiving messages from a distant source.

7. *Spark-Coil.*—In using the wave meter as a sending station it should be actuated by a small spark-coil. Attach the leads from the secondary of the spark-coil to the two sides of the wave meter spark-gap. This gap should be opened not more than a few hundredths of an inch (.1 or .2 millimeters). When the gap is too wide, sparks occur inside the wave meter between the plates of the condenser.

8. *Position.*—The wave meter when used as a sending station should be placed about three meters from the receiving antenna, and should not be approached too closely by the observer who is listening at the telephone of the receiving station, since conduction or induction through the body of the observer and along his telephone leads will result in a general hum that can not be tuned out.

C.—PRECAUTION AND CARE OF THE INSTRUMENT.

9. Do not attempt to open the telephone receiver, and do not change or break the leads of the telephone as injury to the telephone will disturb the calibration.

10. In stowing away the apparatus be careful to leave the pointer free from obstructions. To this end, whenever the instrument is to be transported it is advisable to disconnect the telephone and place it in the clamp in the cover of the box with the leads secured under the wooden buttons.

11. *The receptor loop should be folded in with knob upward so that pointer can be rotated under the loop without interference.*

205. Fig. 97 is a diagram of the original Donitz wave meter with air thermometer. A hot-wire ammeter is now used with this instrument or a detector connected with a galvanometer. This wave meter, called by its inventor an ondameter, is used for other measurements as well as for calibrating. The instructions given in the preceding article for the use of the Pierce wave meter apply in general to all wave meters.

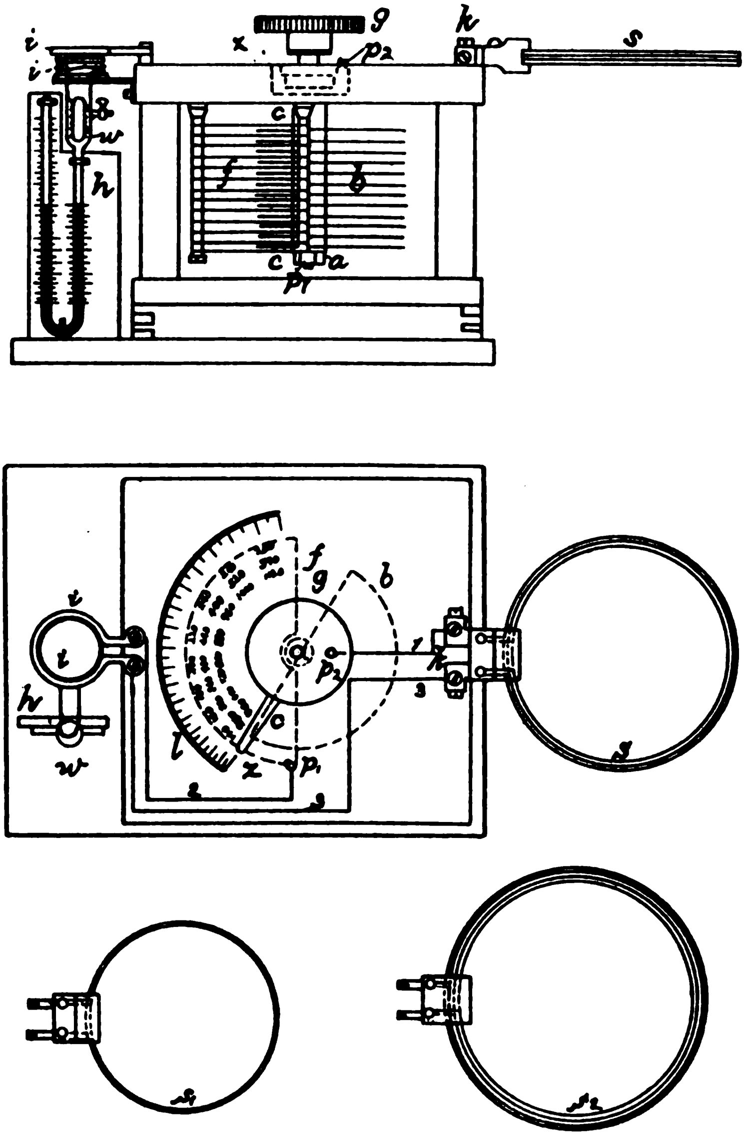


FIG. 97.—Slaby Arco Donitz Wave Meter.

In calibrating closed sending circuits, the *shape,* as well as the length of the leads, must be taken into consideration. This shape must be the permanent one. In sets now being supplied connections of the helix are made so as to avoid any change of shape with change of wave length.

In calibrating the open circuit of receiving sets the same difficulty will be found in obtaining *sharp* resonance as when calibrating open sending circuits. The instructions given in Art. 200 should then be followed; substituting turns of inductance or variometer pointer for condenser pointer, since in this case the wave meter is being used as a sender and readings are by *sound* or galvanometer.

206. Fig. 98 shows calibration curves of closed (1) and open (2) circuits made with a Donitz meter at the Guantanamo wireless station in 1906.

In addition to calibrating sending and receiving circuits it is desirable to measure the sending current and also the received currents.

Calibrating sending and receiving circuits enables us to select and send and set our instruments to receive definite known wave lengths and is the first requisite of tuning. In order that our receiving circuits may be selective, i. e., respond only to the wave lengths for which they are adjusted they must have comparatively large self-induction. In other words, they must be what are known as stiff or rigid circuits. In order that a wave train may be long enough to build up current in a rigid receiving circuit the sending circuit must be a persistent oscillator, i. e., it must be slowly damped. (Fig. 62.)

It must not be forgotten that the currents in a very persistent oscillator like a closed sending circuit are mostly dissipated in heat, while we wish to have their energy radiated in electric waves.

We must therefore strike a mean between the efficient very highly damped sending circuit which radiates nearly all the energy it receives in one or two waves, but which affects all receiving circuits alike and the inefficient persistently oscillating sending circuit which dissipates most of its energy in heat but which is favorable for selective receiving.

Sharp tuning or selectivity depends, therefore, on self-induction in the radiating circuit as well as in the receiving circuits.

207. Curve (7), Fig. 98, shows thermometer readings for wave meter settings at the Guantanamo station—between 900 and 2000 meters. These readings show the upper hump at 1650 meters, lower hump at 1130 meters, with ½ turn inductance in closed circuit—5½ turns in open circuit.

The air thermometer readings in the wave meter measure the received current in the same way that the hot wire ammeter in the aerial measures the sending current. The readings of both meters vary according to the heat generated by the currents and this heat varies as the square of the current.

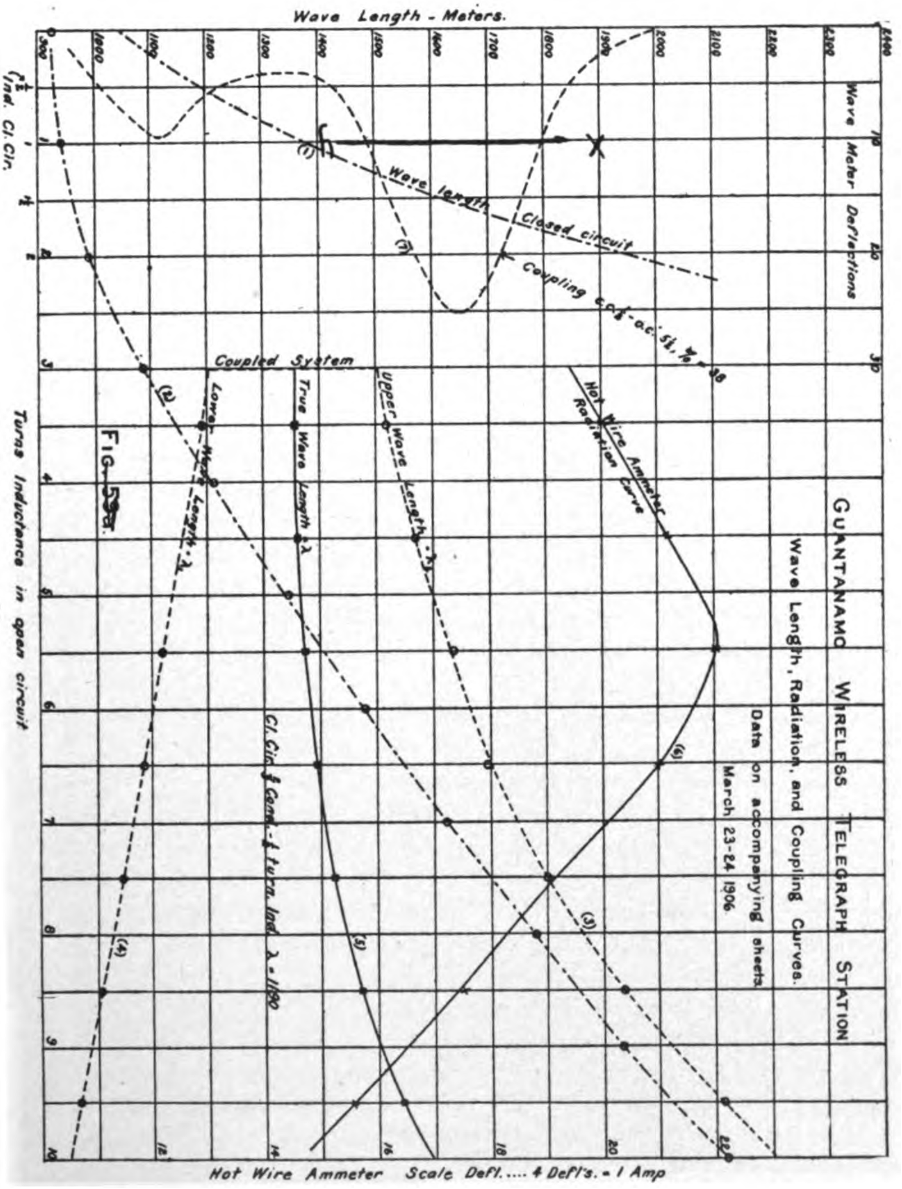

GUANTANAMO WIRELESS TELEGRAPH STATION
Wave Length, Radiation, and Coupling Curves.
Data on accompanying sheets.
March 23-24 1906.
Wave Length - Meters.
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
Wave Meter Deflections
10
20
30
Wave length. Closed circuit
(1)
(7)
Coupling c.c.f.-o.c. 51, % = 48
Coupled System
Lower Wave Length λ
True Wave Length λ
Upper Wave Length λ
Hot Wire Ammeter Radiation Curve
Cl. Cir. & Cond. - ½ turn Ind. λ = 1190
(2)
(3)
(4)
(5)
(6)
0
½
1
1½
2
3
4
5
6
7
8
9
10
½ Ind. Cl. Cir.
Turns Inductance in open circuit
Hot Wire Ammeter Scale Defl..... 4 Defl's. = 1 Amp
10
12
14
16
18
20
22
~~FIG. 53~~

FIG. 98.

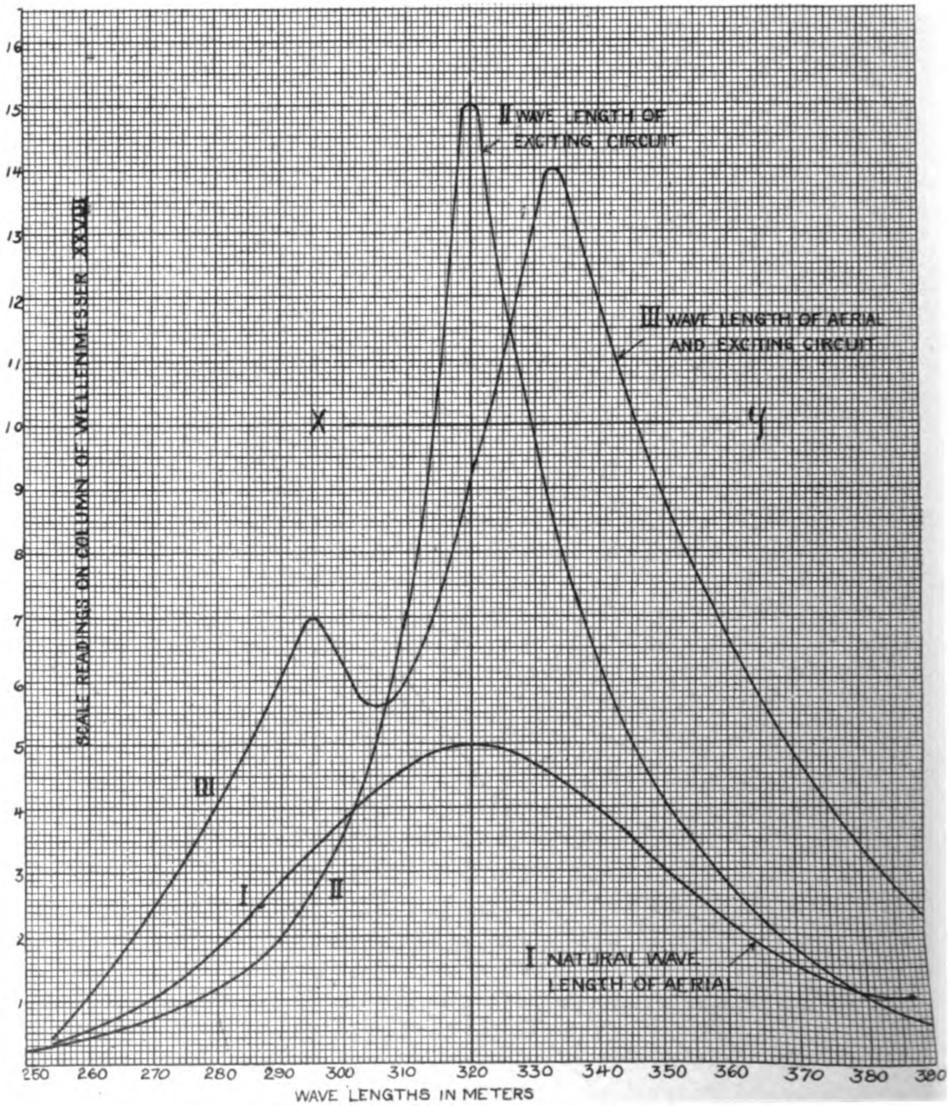

16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
SCALE READINGS ON COLUMN OF WELLENMESSER XXVIII
II WAVE LENGTH OF EXCITING CIRCUIT
III WAVE LENGTH OF AERIAL AND EXCITING CIRCUIT
X
Y
III
I
II
I NATURAL WAVE LENGTH OF AERIAL
250
260
270
280
290
300
310
320
330
340
350
360
370
380
380
WAVE LENGTHS IN METERS

Fig. 99.

Dr. Austin says that if a rectifying detector and galvanometer are used for measuring the received currents the direct currents produced are also proportional to the square of the oscillating currents; so all these ways of measuring are directly comparable. (See curve 7.) The maximum wave meter reading is 25 at 1650 meters; at 1800 meters and 1480 meters it reads 10. By changing the setting of the wave meter either way 150 meters we reduce the strength of the received currents in the value of $\sqrt{25}$ to $\sqrt{10}$ or approximately 5 to 3.

Turn now to cure III, fig. 99. We see that a change of 75 meters in the wave meter setting changes the reading from a maximum of 14 to a reading of 1. Curve III, fig. 99, is a much sharper curve than (7) of fig. 98. The same kind of wave meter being used for measuring the received currents in both cases we conclude that the sending circuit in fig. 99 is a more persistent oscillator than that in fig. 98. Compare also the shape of curve I, fig. 99, from the more rapidly damped open circuit oscillating alone, with the shape of II, produced by the closed circuit alone, and III, produced by the coupled circuits.

The maxima of these curves have no direct relation to each other since they are produced by different amounts of radiated energy and probably by different relative positions of the wave meter and the circuits. It is their *shapes* alone that are the subject of comparison and discussion. The *shape* of each curve will remain the same whatever the position of the wave meter (receiving circuit). Let the portion of each curve above the heavy line X Y in figs. 98 and 99 represent the range of audibility at any distance—say 100 miles from the sending set. Thus in curve II, fig. 99, a change in the receiving circuit of only 8 meters from the position of maximum loudness would render the incoming signals inaudible, while in curve 7, fig. 98, a change of 150 meters would be required to cut out signals. In neither case would the lower hump audibly affect the receiving apparatus. Sharp tuning is not possible with a highly damped transmitter as the shape of these curves show. Neither is it possible without stiff receiving circuits. The latter should, however, be variable; that is, capable of being broadly or sharply tuned as desired (i. e., it should be possible to switch the detector from a highly damped to a rigid circuit or the circuits should be mounted so as to permit wide variations of coupling). There is no more possibility of escape from a whip crack transmitter than from static.

208. In addition to being able to estimate damping from tuning or resonance curves we can measure it directly as follows:

MEASUREMENT OF DAMPING.

It was stated (art. 117) that the damping of any circuit $\delta = \frac{R}{2nL}$, where R is the resistance, n the frequency and L the self-induction of the circuit. If one circuit be used to excite another and if either of the two circuits contains a variable capacity, we may plot a curve connecting the readings of the variable condenser as abscissas and the current in the second circuit as ordinates. (See fig. 100.) This is the resonance curve of the two circuits. The theory of coupled circuits shows that the sum of the dampings of the two circuits $\delta_1+\delta_2=\pi\,\frac{C_m-C}{C_m}\sqrt{\frac{I^2}{I^2_m-I^2}}$, where C_m represents the position of the condenser in degrees for most perfect resonance, and I_m the maximum current in the second circuit corresponding to the position of the condenser C_m, and where I represents the current in the circuit corresponding to any other position C of the variable condenser. This formula becomes much simplified for practical purposes, and gives in general accurate enough results, if, instead of plotting a complete curve, we change the variable condenser so that for the reading C, $I^2=\frac{1}{2}\,I^2{}_m$. The quantity under the radical then becomes unity, and $\delta_1+\delta_2=\pi\,\frac{C_m-C}{C_m}$. Two values of C should be observed one on each side of C_m, and the mean of the two values of the damping taken. If the current is measured by means of a thermo-element or a

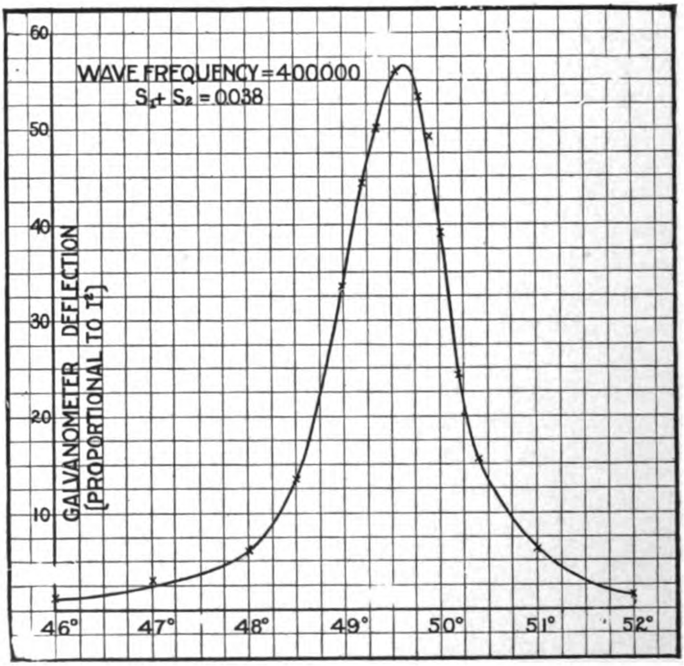


Fig. 100.—Resonance Curve Taken with Wave Meter.

perikon detector in connection with a galvanometer, the readings of the galvanometer are proportional to I^2; that is C is so chosen that the galvanometer deflection is reduced to one-half that observed with C_m. If the current is read with a hot-wire instrument reading directly in amperes, then the reading of the meter corresponding to C should be $\frac{1}{1.43}$ of that corresponding to C_m, since $1.43 = \sqrt{2}$. This expression gives the true value of the dampings of the circuits only when the coupling between them is extremely loose.

If the coupling is not very loose between the two circuits, the apparent value of the damping will be too large. The proper degree of coupling can be ascertained by observing the point beyond which loosening the coupling does not decrease the damping. If the damping of the wave meter circuit be known or can be calculated from the formula $\delta_2 = \frac{R}{2nL}$, by subtracting this from the sum of the two dampings we get at once the damping of the other circuit.

If we wish to express damping in terms of wave length λ instead of capacity or inductance, it may be shown mathematically that the sum of the damping $\delta_1 + \delta_2 = 2\pi \frac{\lambda_m - \lambda}{\lambda}$, where as before λ is the wave length, which reduces the square of the received current to one-half of that found for resonance at λ_m.

209. From the results of damping measurements it has been found that very sharp tuning is impracticable when a wave train contains less than 15 oscillations. This corresponds to a decrement of .2 (see fig. 62). Having measured the damping of the open circuit as coupled and found it too large it is necessary to add inductance in order to decrease it, or to weaken the coupling in order that the total resistance *R* may be decreased. If it is not practicable to change the wave length, the aërial must be shortened to decrease its capacity while retaining the same wave length by adding inductance. Loosening the coupling also decreases the damping.

Fig. 101 shows a resonance curve taken from a loose coupled sending set, showing but one maxima at 330 meters with 5 turns of inductance in the open circuit and less than ½ turn in the closed circuit. This curve is steep enough to permit fairly selective receiving.

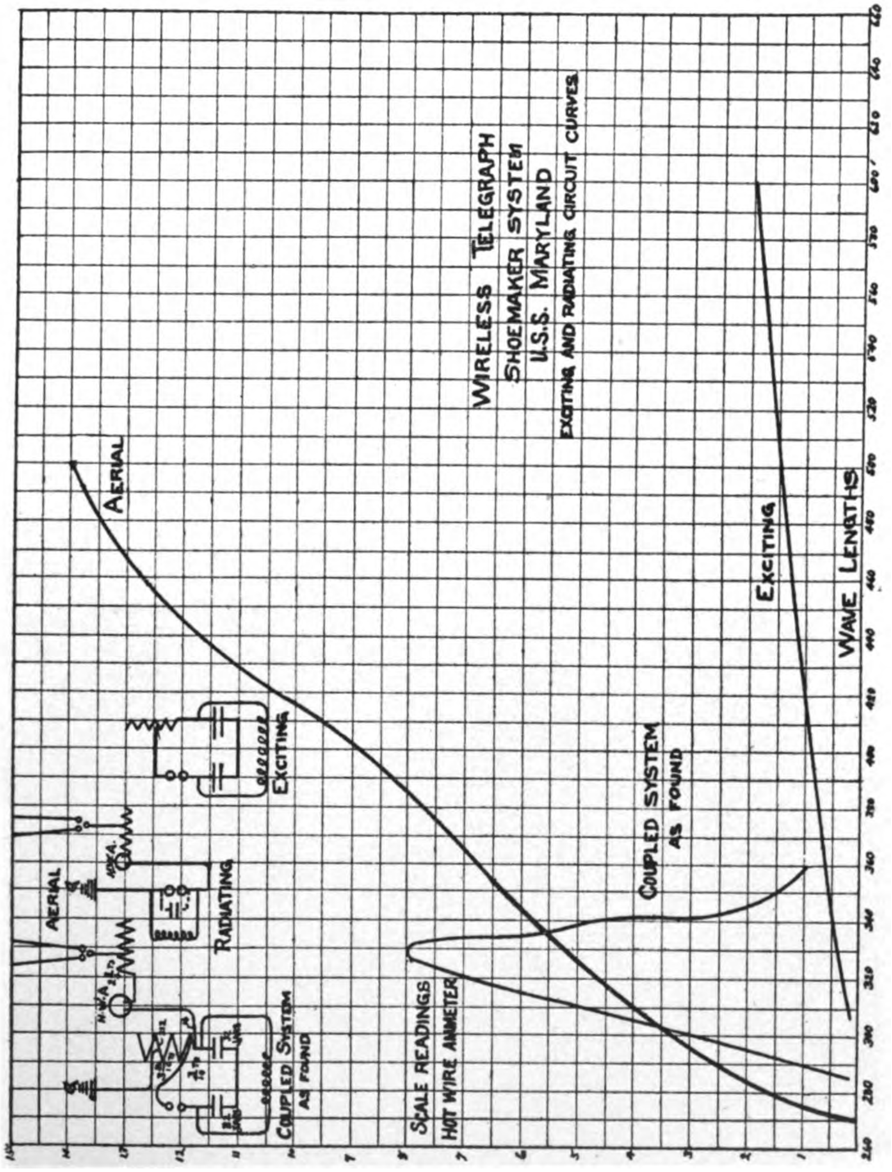

WIRELESS TELEGRAPH
SHOEMAKER SYSTEM
U.S.S. MARYLAND
EXCITING AND RADIATING CIRCUIT CURVES
AERIAL
EXCITING
COUPLED SYSTEM AS FOUND
SCALE READINGS
HOT WIRE AMMETER
WAVE LENGTHS
AERIAL
RADIATING
EXCITING
COUPLED SYSTEM AS FOUND
H.W.A.
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

FIG. 101.

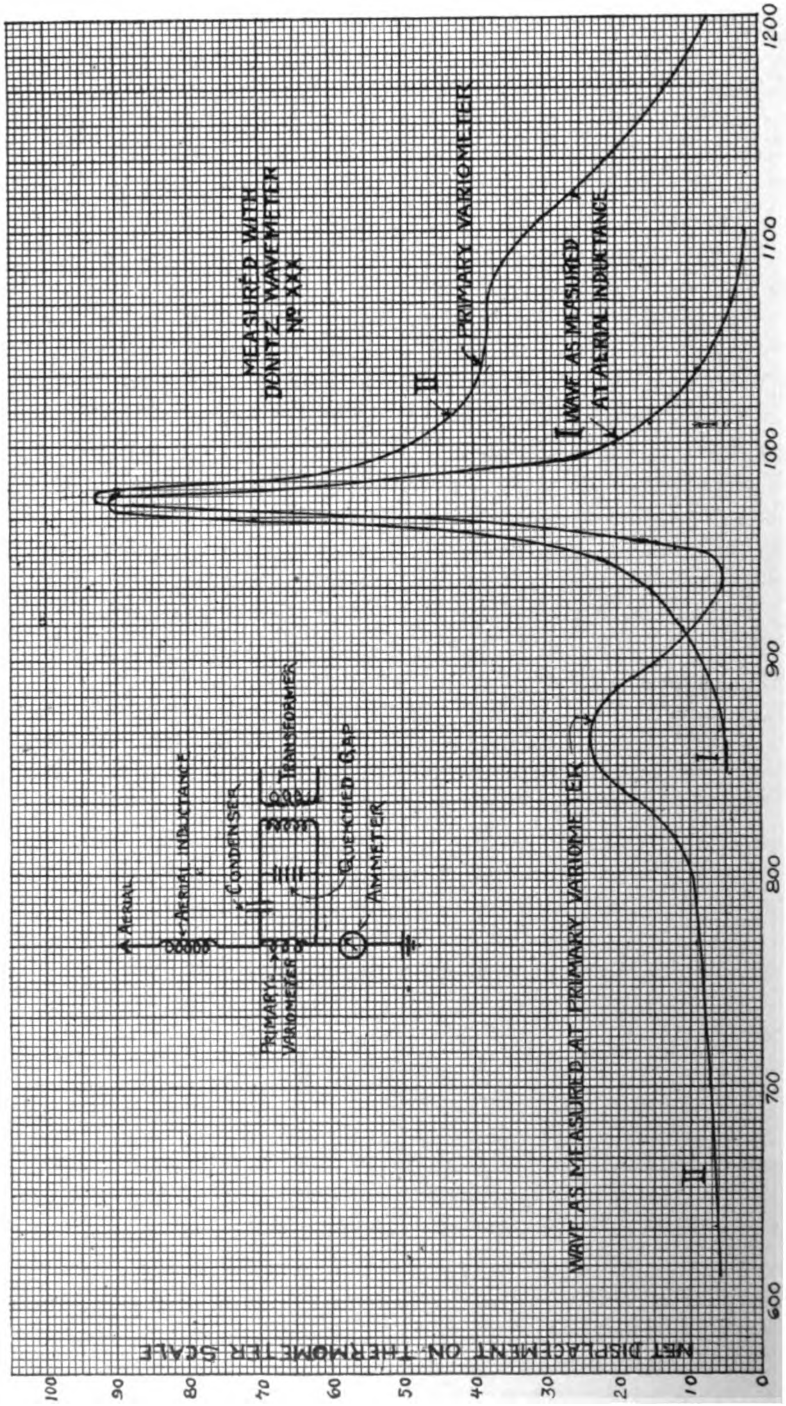

MEASURED WITH
DONITZ WAVEMETER
No XXX
II
PRIMARY VARIOMETER
I
WAVE AS MEASURED
AT AERIAL INDUCTANCE
WAVE AS MEASURED AT PRIMARY VARIOMETER
I
II
AERIAL
AERIAL INDUCTANCE
CONDENSER
TRANSFORMER
QUENCHED GAP
AMMETER
PRIMARY VARIOMETER
NET DISPLACEMENT ON THERMOMETER SCALE
0
10
20
30
40
50
60
70
80
90
100
600
700
800
900
1000
1100
1200

FIG. 102.

Fig. 102 shows much steeper curves taken from a direct connected quenched gap, 500 cycle set.

The position of the two small humps in curve I, fig. 102, taken at the primary variometer indicate a coupling of $\frac{1070-860}{975}=22\%$. This is by no means very loose coupling, but the curve shows that the aerial radiates most of its energy while oscillating in its natural period (in this case 975 meters) and that when so oscillating it is persistent enough to permit very sharp tuning.

Curve II in fig. 102 taken at the aerial inductance shows but one maximum which practically coincides in wave length with the maximum of curve I. (Curve II is drawn to a different scale, so that the coincidence in maximum readings is only apparent. They are in reality smaller for the open than the closed circuit.)

210. Receiving circuits can be stiffened without changing the wave length by putting a condenser in series to decrease the capacity and then adding inductance to keep the same wave length. But the damping of sending circuits can not be conveniently changed in this way on account of the high potentials which would be induced in the series condenser. The method of measuring damping just described is applicable to receiving as well as to sending circuits. Receiving circuits have in general greater resistance than sending circuits, but this is limited by specifications to 4 ohms per millihenry in order not to injuriously increase the damping.

For measuring the sending current a hot wire ammeter is installed directly in the aerial just above the ground connection.

Curve 6, fig. 98, shows hot-wire ammeter readings in open circuit for various couplings and wave lengths at the Guantanamo station. The maximum reading is for a coupling of $\frac{1440-11205}{1375}=23\%$.

The highest hot-wire ammeter reading shows that the circuits are in resonance and is usually taken also to indicate the best coupling; but except for circuits with quenched gaps the highest H. W. A. reading is usually obtained with a coupling which causes the radiating circuit to be too highly damped. It is therefore best to loosen the coupling until the shape of the resonance curves, or actual measurements, show sufficiently small damping; and then, by careful adjustment to resonance, attention to connections, to spark gap, and to regulator, get the highest hot-wire ammeter reading that can be obtained with that coupling and wave length.

211. In order that the performance of different sets can be compared it is necessary that all hot wire ammeters be calibrated for reading directly and correctly in amperes.

A hot wire ammeter which reads correctly on direct current should be calibrated for high frequency as follows:

First remove the shunt and send with reduced power so that the deflections will approximately cover the scale. This can be done either by cutting down the actual power or by loosening the coupling between the closed circuit and aerial. Note the deflections. Then close the shunt and leaving everything else unchanged send again and note the deflection. The relation between the two deflections gives the ratio, for this wave length, of the shunted to the unshunted readings. If any other wave length is used, the shunt must be recalibrated since its effective resistance depends on the frequency.

Reports of current in aerial should always read correctly in amperes and be accompanied by report of exact frequency and input to transformer in amperes and volts. It is found that the distance of transmission varies directly as the oscillating current in the aerial, so that it is important to ascertain correctly what this current is.

THE SHUNTED TELEPHONE METHOD OF MEASURING THE INTENSITY OF SIGNALS.

212. It is often desirable to make quantitative determination of the intensity of incoming signals, especially when tests are being made of either sending or receiving apparatus. This can be done if the station is provided with an electrolytic receiver, preferably of the free-wire type, and a resistance box. The connections are shown in fig. 103.

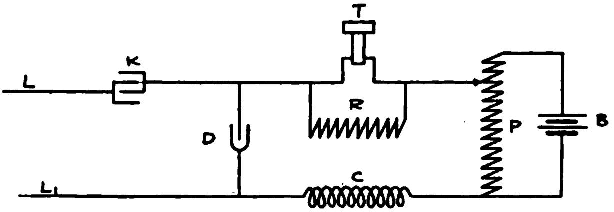


FIG. 103.—Detector Circuit with Shunted Telephone.

Here L and L_1 are wires running to the receiving circuit, K a stopping condenser, D the electrolytic, T the telephone, R a resistance box in shunt across the telephones, P the potentiometer, and C a choke coil to prevent the oscillations running around through R and P instead of passing through D when the shunt R is closed. Two 60-ohm telephones form a suitable choke. Whatever choke coil is used, it should be tested by being placed across LL_1. If the choke is perfect no oscillations will pass through it, and its presence across LL_1 will not diminish the loudness of the signals in the telephones.

The measurement of the intensity of signal is made as follows: After the receiving circuit and detector are adjusted to give maximum loudness in the telephone, the shunt resistance R is closed and the resistance regulated until the signal just remains audible. The value of the current pulses c in the telephone, which are proportional to the energy of the incoming waves in the detector, is expressed by the following formula, where r is the value of the shunt, and t is the resistance of the telephones, and c^1 the least current audible in the telephones:

$$c = \frac{r+t}{r} c^1;$$

c^1 is the audibility current, and the signal is often expressed as being so many times audibility. With care a series of measurements of intensity may be made to agree among themselves to within 5 to 10 per cent.

A station is tuned, when both sending and receiving circuits are correctly calibrated, coupled, and adjusted to the standard damping and wave length.

213. Inductances and capacities can be directly measured by wave meters as follows:

MEASUREMENT OF INDUCTANCE AND CAPACITY.

Inductance.—A circuit is formed containing the unknown inductance, a known capacity (one or more standard jars), and a small spark gap. This circuit is used to excite the wave meter, and the variable condenser is varied until a maximum current in the wave meter is obtained. The two circuits being then in resonance, the product of the inductance and capacity in each is the same; that is, $LC = L^1C^1$, or if L is the unknown quantity, $L = \frac{L^1C^1}{C}$.

Capacity.—If the spark circuit is made up with a known inductance and unknown capacity, by the same process we determine that $C = \frac{L^1C^1}{L}$.

CARE AND OPERATION.

214. At all stations, ship and shore, the best results are invariably obtained and the most satisfactory service given by alert and careful operators who take pride in the condition of their instruments. Wireless telegraph instruments like all others depend for their efficiency on their condition and amply repay good care.

An excellent operator once said that no matter how good he thought his contacts and connections were he always found that by going over them he could make them better and increase his sending and receiving efficiency. A routine, which, if followed, will ensure the proper care of a wireless set, is given in Appendix E.

All sliding contacts, especially in receiver tuning coils, should be clean and bright and free from foreign matter. Sending key contacts should be kept clean and smooth and with faces parallel to each other.

Detectors must be kept in their most sensitive condition and frequently tested by means of the buzzer furnished for the purpose.

When any part of the condenser is injured it should be immediately replaced or repaired. Any change in closed or open circuit without a corresponding change in the other throws the two circuits out of resonance and greatly decreases the sending radius.

If the capacity in the condenser must be *decreased* for any cause then in order to retain the same wave length the inductance in the closed circuit must be *increased.*

215. The following general instructions apply to all stations: The operator shall wear the double head receiver continuously while on watch, except when necessary to communicate otherwise than by wireless. He shall satisfy himself by frequent testing with the buzzer that his detector is sensitive, and while in the vicinity of other vessels or near shore stations and using a detector that may be injured by strong sending, he shall always be alert to protect it by weakening the coupling or by opening the receiving switch.

He shall familiarize himself with all sending and receiving connections and adjustments and be able to tell when they are correct and to renew them when necessary; but he shall not make any changes in any of them without the knowledge and permission of the chief electrician or operator in charge.

He shall be capable of adjusting the spark gap, motor and generator rheostats and reactance regulator, so as to obtain the necessary output for the communication to be made.

He shall use the shortest gap and the least power that will enable his messages to be clearly read. The spark must be kept white and crackling and have considerable volume. He shall be vigilant in noting and keeping in good condition all sending condenser connections and in keeping all articles or instruments which might be injured or cause a ground or sparking well clear of the sending apparatus at all times.

He shall not, except in cases of emergency, call or send any message, when official messages are being sent or received by other vessels or stations in his vicinity.

He shall be careful to file correct copies, on the official forms, of all messages sent and received by him, initialing each and filling in *time* and place and other information as called for on forms.

He shall avoid a short and jerky style of sending. Dots and dashes and intervals must be of proper relative lengths as shown by the code in order that the sending may be clear and legible. Operators must endeavor to attain fair speed, both in sending and receiving.

Where heavy static is encountered, dots and dashes may be longer, but must preserve their relative length. The generator shall be run only during the time necessary to send messages.

Where a number of tunes are ordered to be used the operators shall be careful to see that all circuits are correctly adjusted before attempting to send.

An operator shall turn the station over to his relief clean and neat.

A sending set with all connections good, closed and open circuits in resonance, no sparking from edge of condenser jars or plates, no glow from aerial and no sparking to rigging, is utilizing its power more efficiently and will be heard farther than the same set pushed to the limit but out of resonance with high resistance connections and sparking at all points.

Messages shall not be sent between 11.55 A. M. and noon, 75th meridian time, in the Atlantic, and 120th meridian time in the Pacific. During this interval naval wireless telegraph stations send the noon time signal for the use of navigators in comparing chronometers.

CODES.

215. For official use between ships of the navy and between them and naval shore wireless telegraph stations the Continental Morse code is used.

Commercial shore stations in the United States, and United States coasting vessels use American Morse.

All foreign stations, ship and shore, public and private, use Continental Morse. American Morse is a little faster. Both codes are printed herein. The Continental Morse is a dash and dot code throughout with a maximum of four elements in any letter. The American Morse uses five elements in the letter P, four elements and a space in Y, Z and &, and a long dash for the letter L. It has a relatively less number of dashes than the Continental code and is on that account faster.

It will be noted that A, B, D, E, G, H, I, K, M, N, S, T, U, V and W (fifteen out of the twenty-six letters of the alphabet) are the same in both codes.

It is to be hoped that the use of wireless telegraphy will eventually bring about an international agreement as to the elements for the remaining eleven letters and thus provide a universal code. This will facilitate intercourse between United States ships and those of other nations and relieve operators of the necessity of learning two codes.

When it is desired to communicate by the international signal book (as between two vessels whose operators do not use the same language) the "call" should be followed by the letters P R B in the Continental code.

The international signal of distress is - - - — — — - - -, making the letters S O S of the Continental code.

The two signals given above were adopted at the International Wireless Telegraph Conference at Berlin in 1906. The United States has not yet ratified the convention and is therefore not a party to the International Rules, but the two signals above, especially the signal of distress, are generally recognized. The most important rules of this convention are given in Appendix C.

The rule of this convention that all stations should have three *call letters* is also followed in the United States. A list of these call letters is published by the Navy Department in "Wireless Telegraph Stations of the World" and can be obtained from the Government Printing Office.

Information relative to U. S. naval shore stations and shore stations in some other countries is issued in "Notices to Mariners" and shown on pilot charts published by the U. S. Naval Hydrographic Office. The rules governing communication between naval shore stations and private vessels are published in the same manner. The substance of these will be found in Appendix B.

The Act regulating apparatus and operators on steamers, which goes into effect on July 1, 1911, will be found in Appendix D.

In view of the continually increasing use of wireless telegraphy it is necessary to employ concerted methods of avoiding interference other than static caused by stations, ship and shore, in the same vicinity trying to communicate at the same time, using the same wave length.

These methods are not yet perfected, but are in outline as follows:

(a) Standard calling wave lengths for ships and for shore stations. Say 600 meters for ships, 1000 meters for shore stations.

(b) Standard communicating wave lengths or tunes different from the calling tunes, ranging from 300 to 10,000 meters, and designated by letters of the alphabet as Tune A-300 meters, Tune B-400 meters, etc.

(c) Assigning specific tunes (the long ones) to shore stations which communicate only with other shore stations.

Ship stations, and those which communicate with ships, call and listen for calls on 600 and 1000 meters. The station called when she acknowledges the call directs the calling station what tune, as C or D, to use in sending, so as to avoid interference with other tunes audible in her receiver.

The above methods cannot be generally introduced until all circuits on all ships are properly calibrated and sending and receiving sets constructed so as to permit easy, rapid, and definite changes of wave length while remaining properly coupled.

216. Whatever the speed of sending a dash is equal in length to three dots.

The interval between two elements of a letter is equal in length to a dot.

The interval between letters in a word is equal in length to a dash.

The interval between words in a sentence is equal in length to two dashes.

The length of a "space" is two dots.

The long dash of the letter L in the American Morse equals two ordinary dashes.

TELEGRAPH CODES.

ALPHABETS.

	American Morse.	Continental Morse.
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	· · · ·	— — · ·
&	· · · ·	
Wait		· — · · ·
Understand		· · · — ·
Don't understand		— · · · · — ·
Call		— · — · —
Finish		· — · — ·

NUMERALS.

	American Morse.	Continental Morse.
1	· — — ·	· — — — —
2	· · — · ·	· · — — —
3	· · · — ·	· · · — —
4	· · · · —	· · · · —
5	— — —	· · · · ·
6	· · · · · ·	— · · · ·
7	— — · ·	— — · · ·
8	— · · · ·	— — — · ·
9	— · · —	— — — — ·
0	——	— — — — —

TELEGRAPH CODES.—*Continued.*

PUNCTUATIONS, ETC.

	American Morse.	Continental Morse.
Period	..——..	.. .. ..
Colon	—.— . .	———...
Semicolon	... ..	—.—.—.
Interrogation	—.. —.	..——..
Exclamation	———.	——..——
Fraction line	.	
Dash	—.. .—..	
Hyphen	.... .—..	—....—
Pound sterling	.... .—..	—.—..
Capitalized letter	.. . .—..	
Colon followed by quotation	—.— ..—.	
Dollar mark	... .—..	
Decimal point	Spell "dot"	
Comma	.—.—	.—.—.—
Paragraph	————	
Underline (begin)	..— .—..	..— —.—
Underline (end)	..— —.—.	
Parenthesis (begin)	..... —.	—.— —.—
Parenthesis (end)	....	
Quotation marks (begin)	..—. —.	.—.— .—.—
Quotation marks (end)	..—. —.—.	
Quotation within a quotation (begin)	..—. .—..	
Quotation within a quotation (end)	..—.	
Apostrophe		.————.

COMMON ABBREVIATIONS.

[In use in United States telegraph services.]

Abt	About
Af	After
Agn	Again
Amn	American
Amt	Amount
Anr	Another
Ar	Answer
Arv	Arrive
Atk	Attack
Atl	Atlantic
Awa	Away
Awi	Awhile
Ax	Ask
Ay	Any
B	Be
Bal	Balance
Bd	Board
Bld	Bundle
Bf	Before
Bg	Being
Bn	Been
Bot	Bought
Bro	Brother
Bk	Break or back
Bt	But
Btn	Between
Btr	Better
Bu	Bushel
Byd	Beyond
Bz	Business
Bat	Battery
Bbl	Barrel
C	See
Ca	Came
Cg	Seeing
Chg	Charge
Cr	Care
Ct	Connect
Cty	City
Cvl	Civil
Cx	Capital letter
Col	Collect
Ck	Check
Da	Day
Dd	Did
Deg	Degree
Dld	Delivered
Dr	Doctor
Drk	Dark
Dux	Duplex
DH	Deadhead
Ea	Each
Ed	Editor
Eng	Engine
Etc	Et cetera
Ev	Ever
Evn	Even
Exa	Extra
Fl	Feel
Fld	Field
Flg	Feeling
Flo	Flow
Flt	Felt
Fm	From
Fri	Friday
Frt	Freight
Gr	Ground
G. B. A.	Give better address
G. A.	Go ahead
G. S. A.	Give some address
G. M.	Good morning
G. E.	Good evening
G. N.	Good night
Gen	General
Ger	German
Gg	Going
Gu	Guard
Gv	Give
Gvg	Giving
Hb	Has been
Hhd	Hogshead
Hld	Held
Hlm	Helm
Hm	Him
Hnd	Hundred
Hon	Honorable
Hpn	Happen
Hqrs	Headquarters
Hr	Here
Hs	His
Hu	House
Hv	Have
Hw	How
Ify	Infantry
Imp	Import
Ix	It is
Ixu	It is understood
Kp	Keep
Kpg	Keeping
Kpt	Kept

COMMON ABBREVIATIONS.—*Continued.*

Kw	Know
Kwg	Knowing
Kws	Knows
Las	Last
Lat	Latitude
Lft	Left
Lit	Little
Lk	Like
Lt	Lieutenant
Lv	Leave
Lvg	Leaving
Lvs	Leaves
Lyg	Lying
Ma	May
Mab	May be
Maj	Major
Mar	March
Mas	Master
Mat	Material
Max	Maximum
Mch	Machine
Mcy	Machinery
Md	Made
Mem	Member
Mfd	Manufactured
Mgr	Manager
Mh	Much
Mil	Military
Min	Minute
Mk	Make
Mkg	Making
Mkr	Maker
Mks	Makes
Mkt	Market
Ml	Mail
Mng	Morning
Mny	Many
Mo	Month
Mon	Money
Mrl	Marshal
Msg	Message
Msk	Mistake
Mst	Must
Mv	Move
Myn	Million
Na	Name
Nd	Need
Nec	Necessary
Neg	Negative
Ni	Night
No	No, and New Orleans
Nw	None
Nv	Never
Nun	Now
Nx	Next
N. M.	No more
Ofc	Officer
Ofr	Offer
Ofs	Office
Opr	Operator
Ot	Out
Otr	Other
Ov	Over
O. K.	All right
Pc	Per cent
Pd	Paid
Ph	Perhaps
Pha	Philadelphia
Pm	Postmaster
Po	Post-office
Pod	Post-Office Department
Pot	President of the
Potus	President of the United States
Pr	President
Pra	Pray
Prt	Part
Pt	Present
Qk	Quick
Qmg	Quartermaster-General
Qr	Quarter
R	Are
Rc	Receive
Rcd	Received
Rcg	Receiving
Rcr	Receiver
Rcs	Receives
Rct	Receipt
Rek	Wreck
Rht	Right
Rlf	Relief
Rp	Report
Rpt	Repeat
Rr	Railroad
Ru	Are you
Ruf	Rough
Ry	Railway
Sa	Senate
Scotus	Supreme Court of the United States
Sd	Should
Sdn	Sudden

COMMON ABBREVIATIONS.—*Continued.*

Sec	Section
Sed	Said
Sem	Seem
Sen	Seen
Sh	Such
Shf	Sheriff
Shl	Shall
Sig	Signature
Sik	Sick
Sis	Sister
Slf	Self
Slo	Slow
Slr	Sailor
Sm	Some
Sma	Small
Sn	Soon
Snc	Since
Snd	Send
Snr	Sooner
Snt	Sent
Sor	Soldier
Sp	Ship
Spfy	Specify
Spl	Special
Spo	Suppose
Ss	Steamship
St	Street
Sta	State
Stn	Station
Sto	Store
Str	Steamer
Sud	Surround
Sv	Seven
Svc	Service
Svd	Served
Sve	Serve
Svg	Serving
Svl	Several
Swo	Swore
Sx	Dollar mark
Sy	Say
S. Y. S.	See your service
T	The
Tan	Than
Tg	Thing
Tgh	Telegraph
Tgm	Telegram
Tgr	Together
Tgy	Telegraphy
Th	Those
Thk	Thank
Tho	Though
Thr	Their
Ti	Time
Tk	Take
Tkg	Taking
Tkn	Taken
Tkt	Ticket
Tlk	Talk
Tm	Them
Tn	Then
Tnd	Thousand
Tni	To-night
Tnk	Think
Tr	There
Tru	Through
Ts	This
Tse	These
Tt	That
Ttt	That the (5)
Tuf	Tough
Tw	To-morrow
Ty	They
U	You
Uc	You see
Un	Until
Uni	United
Upn	Upon
Ur	Your
Urg	Urge
Val	Value
Vy	Very
W	With
Wa	Way
Wat	Water
Wd	Would
Wea	Weather
Wg	Wrong
Wh	Which
Wi	Will
Wit	Witness
Wl	Well
Wlk	Walk
Wn	When
Wnt	Want
Wo	Who
Wom	Whom
Wos	Whose
Wr	Were
Ws	Was
Wt	What
Wu	Western Union

COMMON ABBREVIATIONS.—*Continued.*

Wy	Why
Y	Year
Ya	Yesterday
4	Please start me, or where
5	Have you anything for me
9	Important official message
13	Understand
25	I am busy now
30	No more
73	Accept best regards
77	Message for you
92	Deliver

"Wire"—Give instant possession of line for test.

An addition to the foregoing XX is gradually coming into general use as a symbol for "interference" which has no counterpart in wire telegraphy.

Chapter VIII.

WIRELESS TELEPHONY.

WIRELESS TELEGRAPHY USING UNDAMPED OSCILLATIONS, DIRECTION FINDERS AND DIRECTION SENDERS.

217. All wireless telephone sets thus far supplied, having proved unreliable in action, have been withdrawn from service.

The workings of these sets depended on the production of undamped oscillations in the sending circuits. The apparatus was in principle like that shown in fig. 104, using 220 volt direct current. The electrodes were copper and carbon and the arc was horizontal. A small alcohol lamp was placed immediately under the arc with its flame burning in the arc.

The inductance and capacity shunted around the arc formed with it an oscillatory circuit similar to the closed circuit in an ordinary wireless transmitter.

These sets were used with the ordinary ship aerial tuned to the arc circuit. The amplitude of the oscillations induced in the aerial were modified by a carbon transmitter in series with the aerial as shown in fig. 105. Talking into the carbon transmitter varied the aerial resistance.

218. Assume that the undamped oscillations had a frequency of 700,000 and the notes of the human voice varied through two octaves (say from 300 to 1200 vibrations per second). The vibrations of the telephone diaphragm by changing the resistance of the carbon modified the oscillating current in the aerial (and therefore the amplitude of the electric waves generated) in accordance with the vibrations of the voice of the person speaking. The ordinary receiving circuit having a crystal or electrolytic detector serves as well for undamped oscillations as for groups of wave trains, transforming the modified oscillations into human speech in the receiving telephone.

The limit of mechanical or air vibrations recognized as sound is between 30,000 and 40,000 per second. Although the undamped oscillations are of a much higher frequency and therefore produce no sound in themselves, modifications of the amplitude of successive waves may be of such a nature as to produce sound by slower variations in the rise and fall of the received current.

219. The transmitting telephone may be in the arc circuit instead of the aerial as shown, or it may be inductively connected to either the open or closed circuit. There is as yet no standard practice. The telephone transmitters are specially constructed to stand the voltage and current induced in the aerial or that in the closed circuit. It is claimed that a type will soon be perfected that will carry 10 amperes.

It has not been found practicable to vary the arc current sufficiently to produce large powers in the oscillating circuits. Arcs in parallel and in series have been tried but without marked success.

220. The arc method of producing undamped oscillations with direct current was discovered by Professor Elihu Thompson in 1892 and has been developed by many other investigators. In order to prevent the oscillations from running back to the dynamo choke coils or very high resistances must be placed in the D. C. leads. (See figs. 104 and 105.)

The simple theory of the formation of the oscillations is as follows:

When the shunt containing inductance and capacity is closed around the arc in a circuit like that shown in fig. 104, a part of the current flows into the condenser, thus robbing the arc of a part of its current; but as the D. C. potential across an arc increases as the current decreases, this decrease in current increases the potential difference, and the condenser continues to charge. At the next instant, however, the condenser commences to discharge, increasing the direct arc current until it is entirely discharged; then the process repeats itself.

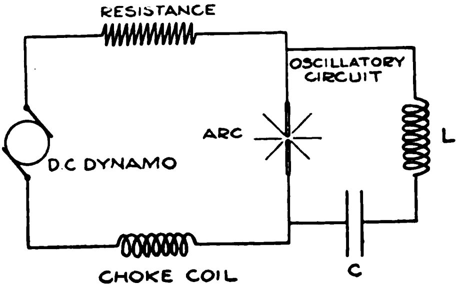


FIG. 104.

Oscillations can be produced in this way from almost any form of arc and over a wide range of voltages, but it is found that high frequency oscillations are best produced when the direct current voltage is high (500 volts or more), and when the positive arc electrode is capable of conducting away heat rapidly. This rapid cooling of the arc plays a very important part in the production of the oscillations, as it causes the arc to die down rapidly and increases the suddenness with which the current flows into the condenser. It has also been found that when the arc is formed in an atmosphere capable of assisting in this cooling, the energy of the oscillations is vastly increased. The best gaseous conductor of heat is hydrogen, and consequently the best results are obtained in an atmosphere of hydrogen or some mixed gas or vapor containing hydrogen. Common illuminating gas gives excellent results, and recently alcohol introduced into the arc chamber drop by drop and vaporized by the heat of the arc has come into use. It has been suspected that these gases and vapors may have some effect on the electrical conductivity of the arc as well as on its cooling, but this point is still unsettled.

221. Another device which is made use of for increasing the energy of the oscillations which can be obtained from the arc is forming it in a magnetic field the lines of force of which are at right angles to the arc length. The action of the magnetic field is twofold; first it deflects the arc to one side, increasing its length and consequently the difference of potential between the arc electrodes, and second, it blows out of the field the conducting ions formed in the gas, thus decreasing the arc conductivity and still further increasing the difference of potential between the electrodes.

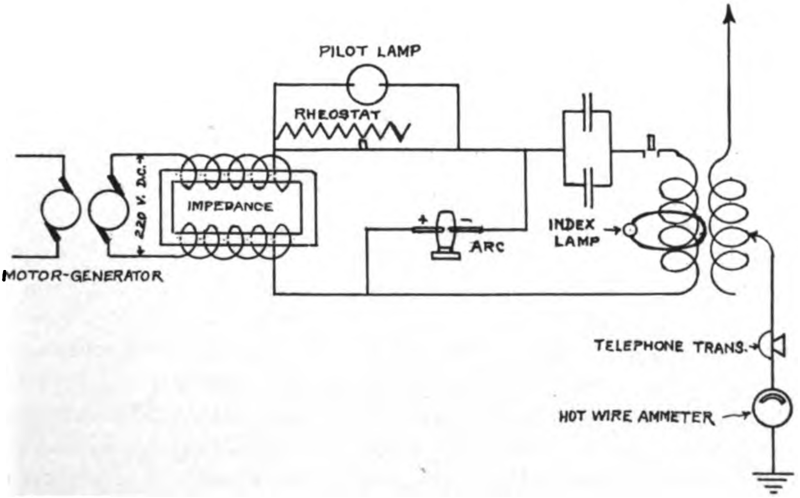


FIG. 105.

For the successful production of oscillations a correct relation must exist between the arc current, the arc length, and the strength of the magnetic field. This relation in general can be obtained only by experiment. If these adjustments are not correctly made several sets of useless superposed oscillations may be produced in the condenser circuit. Therefore it is necessary in working with waves produced from the arc to examine its oscillations from time to time with the wave meter, in which, if the adjustment be correct, but one sharp and powerful maximum will be found.

Fleming states that the best results are obtained when the ratio of the capacity to the inductance in the oscillating circuit is small—about 1 to 20—when both are measured in centimeters.

222. Fessenden has developed another means of producing undamped oscillations by constructing alternators giving as high as 150,000 alternations per second. The open circuit is connected directly to the terminals of these alternators and tuned to the alternator frequency. The use of these very high frequency alternators does away with all transformers, condensers and inductances except the aerial tuning inductance. They are, however, not yet in general use, being difficult to construct and, on account of their high speed, difficult to operate.

They are suitable for either wireless telephony or telegraphy.

223. The advantage to be derived from the use of undamped oscillations is considerable. We have forms of wireless detectors, like the electrolytic and perikon receivers, which respond in proportion to the total energy passing through them. Detectors of this kind will give the same response whether the energy is introduced in the form of an undamped continuous train of small amplitude or a damped train consisting of a few waves some of which are of large amplitude. The undamped waves offer great advantages in the way of sharp tuning, and enable the receiving circuits to be so set up that they may be made comparatively free from the interference from other stations and from atmospheric disturbances.

The advantages at the sending stations are no less important, for there, with the high potentials used in a spark circuit, a considerable portion of the energy is wasted on account of brush discharges in the condensers and in other portions of the circuit, and on account of leakage due to faulty insulation. With the undamped oscillations these difficulties practically disappear, for with maximum potentials not exceeding 1000 volts in the primary circuit, an amount of energy can be transmitted to the antenna which would with the spark circuit require potentials of 30,000 or more volts. It is also claimed for the undamped oscillations that they travel over rough and broken country with much less absorption than is found in the case of the ordinary spark waves, but in regard to this and many other questions concerning the qualities of undamped oscillations we must wait for confirmation until they come into more general use.

In using undamped oscillations for wireless telegraphic purposes it must be remembered that the frequency of the oscillations themselves is too high to be heard in the telephone connected with the ordinary receiving circuit, and when the circuit at the sending station is closed all that would be heard is a slight click, so that there is no way of telling a dot from a dash. This makes it necessary to place a rapidly rotating circuit breaker in the circuit for the purpose of creating a buzz in the telephone at the receiving station when the circuit is closed. This circuit breaker is ordinarily placed in the aerial, while the sending key is placed either in the aerial or shunted around a few turns of the aerial inductance, in which case it serves merely to throw the aerial in and out of tune with the closed circuit.

THE POULSEN TICKER RECEIVER FOR UNDAMPED OSCILLATIONS.

224. If no interrupter is used in the sending apparatus for undamped oscillations, no signals can be read at a receiving station unless the wave trains are there broken up so as to produce a buzz in the telephone. For this purpose the Poulsen ticker is sometimes used, which at the same time does away with the need of any special receiver. It consists essentially of a circuit breaker actuated by a small magnetic vibrator, kept in action by a dry cell. In this receiver the closed circuit is coupled very loosely to the antenna (see fig. 106), and this circuit is intermittently connected to a large condenser K, of the order of a microfarad, by the ticker at A.

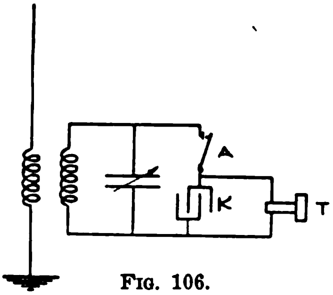


FIG. 106.

During the time of contact the condenser K becomes charged, and when the contact is broken it discharges itself through the telephone, producing a note corresponding in tone to the frequency of the ticker.

DIRECTION FINDERS.

225. The experimental installations of direction finders have been withdrawn, it not being found practicable to operate them. The principle on which they operated was that two vertical wires parallel to the plane of movement of an electric wave, if half a wave length apart, would have electric currents of opposite phase induced in them, which could be made to double the receiving effect as compared with a single wire, while if at right angles to the plane of movement of the wave, the induced currents would be in the same direction and could be made to neutralize each other. If the plane of this direction finder pointed towards the sending station, the strength of the received signals would be a maximum. If at right angles to the sending station, it would be a minimum.

By swinging the ship in azimuth, the compass heading, when the strength of signal was a maximum, would indicate the line of bearing of the sending station. The practical difficulty in the way of operating this system to the best advantage is the very short waves which are necessary on account of the comparatively short distances that can be obtained between wires on board ship. For instance, with masts 200 feet apart the wave length should be 400 feet, whereas the navy standard wave length is 1275 feet. The plane of such an aerial relative to the direction of the electric waves makes a difference in the strength of received signals whether the distance between wires is half a wave length or not. And this fact is utilized in the Bellini-Tosi apparatus where two such aerials are installed (see fig. 63) in planes at right angles to each other. The open circuit receiving coils are mounted so that they are in the same planes as their aerials. The closed circuit coil can be placed in the plane of either aerial or in any intermediate position. Its plane when the strength of signals is a maximum is approximately that of the passing waves.

226. No attempt to send directed waves from ships has been made.

On shore, direction finders can be more successfully used than on ships.

It is found by Marconi that a flat top aerial like fig. 64 sends more strongly in the direction away from the free end of the aerial and receives more strongly from the direction in which it sends the best. This effect with the comparatively short horizontal part of the aerial on ships is not appreciable, but on shore where the horizontal part can be made long as compared with the vertical part it has proved to be of practical use, both as a direction sender and receiver. The trans-Atlantic wireless stations at Clifden and Glace Bay have their aerials pointing away from each other. To be used as a direction finder such an aerial would have to be revolved rapidly or the horizontal part extended in a number of directions like the spokes of a wheel, to any one of which the vertical part could be connected at will.

PORTABLE SETS.

227. These, as their name indicates, are special small sets which have their own source of power, such as a foot or hand operated generator, and when used on shore have portable masts for supporting the aerial. On board ship this single wire aerial can be run up by signal halliards, and if insulated wire is used (since portable sets work usually at low voltages) no particular care need be taken to prevent the wire from touching the mast, deck or rigging.

The suit-case type illustrated in fig. 107 weighs about 75 pounds complete. It has a motor generator for ship use, which has an output of 50 watts and can be plugged in on any lighting circuit. Small gasolene driven generators are used for some portable shore sets, the entire sending and receiving apparatus being mounted on wheels. The power or hand operated generator set of the suit-case type is good for about 20 miles. (See fig. 107.) A complete set is seen with condenser, inductance, and key in the left half; motor generator, quenched gap, transformer, and receiving apparatus on the right half of the case; with the plug for connecting up with the lighting or power circuit at the upper left hand corner.

228. To illustrate an actual wireless telegraph installation the station at Sitka, Alaska, has been selected. This station is situated on Japonski Island (see frontispiece). The masts, rigging and rigging insulators, aerial and buildings are shown in fig. 108; one unit of the generating sets in fig. 109; the receiving apparatus in fig. 110. These figures repay study as illustrating a neat and workmanlike installation. The sending and receiving apparatus is after the designs of Professor Pierce.

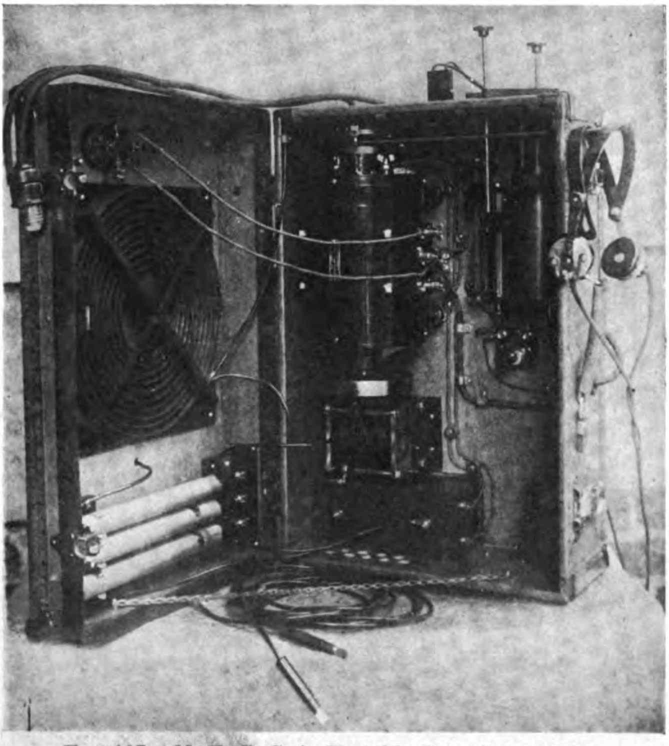


FIG. 107.—N. E. S. Co.'s Portable Set Signal Corps.

Figs. 111 and 111a illustrate actual receiving sets of other types, the elementary diagrams of which are shown in figs. 83 and 86.

The construction and arrangement of both sending and receiving apparatus will continue to vary, but a careful study of elementary diagrams (figs. 40 to 48 and 77 to 88) in connection with installation diagrams like figs. 112, 112a, 112b, 112c, which accompany each set will enable an electrician to connect up and operate any set intelligently. There are too many types of apparatus in use to warrant a detailed description or illustration of each. Such description and instructions are furnished with each set. This manual has therefore been confined to the principles common to practically all wireless sets.

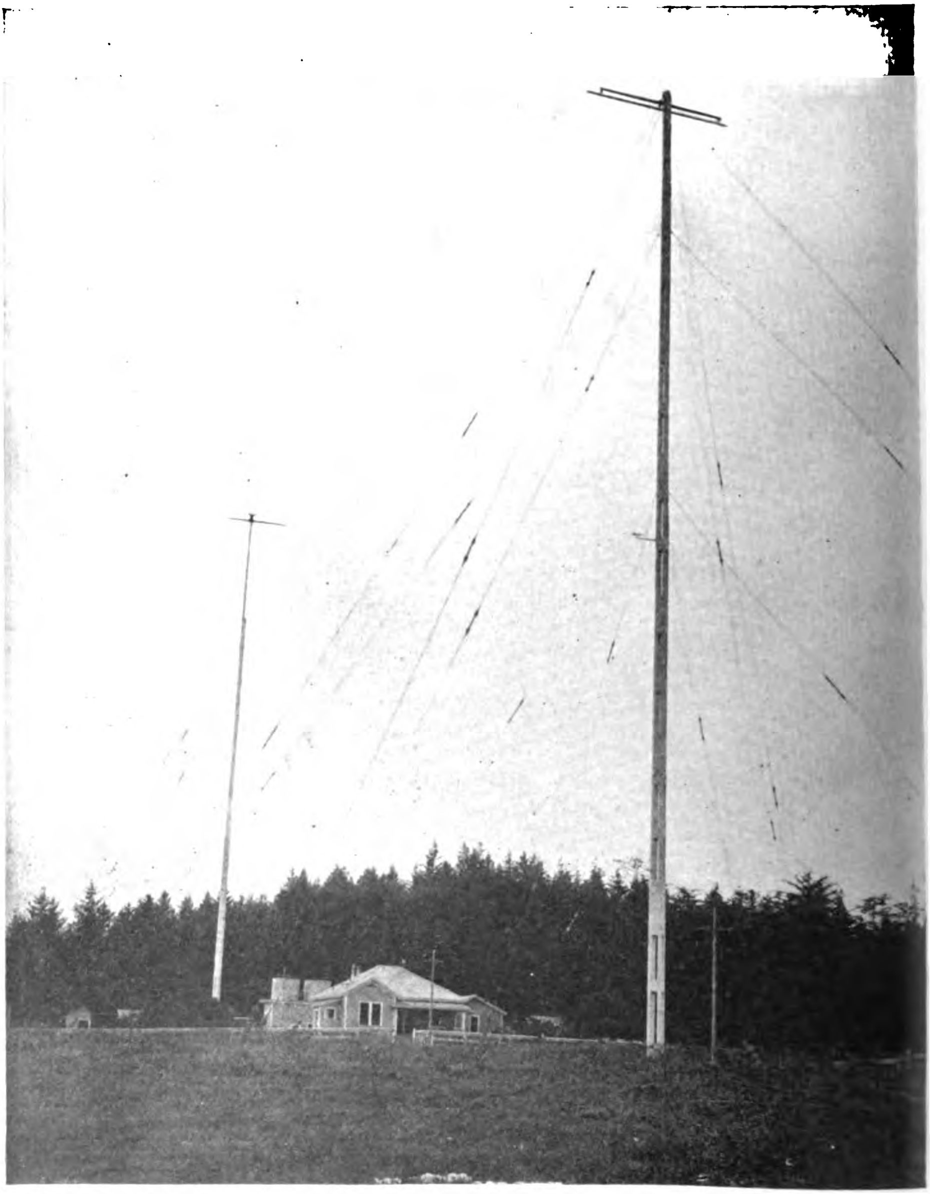


FIG. 108.

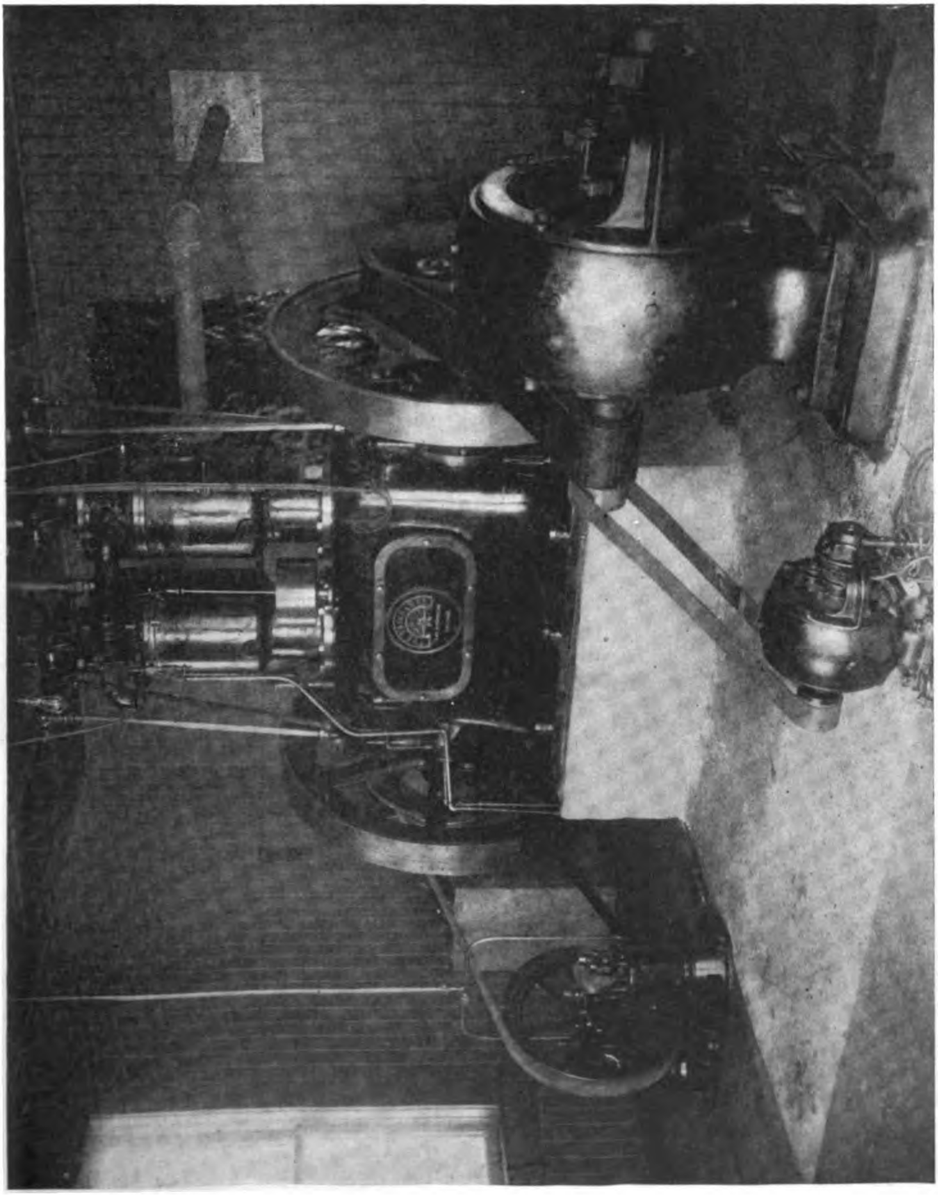


FIG. 109.

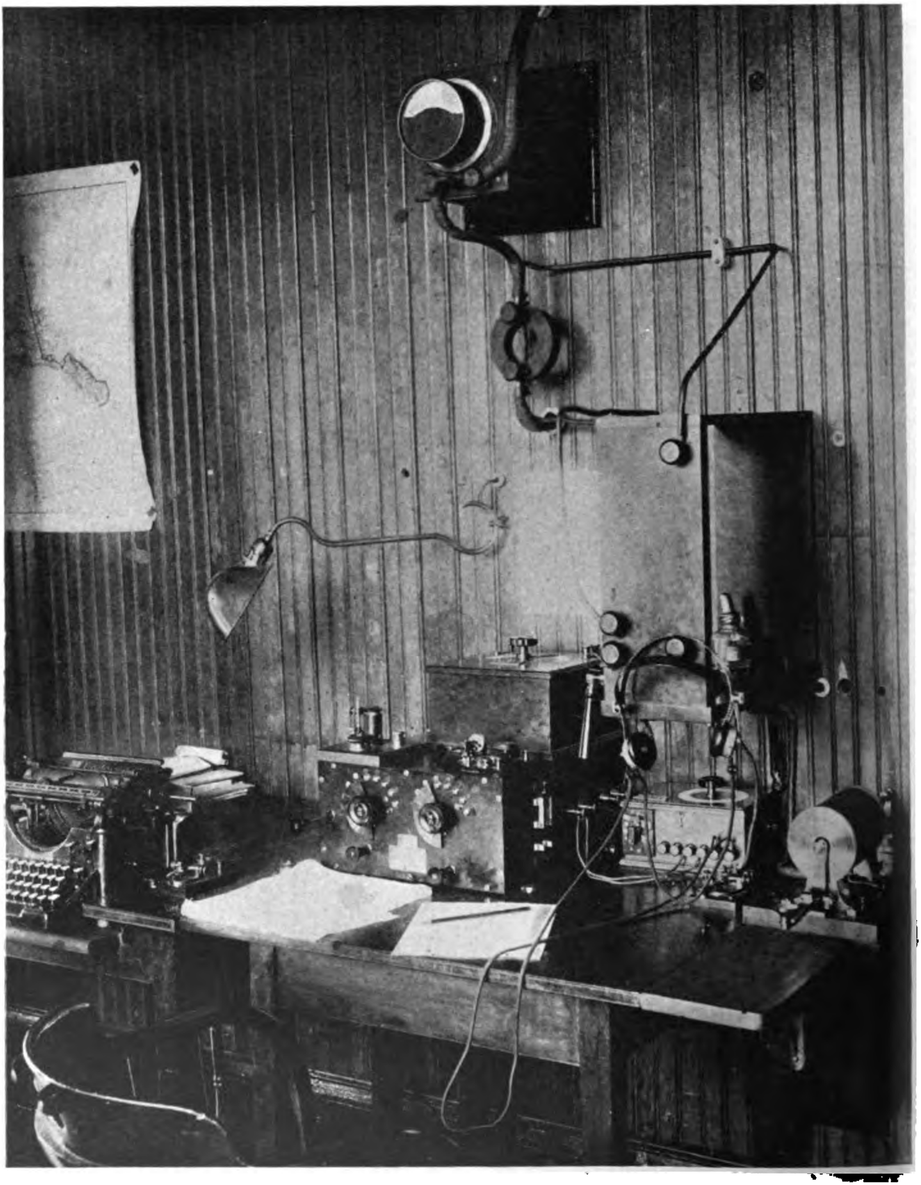


FIG. 110.

FIG. 111.—Wireless Telegraph Receiver.

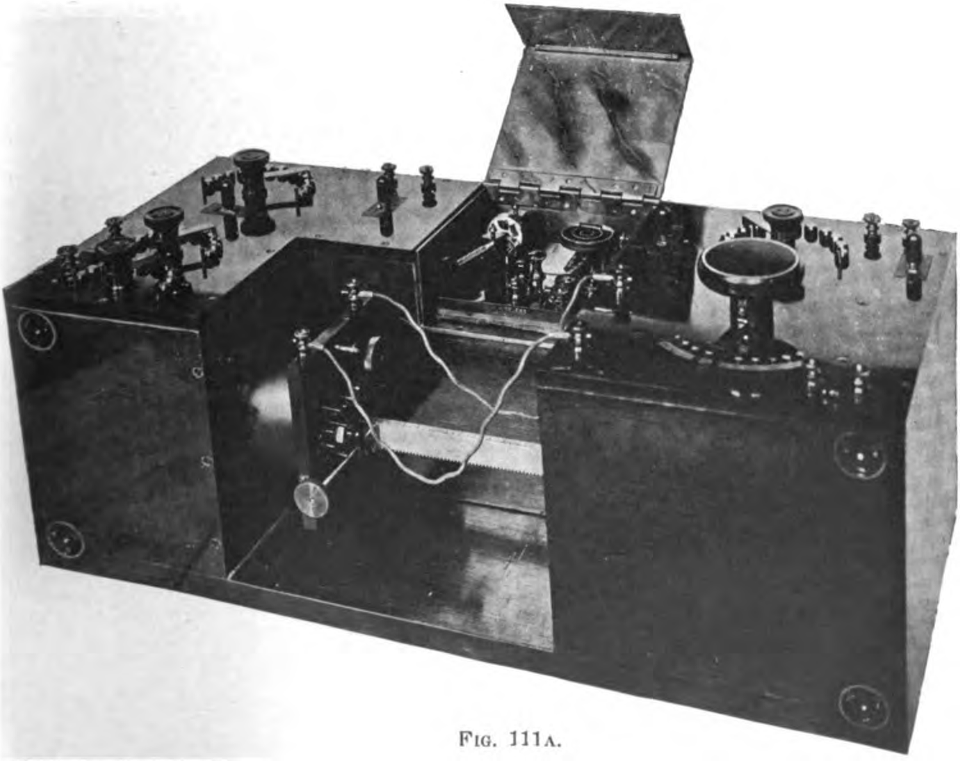
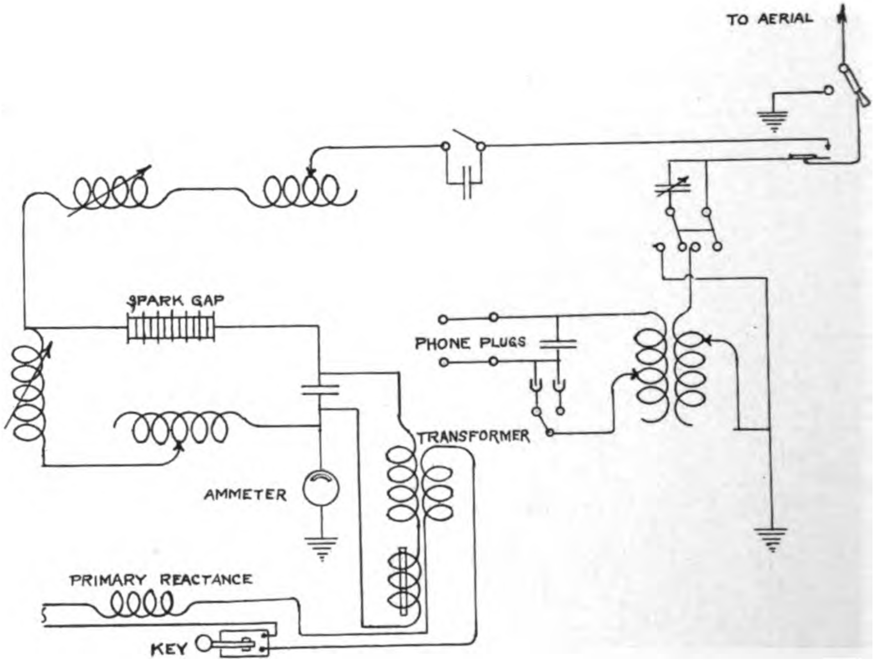
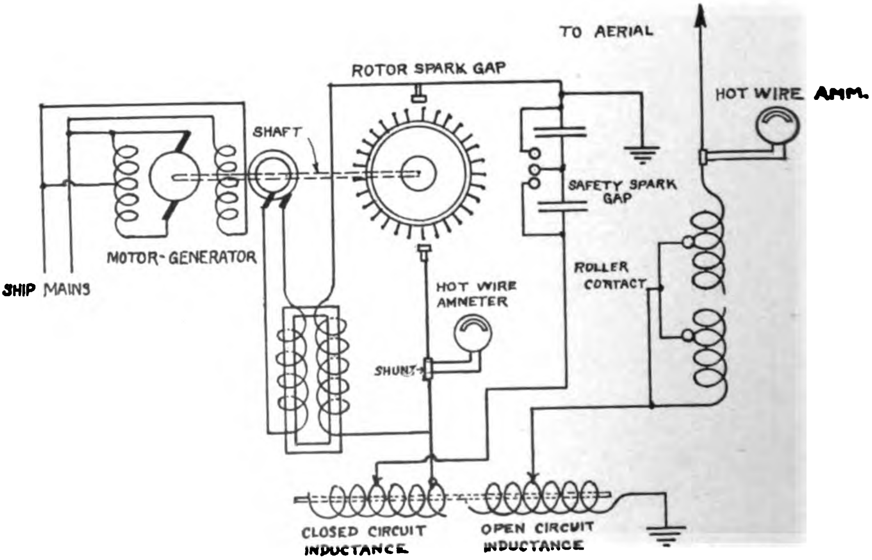


FIG. 111A.



TELEFUNKEN.

FIG. 112.



FESSENDEN

FIG. 112A.

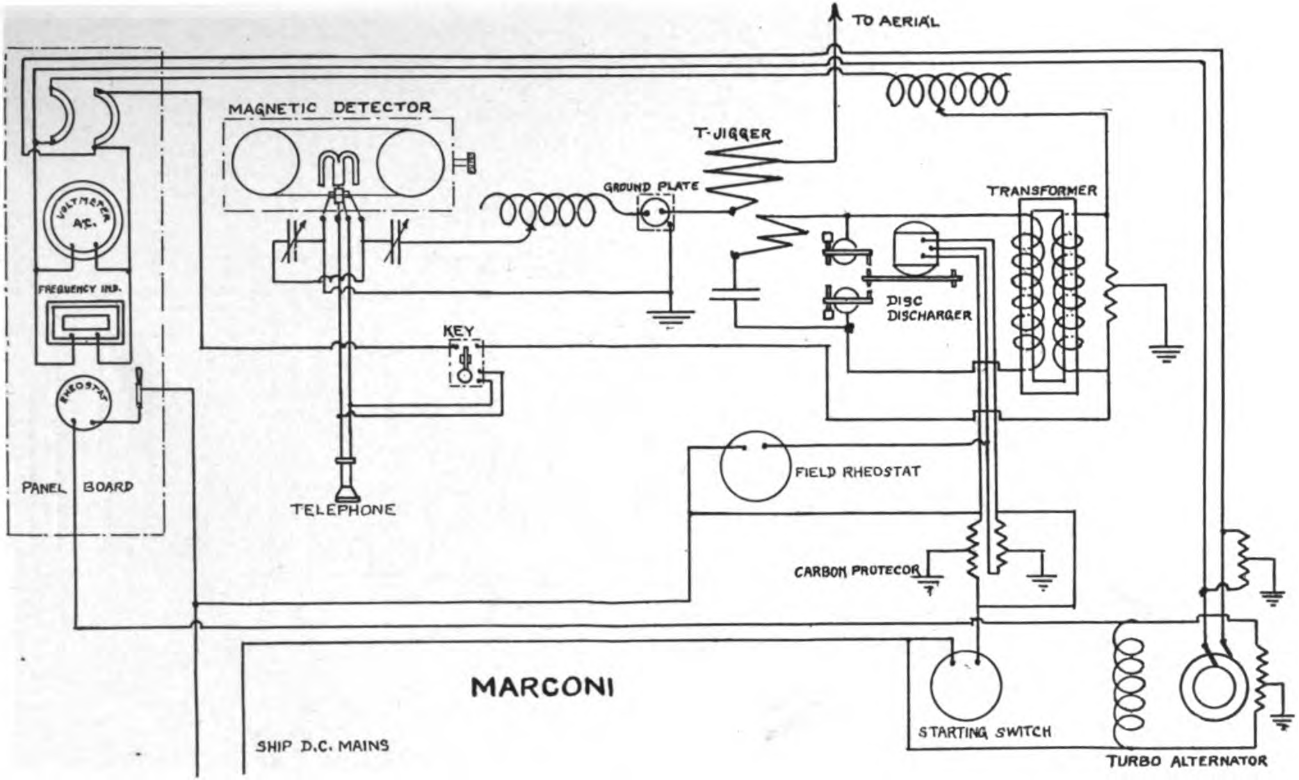

TO AERIAL
MAGNETIC DETECTOR
T-JIGGER
GROUND PLATE
TRANSFORMER
VOLTMETER A.C.
FREQUENCY IND.
KEY
DISC DISCHARGER
RHEOSTAT
FIELD RHEOSTAT
PANEL BOARD
TELEPHONE
CARBON PROTECOR
MARCONI
SHIP D.C. MAINS
STARTING SWITCH
TURBO ALTERNATOR

FIG. 112B.

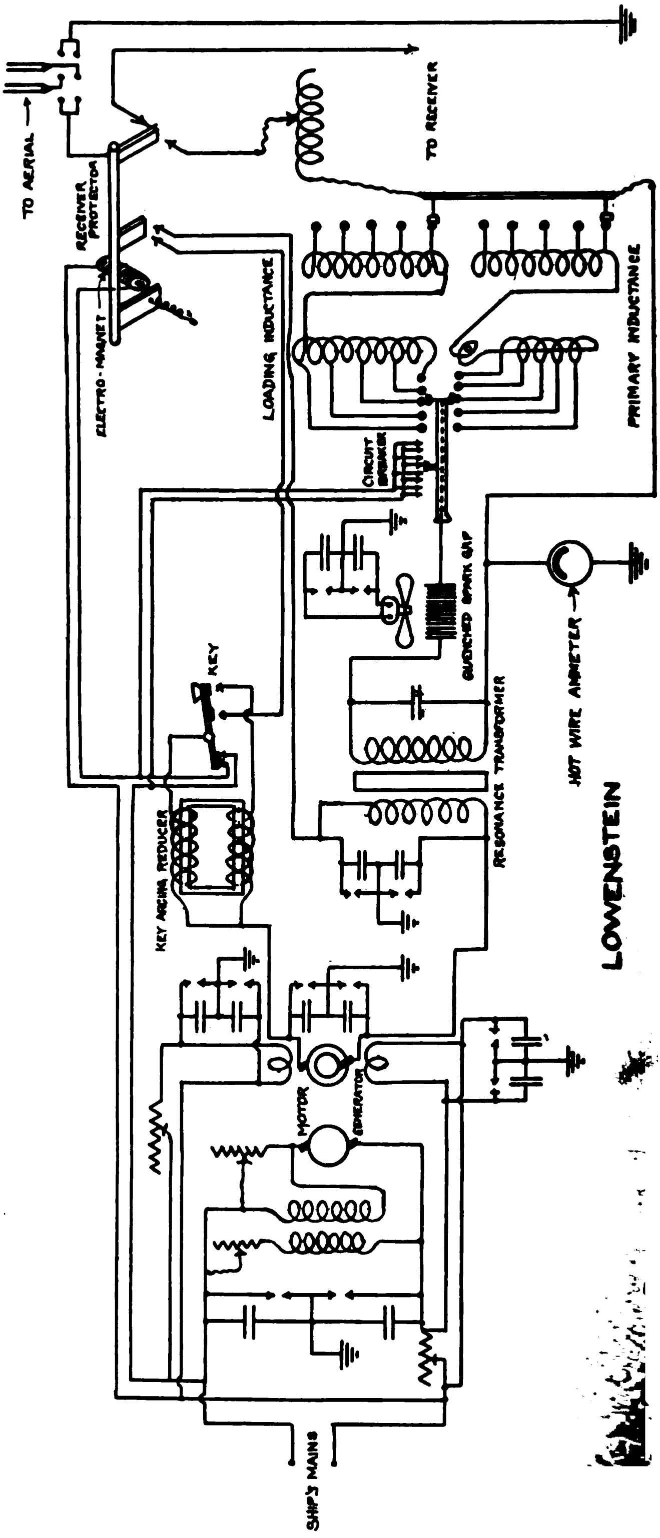

TO AERIAL
RECEIVER PROTECTOR
TO RECEIVER
ELECTRO-MAGNET
LOADING INDUCTANCE
PRIMARY INDUCTANCE
CIRCUIT BREAKER
QUENCHED SPARK GAP
HOT WIRE AMMETER
RESONANCE TRANSFORMER
KEY
KEY ARCING REDUCER
MOTOR
GENERATOR
SHIP'S MAINS
LOWENSTEIN

FIG. 112C.

STATIC AND PREVENTION OF INTERFERENCE.

229. Methods of preventing interference by the use of standard calling wave lengths and codified standard communicating wave lengths were referred to under *codes* (art. 215). The use of undamped oscillations would materially assist in the sharp tuning necessary to accomplish the above successfully; but neither undamped nor damped oscillations can be relied upon to completely eliminate the effects of the vagrant waves and local electrification grouped under the name of "static."

Every lightning discharge produces powerful electric waves which affect conductors at great distances, and since thunderstorms in warm climates, and especially in summer, are almost continuous in the sense of existing somewhere in the area in which they affect detectors, the interference caused by them is almost continuous.

The waves created by lightning discharges vary greatly in length; but are highly damped and affect all aerials more or less. Again, at every wireless station the air at the top and foot of the aerial is at different potentials. The atmospheric potential gradient at any station varies with the time of day, the season of the year, and the local weather conditions. It is usually steeper in summer.

This difference of potential tends to equalize itself through the aerial.

The upper air is usually positively electrified, the earth negatively.

The amount and regularity of the discharge to ground at any time depends on the difference of potential between the upper air and the ground at the time and the amount of electrified air which comes in contact with the aerial.

The discharges are usually intermittent and vary in strength. Sometimes they produce a continuous roar in the telephone.

In this respect the *note* of the spark affects reception and it is possible to read a 500-cycle note through static which would render a 60-cycle note unintelligible.

Whatever tends to selectivity or inertia in receiving circuits, such as large inductances, also tends to decrease static interference.

Inductively coupled receiving sets afford a direct path to ground, so that static charges do not accumulate on the aerial, and the inductive coupling weakens the energy transfer of all induced currents which are out of tune.

We see therefore that loose coupling, small damping and high frequency, which we desire for other reasons, are also desirable as tending to eliminate static interference.

APPENDICES.

NOTE 1.

The following list of metals is arranged in such order that any one will be the positive pole of the battery when used with the metal next below it on the list as a battery element and the negative pole when used with the element next above it, the difference of potential between any two being greater the farther apart they are in the series.

Carbon.
Platinum.
Gold.
Silver.
Copper.
Iron.
Lead.
Cadmium.
Tin.
Zinc.
Magnesium.
Sodium.

The amount of potential difference also depends on the battery solution, and in some instances it may be reversed. Commercial primary batteries are of copper and zinc, with an E. M. F. of approximately 1 volt, and carbon and zinc, with an E. M. F. of from 1.4 in Leclanché cells and some dry cells to 2.1 in some types of wet cells, depending on the electrolyte.

NOTE 2.

The relations existing between electricity and matter have been most exhaustively investigated by Prof. J. J. Thomson, who has proved that electricity has an atomic structure and that it can exist separately from an atom of matter.

When a current is sent through a vacuum tube, the luminous beam proceeding from the cathode has been shown to consist of particles projected from the cathode. These particles are capable of turning a small wheel. The cathode beam can be deflected by either a magnetic or an electric field, and it is found to consist of particles of *negative electricity* or of parts of the atom negatively charged, each having about one-thousandth of the mass of an atom of hydrogen.

These particles are the same, no matter what gas is used in the vacuum tube. They are usually called electrons. When an electron is broken off from an atom, the remaining part is positively charged. Currents of electricity, however produced, are the result of the decomposition of atoms into positive and negative electric charges. There can be no electric current without movement of electrons. Conductors are bodies in which the breaking up of atoms and movements of electrons takes place more or less easily. Some free electrons exist in all bodies. It is by setting these into vibration and by means of this vibration making them break off similar particles from neighboring atoms, and thus propagate the disturbance throughout the mass of the conductor, that electric currents are generated.

APPENDIX A.

TABLE 1.

[Extract from Fleming's Cantor lecture, Journal of Society of Arts, p. 196, January 5, 1906. Taken mostly from A. Heydweiller, "On Spark Potentials." Ann. der Physik, Vol. 248, p. 235 (1898).]

SPARK VOLTAGE BETWEEN BRASS BALLS 2 CENTIMETERS IN DIAMETER FOR VARIOUS SPARK LENGTHS.

Spark length (cms.).	Spark voltage.	Spark length (cms.).	Spark voltage.
0.1	4,700	1	31,300
0.2	8,100	1.5	40,300
0.3	11,400	2	47,400
0.4	14,500	2.5	53,000
0.5	17,500	3	57,500
0.6	20,400	3.5	61,100
0.7	23,250	4	64,200
0.8	26,100	4.5	67,200
0.9	28,800	5	69,800

TABLE 2.

CONDENSER CAPACITY REQUIRED TO GIVE FULL POWER FOR ONE-HALF INCH SPARK GAP AND ONE DISCHARGE PER HALF CYCLE.

K. W.	60 cycles.	120 cycles.	460 cycles.	500 cycles. 10.000 volts (¼" spark).
1	0.019 m. f.	0.009 m. f.	0.002 m. f.	0.010 m. f.
2½	0.047 "	0.023 "	0.006 "	0.025 "
5	0.093 "	0.047 "	0.012 "	0.050 "
10	0.185 "	0.093 "	0.024 "	0.100 "
15	0.278 "	0.139 "	0.036 "	0.150 "
35	0.648 "	0.324 "	0.085 "	0.350 "

1 standard jar condenser = 0.002 m. f.

$$\text{K. W.} = \frac{\text{microfarads} \times \text{volts} \times \text{volts} \times \text{frequency} \times 2}{1{,}000{,}000 \times 1000}.$$

TABLE 3.

INCREASE OF RESISTANCE OF COPPER WIRE AT A FREQUENCY OF 400,000 PER SECOND (750 METER WAVE LENGTH).

Diameter of wire.	Increase in resistance.
0.2 mm.	1 per cent.
0.4 "	22 "
0.8 "	120 "
2.0 "	650 "
4.0 "	1000 "

TABLE 4.

SPECIFIC RESISTANCE OF WATER AND SOILS.

Sea water	100
Fresh water	100,000
Damp soil	10,000 — 100,000
Dry soil	>1,000,000

TABLE 5.

LOGARITHMIC DECREMENT (δ) OF WAVE TRAIN AND THE APPROXIMATE NUMBER OF WAVES (N.) IN THE TRAIN BEFORE THE AMPLITUDE FALLS TO ONE-TENTH OF THE MAXIMUM.

δ	N	δ	N
1.0	3.5	.1	24.0
0.8	4.0	.08	30.0
.6	5.0	.06	39.0
.4	7.0	.04	58.0
.3	8.5	.03	78.0
.2	12.5	.02	116.0

Good tuning is not possible with less than fifteen waves in the train.

TABLE 6.

SOME COMMON UNITS EXPRESSED IN TERMS OF ABSOLUTE UNITS.

1 microfarad $= 1 \cdot 10^{-15}$ c. g. s.
1 millihenry $= 1 \cdot 10^{6}$ "
1 microhenry $= 1 \cdot 10^{3}$ "
1 volt $= 1 \cdot 10^{8}$ "
1 ohm $= 1 \cdot 10^{9}$ "
1 ampere $= 1 \cdot 10^{-1}$ "
1 watt $= 1 \cdot 10^{7}$ "

TABLE 7.

SOME COMMON HIGH-FREQUENCY EQUATIONS.

The time of oscillation of a condenser circuit is

$$T = 2\pi \sqrt{LC} \text{ seconds.}$$

(L in henries, C in farads.)

$$v = n\lambda \text{ and } T = \frac{1}{n},$$

where v is the velocity, n the frequency, and λ the wave length.

The wave length is therefore

$$\lambda = v \cdot 2\pi \sqrt{LC},$$

$$\lambda = 1.885 \sqrt{LC} \,.10^{9} \text{ meters.}$$

In a condenser charged N times per second the energy passing through in one second is

$$P = \frac{1}{2} \frac{CV^2}{10^6} N \text{ watts.}$$

(C in microfarads and V in volts.)

The damping of a single circuit is

$$\delta = \frac{R}{2nL}.$$

(R in ohms and L in henries or both in absolute units.)

The damping of two circuits by the resonance method,

$$\delta_1 + \delta_2 = \pi \frac{C_m - C}{C_m} \sqrt{\frac{I^2}{I_m^2 - I^2}},$$

or

$$\delta_1 + \delta_2 = 2\pi \frac{\lambda_m - \lambda}{\lambda_m} \sqrt{\frac{I^2}{I_m^2 - I^2}}.$$

See art. 208.

The following equation and tables are the results of experiments conducted between Brant Rock station and the cruisers *Salem* and *Birmingham* in 1909-10. See "Some Quantitative Experiments in Long Distance Radio-Telegraphy," by L. W. Austin, Reprint No. 159, from Bulletin Bu. of Standards, Vol. 7, No. 3, Feb. 1, 1911.

Equation: $I_R = 4.25 \times I_S \times \frac{h_1 h_2}{d\lambda} \times e^{-\frac{\alpha d}{\sqrt{\lambda}}}$.

I_S = Antenna current, sending, in amperes.
I_R = Antenna current, receiving, amperes through 25 ohms.
h_1 = Height of flat-top antenna, sending station, in kilometers.
h_2 = Height of flat-top antenna, receiving station, in kilometers.
$\alpha = .0015$.
d = Distance in kilometers.
λ = Wave length in kilometers.
$e = 2.7183$.

25 ohms = high-frequency resistance of ship aerial of 1000-meter wave length.

The above equation covers the normal-day received current over salt water, through 25 ohms for two stations with flat-top aerials of any height, with any value of sending current and any wave length, provided the sending station is so coupled as to give but one wave length.

The following tables (8, 9, 10 and 11, 12) illustrate the application of this equation:

TABLE 8.

For good communication received current should be equal to $I_R = 40 \times 10^{-6}$ amperes through 25 ohms $= 40 \times 10^{-8}$ watts $= \frac{4}{10}$ erg per second.

For audible signals $I_R = 10 \times 10^{-6}$ amperes through 25 ohms $= 2.5 \times 10^{-9}$ watts $= \frac{1}{40}$ erg per second.

TABLE 9.

Calculated Relation between Antenna Current and Distance for Two Ships with Antenna Heights of 130 Feet.

$\lambda = 1000$ m.

Antenna Current I_S.	Working Distance 40.10^{-6} amp.		Extreme Distance of Audibility 10.10^{-6} amp.	
	Day.	Night. (Zero Absorption)	Day.	Night. (Zero Absorption)
1 amp.	75 miles	90 miles	200 miles.	360 miles
2	135	180	300	720
3	180	270	375	1080
5	235	450	475	1800
7	280	630	550	2520
10	345	900	630	3600
15	420	1350	725	5400
20	475	1800	790	7200
25	525	2250	840	9000
30	565	2700	900	10800
40	630	3600	970	14400
50	685	4500	1075	18000
60	725	5400	1150	21600

TABLE 10.

Good Working Distance and Sending Current for Two Stations with Flat-Top Antennas 450 Feet High.

Nautical Miles.	$\lambda = 1000$ m.	$\lambda = 2500$ m.	$\lambda = 3750$ m.	$\lambda = 6000$ m.
1000	15 amp.	13.5 amp.	15 amp.	17 amp.
1250	88	27	27	30
1500	91	49	44	46
1750	200	95	77	74
2000	490	155	122	105
2250		245	200	160
2500		470	314	235
2750			500	335
3000			775	500

TABLE 11.—Currents in Microamperes Received through 25 Ohms for a Sending Current of 30 Amperes and Sending and Receiving Flat-Top Antenna Heights of 130 Feet, over Salt Water. [Calculated from Eq. 3.]

Nautical Miles.	d – Km	λ = 300 m.		λ = 600 m.		λ = 1000 m.		λ = 1500 m.		λ = 2500 m.		λ = 3750 m.		λ = 6000 m.	
		K = 6.67.10⁵.		K = 3.33.10⁵.		K = 2.10⁵.		K = 1.33.10⁵.		K = 8.10⁴.		K = 5.33.10⁴.		K = 3.33.10⁴.	
		$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R	$\frac{K}{d}$	I_R
20	37	18000	16300	9000	8350	5400	5100	3590	3430	2160	2080	1440	1400	900	880
50	92.5	7200	5600	3600	3020	2160	1880	1435	1282	864	790	576	536	360	340
100	185	3600	2170	1800	1270	1080	817	720	578	431	361	280	249	180	161
200	370	1800	650	900	433	540	310	359	228	216	152	144	108	90	71.8
300	556	1200	263	600	205	360	156	240	122	144	85	96	62.4	60	42.7
400	740	900	116	450	107	270	89	180	73	108	53.6	72	40.8	45	28.6
500	925	720	55.4	360	60.2	216	53.8	144	46.3	86.4	35.9	57.6	28.2	36	20.5
600	1110	600	27.6	300	34.8	180	34.2	120	31.1	72	25.3	48	20.4	30	15.2
800	1480	450	7.72	225	12.8	135	14.7	90	14.8	54	18.1	36	11.5	22.5	9.06
1000	1850	360	2.27	180	4.97	108	6.7	72	7.5	43.1	7.42	28.8	6.77	18	5.80
1200	2220	300	0.66	150	2.0	90	3.24	60	3.95	36	4.36	24	4.34	15	3.89
1500	2780	240	0.12	120	0.54	72	1.10	48	1.58	28.8	2.04	19.2	2.25	12	2.18
2000	3700	180	0.0061	90	0.069	54	0.205	36	0.385	21.6	0.64	14.4	0.817	9	0.928
2500	4630	144		72	0.0066	43.2	0.088	24.8	0.098	17.3	0.218	11.5	0.318	7.2	0.418
3000	5560	120		60	0.0010	36	0.0079	24	0.031	14.4	0.078	9.1	0.129	6.0	0.198

TABLE 12.—Sending Currents Required to Produce Received Currents as Given in Table 11 for Various Antenna Heights.

$h_1 = h_2$.	I_S amp.		$h_1 = 450$ ft.			$h_1 = 200$ ft.			$h_1 = 130$ ft.			$h_1 = 100$ ft.	
			h_2.	I_S amp.		h_2.	I_S amp.		h_2.	I_S amp.		h_2.	I_S amp.
32.5 ft.	490		32.5 ft.	34.5		32.5 ft.	78		32.5 ft.	120		32.5 ft.	156
65	120		65	17.3		65	39		65	60		65	78
100	[illegible]		100	11.3		100	25.3		100	39		130	39
130	[illegible]		130	8.7		130	19.5		160	24.4		160	31.8
160	[illegible]		160	7.1		160	15.8		200	19.5		200	25.4
200	[illegible]		200	5.6		300	8.5		300	13		300	16.9
300	[illegible]		300	3.75		450	5.65		450	8.7		450	11.3
450	[illegible]												

APPENDIX B.

1. The facilities of the naval coastwise wireless telegraph stations (including the one on the Nantucket Shoal light-ship), for communicating with ships at sea, where not in competition with private wireless telegraph stations, are placed at the service of the public generally and of maritime interests in particular under rules which are subject to modification from time to time, for the purpose of—

(*a*) Reporting vessels and intelligence received by wireless telegraphy with regard to maritime casualties, derelicts at sea, and overdue vessels.

(*b*) Receiving wireless telegrams of a private or commercial nature from ships at sea, for further transmission by telegraph or telephone lines.

(*c*) Transmitting wireless telegrams to ships at sea.

2. For the present, this service will be rendered free. All messages will, however, be subject to the tariffs of the land lines. Arrangements have been made with both the Western Union and Postal Telegraph companies for forwarding messages received from ships at sea. When a message is not prepaid the company delivering it will collect the charges. Shipowners should arrange with companies operating the land lines as to tariffs and the settlement therefor.

3. The light-ship stations will report vessels and transmit messages from them if the signals are made by the international code or any other known to the officers on the light-ship.

4. When notified by the Weather Bureau of the Department of Agriculture, naval wireless telegraph stations will give storm warnings to vessels communicating with them by wireless telegraphy. Storm warnings will be sent to the light-ships by wireless telegraphy, and storm signals furnished by the Weather Bureau will be displayed therefrom to warn passing vessels. Storm warnings and hydrographic information, such as location of derelicts and other dangerous obstructions to navigation, are sent broadcast at 8 A. M., noon (immediately after noon-time signal), 4 P. M. and 8 P. M. local standard time when received. Weather reports and other hydrographic information on file are furnished on request.

5. All vessels having the use of the naval wireless telegraph service are requested to take daily meteorological observations of the weather when within communicating range and to transmit such observations to the Weather Bureau by wireless telegraphy at least once daily, and transmit observations oftener when there is a marked change in the barometer.

6. All shipowners desiring to use any special code of signals for communicating with the Nantucket Shoal light-ship station or any of the shore stations, or make any other special arrangements, should communicate with the Navy Department, Washington, D. C.

7. All chambers of commerce, maritime exchanges, newspapers, news agencies, and others desiring to have vessel reports and general marine news forwarded to them regularly should communicate with the Navy Department in order that necessary arrangements for the service may be made. In no case will an operator attached to a station be allowed to act as an agent for any individual or corporation, but all vessel reports and marine news not of a private nature will be supplied to all applicants, so long as this service does not too greatly tax the personnel of the stations, when it will be necessary for those desiring information involving much time for its distribution to appoint agents, who will be allowed access to the station bulletins.

8. Naval wireless telegraph stations are equipped with apparatus of several systems and can communicate with all the wireless telegraph systems now in use, if tuned to the same wave length. The Department is desirous of co-operating with all shipowners wishing to avail themselves of its wireless telegraph service, and it is believed that there will be little or no difficulty in arranging for communication between its stations and ships equipped with apparatus of other systems, if the owners of the apparatus as well as the owners of the ships are desirous of establishing such communication.

INSTRUCTIONS FOR COMMUNICATION BY WIRELESS TELEGRAPHY BETWEEN WIRELESS TELEGRAPH STATIONS AND SHIPS.

I. A vessel wishing to communicate with a station and having ascertained by " listening in " that she is not interfering with messages being exchanged within her range should make the call letter of the station.

II. The call should not be continuous, but should be at intervals of about three minutes in order to give the station a chance to answer.

III. After the station answers the vessel should send her name, distance from station, weather, and number of words she wishes to send; then stop until the station makes O. K., signals the number of words she wishes to send to vessel, and signals go ahead.

IV. Then the vessel begins to send her messages, stopping at the end of each 50 words and waiting until the station signals O. K. and go ahead; when all messages have been sent she will so indicate. If the sender desires to designate the Western Union or Postal Telegraph system for further transmission of his message, he should do so immediately after the address, as, for example " A. B. C., Washington, D. C., via W. U. (or P. T.)."

V. When a vessel has indicated that she has finished, the station will send to the vessel such messages as she may have for her in the following order:

(*a*) Government business, viz., telegrams from any Government Departments to their agents on board.

(*b*) Business concerning the vessel with which communication has been established, viz., telegrams from owner to master.

(*c*) Urgent private dispatches, limited.

(*d*) Press dispatches.

(*e*) Other dispatches.

VI. In the case of the Nantucket Shoal light-ship, it will, immediately on receiving the vessel's call, acknowledge, and (after receiving vessel's name, distance, weather report, and number of words she wishes to send) transmit the first three to Newport, and then tell the vessel to go ahead with her messages.

VII. After receiving these and sending the vessel any message on file for her, the light-ship will transmit to Newport messages received from the communicating vessel in the following order:

(*a*) Government business.

(*b*) Urgent private dispatches, limited.

(*c*) Press dispatches.

(*d*) Other dispatches.

VIII. A naval wireless telegraph station has the right to break in on any message being sent by a vessel at any time, and the right of way may be given at any time to a government vessel or one in distress.

IX. When two or more vessels desire to communicate with a naval wireless telegraph station at the same time, the one whose call is first received will have right of way, and the others will be told to wait and will be taken up in turn. Vessels having been told to wait must cease calling.

X. In case communication is not established with any ship for which messages are on file, the naval wireless telegraph station will notify the telegraph company from which the messages were received, giving sufficient information for them to identify the telegrams and notify the sender.

XI. In order to obtain the best results, both sending and receiving apparatus should be tuned to wave length of 425 meters. (Subject to change.)

XII. In order that all messages received at naval wireless telegraph stations may be forwarded to ships for which they are intended, and in order that all ships equipped with wireless telegraph apparatus may receive storm warnings, they should always report when in signaling distance of a naval wireless telegraph station.

XIII. The service being without charge at present, the Government accepts no responsibility for the reception or transmission of messages from or for passing vessels. Every effort will be made to transmit all messages without error and as expeditiously as possible. It must be remembered that errors are not uncommon in ordinary telegraph and cable messages, so that due allowance should be made.

XIV. In order that the service may be made as good and as useful as possible, complaints should be promptly reported to the Navy Department as soon as possible after the cause therefor, giving date, hour and other details, to enable the Department to investigate the case.

XV. Information regarding the naval wireless telegraph service will be published in "Notices to Mariners," issued by the Hydrographic Office of the Navy Department.

(Rules XV to XXXII, adopted by the International Wireless Telegraph Conference of Berlin, 1906, are in force at U. S. Naval coastwise wireless telegraph stations. See Appendix C for the most important of these.)

APPENDIX C.

SERVICE REGULATIONS ANNEXED TO THE INTERNATIONAL WIRELESS TELEGRAPH CONVENTION.

[Extracts from International Wireless Telegraph Convention, Berlin, November, 1906.]

ARTICLE 2.

By "coastal stations" is to be understood every wireless telegraph station established on shore or on board a permanently moored vessel used for the exchange of correspondence with ships at sea.

Every wireless telegraph station established on board any vessel not permanently moored is called a "station on shipboard."

ARTICLE 3.

The coastal stations and the stations on shipboard shall be bound to exchange wireless telegrams without distinction of the wireless telegraph system adopted by such stations.

IV.

It is understood that, in order not to impede scientific progress, the provisions of Article 3 of the convention shall not prevent the eventual employment of a wireless telegraph system incapable of communicating with other systems, provided, however, that such incapacity shall be due to the specific nature of such system and that it shall not be the result of devices adopted for the sole purpose of preventing intercommunication.

1. ORGANIZATION OF WIRELESS TELEGRAPH STATIONS.

I.

The choice of wireless apparatus and devices to be used by the coastal stations and stations on shipboard shall be unrestricted. The installation of such stations shall, as far as possible, keep pace with scientific and technical progress.

II.

Two wave lengths, one of 300 meters and the other of 600 meters, are authorized for general public service. Every coastal station opened to such service shall use one or the other of these two wave lengths. During the whole time that a station is open to service it shall be in condition to receive calls according to its wave length, and no other wave length shall be used by it for the service of general public correspondence. Each government may, however, authorize in coastal stations the employment of other wave lengths designed to insure long-range service or any service other than for general public correspondence established in conformity with the provisions of the convention, provided such wave lengths do not exceed 600 meters or that they do exceed 1600 meters.

III.

1. The normal wave length for stations on shipboard shall be 300 meters. Every station on shipboard shall be installed in such manner as to be able to use this wave length. Other wave lengths may be employed by such stations provided they do not exceed 600 meters.

2. Vessels of small tonnage which are unable to have plants on board insuring a wave length of 300 meters may be authorized to use a shorter wave length.

IV.

1. The International Bureau shall be charged with drawing up a list of wireless telegraph stations of the class referred to in Article 1 of the convention. Such list shall contain for each station the following data:

(1) Name, nationality and geographical location in the case of coastal stations; name, nationality, distinguishing signal of the International Code and name of ship's home port in the case of stations on shipboard.

(2) Call letters (the calls shall be distinguishable from one another and each must be formed of a group of three letters).

(3) Normal range.

(4) Wireless telegraph system.

(5) Class of receiving apparatus (recording, acoustic or other apparatus).

(6) Wave lengths used by the station (the normal wave length to be underscored).

(7) Nature of service carried on by the station.

General public correspondence.

Limited public correspondence (correspondence with vessels . . . .).

(8) Hours during which the station is open.

(9) Coastal rate or shipboard rate.

2. The list shall also contain such data relating to wireless telegraph stations other than those specified in Article 1 of the convention as may be communicated to the International Bureau by the management of the Wireless Telegraph Service ("administration") to which such stations are subject.

V.

The exchange of superfluous signals and words is prohibited to stations of the class referred to in Article 1 of the convention. Experiments and practice will be permitted in such stations in so far as they do not interfere with the service of other stations.

VI.

1. No station on shipboard shall be established or worked by private enterprise without authority from the government to which the vessel is subject. Such authority shall be in the nature of a license issued by said government.

2. Every station on shipboard that has been so authorized shall comply with the following requirements:

(*a*) The system employed shall be a syntonized system.

(*b*) The rate of transmission and reception, under normal conditions, shall not be less than twelve words a minute, words to be counted at the rate of five letters each.

(*c*) The power transmitted to the wireless telegraph apparatus shall not, under normal conditions, exceed 1 kilowatt. Power exceeding 1 kilowatt may be employed when the vessel finds it necessary to correspond while more than 300 kilometers distant from the nearest coastal station, or when, owing to obstructions, communication can be established only by means of an increase of power.

3. The service of the station on shipboard shall be carried on by a telegraph operator holding a certificate issued by the government to which the vessel is subject. Such certificate shall attest the professional efficiency of the operator as regards:

(*a*) Adjustment of the apparatus.

(*b*) Transmission and acoustic reception at the rate of not less than 20 words a minute.

(*c*) Knowledge of the regulations governing the exchange of wireless telegraph correspondence.

4. The certificate shall furthermore state that the government has bound the operator to secrecy with regard to the correspondence.

2. Hours of Service of Coastal Stations.

VIII.

1. The service of coastal stations shall, as far as possible, be constant, day and night, without interruption.

XVI.

Ships in distress shall use the following signal:

● ● ● ▬ ▬ ▬ ● ● ●

repeated at brief intervals.

As soon as a station perceives the signal of distress it shall cease all correspondence and not resume it until after it has made sure that the correspondence to which the call for assistance has given rise is terminated.

In case the ship in distress adds at the end of the series of her calls the call letters of a particular station the answer to the call shall be incumbent upon that station alone. If the call for assistance does not specify any particular station, every station perceiving such call shall be bound to answer it.

XVII.

1. The call letters following the letters

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"P R B" signify that the vessel or station making the call desires to communicate with the station called by means of the International Signal Code.

The combination of the letters "P R B" as a service signal for any other purpose than that specified above is prohibited.

2. Wireless telegrams may be framed with the aid of the International Signal Code.

Those addressed to a wireless telegraph station with a view to being forwarded by it are not to be translated by such station.

3. Method of Calling Wireless Stations and Transmission of Wireless Telegrams.

XIX.

1. As a general rule, it shall be the shipboard station that calls the coastal station.

2. The call should be made, as a general rule, only when the distance of the vessel from the coastal station is less than 75 per cent of the normal range of the latter.

3. Before proceeding to a call, the station on shipboard shall adjust its receiving apparatus to its maximum sensibility and make sure that the coastal station which it wishes to call up is not in correspondence with any other station. If it finds that any transmission is in progress, it shall wait for the first pause.

4. The shipboard station shall use for calling the normal wave of the coastal station.

XX.

1. The call shall comprise the signal.

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the call letters of the station called repeated three times, the word "from" ("de") followed by the call letters of the sending station repeated three times.

2. The called station shall answer by making the signal

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followed by the call letters of the corresponding station repeated three times, the word "from," its own call letters, and the signal

▬ ● ▬

XXIV.

Before beginning the exchange of correspondence the coastal station shall advise the shipboard station whether the transmission is to be effected in the alternate order or by series (Article XVIII); it shall then begin the transmission or follow up the preliminaries with the signal

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(invitation to transmit).

XXV.

The transmission of the wireless telegram shall be preceded by the signal

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and terminated by the signal

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followed by the name of the sending station.

XXVI.

When a wireless telegram to be transmitted contains more than 40 words, the sending station shall interrupt the transmission after each series of about 20 words by an interrogation point

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and shall not resume it until after it has obtained from the receiving station a repetition of the last word duly received, followed by an interrogation point.

In the case of transmission by series, acknowledgment of receipt shall be made after each wireless telegram.

XXVII.

1. When the signals become doubtful every possible means shall be resorted to to finish the transmission. To this end the wireless telegram shall be repeated at the request of the receiving station, but not to exceed three times. If in spite of such triple repetition the signals are still unreadable the wireless telegram shall be canceled. If no acknowledgment of receipt is received the transmitting station shall again call up the receiving station. If no reply is made after three calls the transmission shall not be followed up any further.

XXVIII.

All stations are bound to carry on the service with as little expense of energy as may be necessary to ensure safe communication.

4. Acknowledgment of Receipt and Conclusion of Work.

XXIX.

1. Receipt shall be acknowledged in the form prescribed by the International Telegraph Regulations, preceded by the call letters of the transmitting station and followed by those of the receiving station.

2. The conclusion of a correspondence between two stations shall be indicated by each station by means of the signal

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followed by its call letters.

APPENDIX D.

[PUBLIC—No. 262.]

[S. 7021.]

An Act to require apparatus and operators for radio-communication on certain ocean steamers.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the first day of July, nineteen hundred and eleven, it shall be unlawful for any ocean-going steamer of the United States, or of any foreign country, carrying passengers and carrying fifty or more persons, including passengers and crew, to leave or attempt to leave any port of the United States unless such steamer shall be equipped with an efficient apparatus for radio-communication, in good working order, in charge of a person skilled in the use of such apparatus, which apparatus shall be capable of transmitting and receiving messages over a distance of at least one hundred miles, night or day: *Provided,* That the provisions of this Act shall not apply to steamers plying only between ports less than two hundred miles apart.

SEC. 2. That for the purpose of this Act apparatus for radio-communication shall not be deemed to be efficient unless the company installing it shall contract in writing to exchange, and shall, in fact, exchange, as far as may be physically practicable, to be determined by the master of the vessel, messages with shore or ship stations using other systems of radio-communication.

SEC. 3. That the master or other person being in charge of any such vessel which leaves or attempts to leave any port of the United States in violation of any of the provisions of this Act shall, upon conviction, be fined in a sum not more than five thousand dollars, and any such fine shall be a lien upon such vessel, and such vessel may be libeled therefor in any district court of the United States within the jurisdiction of which such vessel shall arrive or depart, and the leaving or attempting to leave each and every port of the United States shall constitute a separate offense.

SEC. 4. That the Secretary of Commerce and Labor shall make such regulations as may be necessary to secure the proper execution of this Act by collectors of customs and other officers of the government.

Approved, June 24, 1910.

APPENDIX E.

WIRELESS TELEGRAPH STATION ROUTINE FOR UPKEEP OF STATION OUTFIT.

DAILY.

Wipe off all instruments with care.

Tighten contacts of receivers.

Clean commutators and collector rings.

Clean zinc oxide from zinc spark points, if fitted.

Blow water out of air lines.

Fill cylinder oil cup and lubricate governor.

In winter, tend heating apparatus carefully to prevent freezing of water in cylinders, pipes, etc., and keep oil fluid if necessary.

WEEKLY.

Rub down slate panels and instrument cases, examine contacts on panels, and vaseline moving contacts lightly.

Blow out armatures and fields of motor-generators, generators, and motors.

Lubricate chains on engines.

Clean bushings and exterior of transformers or induction coils.

Wipe off glass of condenser jars in air and clean contacts if necessary.

Clean jar rack.

Pump up compressed air condensers, if installed.

Clean and polish inductances and exposed leads of transmitter.

Clean thoroughly and set up all contacts of transmitter with care.

Clean and polish spark gap.

Polish key.

Polish wood, metal, and rubber of receiver.

Vaseline lightly the contacts of receiver switch and aerial switch if fitted, after cleaning.

Clean lightning switch and vaseline contacts lightly.

Clean all strainers.

Lubricate pistons of magnetic air valves and reducing valves.

Lubricate cylinders and bearings.

Lubricate working parts of valves in pipe lines and operate same.

MONTHLY.

Make cadmium tests of storage battery, if installed.

Clean oil injection nozzles.

Pack stuffing boxes of valves in pipe lines.

Clean and tighten contacts of ground where accessible.

SEMIANNUALLY.

Change oil of motor-generators, motors, and generators.

Refit and line bearings of same.

Empty oil storage tank and clean gauze strainer.

Dismount and clean oil tubes of lubricating system.

Dismount and seat check valves.

Dismount and clean tubes of feed oil distribution system.

Renew asbestos packing of oil pump.

Clean port openings, combustion spaces, exhaust ports, joint screws, and jackets of cylinders, and renew gaskets.

Dismount leyden jar condenser and clean thoroughly.

Lower aerial, wipe off insulators, oil blocks, overhaul halliards, and renew same when necessary.

Polish hard rubber of receiver, etc., using bisulphide of carbon.

APPENDIX F.

RESUSCITATION FROM APPARENT DEATH FROM ELECTRIC SHOCK.

BY AUGUSTIN H. GOELET, M. D.

The urgent necessity for prompt and persistent efforts at resuscitation of victims of accidental shocks by electricity is very well emphasized by the successful results in the instances recorded. In order that the task may not be undertaken in a half-hearted manner, it must be appreciated that accidental shocks seldom result in absolute death unless the victim is left unaided too long, or efforts at resuscitation are stopped too early.

In the majority of instances the shock is only sufficient to suspend animation temporarily, owing to the momentary and imperfect contact of the conductors, and also on account of the resistance of the body submitted to the influence of the current. It must be appreciated also that the body under the conditions of accidental shocks seldom receives the full force of the current in the circuit, but only a shunt current, which may represent a very insignificant part of the whole.

When an accident occurs, the following rules should be promptly executed with care and deliberation:

1. Remove the body at once from the circuit by breaking contact with the conductors. This may be accomplished by using a dry stick of wood, which is a nonconductor, to roll the body over to one side, or to brush aside a wire, if that is conveying the current. When a stick is not at hand, any dry piece of clothing may be utilized to protect the hand in seizing the body of the victim, unless rubber gloves are convenient. If the body is in contact with the earth, the coat tails of the victim, or any loose or detached piece of clothing may be seized with impunity to draw it away from the conductor. When this has been accomplished observe rule 2. The object to be attained is to make the subject breathe, and if this can be accomplished and continued he can be saved.

2. Turn the body upon the back, loosen the collar and clothing about the neck, roll up a coat and place it under the shoulders, so as to throw the head back, and then make efforts to establish respiration (in other words, make him breathe), just as would be done in case of drowning. To accomplish this, kneel at the subject's head, facing him, and seizing both arms draw them forcibly to their full length over the head, so as to bring them almost together above it, and hold them there for two or three seconds only. (This is to expand the chest and favor the entrance of air into the lungs.) Then carry the arms down to the sides and front of the chest, firmly compressing the chest walls, and expel the air from the lungs. Repeat this maneuver at least sixteen times per minute. These efforts should be continued unremittingly for at least an hour, or until natural respiration is established.

3. At the same time that this is being done, some one should grasp the tongue of the subject with a handkerchief or piece of cloth to prevent it slipping, and draw it forcibly out when the arms are extended above the head, and allow it to recede when the chest is compressed. This maneuver should likewise be repeated at least sixteen times per minute. This serves the double purpose of freeing the throat so as to permit air to enter the lungs, and also, by exciting a reflex irritation from forcible contact of the under part of the tongue against the lower teeth, frequently stimulates an involuntary effort at respiration. To secure the tongue if the teeth are clenched, force the jaws apart with a stick, a piece of wood, or the handle of a pocketknife.

4. The dashing of cold water into the face will sometimes produce a gasp and start breathing, which should then be continued as directed above. If this is not successful the spine may be rubbed vigorously with a piece of ice. Alternate applications of heat and cold over the region of the heart will accomplish the same object in some instances. It is both useless and unwise to attempt to administer stimulants to the victim in the usual manner by pouring them down his throat.

While the above directions are being carried out, a physician should be summoned, who, upon his arrival, can best put into practice rules 5, 6, and 7, in addition to the foregoing, should it be necessary.

For the Physician Summoned.

5. Forcible stretching of the sphincter muscle controlling the lower bowel excites powerful reflex irritation and stimulates a gasp (inspiration) frequently when other measures have failed. For this purpose, the subject should be turned on the side, the middle and index fingers inserted into the rectum, and the muscle suddenly and forcibly drawn backward toward the spine. Or, if it is desirable to continue efforts at artificial respiration at the same time, the knees should be drawn up and the thumb inserted for the same purpose, the subject retaining the position on the back.

6. Rhythmical traction of the tongue is sometimes effectual in establishing respiration when other measures have failed. The tongue is seized and drawn out quickly and forcibly to the limit, then it is permitted to recede. This is to be repeated 16 times per minute.

7. Oxygen gas, which may be readily obtained at a drug store in cities or large towns, is a powerful stimulant to the heart if it can be made to enter the lungs. A cone may be improvised from a piece of stiff paper and attached to the tube leading from the tank, and placed over the mouth and nose while the gas is turned on during the efforts at artificial respiration.

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