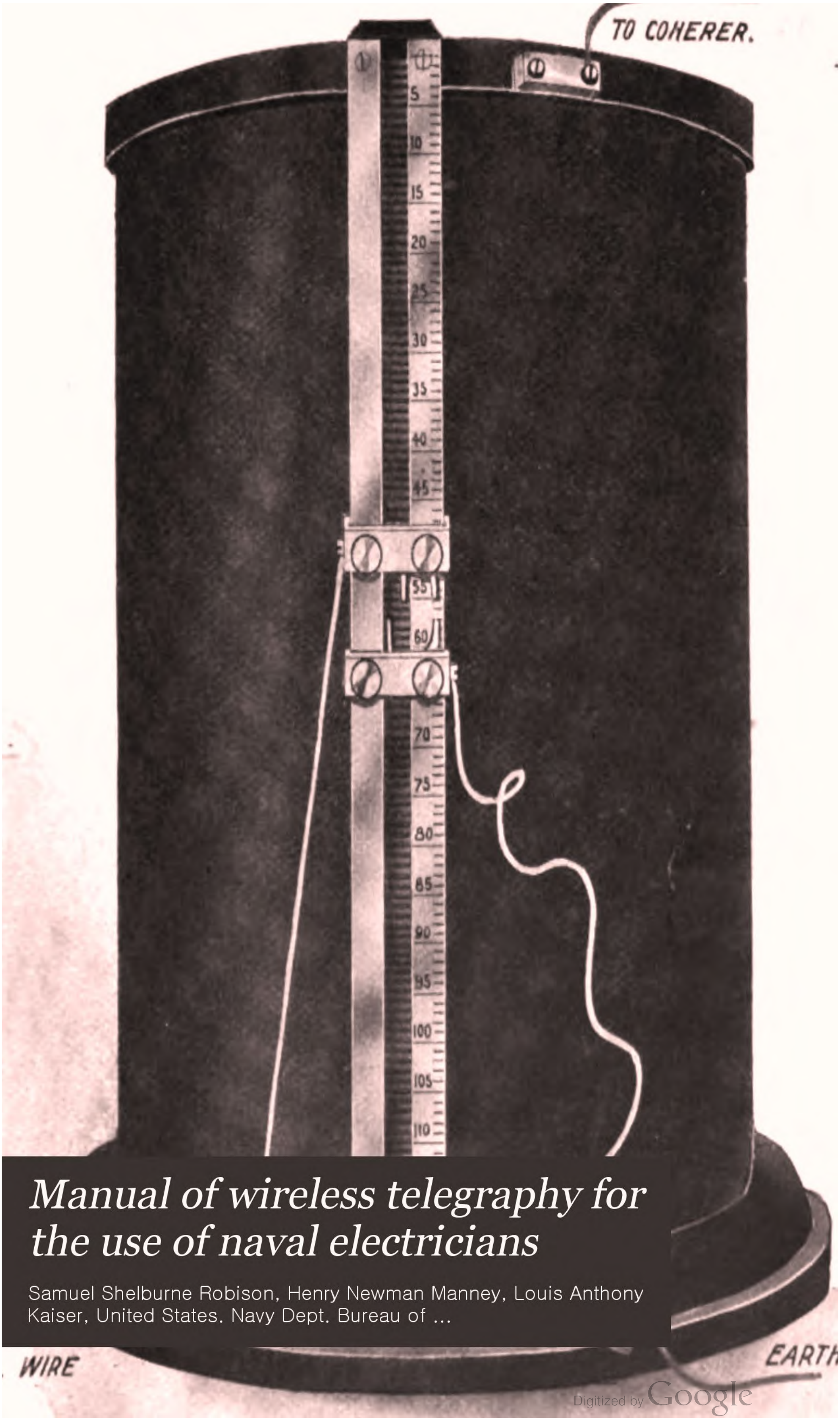
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WIRE

MANUAL

OF

WIRELESS TELEGRAPHY

FOR THE USE OF

NAVAL ELECTRICIANS.

By

LIEUTENANT-COMMANDER

S. S. ROBISON,

U. S. Navy.

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NOTE.

This manual has been prepared by the Bureau's direction to replace "Instructions for the use of Wireless Telegraph Apparatus," issued by the Bureau October 17, 1903, and prepared by the late Lieut. J. M. Hudgins, U. S. Navy, to whose work in wireless telegraphy the Navy is so greatly indebted.

Rear-Admiral H. N. Manney, U. S. Navy, and Lieut. Commander L. A. Kaiser, U. S. Navy, were associated with Lieut. Commander S. S. Robison, U. S. Navy, in the preparation of this manual.

This art has not yet reached a state where its instruments can be standardized without danger of becoming obsolete. It will therefore be necessary to revise this manual from time to time. The instructions herein should be carefully observed.

All errors found in text or figures should be promptly reported to the Bureau.

WM. S. COWLES,
Chief of Bureau.

BUREAU OF EQUIPMENT, NAVY DEPARTMENT,
July 10, 1906.

INTRODUCTION.

This book is divided into four chapters.

Chapter I contains a review of facts concerning electricity and magnetism which are directly connected with wireless telegraphy.

In the course of this review the vocabulary is partly developed, methods of producing and transforming electric power briefly discussed, and explanations given of electric and magnetic actions which will assist in making the theory and practice of wireless telegraphy easier to comprehend.

In Chapter II the derivation of electro-magnetic units and their names are explained, and illustrations given of their use in determining values of the constants and the power expended in wireless-telegraph circuits.

Chapter III is devoted mainly to a comparison of the different kinds of wireless-telegraph sets now in service, in the course of which some instructions relative to their use are given and the various parts described.

Chapter IV relates particularly to the adjustment of wireless-telegraph sending and receiving circuits, to which is added a description of the standard method of installation adopted, general instructions for installing and operating all sets, a short discussion of the interferences to which wireless telegraphy is subject, and the codes in use.

Where detailed descriptions or instructions would break the continuity of a chapter, they are given in full in numbered appendices and are only referred to in the text.

These appendices are:

A.—Spark voltages in air.

B.—Description and method of construction of ship aerials for wireless telegraphy.

C.—Instructions for fitting rigging on ships having wireless-telegraph sets.

D.—Instructions for the care of Slaby-Arco receiving instruments.

E.—Specification for receiving telephone for wireless-telegraph sets.

F.—Instructions for resuscitation from apparent death by electric shock.

G.—Regulations governing use of United States naval coastwise wireless-telegraph stations.

H.—Regulations for the government of wireless-telegraph stations.

I.—Instructions for keeping log books at wireless-telegraph stations.

K.—Instructions for installing and operating storage batteries.

L.—Deduction of fundamental equation of wireless telegraphy.

M.—Report on the calculation of self-induction.

They follow Chapter IV in order of their numbers, and are preceded by the two notes referred to in the text.

All figures and plates referred to in the text will be found in the back of the book, arranged in consecutive order. Figs. 1 to 51, inclusive, were drawn by H. D. Crocker, electrical draftsman, Bureau of Equipment.

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MANUAL OF WIRELESS TELEGRAPHY.

Chapter I.

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 *positive* element or *pole* of the cell and the zinc the *negative* element or *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.)

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.

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

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.

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 an electro-magnet is from the north to the south pole outside of the spiral, and from the south to the north 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. 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.

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 paragraph 8 that the strength of the magnetic field around an electro-magnet 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 (par. 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.[a]

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 (A B) of this wire is parallel, 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 (par. 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.

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

[a] By Professor Rowland, Johns Hopkins University.

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 paragraph 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.

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 (Par. 1), by chemical action (Par. 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 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 produces tresses 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 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. Movement 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. When equilibrium is restored one field or the other has disappeared, though they can coexist in a transitory state.

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.

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

19. 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.

20. 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.

21. 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.

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.

22. 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.

23. If A B is coiled into a spiral and C D into a similar spiral, 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.

24. We know that A B when coiled as in fig. 13 and traversed by a current forms an electro-magnet (par. 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 electro-magnet is iron, as in fig. 14, instead of air, the effect on C D is very much more powerful—i. e., the number 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, 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.

25. If the iron of fig. 14 is extended to include C D, as in fig. 14a, the effects 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.

26. 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 electromotive 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 are 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.* Auto transformers are very generally used in wireless telegraph sending circuits.

27. 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.

28. 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 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.

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

29. 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 disturbance 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.

30. 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 paragraph 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.

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. 15, 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. 15 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. 15. 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.

31. 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 paragraph 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 that (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.

32. 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.

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 C D is horizontal, as in fig. 16, the lines of force included will be zero, and when vertical, as in fig. 15, 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. 17)—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.

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 is moving parallel to the lines of force and therefore there are none being cut. 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.

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. 17 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.*

33. This can be shown graphically in fig. 18, where the rate of cutting 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 representing 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.[a]

[a] 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 angle. 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.

34. 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 an electro-magnet 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 the 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.

The currents in the coil E F are supplied from C D, and they are induced in C D by its movement 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 is now being replaced by alternate current.

35. 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 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.

36. 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 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.

38. 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 par. 24.)

39. The tendency to current flow in C D created by cutting lines of force is called the *electro-motive force* in C D (see par. 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 electro-motive 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.

40. In paragraph 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.

41. 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*.

42. The fact that magnet poles of unlike polarity attract each other (par. 6) applies to electro-magnets, with or without iron cores, as well as to permanent magnets. So that 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.

43. If, in fig. 17, C D, instead of being revolved by some outside agency is supplied with a current flowing through it in the direction shown, it will revolve in the opposite direction. This revolution is caused by the pull exerted by the field magnets on C D because of the current in C D, or, taking into account (fig. 21) the position of the magnetic poles created in the armature by the current flowing in the coils, the movement of C D may be considered as being 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 and the reverse action of the field poles on the south pole of the armature.

The movement will be continuous, because, as the top of the armature moves toward the south 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 and halfway between the field magnets.

44. C D 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.

45. The pulling power of 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.

METHODS OF PRODUCING CURRENTS USED IN WIRELESS TELEGRAPHY.

46. In wireless telegraphy the source of current may be:

(*a*) A *primary battery* (par. 5).

(*b*) A *direct current dynamo* (par. 35).

(*c*) An *alternating current dynamo* (par. 35).

(*a*) supplies current through an interrupter to the primary winding of a step-up transformer (par. 26).

(*b*) supplies current either through an interrupter to the primary winding of a step-up transformer or to a motor-generator, the generator of which supplies alternating current to the primary winding of a step-up transformer, or (*b*) supplies current to a *storage battery* (par. 4), which furnishes interrupted current direct to the transformer or direct current to a motor-generator which furnishes alternating current to the transformer.

(*c*) supplies alternating current to the primary winding of a step-up transformer.

Alternating current is preferred as being more efficient and uniform in action.

Step-up transformers supplied with alternating or interrupted current are part of all wireless telegraph sending apparatus.

ELECTRIC AND MAGNETIC FIELDS.

47. Electricity produced by friction (par. 1) is sometimes called *frictional electricity;* by primary batteries, *voltaic electricity;* by electro-magnetic 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.

48. 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 or stretches in the ether 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.

49. 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 (par. 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*.

50. If two plates, oppositely charged by being connected to the poles of a battery, as in fig. 22, 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.

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.

51. 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 par. 24.)

In the same way its permeability for electric induction is 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 which 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*.

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 glass is the dielectric, is nine times as strong as that created when the medium intervening between the charges is air, and it requires nine times as much work to create it.

52. 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 magnetic force will increase. When in this condition the magnetized body is said to be saturated.

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 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.

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.

53. 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.

54. 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 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.

55. 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.

56. 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, and are represented either as in fig. 23 or fig. 23a, alternate plates being similarly charged. This arrangement fulfills the requirements of surface and nearness of opposite charges with intervening dielectric. Condensers 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, or mica. 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 on a glass jar, the glass being the dielectric. A photograph of a Leyden jar is shown in Pl. I. 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.

DISCHARGE OF CONDENSERS.

57. 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.

58. 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 filed 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 friction 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.

59. 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. 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 (par. 193) and by their oscillatory movements.

60. 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* (par. 28) 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.

The attraction of the unlike charges for each other is analogous to the attraction of gravity in 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 wires of the condenser (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.

61. 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*.

62. Since every body has electric capacity in proportion to its surface (par. 52), 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.

63. 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.

64. We can see in a general way why 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.

65. It was stated (par. 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 velocity of electricity, which we know to be that of light, or 300,000,000 meters per second, and the number of complete oscillations per second is the reciprocal of its period.

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*.

65a. 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 current having small mechanical length, but comparatively great electrical length, can be made up in a small space.

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.*

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 num-

N. B.—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.

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ber of oscillations for one charge and prevents the complete discharge of the condenser, because the oscillations cease as soon as the potential falls below that necessary to rupture the gap. 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 it will not rupture the spark gap.

66. As stated in paragraph 52, 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 represents an *inductive resistance*, or simply an inductance, since it is assumed that all wires have resistance.

Fig. 27a represents a *noninductive resistance*, the uses of which will be explained later.

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.

67. 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. Oscillating circuits now used in wireless telegraphy have electrical lengths varying from 100 to 1,500 meters, giving from 1,500,000 to 100,000 oscillations per second. Those first used by Marconi had electrical lengths of about 12 centimeters and oscillated approximately 2,500,000,000 times per second.

ETHER WAVES.

68. As stated in paragraph 60, 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 electro-magnetic (ether) disturbances spread in all directions with the speed of light, and when sent out by an oscillating circuit succeed each other at equal intervals of time, and since the lines of magnetic and electric force in oscillating circuits change direction during each alternation, just as the particles of water rise to the crest or fall to the hollow of a wave, the positive and negative amplitudes may represent the crests and hollows of waves separated by half periods or half waves length, an oscillating circuit may be called a wave producer, and the oscillations considered as moving through the ether may be called ether waves.

69. The vibrations of particles producing sound waves, as in air, consist 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.

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 (par. 61) 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 larger 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.

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 and 1,500 trillions of vibrations per second we have the ultraviolet and X rays, and from 430 down to 300 trillions of vibrations per second the 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.

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 impulses, 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. 18e.

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

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. 18f, which represents the relative positions of current and potential nodes and loops in stationary electric waves, and illustrates the statements made in paragraph 60 (figs. 25a, etc.), relative to the alternations of electric and magnetic fields in oscillating condenser discharges.

If an oscillating current be set up in a free wire (fig. 18d) by a neighboring discharging circuit in resonance with it, this 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.

If at the same time the current in the 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.

69a. 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 pressure decreases with distance above the earth's surface, and its insulating qualities decrease with the decrease of pressure. At a height of approximately 45 miles above the earth's surface its pressure is about 1 millimeter of mercury. At 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. 18g 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.

REFRACTION OF ETHER WAVES.

69b. 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 gain on it or fall behind it. 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.

69c. 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 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 also takes place at the summit, as well as at the water's edge. 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. 18h, 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.

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 ballotted from thunder clouds at one point and absorbed by semiconducting gases at another, may be said to pursue an adventurous journey.

70. 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*.

The secondary winding of the transformer is very long, 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 it 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, paragraph 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 (par. 12), and C D becomes a source of *ether waves.*

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 form the primary and secondary, respectively, of an air-core transformer (par. 26). 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 autotransformer (fig. 14d) and A B and C D are said to be *direct* connected.

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 are 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.

71. 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.

UNITS.

72. 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*.

73. 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.

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.

74. 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.

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.

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 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*.

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.

An *erg* by definition is a dyne overcome through a centimeter, and a *foot-pound* is 453.59 × 981 dynes overcome through 30.48 centimeters; therefore a *foot-pound* equals 453.59 × 981 × 30.48 = approximately 13,570,000 ergs, and a horse power, which equals 550 foot pounds, per second = 453.59 × 981 × 30.48 × 550 = approximately 7,460,000,000 ergs per second.

75. On account of the fact that the names adopted for the *practical* electro-magnetic 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.

The absolute units used in electrical measurements are those of electro-motive force, current, and resistance. They are defined in terms of the c. g. s. system.

76. The flow of electric current in any conductor is found to be governed by the tendency to flow (the electro-motive force) and the resistance of the conductor.

The resistance is found to be governed by the material, size, and length of the conductor.

An electric current generated by moving a conductor in a magnetic field creates its own magnetic field around the conductor. The stronger the current, the stronger its magnetic field, and the greater the reactive effect or pull on the conductor in which the current is flowing, and consequently the greater the amount of work necessary to keep the conductor moving across the lines of force.

The E. M. F., which causes the current, depends on rate of cutting or rate of movement. The force opposing this movement depends on the current flowing, and this again on the resistance of the circuit.

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 at 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).

If the resistance of the circuit is decreased one-half the current is doubled, opposition to movement is also doubled, and consequently the work is doubled. In other words, the current varies inversely as the resistance and the work done varies directly as the current.

If the rate of movement is increased so that 2 square centimeters of the field (two lines of force) are cut per second the E.M.F. is doubled, the current is doubled, the opposition to movement is doubled, and consequently the work per second is quadrupled because it represents the force of 2 dynes overcome through 2 centimeters in one second. This shows that the work done varies with the electro-motive force as well as with the current, and the work per second or the power therefore varies as the product of the E. M. F. and current, since it varies directly with each.

It also shows that the current varies directly with the E. M. F.

We have seen that it varies inversely as the resistance.

We can state therefore that current $= \frac{\text{E. M. F.}}{\text{Resistance}}$ (1) and that the the work done in creating the current is equal in ergs per second to E. M. F. $\times$ current (2).

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

Equation (1) can therefore be written $I = \frac{E}{R}$ (3) and (2) written $P = \frac{W}{T} = I\,E$ (4).

Equation (3) 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."

77. Since magnetic fields containing 125,000 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, and 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 $I = \frac{E}{R}$ (3), 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. $I = \frac{E}{R}$ (3) or amperes $= \frac{\text{volts}}{\text{ohms}}$, because this equation in terms of the aboslute 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 $I = \frac{E}{R}$ (3). 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 (4)) equals unit E. M. F. $\times$ 100,000,000 $\times$ $\frac{\text{unit current}}{10}$, or 10,000,000 ergs per second. Therefore 1 watt equals 10,000,000 ergs per second, and the power expended in any circuit in watts equals the product of the volts and amperes in the circuit, or $P = E\,I$ (4).

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 watt $= \frac{1}{746}$ H. P. = approximately 0.737 foot-pounds per second.

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

However, by balancing them against known weights, the actual *pulls* produced by currents and the work necessary to create them can be determined, and thus the absolute values of the currents and E. M. Fs. themselves determined.

The current from certain primary batteries is found to be constant when their terminals are connected by the same wire. This affords a means of directly comparing the resistances of wires of various sizes, lengths, and materials.

It is also found that the decomposition of an electrolyte (par. 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 and determining their absolute values.

The relation between heat and mechanical energy being known, the relation between electrical and mechanical energy was practically determined by measuring the heat produced by electric currents, and the absolute values obtained by the methods outlined above were verified.

79. On account of the relation $I = \frac{E}{R}$ (3) 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, held in Berlin in October, 1905, 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* is defined as the E. M. F. which produces an electric current of 1 ampere in a conductor whose resistance is 1 ohm.

In this conference the United States delegate contended for the volt and the ohm as the theoretically independent units, and it is not yet certain that these two will not be those finally selected as standards.

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 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 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 1,000.

(A Clark cell consists of zinc, or an amalgam of zinc with mercury, and of mercury in a neutral saturated solution of zinc sulphate and mercurous sulphate in water, prepared with mercurous sulphate in excess.)

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 1.025 volts.

(The Weston cadmium cell consists of cadmium amalgam, covered with a layer of crystals of cadmium sulphate and pure mercury in contact with a paste of mercurous sulphate, cadmium sulphate crystals, and metallic mercury, the electrolyte being a concentrated aqueous solution of cadmium sulphate and mercurous sulphate.)

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

80. 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.)

HENRY.

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 E. M. F. (par. 89)—tending to oppose the change is 1 volt.

81. While the volt, the ampere, and the ohm are really practical units, the farad and henry are not.

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 $\frac{1}{1,000}$ 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. In fact, the real 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 microfarau and the millihenry.

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

82. The *voltage*, or E. M. F., in any circuit connected with a dynamo depends only on the rate of cutting of lines of force.

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 (henrys) in any circuit depends only on the shape and length of the circuit, on the magnetic permeability (par. 24) 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 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.

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.

83. Referring now to the definitions of the henry and farad, it is evident that they depend on the units of E. M. F. and current.

If these definitions 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.

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.

84. We can now add to our table of value in paragraph 82 the following:

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

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

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

A millihenry $=\frac{1}{1,000}$ henry $=10^6$ absolute units of self-induction.

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

Both self-induction and capacity are sometimes expressed in centimeters.

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 a meter represents, theoretically, $\frac{1}{10,000,000}$ part of an earth quadrant—i. e., the distance from the equator to the North Pole. Since a quadrant = 1,000,000,000 centimeters, and since the henry = 1,000,000,000 absolute units of self-inductance it may be said to = 1,000,000,000 centimeters.

In this notation, which is still used by some writers, a millihenry = 1,000,000 centimeters.

The *units* which have been considered in this chapter have been derived from the relations between electric currents and magnetic fields and are called *electromagnetic units*. Another system of units, also based on the centimeter, gram, and second, called *electrostatic 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 electromagnetic unit of quantity $= 3 \times 10^{10}$ electrostatic units.

The coulomb, being one-tenth of the absolute unit, $= 3 \times 10^{9}$ electrostatic 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 paragraph 80, we see that the quantity of electricity in a condenser equals in coulombs the potential in volts multiplied by the capacity in farads, or $Q = VC \therefore C = \frac{Q}{V}$, and substituting for Q and V 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 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.

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A microfarad, $=10^{-6}$ farads, is equal to a capacity $9\times10^{11}\times10^{-6}=9\times10^{5}$, or 900,000 centimeters.

The earth's radius is approximately 65×10^{7} centimeters; its capacity should be approximately 7,000 microfarads.

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, alone, will be used in this book, and where centimeters are used, as they frequently are in catalogues of electrical apparatus and in 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 almost endless difficulties to students.

SELF-INDUCTION.

86. 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 $=\frac{L\,I}{T}$. 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 $\frac{L\,I}{T}\times I\times T=L\,I^2$ 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 $=\frac{L\,I^2}{2}$. 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 henrys by the square of the current in amperes. Therefore in a circuit whose self-induction is 2 henrys 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 73.7 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.

86a. Now suppose we wish to determine the work done in charging a condenser of capacity C to a voltage or potential V 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 $Q = VC$, and assuming that the condenser is charged at a uniform rate the coulombs per second flowing into it $= \frac{VC}{T}$ 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 V and the total work done during the time T must equal the average potential $\frac{V}{2} \times$ rate of charge $\times$ by time $= \frac{V}{2} \times \frac{VC}{T} \times T = \frac{V^2C}{2}$.

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 henrys.

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.

Common potentials in wireless telegraphy are 30,000 volts and common condenser capacities 0.014 microfarad. The work done in charging such a condenser to 30,000 volts $= \frac{14}{1,000,000,000} \times \frac{(30,000)^2}{2} = \frac{14 \times 900,000,000}{2 \times 1,000,000,000} = 6.3$ joules = approximately 4.65 foot-pounds.

This 4.65 foot pounds represents the energy stored in the electric field of the condenser, just as the 73.7 foot-pounds referred to in paragraph 85 represented the energy stored in the magnetic field.

COMBINATION OF SELF-INDUCTION AND CAPACITY IN OSCILLATING CIRCUITS.

87. 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, etc., the conversion would be perfect, the work in the magnetic field of the circuit referred to in the preceding paragraph would equal 4.65 foot-pounds, and this, in turn, would be again transformed into electric energy when the condenser recharges. (See par. 60.)

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.

88. Let us consider a condenser having a capacity of 0.02 mf., 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 × 0.0006 = *1,200* 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 $\frac{5}{1,000,000}$ second = 1,800,000 per second = 1,800 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.

The total work, 9 joules, looks much more formidable if read in *ergs*, since it equals 90,000,000 ergs. The only published experiments on the sensitiveness of wireless telegraph detectors (those of Professor Fessenden) state that in the most sensitive detector the least amount of work which will render a signal readable is 0.007 erg per dot, so that if we are able to concentrate approximately $\frac{1}{12,000,000,000}$ part of our energy on the receiving apparatus the signals sent out can be read.

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

89. 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 (par. 29). 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, as in primary sending circuits, I = approximately $2\pi nL$, or the current depends almost entirely on the reactance of self-induction. As will be seen later (from figs. referred to in par. 189), the current in wireless-telegraph sending circuits is governed by reactance regulators placed in the primary circuit.

FUNDAMENTAL EQUATION OF WIRELESS TELEGRAPHY.

90. 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 $2\pi\sqrt{LC}$ when L is measured in henries and C is measured in farads (see Appendix L.) This is called the fundamental equation of wireless telegraphy.

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.

TIME CONSTANTS OF CONDENSERS AND INDUCTIVE CIRCUITS.

91. We know that it takes *time* for electrical actions to take place and that one capacity or inductance may be equal in value to other capacities or inductances, but be made up differently with different materials whose resistance varies the time it takes to create the electric or magnetic fields, respectively.

Every capacity and inductance has what is called its *time constant*. The time constant of a condenser is equal to CR—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 neghoms, 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. The amount which the potential falls short of its full value at any time T is a fraction of its full value equal to $\frac{1}{2.718^{\left(\frac{T}{CR}\right)}}$.

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 given strength in it. The amount which the current falls short of its full value at any time T is a fraction of its full value equal to $\frac{1}{2.718^{\left(\frac{T}{\frac{L}{R}}\right)}}$.

SKIN EFFECT IN HIGH FREQUENCY-ALTERNATING CURRENTS.

92. 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, to be described later, the inductance coils are wound with wire of such size that for the frequency intended the current will penetrate to the center and there will be no waste 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 $\frac{1}{5000}$ 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.

93. The capacity and self-induction of all but very simple forms of circuits is 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-microfarads $C = \frac{l}{4.1454 \; log \left(\frac{2l}{d}\right)}$.

Fleming states that a wire 111 feet long and diameter 0.085 inch, suspended vertically, was found to have a capacity of 0.000205 mf., or approximately one-tenth of one Slaby-Arco Leyden jar. Four wires of the above size and length, being 6 feet apart, were found to have a capacity of 0.000583 mf., 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 $2\,l\,(2.3026 \log. \frac{4\,l}{d} - 1)$, values, being given in centimeters. The self-inductions 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. (See Appendix M for method of calculating inductances.)

METHOD OF SHORTENING AN AERIAL BY ADDING CAPACITY IN SERIES.

94. 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 wire, thus giving it a period slightly longer than half of the original period.

If, the wires remaining as before, conducting plates are attached to adjacent ends of each, this condenser is enlarged, its capacity increased, and the period of each wire lengthened, but the two wires or two open circuits, as we may call them, would vibrate in resonance and may be considered as forming one oscillating circuit of shorter period than the original wire. From the above it appears that we can shorten the electrical length of an aerial by putting a condenser in series with it, but we cannot shorten it to less than one-half its original period.

As we increase the size of the condenser the period increases, but it is found that a straight wire attached at one end to a large capacity, such as the earth, has a wave length (like that of an organ pipe open at one end and closed at the other) equal to four times its natural wave length, so that by increasing the capacity sufficiently the wave length could be doubled.

We know, however, that by coiling the wire we can increase its wave length to any amount we desire, so that capacity is only added in series for shortening the wave length of aerials; they are lengthened by adding inductance. (See fig. 40a, illustrating Telefunken receiving sets.)

TOTAL CAPACITY OF CONDENSERS IN SERIES AND IN PARALLEL.

94a. Looking at this from another point of view we find that two equal condensers in series have only half the capacity of one, while two equal condensers in parallel have twice the capacity of one. Condensers follow in this respect the law of resistance. Conductivity is the reciprocal of resistance, and the total conductivity of two resistances in parallel is equal to the sum of their separate conductivities.

This fact has a practical use in wireless-telegraph condensers where any particular voltage is used. 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.

Chapter III.

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

95. 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 = 2,000 watts = 2,000 joules per second = 1,474 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 = 0.0186 mf., or approximately nine 0.002 mf. jars in parallel.

96. 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 twice or 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 100 foot-pounds per dash.

97. 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.

98. It was stated in paragraph 62 that the period of electrical vibration of any circuit depends only on the capacity and self-induction of the circuit, and in paragraph 90 that, when the ohmic resistance of the circuit is small, the period (the time of one complete vibration) is equal to $2\pi\sqrt{LC}$, where L is the self-induction in henrys, C the capacity in farads, and π the ratio of the circumference of a circle to its diameter.

This shows that a circuit having a self-induction of 1 henry and a capacity of 1 farad would have a period of $2\pi = 6.2832$ second. Its electrical length would be equal to approximately 584,000 miles and its wave length would be 1,168,000 miles.

The standard wave length originally adopted for naval wireless telegraph stations was 320 meters; the electrical length of such circuits is 160 meters, and their period approximately $\frac{1}{900000}$ second. That is, they make approximately 900,000 complete vibrations per second. The usual capacity in these circuits was 0.014 microfarad (seven 0.002 mf. 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~~ 1.444 times its former value. Doubling both inductance and capacity doubles the period.

99. By comparison with standard inductances and capacities, the capacity and self-induction of circuits can be measured and their periods calculated. Their periods can also be directly measured by measuring the time between successive sparks. 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.

Prof. 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 10,00C 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.

Fig. 18c is an attempt to show graphically the oscillating discharge of a condenser, when the spark gap is set to break down at the maximum charging potential. (Fig. 18c can not be drawn to scale on account of the very short length of time it takes to discharge the condenser, compared to the time it takes to charge it.)

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.

100. The electric waves produced during one set of oscillations are called a *wave train.* 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 is connected to an auto transformer, as in fig. 14d. or to an ordinary air core transformer, as in fig. 29, with one end free and the other earthed, like C D in fig. 29, 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 connection, the *open* or *radiating circuit.* (See par. 70.)

COUPLING.

101. When the closed and open circuits have some turns of inductance in common, as in fig. 32, they are said to be *direct connected;* when they have no common turns, as in fig. 29, they are said to be *inductively connected.*

It is found that when the common turns in direct connected circuits are large in number, or the coils of inductively connected circuits close together, the damping is greater, and the energy being therefore radiated faster, the duration of a wave train is less. Such circuits are said to have *close* or *tight* coupling, and they are found to have two periods of vibration—one longer and the other shorter than the natural electrical period of either circuit.

When the coils of inductively connected circuits are not very close together, or the common turns in direct connected circuits are comparatively few, the transfer of energy from one circuit to the other is slower, the damping less, and the duration of a wave train greater. Such circuits are said to have *loose coupling,* and it is found that the looser the coupling the more nearly the two periods of vibration of the coupled circuits approaches the natural period of each.

DURATION OF WAVE TRAINS.

102. We see, therefore, that the duration of a wave train depends on the *coupling* or the mutual induction between the *oscillating* and *radiating* circuits. It also depends on the self-induction in each circuit. The interval between wave trains depends, however, on the power supplied to the transformer (the foot-pounds of work it can do in a given time) for charging the condenser and on the *time constant* (see par. 91) of the latter and on the length of the spark gap. If the condenser has a capacity of 0.02 mf., the work necessary to charge it to 10,000 volts = 1 joule, or 0.737 foot-pounds, so that it will require about $\frac{1}{2000}$ second for a power of 2 kilowatts to charge it to that potential. If the current has a frequency of 900,000 and there are nine complete oscillations in one wave train, the duration of a wave train is $\frac{1}{100000}$ second, so that the time necessary to charge the condenser may be fifty times as long as the time taken to discharge it.

In such a circuit, if we do work at the rate of 2 kilowatts in charging, we do it at the rate of 100 kilowatts in discharging.

If the waves are so rapidly damped that the condenser is discharged in one complete oscillation, the whole energy will be radiated in $\frac{1}{900000}$ second, or at the rate of 900 kilowatts.

The effect of quickly and slowly damped wave trains on detectors will be discussed later.

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 par. 86); but the total work done may be equal, on account of the greater number of discharges.

N. B.—It is on this account that a hot-wire ammeter (see par. 180) is not always a good indicator of the best adjustment of a wireless-telegraph sending circuit. Its readings indicate the *total* energy radiated instead of the energy in any particular wave train. If, however, the amplitude of the waves in each train is not great enough to produce readable effects in the detector, the group of wave trains in a single alternation will not help matters, because the wave trains are so widely separated in comparison with their length that the effect of one train on the detector has disappeared before the succeeding train arrives.

103. 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.

104. 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.

DIELECTRIC STRENGTH OF AIR.

105. The dielectric strength of air is considered to be about 4,500 volts per millimeter for gaps of about 1 millimeter in length, and about 3,000 volts per millimeter for gaps of the length of a centimeter or more. Fig. 30 shows sparking distances in air between needle points, as determined by experiment. These distances are usually greater than those produced by equal voltages between the blunt spark points used in wireless telegraphy. The latter probably correspond more closely to the table given in Appendix A. On the other hand, the table of spark distances is 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.

106. 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.

LIMITATIONS ON WAVE LENGTHS.

107. 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, and since condensers of any desired capacity can readily be obtained, it is easy to make the closed circuit any electrical length we desire.

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 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. We find, however, 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.

POWER THAT CAN BE EFFICIENTLY USED WITH A GIVEN WAVE LENGTH.

108. It is probable, though this has not been definitely proved, 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. (See par. 95.) 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 using a shorter gap, and thus more than one wave train per alternation, and also 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.

By the first method waves of the greatest amplitude (and therefore containing the greatest amount of energy) of which the set as a whole is capable are sent out every alternation, and, other things being equal, they should be detected at the greatest distance.

By the resonance method such waves are sent out every second, third, or fourth alternation. (See par. 147 and footnote.)

109. Having seen that large currents flow during the oscillating discharge of even a comparatively small condenser, and that owing to the high frequency these currents are only on the surface of the conductors, the necessity for ample surface on condenser connections and inductances is obvious.

110. A large number of the sending circuits in use at present are of the direct connected type, like the auto-transformer shown in fig. 32.

The wave length of the open and closed circuits is made variable at will, and change of coupling without changing the wave length of either circuit is made possible by the use of three variable connections, as shown in fig. 32. It will be seen that the closed circuit has one permanent and one variable connection to the sending inductance, or helix, and that both the aerial and ground connections are variable. Condensers in sending circuits are not usually variable, though they are frequently in parallel, as in fig. 31, or in

FOOTNOTE.—With a given transformer and given condenser capacity the *power* that can be obtained in any wave train depends, when using the resonance method, on the *damping* in the secondary circuit (condenser and transformer-secondary) as well as the power in the primary circuit. This fact modifies the statements in par. 108 and shows that the *power* of a sending set may not depend entirely on the size of the motor-generator used with it.

series, fig. 31a. Condensers in series may be on either side of the spark gap, as in fig. 31b.

Series-parallel connections are also used, just as in primary batteries.

It will also be seen that instead of connecting the spark gap across the power leads from transformer to condenser, that the condenser may be placed across these leads and the spark gap in one leg or the other, as in figs. 33 and 34.

SLABY-ARCO SENDER.

111. Fig. 32 shows the connections of the Slaby-Arco sets—i. e., spark gap across secondary leads, condenser in one leg of secondary lead and made up of seven Leyden jars in parallel, each jar of 0.002 mf. capacity.

MASSIE SENDER.

112. Fig. 33 shows the connections used in the *Massie* sets. The spark gap and condenser are interchanged, as compared with the Slaby-Arco. In the Slaby-Arco sets the condenser is charged on one side directly from the transformer and on the other through the inductance, but the self-induction of the latter is so small that its time constant must be small and the charging of the condenser very little, if at all, delayed.

The Massie condensers are made up of glass plates covered with tin foil; capacity of each plate, 0.0083 mf. Plates can be connected in groups and used in parallel, series, or series-parallel, as desired. The glass is used as the dielectric, though this type of condenser can be connected so as to use the air between the plates as the dielectric if desired.

FESSENDEN SENDER.

113. Fig. 35 shows the connections of the Fessenden sets. If this figure is compared with that showing the Slaby-Arco connections, it will be seen that the condenser has been moved to the other leg of the secondary leads, and that the ground lead instead of being direct from the inductance, as in the Slaby-Arco (and other sets to be described), is taken off between the condenser and the transformer. This gives the aerial a path to ground through the condenser *or* spark gap. All other sets have direct path from aerial to ground, and path through condenser *and* spark gap.

One leg of the secondary, being directly grounded, if the aerial be touched while current is on the transformer the circuit is completed and a severe shock may be felt. This method of connection must also be taken into consideration while adjusting the closed and open circuits to the same natural wave length.

The Fessenden 2 kilowatt ship sets are furnished with condensers of 0.004 mf. capacity, made up of tin-foil-covered glass or mica plates in paraffin, or with tin-foil-covered plates either in compressed air or air at ordinary pressure, the paraffin in the one case and the air in the other being used as the dielectric.

This capacity is less than one-third of that used in the Slaby-Arco sets, but the method of connection—i. e., grounding the circuits between the condenser and transformer—tends to increase the apparent capacity by keeping the earth and the aerial oppositely charged. With this low capacity the inductance of the sending circuit must be made correspondingly large in order to retain the same wave length.

DE FOREST AND SHOEMAKER SENDERS.

114. Fig. 34 shows the connection of the De Forest and Shoemaker sets.

It will be noted that the only change from the Massie sets is that the spark gap is changed to the other leg of the secondary, which brings one side of the gap in direct connection with the ground.

The De Forest sets for ship use have Leyden jar condensers of 5 to 9 jars capacity .002322 mf. per jar. For large sets the De Forest Company uses tin-foil-covered glass plates in oil.

The Shoemaker sets are furnished either with regular Leyden jars or with tubes. (Leyden jars open at both ends to give circulation of air.) The total capacity varying with the *power* desired.

TELEFUNKEN SENDERS.

115. The Telefunken Company uses the same connections as the Slaby-Arco and furnishes Leyden jar condensers of various types and capacities.

STONE SENDERS.

116. Fig. 36 shows the connections of the Stone sets, which are inductively connected, as distinguished from the direct-connected sets which have been under discussion. This inductive connection is shown diagrammatically in fig. 36. As actually constructed, the closed circuit is the same as in any other set, and has one variable connection to the inductance; but the open circuit inductance is mounted above that of the closed circuit, as shown in fig. 36a, and has one variable connection.

The entire aerial helix is also movable at will, so that the mutual induction between the two circuits, and therefore the coupling, can be varied at will.

The Stone Company's condensers are made of tin-foil-covered glass plates embedded in a mixture of beeswax and rosin, or the glass may be dispensed with and the beeswax and rosin mixture with intervening sheets of tin foil alone used; ordinary sets are made up of seven condensers in parallel, each of 0.0015 mf. capacity.

Condensers are made up in rectangular blocks of six or more plates each and stowed on shelves in a wooden condenser case. These blocks can be connected in parallel or in series, or in a combination of the two, as desired, depending on the voltage and capacity.

117. Efficiencies of different types of senders (see present par. 126).

MATERIAL USED AS DIELECTRICS IN CONDENSERS.

118. Practically nearly all insulators have a greater specific inductive capacity than air at ordinary pressure, and nearly all of them have a greater dielectric strength than air. 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, has 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 *5,000 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 are cheap and easily obtained. Another quality of dielectrics which governs their use to a certain extent is what is known as their hysteresis loss.

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. Loss of energy due to sparking from the edges of the tin foil around the edges of the dielectric to the opposite foil is frequently noticed. This can be partly remedied by covering edges of foil and plates with an insulating compound. Fleming has shown that the lengths of discharge paths of all condenser elements should be equal.

119. Tables showing the specific inductive capacity of a number of different dielectrics and their dielectric strength 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	[a] 4,500 [b] 3,000
Hard rubber	2.29	[c] 40,000
India rubber	2.10	[c] 30,000
Mica	6.64	[c] 60,000
Micanite		[c] 40,000
Typewriter linen paper		[c] 45,000
Paraffine oil	2.71	[c] 7,000
Glass (crown)	6.96	[cd] 20,000
Glass (plate)	8.45	
Glass (light flint)	6.72	
Glass (extra dense flint)	9.86	

[a] Per millimeter for thicknesses up to 1 millimeter.
[b] Per centimeter.
[c] Per millimeter.
[d] Approximate.

Dielectric strength 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 mm. of mercury, when it increases.

Dielectric strength of a vacuum should be infinitely great.

Mica if it could be obtained in large sheets would be the best material for the dielectric of condensers for use in wireless telegraphy, having both high specific inductive capacity and great dielectric strength.

120. 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. Capacity varies *inversely*, as the thickness 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.

An indestructible form of condenser can be made up of metal plates in compressed air. The metal plates being already conducting do not require tin-foil coverings. Compressing the air gives it great dielectric strength, and should this be exceeded the air at once repairs the puncture.

An entirely satisfactory form of condenser for wireless telegraphy has not yet been designed.

SENDING KEYS.

121. The sending key in small sets is placed in one leg of the primary circuit between the source of current and the transformer or induction coil.

Pl. XXII shows the Morse key furnished with Slaby-Arco sets. It is of massive construction, with heavy platinum-tipped contacts. Several types are furnished, one with a magnetic blow-out for extinguishing sparks; another with a hinged contact plate having the armature of an electro-magnet attached to it. The primary current energizes the electro-magnet, which holds its armature when down till the current is interrupted, when it is drawn up by its spring, and the key contacts separate without spark.

Condensers are shunted around sending keys in some cases to absorb the induced current which causes the spark at break. Most of the other sets furnished use the ordinary telegraph key, with somewhat larger contacts. Silver contacts of comparatively large diameter are used with the Stone keys. In all keys the contacts must be kept smooth and their faces parallel.

For breaking large currents various devices are employed, that most generally used being to energize a solenoid by closing the sending key, the solenoid armature making and breaking the primary current *in oil.*

Sending keys are shown in outline in figs. 65 to 71, inclusive.

The method of installing the key in shunt with an inductive resistance and in series with another inductive resistance is shown in fig. 70 and in standard diagrams, figs. 72, etc.

For sending time signals a Western Union relay is used to close a local battery, which energizes an electro-magnet whose armature carries a lever which presses and releases the sending key in unison with the impulses sent from the standard clock at the Naval Observatory. Sending keys should have just sufficient movement to prevent arcing and permit well-defined movement in making and breaking.

SPARK GAPS AND SPARK POINTS.

122. The table of sparking potentials given in Appendix A and referred to in paragraph 105 and the curves showing sparking potentials between needle points are obtained from constant potentials. While the first spark in each wave train in wireless telegraph sets depends on the transformer potential, succeeding sparks depend on the shape and constants of the oscillating circuit and the material of the spark points.

The spark must be kept white and crackling—if too long, it will be stringy; if too short an arc will be formed.

There is no doubt that much of the irregularity noticed in sending is due to irregular action in the spark gap.

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, which indicates the great amount of energy that must be lost in the gap. The mercury interrupter, however, is difficult to keep in good adjustment.

A great deal of thought and ingenuity has been expended in the direction of improving the action of spark gaps. For instance, the use of magnetic blow-outs, induced and forced air drafts across the gap, dividing it into a series of short gaps, placing gaps in parallel, enclosing them in compressed air and in nitrogen gas, cooling hollow spark points with air and water. None of these are markedly better, except when large powers are used, than the ordinary gap in air between two zinc rods about one-fourth of an inch in diameter. There are two points common to all spark gaps which are necessary for good working (*a*) the points or balls must be smooth and clean; (*b*) they must be kept from heating.

The effect known as "soaring" is probably due to inequalities in the action of the spark gap and condensers.

Zinc is the best of all metals for spark-gap electrodes. Its action in relation to electric discharges is almost as peculiar as that of iron in relation to magnetic effects.

Brass is probably the next best.

All spark gaps should be well muffled, for obvious reasons.

Slaby-Arco sets are fitted with plain zinc spark electrodes.

Telefunken sets are fitted with a number of gaps in series, any number of which can be included at will.

Stone ship sets are fitted with six gaps in parallel, between brass spark balls.

Fessenden and De Forest ship sets have the gap divided into two parts by a movable disk, whose center is out of the line joining the spark electrodes, so that the points of the disks through which the spark passes can be varied at will. All spark gaps are adjustable. Provision is made for cooling them except in case of small sets.

In the large Massie sets the electrodes are kept cool by being made hollow, with fine holes, through which compressed air is forced, drilled from the outside to the hollow center.

The increased radiation with the cooled spark points is very evident.

HOW ETHER WAVES ARE DETACHED FROM AERIALS.

123. Let fig. 50 represent a closed circuit inductively connected to an open circuit with a vertical air wire, 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 flowing in the closed circuit, and therefore no current and no charge in the open circuit; the energy is all electrostatic, all in the closed circuit, and practically all in the electrostatic field between the condenser plates, the capacity of the spark points and other parts of the circuit being very small.

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, positive in one direction, negative in the other, the starting point of the disturbance being the open-circuit inductance. As the charges separate they are connected by electrostatic 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, so that the whole action appears like that of a rapidly growing sphere, having the wire for an axis. The magnetic field around the wire becomes a maximum at the end of a quarter period, but the electrostatic field becomes a maximum at the end of a half period, at which time the magnetic field has partly collapsed on the wire and the charge at the top of the aerial reaches its maximum potential. The spherical condition has been maintained only until the charge repelled to ground reaches the ground, when it travels off, guided by the ground plate and the moist earth connected therewith, so that, at the expiration of a half period of the closed circuit, conditions in the open circuit are as shown in fig. 50a, with the energy all electrostatic in both circuits.

During the first half of the second half period the energy in both circuits unites in creating an electro-magnetic field in the opposite direction in the aerial, while the electrostatic field tends to collapse on the wire.

During the second half of the second half period the reversed electro-magnetic field tends to collapse on the wire, while an electrostatic field, reversed in direction, is created, reaching a maximum at the end of the period.

If the charges can be represented as meeting in the open-circuit inductance, the electrostatic field at the middle of the second half period can be shown as in fig. 50b, where the mutual repulsion of the lines of electrostatic force outside of the wire have kept them from returning as fast as the charges travel up and down the wire. As these charges pass each other the ends of the lines unite and become closed circuits (fig. 50c) or electric whorls shaped like smoke rings, which, owing to their mutual repulsion, expand in all directions except toward the air wire, because their direction on the side next the air wire is coincident in direction with that of the outside of the succeeding whorl, and therefore the two are mutually repulsive and do not neutralize each other.

124. It is in this manner that we conceive energy to be detached and sent off into space from wires forming open oscillating circuits. The expanding rings soon touch the earth and are guided by it, as by any other conductor, thus resembling at a short distance from the wire expanding hemispheres. In these hemispheres the magnetic lines of force are the parallels of latitude, the electrostatic lines are the meridians. The maximum strengths of field due to each, are a quarter of a period apart. Each one is zero where the other is a maximum.

Considered from this point of view the energy in any part of the field should vary as the square of the distance from the radiating wire.

125. The direction of the magnetic lines of force at any point 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 electrostatic lines of force at any point is perpendicular to the earth's surface.

The earth's magnetic lines of force, whose direction determines the direction in which magnets point, are parallel to the magnetic lines in electric waves at points east and west of the radiating wire and at right angles to them at points north and south of the radiating wire. In east and west directions the magnetic waves alternately reenforce and oppose the earth's magnetic force. In other directions their effect varies with the direction. An iron wire placed horizontally at right angles to the line joining its position with the radiating station would be parallel to the lines of magnetic force and would become magnetized, just as iron wires held in the magnetic meridian become magnetized. Pointed in the direction of the station this 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 thus induced in vertical conductors that electric waves are usually detected.

It also has a difference of potential, created in its ends by joining two points of the advancing wave whose electric potential differs.

If two horizontal conducting plates, forming a condenser, are in the path of the wave, they will have electrostatic charges of different potentials induced on them, and if joined by a conductor, oscillating currents will be produced in the conductor.

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

It would seem that by the last method we should be able to abstract the greatest amount of energy from the wave.

126. It will readily be seen that the induction of currents in another aerial, however great the distance from the inducing wave, is not different in principle from the inductive actions of the wires

A B and C D on each other, which has been discussed in the early part of this book.

It was there pointed out that the 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 nonreturnable energy. Oscillating circuits of high frequency appear to send out more nonreturnable energy than those of the low frequencies used for lighting and power.

EFFICIENCIES OF DIFFERENT TYPES OF SENDERS.

Sheet 31—117. The efficiencies of the various forms of closed circuits shown in figs. 32, 33, and 34 differ, if at all, only on account of the materials of which they are made and their dimensions, since they are the same in principle.

The means of connecting them to the open circuit are also practically alike.

Whether direct or inductively connected sets are the more efficient has not yet been definitely determined. Inductive coupling offers a convenient means of weakening the mutual induction, and thus making the two waves more nearly equal to the natural period of each circuit, but there may be more losses on this account.

ARRANGEMENT OF WIRE IN AERIALS.

127. The *aerial wire* with which the open-circuit inductance is connected, is shown diagrammatically in the forms preferred by different inventors, in figs. 51a, b, c, d, e, f, and g. Certain shapes are found to radiate better than others. The best form has probably not yet been determined. That now used on board ship is what is known as the flat-topped type. It works well with all forms of closed circuits here shown, and is easily understood from the photograph (Pl. II) and from the description given in Appendix B.

Connection with wires to operating room may be made at either end or at the center, and at shore stations leads may be taken from both ends. Where leads are taken from the center, as in fig. 51e, both ends of the flat-top are subject to high potentials. Where taken from one end the free end is subject to high potential, as in fig. 51f. Where leads are taken from both ends the highest potential is in the center of the flat-top, as shown in fig. 51g. One advantage of the last method of connection is that the wires, where they are supported, do not need to be as highly insulated as when the highest potential exists at one of the ends.

It is not generally convenient on board ship to take leads to operating room from both ends, so that the aerial shown in fig. 51g is more useful on shore.

128. It will be noted in figs. 41 and 42 that the De Forest and Shoemaker aerials are constructed so as to form a *loop* beyond three spark points arranged in the form of a triangle, and that the lead from the inductance is connected to one of these points.

These spark points form what is known as an *anchor spark gap.* The gaps are so short that the high potential currents used in sending easily pass over them. Both sides of the loop are at the same potential, and the maximum potential is reached at the middle of the cross connection at the top. The receiving circuit is connected to the two ends of the loop above the anchor spark gap and the loop thus continued to the tuning coil. The receiving potentials are too low to cross the gap, so that it serves as a cut-out for the sending current when receiving. A single gap is used in the Slaby-Arco sets for this purpose.

The *loop* in the flat-topped aerial is arranged in various ways. These arrangements do not affect the use of the aerials for those forms of tuning coils which are constructed for receiving in other than a looped circuit. For such tuning coils the two sides of the loop are simply brought together and used as one wire.

KINDS OF WIRE USED IN AERIALS.

129. Except where they pass near conducting objects or through decks, all parts of the aerial wires are left bare. This probably detracts very little from their efficiency as radiators, and is more convenient on account of the lighter weight and smaller surface exposed to wind pressures as compared with insulated wires.

The size generally used is made up of 7 strands of No. 20 B. & S. phosphor or silicon bronze wire having fairly high elastic strength.

Wire, composed of strands having much greater surface than solid wire of the same size, offers less resistance to high frequency currents; it is also more flexible. Its elastic strength is sufficient to prevent permanent elongation and consequent sagging, to the extent shown by pure copper wire. A detailed description of the method of construction of flat-topped aerials for given wave lengths, as followed at the New York yard, is given in Appendix B.

HIGH POTENTIALS FROM INDUCED CURRENTS AND PROTECTIVE DEVICES.

130. The large momentary currents in aerials produce large inductive effects in conductors near, and parallel to them, and thus cause waste of energy. This is more noticeably the case when the conductors, such as wire stays, shrouds, braces, etc., have nearly the same electrical length as the aerial. On this account rigging, subject to induction on account of its proximity to the aerial, is divided into short electrical lengths by choke coils made of No. 26 B. & S. soft iron wire served around them for a length of about 10 feet. Rigging near the aerial is set up—and thus insulated from the hull—by hemp lanyards.

General instructions to provide against losses due to these inductive effects are given in the Appendix.

Special care is taken to secure good insulation of the aerial where it passes through decks and where it enters the operating room.

It should 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 of the dynamo armature or cause sparking between the lead and other conductors in the vicinity of combustible material, thereby causing fires. Both of these effects have been experienced. They are especially frequent and dangerous to motor generators in operating rooms, and it is on this account that the protective devices shown in standard diagram for installation of wireless-telegraph sets (fig. 72, etc.) are installed. Care should be taken in installing sets to see that low and high potential leads are not parallel or near to each other at any point.

GROUNDS AND GROUND CONNECTION.

131. On board ship the ground lead is well soldered to some portion of the hull. At shore stations it is connected either to copper plates in contact with moist earth, fig. 78, to radiating lines of galvanized-iron telegraph wire ending in pipes driven to moist earth, fig. 79, or to wire netting spread on the surface of the ground.

The exact function of the "ground" in wireless telegraphy is somewhat obscure (see par. 123); but it is well settled that large area of good contact with moist clay furnishes the best ground.

Except where the station is built close to the permanent water level and the ground plate can be kept below that level at all times, the ground formed by radiating lines of galvanized-iron wire connected to pipes is usually the most satisfactory. This differs very little from the wire-netting "ground," whether laid on the earth or supported at a distance above it. In the latter case it acts upon and is acted upon inductively by the earth.

Where and when the soil is very dry, it is necessary to pay much greater attention to the ground connections, and at some stations arrangements are made for supplying water to the ground plate.

132. It is noted that where the resistance of the earth in the vicinity of the station is high, the station is a poor radiator. At such stations radiation can usually be improved by increasing the size of the artificial ground.

132a. An oscillator formed of a straight wire free at both ends has high potentials at both ends, and its electrical period is equal to twice its length.

An oscillator formed of a vertical wire free at one end and attached to the earth at the other, has high potential at the free end only if the earth connection is good. If it is *not* good, the tendency is to choke the current passing in and out of the earth, and thus to cause a rise of potential and consequent sparking at the earth connections.

The natural period of such an oscillator, which should be approximately four times its length, is, on account of the choking effect of the poor ground shortened and made irregular, and the sending qualities of the station thereby impaired.

It is found that the resistance of the earth between two similar rods, driven into it to the same depth, at the same distance apart, varies widely in different localities, the resistance at some places being as much as 20 times greater than at others. It varies continually with the moisture and probably with other conditions near the surface.

Low-ground resistance at a station is usually accompanied by good radiating qualities.

Ample surface on lead to the ground from the sending inductance and good electrical connection with the ground wires or plates are essential on account of the large momentary currents created when sending. (See par. 88.)

SENDING EFFICIENCY.

133. The efficiency of our means for electric wave making is difficult to determine. Estimating that 50 per cent of the energy in each condenser discharge is dissipated in light, sound, and heat in the closed and open circuits, we have in a condenser capacity of 0.02 mf. charged to a potential of 30,000 volts, the remaining 50 per cent of 6.64 foot-pounds = 3.32 foot-pounds of energy sent out in each wave train. This is equal approximately to 45,000,000 ergs per wave train, and it has been estimated, as stated in paragraph 88, that the most sensitive electric wave detectors require to operate them approximately 0.007 erg per dot. We have also the statement that the energy in any part of the wave train varies inversely as the square of its distance from the sending station. In other words, the strength of received signals should be four times as great at 100 miles as at 200 miles.

RECEIVING CIRCUITS.

134. In practically all cases the same aerial wire is used for sending and receiving both at ship and shore stations.

The advancing lines of electric and magnetic force cut the aerial wire and induce in it alternating currents of the same period as those in the sending circuits.

If the receiving aerial has a natural period equal to that of the passing waves, the currents in it will rise, until the energy received per wave is equal to that dissipated.

If the receiving aerial is directly or inductively connected to a closed oscillating circuit to which nearly all the energy received per wave is transferred at each half period, instead of being re-radiated, as would otherwise be the case, the closed oscillating circuit will absorb the energy, and if its period is equal to that of the arriving waves the oscillations will increase in amplitude with each transfer of energy. If a detector is placed in this circuit, 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 the radiating circuit absorbs this radiated energy and transfers it to the closed circuit. 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 circuit should have the same dimensions or arrangement as the sending circuit; but in all other features receiving circuits are the exact analogue of sending circuits, with the detector in place of the spark gap. The detector can be placed in the spark gap of a sending circuit and the latter used as a receiving circuit, but it is not convenient to do so, and it may be in some respects less efficient than a receiving circuit specially designed.

135. None of the direct-connected sets already described were originally designed to permit the coupling to be varied without varying the wave length of either the open or closed sending circuits, but they are all now fitted in that way, and it is found desirable to connect receiving circuits in the same way.

136. All close-coupled sets send out two waves, one shorter and one longer than the natural period of either circuit. It is possible to adjust the receiving circuits so that they respond better to one of these waves than to the other, but the best results are obtained when the open and closed receiving circuits have the same natural periods and the same *coupling* as sending circuits. Sender and receiver are then in resonance, and the latter will respond better than when tuned to but one of the two waves.

It is more difficult to determine the coupling of receiving than of sending circuits, and also to measure the natural period of such circuits. The high resistance of some receiving circuits prevents their having a pronounced period of oscillation, and on this account variation of coupling is not always considered in tuning receivers, and they are usually adjusted to but one of two waves.

SLABY-ARCO RECEIVING CIRCUITS.

137. The Slaby-Arco receiving circuits are shown in fig. 37. They consist of a variable inductance in the open circuit and a fixed condenser, variable inductance, and detector in the closed circuit. The construction marked "D" (fig. 37) will represent the detector in all diagrams. A condenser of considerable capacity is sometimes placed in parallel with the detector in these circuits to prevent the change of capacity in the detector from greatly affecting the period of circuit.

MASSIE RECEIVING CIRCUITS.

138. Fig. 37 also serves to represent the Massie receiving circuits, which are the same as the Slaby-Arco.

The only difference between the Slaby-Arco and the Massie sending circuits, as will be seen by an inspection of figs. 32 and 33, is the unimportant interchange of relative position of transmitting condenser and spark gap. The receiving connections are alike in principle though not in appearance.

TELEFUNKEN RECEIVING CIRCUITS.

139. The Telefunken receiving circuits of the latest type are connected for what is called plain aerial, as in fig. 40, or inductively connected with variable condenser in the closed circuit, as shown in fig. 40a. The inductance is also variable in *steps*. Provision is made for direct connection if desired. When inductively connected the *coupling* can be varied at will by adjusting the distance and direction of the two coils K and M from each other.

FESSENDEN RECEIVING CIRCUITS.

140. The Fessenden receiving circuits are shown in fig. 38. They are direct connected, with variable *roller* inductance and fixed condenser. When it is desired to prevent interference from other stations using wave lengths not greatly different from the ones it is desired to receive, a special type of inductive connection, called an interference preventer, is used. This is shown in fig. 38a.

This gives two paths to ground for the induced current from the aerial. Each one of these is variable at will, and at the same time the period of the circuit formed by the two fixed inductances and two variable capacities can be kept constant, and equal to the wave length it is desired to receive, while the waves it is desired to exclude, pass through one path or the other to ground.

This interference preventer works well in practice.

STONE RECEIVING CIRCUITS.

141. The Stone receiving circuits are shown in fig. 39. They are inductively connected, with variable condensers and fixed inductances. The latter, however, are movable as a whole, so that the *coupling* can be varied at will.

Inspection of fig. 39 will show that the Stone set has a *variable* condenser, in parallel with a fixed inductance (A), below the variable inductance (B), in the aerial leads, and that an additional closed circuit (C), with fixed inductance and variable condenser, is interposed between this direct-connected circuit (A) and a second closed circuit (D), with two variable condensers, one in series and one in parallel with the detector.

The circuit marked (C) is called a *weeding-out circuit*, and it is used in connection with (D) when sharp tuning is necessary to prevent interference. Provision is made for cutting out circuit (D) and placing the detector in circuit (C) when sharp tuning is not necessary.

DE FOREST AND SHOEMAKER RECEIVING CIRCUITS.

142. The De Forest and Shoemaker receiving connections are shown in figs. 41, 41a, 42, and 42a.

They are alike in general principle, but differ considerably in the actual arrangements, the original idea being not to tune the receiving circuit to the same wave length as that emitted by the sender, but to set up *stationary waves* in a closed receiving circuit grounded at one point and having a period equal to some multiple of the wave length it is desired to receive, and, by changing the relative positions of the inductances and capacities in the receiving circuit, change the position of the nodes and loops of current and potential in the stationary waves, and thus bring the coherer detector to a potential loop, or the electrolytic detector to a current loop.

SENDING AND RECEIVING CIRCUITS IN GENERAL.

143. Inspection of the elementary diagrams of sending and receiving circuits discussed, shows that the sending circuits vary little from two common types—the *direct* and the *inductively* connected. Each is composed of a standard, closed, oscillating circuit forming part of, or inductively connected to an open radiating circuit, with provision for changing the natural period of both circuits.

The receiving circuits are seen to be, in general, the counterpart of the above, with the detector in place of the spark gap. It is found that when, for the purpose of obtaining greater selectivity, and thus comparative immunity from interference from waves whose period differs somewhat from that of the receiving circuit, the latter is made more complicated, as in the Fessenden interference preventer, fig. 38a, and the Stone weeding-out circuit, fig. 39, the range of reception is somewhat decreased.

We attain great selectivity but lose sensitiveness. There is a loss of energy in the various transformers. Signals which can be perceived when the simpler connections are used, are inaudible when the arrangements necessary to secure great selectivity are in use.

Direct-connected sets are usually considered the stronger for sending, but the best results have been obtained where the number of turns common to the two circuits is less than one turn; in other words, when the *mutual induction* or *coupling* is *very loose*, and the lengths of the two waves produced, so nearly alike that they can not be distinguished in the wave meter.

Equally good results are obtained when the *coupling* between inductively connected sets is just loose enough to bring the two waves practically together. Such sets of either type should have *loose coupled receiving circuits.*

All wireless-telegraph sets installed on board ship or at shore stations are so fitted that the throw of a single switch disconnects the sending circuits from, and connects the receiving circuits to the aerial, and vice versa. The use of this switch prevents damage to the receiving apparatus, which would result by sending while it is connected to the aerial.

DETECTORS.

144. The four types of detectors in general use include *coherers* and *microphones* (usually considered as imperfect contact or voltage operated detectors), *magnetic* and *electrolytic* (usually considered as current-operated) detectors.

Of these four types all are self-restoring, except the first, which requires tapping or some other mechanical shock to restore its sensitiveness after cohering. All, except the first, are used in connection with a telephone. Their sensitiveness depends largely on their adjustment, but when properly adjusted it is inversely as the order in which they are given above. Microphonic detectors are not extensively used in the Navy, and magnetic detectors practically not at all. The coherer at present is largely used as an auxiliary, the great majority of wireless-telegraph sets being fitted with some form of the electrolytic type in addition.

Coherer detectors have the great advantage over all other forms thus far produced, in that they change under the action of electric waves from a nonconducting to a comparatively good, conducting state, and in this condition permit the passage of sufficient current to ring a bell and thus attract attention. The change in conductivity, and consequently in the current passing through the other forms of detectors, is so slight, that all efforts thus far to create visible mechanical movement by means of this change have been unsuccessful at any great distance, and the only means of utilizing them is in connection with telephones.

The detector, in addition to forming part of the closed receiving circuit, has its terminals connected to a local circuit containing a source of current (usually one or more primary cells). The alternating currents induced in the closed receiving circuit change the resistance of the detector, and thereby change the current in the local circuit, producing a sound in a telephone, or causing a movement of a relay tongue which closes another circuit, in which is the *bell* and Morse register.

DURATION OF EFFECT IN DETECTORS.

145. Before describing the connections and accessories of the various types, it may be well to note that data on the duration of the effect on a self-restoring detector, of a wave train lasting a given time, is almost entirely lacking, though it is of importance, as determining the interval it is possible to have between wave trains, and yet make their effects cumulative, both on the detector and on the ear.

For instance, it was shown in paragraph 96, that when sending at such speed that the duration of a dot is $\frac{1}{15}$ of a second, using 60-cycle current, with a spark gap set at maximum potential distance to give but one wave train per alternation, a dot is made up of 8 distinct wave trains, each lasting approximately $\frac{1}{100000}$ of a second and separated by an interval of $\frac{1}{120}$ of a second. In other words, that the interval between wave trains is nearly one hundred times as long as the duration of one train, and that about 50 foot-pounds of energy is expended per dot when utilizing 2 kilowatts. It is a question whether the 50 foot-pounds available produces the loudest signals when sent out in 8 wave trains of a certain amplitude. It is possible that with the same power concentrated in 4 trains of greater amplitude, or diffused in 16 trains of lesser amplitude, louder signals might be produced. It was pointed out in paragraph 97 that a frequency as low as 7½ cycles would give one wave train per dot and two per dash at the sending rate given, so that it is quite probable that some other frequency than 60 cycles per second will give better results in the receiving apparatus.

It should also be noted that the energy in a wave train depends on the amplitude and number of its oscillations. The effect on the detector being cumulative, there is probably some number of oscillations per train, which is most efficient. Therefore in considering the action of electric-wave detectors we should look upon it as being produced by electric *wave trains* of a certain number of oscillations or waves per train, and a certain number of trains per second, or per dot, and the most efficient use of any given power will be made when the energy is best distributed, both in any train and in the number of trains per second.

146. A telephone diaphragm receives impulses from the pulsating current produced by the constant E. M. F. and varying resistance in the detector circuit. It responds only to entire wave trains, and not to particular waves, and only to groups of wave trains if the latter are very close together, so that, generally speaking, we may say that the *pitch*—that is, the number of vibrations per second of the sound heard in a telephone—is that, due to the number of alternations or interruptions of the primary sending circuit per second.

By distributing the available energy over a greater number of wave trains per second, a *weaker sound* but a *higher note* is produced.

The human ear is not equally affected by sounds of equal loudness, regardless of their pitch.

The note of a 60-cycle alternator is an octave above that of a mercury turbine interrupter, making 1,800 revolutions per minute, and having a two-segment ring—that is, two breaks per revolution and sparking only on the break. The higher frequency produces a more piercing spark, one that can be distinguished farther than the one of lower frequency, though probably of greater intensity.

In order to get the very best results the frequency used should be that to which the operator's ear and the telephone diaphragm are most sensitive. Telephone diaphragms which will respond best to sounds if a particular frequency can be made.

147. *Resonance* is thus seen to be a highly important quality in wireless-telegraph circuits. (1) *Resonance* of primary alternator frequency with secondary of transformer and capacity in closed circuit; (2) *resonance* of closed oscillating circuit, with open radiating circuit; (3) *resonance* of coupled receiving circuits, with coupled sending circuits; (4) *resonance* of telephone diaphragm with primary frequency; (5) *resonance* of human ear with telephone diaphragm. All these are changeable at will except the last, which can not be changed, and is different for different people. Experimental data on this subject are exceedingly limited, but such as we have indicate that the average human ear is most sensitive to notes of higher frequencies than those thus far generally used in wireless telegraphy.

DETECTORS AND THEIR CONNECTIONS IN RECEIVING CIRCUITS.

148. The coherer detector used with the Slaby-Arco sets is shown in fig. 52. It consists of an exhausted glass tube containing two silver plugs fitting snugly in the tube. These plugs have well-polished, slightly sloping ends. The wedge-shaped space between the two plugs or electrodes varies from 2 to 4 millimeters in length and contains filings of oxidized nickel-silver alloy. A great many other kinds and mixtures of filings have been used but without better results.

The plugs are connected to metal caps on the ends of the coherer by platinum leading-in wires.

The coherer is slightly adjustable in sensitiveness by turning the point of the wedge up or down. It is most sensitive with the point down, but this is not necessarily the best working position. Coherers vary materially in sensitiveness and in the conditions under which they will work best. Their sensitiveness depends on the size, amount, and degree of *oxidation* of the filings and the distance between the electrodes. Their sensitiveness changes somewhat with age and use.

The least sensitive ones are usually the best for short distances, while they may not work at all at distances at which more sensitive ones work well.

They offer a very high resistance to the passage of very low voltage current. This resistance can be broken down by a certain voltage or potential called the *critical* potential, which is usually about 1.5 volts. When so broken down, the resistance of the coherer for steady current is between 2,000 and 3,000 ohms. When tapped or shaken the filings resume their nonconducting character. The electric induction between the filings when above a certain amount brings them together and they form conducting chains, which are broken by being shaken or tapped. When thus brought together the filings are said to *cohere*, hence the name *coherer*. The tapper, which is usually an electric bell, is called a *decoherer*.

Coherers when used continuously become magnetized and do not decohere easily. They will recover their normal state if allowed to rest for a few days.

Their action lacks uniformity, because at every tap of the decoherer the filings assume new positions, which may or may not be as well adapted for cohering as other positions.

Coherers should be tested out as opportunity offers and marked as useful for long or short distances, as the case may be. When not in use, they should be kept in their box and away from the vicinity of the strong magnetic fields in the neighborhood of the sender.

SLABY-ARCO DETECTOR CONNECTIONS.

149. Fig. 43 is an elementary diagram of detector connections in the Slaby-Arco sets.

In this diagram R represents a relay, T a relay tongue, D a decoherer, and M the magnets and armature of a Morse writer. By tracing the connections it will be seen that a circuit commencing at one terminal of the detector passes through a single primary cell to the tapper of the decoherer, thence through the relay magnets to the bottom of the receiver tuning coil, and is completed through this coil to the other terminal of the detector. A second circuit, containing four primary cells, passes through the decoherer magnets and is broken at the relay tongue. Its other leg passes through the Morse-writer magnets to the relay tongue.

It will be seen that the second circuit will be closed by a movement of the relay tongue to the right and that the first circuit will be opened by a downward movement of the tapper.

The decoherer and Morse writer are shown in series in the second circuit for simplicity. They are usually connected in parallel. The single-cell circuit is completed through the tuning coil in the sets as furnished, but it can be connected with equally good results direct to the other terminal of the detector.

A general statement can be made to the effect that the local circuits for receiving signals through any type of detector are shunted directly across its terminals.

Pl. III is a photograph of a complete receiving instrument.

The *relay* is a Siemens polarized relay wound to a resistance of 4,000 ohms. It will work on the current produced by a single cell through a resistance of 60,000 to 80,000 ohms.

150. The *Morse writer* is fitted with clockwork for reeling off the tape, with an inker or printer for making the dots and dashes, and with magnets, whose armature, when attracted, starts the clockwork and lifts the inker against the tape. When released, the armature drops the inker and stops the clockwork.

The four primary cells furnish sufficient current to actuate the decoherer armature and Morse-writer armature at the same time.

The *first* circuit will be called the *coherer* circuit, the *second* the *decoherer* circuit.

The critical potential of the coherer is higher than that of the single primary cell in the coherer circuit, so that the coherer remains in the nonconducting condition until the increase of potential due to the alternating currents produced by the passing electric waves equals the critical *potential*, when its resistance drops to from 2,000 to 3,000 ohms and current from the single cell energizes the relay magnets in the *coherer* circuit. The relay tongue T at once closes the *decoherer* circuit. The current in this circuit energizes the Morse-writer magnets, its armature starts the clockwork, and presses the inker against the tape.

At the same time the same current energizes the magnets of the decoherer and the armature of the latter pulls the tapper down, thereby *breaking* the coherer circuit and tapping the coherer.

The relay tongue T immediately opens the decoherer circuit. The decoherer armature flies back and the Morse writer armature drops the inker and stops the tape. Everything is in readiness for another signal.

The connections above described provide for breaking the coherer circuit at the decoherer tongue prior to tapping the coherer, thus protecting the latter from the spark at break. They also provide for breaking the decoherer circuit at the relay. This circuit has an E.M.F. of six volts, and the self-induction of the decoherer and Morse writer magnets is large enough to produce a spark at break sufficient to injure the relay contacts.

In the coherer circuit the self-induction of the relay magnets is large, but there being but one cell in the circuit the spark at break is smaller, so that connections are now made to *break* the *decoherer circuit* at the tapper like an ordinary electric bell and *break* the *coherer circuit* in the coherer.

151. When a dash is made, several movements of the decoherer and relay take place in quick succession. In order to prevent a dash from appearing as a succession of dots on the tape, the movement of the Morse writer armature must be sluggish enough not to release the inker during the rapid interruptions of current when receiving a dash, but quick enough to release it during the interval between dashes and dots.

When sending rapidly, the intervals between the elements of letters are shortened and a point may be reached where, though the coherer may function properly, the mechanical movements in the Morse writer are too slow, and a continuous mark is made on the tape.

It is for this reason (though the qualities of different instruments vary) that a receiving speed of about 20 words a minute is generally the limit of tape recorders, while more than double that number can be received by sound.

The relay, decoherer, and Morse writer are all interdependent and must all be adjusted together, or readable signals on the tape can not be produced. Detailed instructions for their adjustment are given in Appendix D.

152. A well-adjusted relay will work when the coherer is bridged by two fingers of one hand, one finger on each cap of the coherer.

For testing the sensitiveness of the complete receiving instrument and its readiness for receiving a buzzer is furnished. The short electric waves sent out by the buzzer affect the coherer, and consequently the relay, at short distances. The relay should be dead-beat, as well as sensitive—i. e., it should not chatter.

To prevent injury to the relay contacts when the decoherer circuit is broken, either intentionally or accidentally, a battery of five polarization cells in series is shunted around them. These are *secondary* cells, having dilute sulphuric acid as an electrolyte and platinum wire electrodes. They polarize very quickly on sudden increase of current, but partially prevent the spark at break.

It was not known at the time these sets were constructed that these polarization cells, if one of the terminals is made very fine, are much more sensitive detectors than the coherer in connection with which they are used.

COMBINATION SWITCH FOR CHANGING FROM SENDING TO RECEIVING, AND VICE VERSA.

153. The switch referred to in paragraph 134 for changing from sending to receiving and vice versa is shown in Pl. III. It is a multiple, double-throw switch.

When in position for receiving, the primary sending circuit is broken, so that pressing the sending key does not close the circuit. When thrown into position for sending, the multiple switch closes the break in the primary sending circuit, breaks the connection between receiver, tuning coil, and aerial; breaks coherer connections to closed receiving circuit at both ends of coherer; breaks decoherer circuit on both sides of relay tongue and coherer circuit, near relay magnets. These circuits are broken to protect them from induced high potentials, due to the vicinity of the sending circuits.

In some receiving instruments the coherer is lifted to a vertical position when the multiple switch is thrown to the sending position. The filings in this position separate entirely from the upper electrode, and the coherer is thus more effectively protected.

When receiving circuits are inductively connected, as in the Stone sets, a special switch for throwing from sending to receiving is not required. It is, however, necessary to protect the detector, and the Stone sets are fitted with an ingenious and useful device for this purpose, whereby 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. The operator always wears his telephone while sending, and the receiving station can "break" him in the middle of a word or message by a call, which he can hear in the intervals between his own dots and dashes.

This will be referred to in the description of the Stone circuits.

154. Various methods of revolving coherers have been proposed and used to a certain extent.

When the filings in a revolving coherer are made conducting by the impact of electric waves on the aerial, they are immediately decohered by their own weight so that they are in a sense self-restoring and can be used in connection with a telephone.

MASSIE DETECTOR CONNECTIONS.

155. The other types of detectors in use are self-restoring. The simplest of these is the Massie microphone (or oscillaphone, as it is called by the inventor), which consists of a needle held in light contact as a bridge between two pieces of carbon. Where there is no motion the needle's own weight is sufficient to make contact. On board ship a permanent magnet holds the needle in place against all but very violent shocks. The carbon edges should be kept sharp and needle bright.

Fig. 44 is an elementary diagram of the microphone connections, and Pl. IV is a photograph of a complete receiving instrument.

If fig. 44 is compared with the preceding fig. 43, showing the Slaby-Arco detector connections, it will be seen that the Morse writer and decoherer circuit does not appear, that a telephone has taken the place of the relay, and instead of having a single cell in the telephone circuit there are two or more in circuit with a variable resistance, which permits the voltage at the terminals of the microphone to be varied until the "critical" potential is reached. Also that the telephone circuit, unlike the coherer circuit in the Slaby-Arco sets, is not in series with the tuning inductance, but is shunted directly around the microphone.

The carbon steel microphone, of which this detector is a type, is usually classed among imperfect contact detectors, but it is self-restoring and its change of resistance is not sufficiently great to work a relay so that its use is restricted to the telephone. Receiving circuits having telephones are simpler and much easier to keep in adjustment than those with the relay and Morse writer.

156. All detectors of the microphone type are somewhat irregular in their action and more or less unsatisfactory on that account. They are considerably more sensitive than the coherer and generally less sensitive than detectors of the electrolytic type about to be described. They can occasionally be used to advantage when more sensitive detectors can not. Their reliability is improved in the Father Murgas type by using a number of detectors in multiple and revolving the needle (in this case a small steel shaft) slowly by clock-work. This produces a very weak, musical note in the telephone, which does not interfere with the reception of messages, while the constant change or renewal of contacts keeps the instrument always in operative condition.

Like the coherer, the microphone becomes conductive at a critical potential, just below which it is kept by the use of the potentiometer in circuit. The slight increase of potential caused by the induced currents in the aerial changes its resistance enough to produce a sound in the telephone.

By adjusting the potentiometer to a point just below which a frying sound is heard in the telephone, the microphone is kept close to the critical potential at all times and thus in its most sensitive condition.

It is to be noted, as pointed out by Prof. Oliver Lodge, that the attraction between electrified bodies varies as the square of the distance, and that the unit of distance is 1 centimeter. Between bodies so close together that the distance between them can not be measured, the attraction may be very pronounced even though the difference of potential is very small.

157. The multiple switch on the Massie sets when changed from receiving to sending closes the primary sending circuit, breaks the lead from receiver to aerial and also breaks the battery circuit.

As a "call" in connection with the microphone a coherer with tapper and relay is furnished. The relay closes a circuit containing an alarm bell. The limit of this "bell alarm" is determined by the sensitiveness of the coherer with which it is connected. It is useful only when working with a station within its radius.

FESSENDEN DETECTOR CONNECTIONS.

158. Fig. 45 shows the detector connections of the Fessenden sets and Pl. XXIII a complete set of sending and receiving apparatus.

The detector is of the electrolytic type and consists of a fine platinum wire, just touching an electrolyte made either of a 20 per cent solution of nitric or sulphuric acid, or an alkali. Of these nitric acid is preferred. The other terminal of the detector is also platinum. The containing cup is made quite small so that the cohesive power of the electrolyte will prevent splashing in a seaway.

This detector is self-restoring. Its change of resistance on the impact of electric waves is so small that the increased amount of current in the local battery circuit will not work a relay except when the signals are very strong. It must be used with a telephone.

An examination of the detector connections in fig. 45 shows that, except in the arrangement of the potentiometer resistances, they are the same in principle as those of the Massie sets. The electrolytic detector must, however, have the *fine* wire terminal (if but one terminal is fine) connected to the positive pole of the local battery, as shown in fig. 45, otherwise the device is not operative. If both terminals are fine or comparatively small in area, it makes no difference which is anode and which cathode; but the *finer* the *anode* or, rather, the *smaller* the *area* of the portion in contact with the electrolyte, the more sensitive the detector. Wire less than 0.0004 of an inch in diameter is used for detector *points*. At the same time an efficient and rugged detector for short distances can be quickly made from a 1 or 5 candlepower incandescent lamp by breaking a hole in the bulb, removing the filament, and covering the leading-in wires with the solution referred to above.

This form is called the Delaney lamp detector, having been invented by Chief Electrician Delaney.

The extremely fine, almost invisible, wire used when great sensitiveness is required in order to pick up weak signals is easily burned out, and for *nearby* signaling the Delaney detector is very useful.

The platinum wire is drawn down to the extreme fineness referred to by being worked with a larger silver wire, of which it forms the core. The silver wire surrounds and protects it. Before using, the silver wire is removed by immersion in strong nitric acid.

The "point" thus made is clamped in a holder over the detector cup. The position of the holder is adjustable vertically by a screw, so that the immersion of the point can be varied at will.

159. In the hands of expert wireless operators the bare wire thus adjusted is found to be slightly more sensitive than any other form of detector thus far developed, but to keep the proper adjustment requires constant attention. The results of experiments by Doctor Ives are to the effect that with 0.04 mil wire a depth of immersion of 3 mils gives the best results.

A much more convenient method of using this detector is to seal the fine wire in a glass tube, leaving only a minute portion of the end projecting. Neither nitric nor sulphuric acid affects glass, and since platinum and glass having the same coefficient of expansion a perfect joint can be made between them, so that no capillary action occurs to increase the area of contact between the platinum point and the electrolyte. On this account the depth of immersion of glass points is not of great importance.

This detector was first called a *liquid barretter*, but has received the name electrolytic detector because it is electrolytic in its action.

160. When a current flows through an electrolytic cell the electrolyte is decomposed and oxygen is liberated at the anode. This gas is a nonconductor and its accumulation at the anode interferes with the passing of the current. This action is called *polarization*. A complete explanation of this action has not yet been given.

The potential of the battery in the detector circuit produces a current through the detector until enough oxygen accumulates around the *fine wire anode* to insulate it. The critical potential of the electrolytic detector is just below that necessary to break down this insulating or nonconducting 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 telephone, then resistance is cut in until this sound just ceases. Any increase in potential above the critical potential, such as that due to the alternating currents induced in the aerial by electric waves, will break down the polarization layer and start a current in the detector circuit, which will make a short or long sound in the telephone according to the number of wave trains passing. As soon as the additional potential disappears the detector is again polarized, the current ceases, and the detector is ready to receive another signal.

This rapid self-restoring quality of the electrolytic detector and microphone enables them to receive signals as fast as they can be sent. When the electrolytic detector is depolarized, gas bubbles are set free from the fine wire anode. To facilitate this action hook-shaped glass points have been made with the end of the fine wire pointing upward instead of downward. No definite increase of sensitiveness has been noted on this account.

When in use any drop of potential in the local battery circuit will decrease the sensitiveness of the detector by increasing the additional potential necessary to depolarize it, so that frequent adjustment of the potentiometer is necessary.

161. In the Fessenden receivers, the buzzer for testing the sets readiness to receive is a permanent mounting on the operating table.

The multiple switch for changing from sending to receiving is worked by a lever passing through the operating table. When thrown to the sending position this switch breaks the connection between receiver and aerial and receiver and ground, closes a shunt around the detector, breaks detector circuit near battery, and disconnects both telephone leads. (See fig. 67.)

When thrown to the receiving position it breaks the connection between the sending circuits and the aerial and breaks one leg of the primary circuit.

When the interference preventer is used no change is made in the detector circuits but the additional transformation of the received energy causes a loss which decreases the receiving range somewhat.

STONE DETECTOR CONNECTIONS.

162. Fig. 46 is an elementary diagram showing the Stone receiving circuits and detector connections. Pl. XX is a photograph of a complete set at the Portsmouth Navy-Yard.

These sets as furnished have, as will be seen from an inspection of the figure, the detector circuit completed through the tuning inductance which, as previously stated, is generally unnecessary, equally good results being obtained when connection is made direct to detector terminals.

The detectors used with these sets are of the electrolytic type. Provision is made by means of a double throw switch for connecting the detector and its accessories, either in circuit C or D, as desired. Circuit D is used when interference is to be cut out but the double transformation through the weeding-out circuit C causes a loss which decreases the receiving range somewhat.

The glass points used have their upper ends filled with mercury. Two are mounted together, either of which can be put in circuit by means of a movable contact-maker or switch dipping in the mercury. Having a spare point ready for use if one is burned out while receiving a message results in saving time.

The material and mounting of this switch must be of something with which mercury will not amalgamate.

The Stone sets, having only inductive connections between circuits, do not require as many precautions for the protection of the receiving apparatus from the sender as those previously described. No multiple switch is required, but the detector is protected by means of the sending key which breaks the detector circuit just before making contact and when contact is made grounds the aerial direct instead of through one of the closed receiving circuits. The advantages of being able to *break* an operator at any time while sending are evident.

DE FOREST DETECTOR CONNECTIONS.

163. These are the same in the three and two coil tuner. Fig. 47 shows the connections in the three-coil tuner and Pl. V is a photograph of a complete receiving instrument.

An examination of fig. 47 shows that the detector circuit is shunted around the detector terminals. The local battery, potentiometer, and telephone are in series, as in the Massie sets. A battery switch is furnished also by which the number of cells in the detector circuit can be regulated, one or more being cut in as desired.

In the De Forest Company's receiving sets the detector and its mounting is called the *responder*. The detector is of the electrolytic type. A glass cup is used to hold the electrolyte instead of a platinum cup, as in the Fessenden sets. Either bare wire or glass points may be used. In detectors of the electrolytic type, when acid is used as the electrolyte, care must be exercised in filling the cup to prevent damage to the mountings from the acid. This is necessary not only on account of corrosion but on account of current leaks thus formed which weaken signals and rapidly destroy the local battery. All electrolytes tend to creep and thus form conducting paths.

The multiple switch for changing from sending to receiving and vice versa breaks the primary circuit when receiving. When sending both leads to aerial from receiver and lead to ground from receiver are broken. A second switch on the *responder* short circuits the *detector* and breaks the local battery current.

TELEFUNKEN DETECTOR CONNECTIONS.

164. The same connections are used for the local battery in the *plain* aerial as when the receiving circuits are inductively connected. The former is shown in fig. 49 and Pl. VI is a photograph of an entire receiving set inductively connected.

It will be noted that the local battery and telephone are connected directly to the detector terminals and that there are small inductances or choke coils in both leads. These are for the purpose of keeping the induced currents, due to electric waves, from passing to ground through the local battery and telephone and are not absolutely essential. The battery consists of five cells, three in parallel and two in series, with the usual potentiometer for regulating the potential to the critical point at the detector terminals. It will be noted that the detector is shunted by one variable and two fixed condensers. These can be removed without greatly changing the action of the set.

Coherer detectors are sometimes connected with a condenser in parallel, the object being to give the circuit a definite period independent of the coherer, whose capacity is small but irregularly variable. By inserting additional capacity the ratio of the coherers' capacity to the total capacity in circuit is small, and any change in the coherer has less effect on the natural period of the circuit.

The same reason is given for connecting the condensers as shown around the Telefunken detector, which may be of the electrolytic or other self-restoring type.

The Schloemilch electrolytic detector originally supplied with Telefunken sets were hermetically sealed and nonadjustable, only the terminals for connection to the receiving circuit being exposed. Except to regulate the local battery potential the action could not be varied, and when for any reason the detector failed to operate the cause could not be ascertained. They were not as satisfactory on this account as the noninclosed type furnished with other sets and generally not as sensitive.

Two types—sensitive and highly sensitive—were supplied. Schloemilch cells are now being replaced with other types.

SHOEMAKER DETECTOR CONNECTIONS.

165. These are shown in fig. 48, Pl. VII, showing a complete receiving instrument.

The Shoemaker detector is of the electrolytic type, but differs from all the others in having its own source of potential. It is called by the inventor a primary cell detector. The primary cell has a potential of approximately 0.7 volt and consists of a fine platinum wire and a zinc rod amalgamated with mercury, both immersed in a 20 per cent solution of *sulphuric* acid.

The platinum wire is the positive and the zinc the negative pole of the cell. Having its own potential, no local battery is required. The telephone is simply shunted across the detector terminals without any adjustable resistance, making this the simplest of all detector circuits.

The telephone connections are the same for both forms of Shoemaker receiving circuits (figs. 42 and 42a). The platinum-wire terminal is usually sealed in glass and the sensitiveness of the detector is governed like the other types described by the area of the wire exposed to the *battery solution*.

The zinc rods must be kept well amalgamated and the glass points ground off so as to present the end of the platinum wire to the action of the *battery solution*.

166. 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. This is called "burning out." In the case of the bare wire reimmersion in the electrolyte is necessary. When glass points are used, the effect is apparently to carry away the wire, so that its end is shrouded by the glass. The gas bubble formed by polarization is held in the recess by friction and pressure and the detector is inoperative.

The glass points furnished with the Shoemaker sets are filed off to give a flat end with the platinum wire flush with surface, and it is occasionally necessary to tap an otherwise good point to assist the gas to escape from the blunt end of the glass.

Burned-out De Forest points may be repaired by partially melting the glass tip over an alcohol flame until it recedes and exposes a portion of the wire. The wire thus exposed is cleaned by dipping in strong nitric acid and the point is again ready for use.

It is found that Shoemaker points, after being renewed by filing, are improved by cleaning with strong nitric acid.

167. It is known that polarization due to electrolysis takes place at the anode in all electrolytic detectors; but it can not with certainty be stated that when the signals are received the breaking down or disengagement of the gaseous layer is due to its actual rupture.

In any case, it is known that when the critical potential is exceeded the boiling or hissing noise produced is due to the changes of resistance caused by the successive disengagement of gas bubbles. And when strong signals are received the disengaged bubbles can be seen with a microscope.

From this point of view, the action of electrolytic detectors is not greatly different from that of coherer detectors, except in the matter of being self-restoring.

The electrolyte used has a decided effect on the critical potential of the detector and on its sensitiveness.

It is found by experiment at the New York yard that a saturated solution of sal ammoniac between platinum-platinum electrodes has, under certain conditions, a very low critical potential and is more sensitive than the different acid solutions or any weaker solution of sal ammoniac. It has, however, the defect of not being immediately self-restoring after receiving strong signals and the further practical defect of depositing salts, which renders it difficult to operate.

A slight addition of nitric acid to the sulphuric acid in the Shoemaker solution has been tried with good results.

The distance between the electrodes in the electrolytic detector also affects its sensitiveness. The best results have been obtained with a distance of approximately one-fourth inch.

MAGNETIC DETECTORS.

168. 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. This fact was investigated and utilized by Prof. E. Rutherford for detecting electric waves. He published an account of his experiments in 1896, and since that time 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 winding are placed similar poles of two horseshoe magnets, which magnetize the iron band slowly moving under them. Electric oscillations in the aerial, 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. 52b. Like the Shoemaker detector, it requires no local battery, and, not being subject to burn-outs except from very high potentials or large currents, it is a very convenient instrument.

LODGE-MUIRHEAD DETECTOR.

169. A great many other forms of detector have been devised, among them the Lodge-Muirhead detector, which is more sensitive than any of the filings coherers in use and is adapted to work a siphon recorder.

It consists of a polished steel disk 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 disk as it revolves keeps it clean and bright.

This coherer may be direct or inductively connected in or to the aerial. As stated, its conductivity changes sufficiently to relay a current for working a siphon recorder and it has the further advantage of being self-restoring and can therefore be used with the telephone.

Other forms of steel mercury detectors are found to be unreliable in their action.

Fig. 52a is a diagram of the Lodge-Muirhead detector described above.

RECEIVING TELEPHONES.

170. Constant improvements are being made in the head telephones used with self-restoring detectors.

As has been stated, the change of resistance in these detectors due to the passing waves is generally so small that the current change in the local circuit can not be made to work a relay.

The low-resistance telephones in ordinary use are found to be unsuitable for wireless work, their windings not having sufficient turns to make the weak current affect the diaphragm except at short distances.

The detector having a high resistance, doubling the number of turns of a given sized wire on the telephone magnets does not double the resistance of the circuit, and therefore the ampere turns (the magnetizing effect) are increased if the additional turns are efficiently placed.

By using wire with very thin silk or enamel insulation wound in the most efficient manner close to the magnet cores, and by decreasing the thickness of the telephone diaphragm, great improvement in the reception of distant and weak signals has resulted.

Pls. VIII, IX, and X are photographs showing particulars of the best types of head telephones yet developed. Of these, the type shown in Pl. VIII is the most sensitive. Specifications relating to them will be found in appendix E. The general use of pneumatic ear cushions in connection with head telephones has improved reception in stations subject to local noises.

Chapter IV.

TUNING.

171. By tuning is meant the adjustment of the closed and open sending and receiving circuits to the same wave length and to any desired wave length within their limits.

The wave length assigned to a station might be called its tune.

The standard wave length for ships and shore stations was first set at 320 meters; this has recently been changed to 425 meters.

Three hundred and twenty meters was selected as being near the natural wave length of the *cage* type of aerials with enough inductance in circuit for the necessary coupling.

It was found feasible to give the flat-topped aerials now in use a longer natural wave length. This enables the power that can be effectively used in ships' stations to be increased somewhat, and the longer wave length is an advantage when land intervenes between the sending and receiving stations.

Standard oscillating circuits, called *wave meters*, which are adjustable at will to a great number of known wave lengths, are used for tuning. When adjusted to resonance with the circuits to be measured, the fact is indicated, according to the type of the wave meter, either by a maximum glow in a vacuum tube, a maximum movement of the pointer of a hot wire ammeter, the brightness of a glow-lamp, or the maximum reading of an air thermometer heated by the currents induced in the wave-meter circuits.

The open and closed *sending* circuits are tuned separately. The wave meter is set by means of the pointer on its scale to the desired wave length; then the inductance in the circuit to be measured is varied until a maximum of energy in the wave meter is indicated, as above. This shows that the two circuits (the standard and the one to be measured) are oscillating in resonance and therefore have the same period and wave length—namely, that indicated on the wave-meter scale.

The two circuits thus independently tuned are then coupled together.

After coupling, two points of maximum intensity are generally found in the wave meter, indicating by their positions on the scale the wave lengths of the two waves sent out. One of these is longer and the other shorter than that to which the two circuits were independently adjusted.

For tight coupling, if desired, the mutual induction between the two circuits is then varied until the two maxima are at the desired points.

If very loose coupling is desired the mutual induction between the two circuits is decreased until but one sharp maximum is indicated by the wave meter. This will be very near the wave length to which the circuits have been separately adjusted.

It will be seen that two senders, in order to emit similar waves, must not only have the closed and open circuits in resonance, but they must also have the same coupling.

172. Writers on this subject call the *coefficient of coupling* the ratio between the mutual induction and the square root of the product of the self-inductions of the two circuits, expressing it as a percentage.

If M = mutual induction,
L = self-induction of one circuit,
L^1 = self-induction of the other circuit.

The coefficient of coupling according to the above definition

$$= \frac{M.}{\sqrt{LL^1}}$$

None of these quantities can be obtained without very careful measurements, and therefore the above is of very little practical use in comparing wireless telegraph circuits. If, however, the *percentage of coupling* is called the ratio of the difference in length of the two waves sent out to the natural wave length of each circuit, it is easily determined.

For instance, suppose a close-coupled circuit shows a maximum at 280 and another at 360 when both circuits are tuned to 320 meters, the *percentage of coupling* by the above definition is $\frac{360-280}{320} = \frac{80}{320} = 25$ per cent.

The percentage of coupling when but one maximum is found is apparently zero. It is in reality very small, but can not be zero as long as any energy is transferred from one circuit to the other.

Whether sending circuits should have tight or loose coupling, or *tight* coupling for distance and *loose* coupling for selectivity, is not yet definitely determined.

In tuning receiving circuits the wave meter is used as a sender. Waves of a definite length, indicated by its pointer, are sent out and the position of resonance in the receiver is shown by a maximum of sound in the telephone

By the means indicated above (which will be more particularly described later) the wave lengths for the entire range of each circuit, both sending and receiving, can be plotted as curves. These are called *tuning curves*. By inspection of these curves the adjustments for the different circuits can be ascertained and the circuits coupled, both for sending and receiving any desired wave lengths.

TYPES OF INDUCTANCE AND CAPACITIES.

173. To render them capable of adjustment, all wireless telegraph oscillating circuits have either variable capacities or inductances, or both, and provision is also made in most sets for varying the mutual induction between related circuits.

These capacities and inductances vary greatly in design, and those for sending circuits, on account of the high potentials used, are very different in construction and mounting from those used in receiving circuits.

Both fixed and variable capacities and fixed and variable inductances are used separately or together. (It must be remembered that any conductor, whatever its shape or position, has both inductance and capacity, but the inductances and capacities referred to here are those concentrated in coils and condensers, as distinguished from the distributed inductance and capacity inherent in the conductors.)

Variable capacities are of the step-by-step and the sliding type. The former have a definite number of variations equal to the number of steps, the latter having any number of variations between their highest and lowest limits.

Both types are peculiar to receiving circuits alone, in the sense of being movable at will, the capacities in sending circuits usually being fixed.

Variable inductances are of the sliding type, the step-by-step type, and the roller type. The sliding type is used almost exclusively in the sending circuits.

In sending circuits the variable inductance consists of a helix of comparatively large, bare wire, mounted on an insulating frame of large diameter. The turns are widely separated and are fitted usually with three clips or sliders, by means of which connection can be made to any point of the helix. This is illustrated diagrammatically in fig. 32, Pl. XI is a photograph of a large antenna helix, and Pl. XII is a photograph of the Slaby-Arco combined antennæ helix and Leyden jar case.

The closed circuit is permanently connected to one end of the antenna helix and the circuit completed by the wire from the movable clip, which can be attached to any desired point of the helix.

The open circuit in *direct connected* sets has the ground and aerial wires, respectively, attached to the other two clips (see fig. 32), and these can be attached to such points on the helix as will give the open circuit the same wave length as the closed, and at the same time give the two circuits the number of turns in common necessary for the desired *coupling*.

In *inductively connected* sets (see fig. 36) the open-circuit helix is permanently attached to the ground lead, and the antenna lead is attached to whatever point is necessary to give the desired wave length. The closed-circuit helix is the same as before.

The mutual induction and coupling are varied by moving the open-circuit helix as a whole.

174. The step-by-step and roller types of inductances are used exclusively in receiving circuits. The former is sometimes made up with plug steps, giving a limited number of changes, but usually consists of a cylindrical coil of insulated wire wound on ebonite, glass, or other insulating material, one point on each turn being bare. Across these points a sliding contact moves, giving as many adjustments as there are turns of wire in the coil. (Flat coils of this type have also been made by the De Forest Company.) Pl. XIII shows the Slaby-Arco tuning coil.

The single-roller type consists of a bare conducting wire 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 different lengths of wire are put in circuit and an infinite number of adjustments can be obtained.

The double-roller type is also adjustable to any desired fineness. It has two grooved ebonite cylinders parallel to each other and connected so as to revolve simultaneously in either direction, reeling the conducting wire from one to the other as desired. On one cylinder the turns are insulated from each other, and on the other they are short-circuited so that any desired length can be used.

Single-roller inductances are furnished with Shoemaker sets, double-roller inductances with the larger Fessenden sets. They have also been used in some Telefunken sets. The earlier Shoemaker sets and the smaller Fessenden sets have step-by-step inductances. The De Forest, Massie, and Slaby-Arco sets also have the step-by-step type, varying by one turn of the coil at a time. If the contact touches more than one turn at a time, the strength of signals is decreased.

175. None of the types of variable receiving inductances in use can be readily mounted so as to vary the mutual induction between them by any definite amount.

For this reason fixed inductances are used in the closed circuits of the Stone and Telefunken receiving sets and the wave length varied by the use of variable condensers only. The variable condensers are of the sliding type in both these sets, and the circuits have inductive coupling, which is varied by varying the distance of the fixed inductances from each other.

Closer adjustment of a circuit to a given wave length can be made with a sliding condenser or with a roller inductance than with any of the other types, but only fixed inductances are suitable for definite variations of coupling.

Since such variations of coupling are necessary, it follows that if variable inductances are also necessary an efficient arrangement is difficult to devise.

Where great selecticity is required to prevent interference, a receiving circuit should have a very pronounced natural period, and this can only be given by a comparatively large inductance. The inductance need not, however, be variable, since the variations necessary in the wave length can be obtained by the use of variable capacities.

To illustrate the effect of comparatively large self-induction (electro-magnetic inertia) in prolonging the oscillations in electric circuits, a series of photographs of an oscillating circuit having a very long period was taken by means of an oscillagraph at the Pender Electrical Laboratory, University College, London. In a circuit having a capacity of 7 mf., an inductance of 31.5 millihenrys, and a resistance of 7 ohms, 2.5 complete oscillations were photographed. By keeping the self-induction and resistance constant and decreasing the capacity gradually to 0.5 mf. the number of complete oscillations increased to 8. If the capacity had remained constant and the self-induction had been increased, the same result would have been noted.

To illustrate the dampening effect of resistance, the capacity and inductance which gave 8 complete oscillations was kept constant and the resistance of 7 ohms increased: 23 ohms gave but 6 complete oscillations; 59 ohms gave but 4 complete oscillations.

This shows that receiving circuits of high resistance may have no pronounced period.

176. Where it is required to greatly increase the wave length of an aerial in order to receive from stations using a much longer wave than that of the receiving station, it is necessary to insert a loading coil (in the shape of a variable inductance) in the aerial, unless a large capacity in series with the aerial is already installed. As this is not usually the case, it follows that the only means of lengthening the aerial is by adding inductance; but since this can be added at a different point from the inductance necessary for transferring energy to the closed circuit, the latter can remain fixed. (See fig. 40a.)

From the foregoing considerations it appears that, generally speaking, we have fixed capacities and variable inductances in sending circuits, and variable capacities and fixed inductances in receiving circuits, and where variable inductance is necessary in a receiving circuit it can be added in a special coil without affecting the mutual induction between circuits.

Where receiving circuits have high resistance it is found by experience, as was predicted by Prof. G. W. Pierce, that while it is necessary to adjust the *open circuit* of the receiver to the incoming waves, the *closed circuit,* after a definite relation of its capacity and inductance has been obtained, need not be adjusted further, because no increase of its natural period given by adding capacity will increase the strength of signals, no matter how much the open circuit is increased. Any decrease of capacity below the critical amount, however, rapidly decreases the strength of signals.

DONITZ WAVE METER AND ITS USE.

177. Fig. 53 is an illustrative diagram of a Donitz wave meter and Pl. XIV a photograph of the instrument.

It consists of a standard closed oscillating circuit containing a fixed inductance and variable condenser inductively connected to a small closed circuit containing a coil of fine platinum wire in series. This wire is in the bulb of an air thermometer. If the standard oscillating circuit is placed near another oscillating circuit (such as the open or closed sending circuit), so that the lines of force cut its plane, oscillating currents will be induced in it. The currents in the standard circuit induce other currents in the circuit containing the platinum wire, which becomes heated and heats the air in the thermometer. The air expands and elevates a column of liquid to a point which can be read on the thermometer scale.

By movement of the variable condenser plates, the capacity, and therefore the wave length, of the standard circuit can be varied at will, the pointer on the condenser moving over a scale graduated directly in wave lengths.

When the standard circuit is in resonance with the circuit whose wave length it is desired to ascertain, the current in the standard is a maximum as is also the induced current in the circuit containing the platinum wire, and consequently the heating effect on the platinum is a maximum. This is indicated by a maximum reading of the thermometer.

Three fixed inductances are furnished with this wave meter, called by its inventor an ondameter, and there are three scales, one for each coil in combination with the condenser. The condenser is made up of 24 movable metal plates and 25 fixed metal plates immersed in paraffin oil. The instrument has an ebonite top and base and glass sides.

178. The fixed inductances furnished with the instrument are for a range of wave lengths from about 45 to 1,200 meters:

Coil I inductance=0.0028 millihenry or 2.8 microhenrys.
Coil II inductance= .021 millihenry or 12.1 microhenrys.
Coil III inductance= .05 millihenry or 50 microhenrys.
The least capacity of the variable condenser is 0.000179 mf.
The greatest capacity of the variable condenser is 0.00779 mf.
With coil No. I wave lengths up to approximately 300 meters can be measured.
With coil No. II wave lengths up to approximately 600 meters can be measured.
With coil No. III wave lengths up to approximately 1,200 meters can be measured.

It will be noted that each inductance is approximately four times as large as the next lower.

The wave length can be calculated from the formula: Wave length in meters $= 1,884.95 \sqrt{CL}$ where C is in microfarads and L is in microhenrys, the formula being derived from the fundamental one $T = 2\pi\sqrt{LC}$ where T is the time of complete oscillation.

179. Connections for measuring the wave length of the open, closed, and coupled circuits are shown in I, II, III, upper left-hand corner, fig. 54.

When the wave length of the closed or exciting circuit (II) is being measured, the open circuit is disconnected and the closed circuit excited with sufficient energy to give a clear, bright spark of moderate length.

The capacity of the closed circuit is such that a relatively large amount of energy is contained in it.

The large, oscillating currents produce correspondingly strong magnetic fields, so that good readings on the thermometer can be obtained without difficulty when the wave meter is one or more feet distant from the helix. The plane of the wave-meter coil must, of course, be parallel to the plane of the helix.

Aerials for wave lengths up to 425 meters have very small capacities as compared with those in the closed circuit, so that the magnetic field is weak and good readings more difficult to obtain. On this account a special coil of one turn is furnished with the instrument for insertion inside the wave-meter inductance in series with the aerial. The inductance of this turn is so small that its effect in increasing the wave length of the aerial is negligible.

In measuring the *natural* wave length of the aerial (I) the latter is disconnected from the closed circuit and a spark gap inserted in series between it and the ground. A sufficient number of turns of the common helix in direct-connected sets, or of the aerial helix in inductively connected sets, is added to give it the period desired after its natural period has been obtained.

A maximum reading of the thermometer shows the position of resonance and corresponding wave length. Other readings, when plotted (Curves I and II, fig. 54) with corresponding pointer readings, as abscissæ and thermometer readings and as ordinates, give a number of points which may be joined by a curve. The latter indicates by its shape the sharpness of resonance and in a general way the distribution of energy.

After the range of wave lengths it is possible to obtain in the closed and open circuits is ascertained (fig. 55) and the shape of the waves determined (Curves I and II, fig. 54), the circuits are coupled together, the shape and length of the two waves sent out plotted (Curve III, fig. 54), and the percentage of coupling obtained. The percentage of coupling on all Slaby-Arco sets varied between 10 and 15 per cent.

Fig. 56 shows a combination of curves like those in figs. 54 and 55. It represents the original installation on the *West Virginia*, with a very close coupling, nearly 40 per cent.

Fig. 57 shows the original installation on the *Maryland*, and is an example of very *loose* coupling, there being but one wave length found. Excellent results with this set have been obtained.

Fig. 58 shows the original and present installations on the *Charleston*, which show two maxima—one 12 per cent and the other 7 per cent coupling. Figs. 58a and 58b those on the *Indiana* and *Minneapolis*.

Figs. 59 and 59a show the installation at the Guantanamo station; coupling, approximately 38 per cent.

The method of tuning receiving circuits, by using the wave meter as a sender, has already been described.

Fig. 61 shows a tuning curve of a Slaby-Arco syntonizing coil with an aerial of 325 meters.

Fig. 62, that of a Shoemaker coil at the Jupiter Inlet station.

180. Were it not for the fact that the values of the capacity and inductance in an aerial can not usually be determined prior to its erection, standard lengths of connecting wires used in installing wireless telegraph sets could be adopted, and the entire range of sending and receiving wave lengths and the correct coupling of any wireless telegraph set might be determined beforehand. It is to be hoped that this will yet be done.

USE OF HOT-WIRE AMMETER.

180a. The hot-wire ammeter furnished for tuning the open and closed circuits to resonance is probably a more sensitive indicator for use in the wave meter than the air thermometer furnished and is frequently used in place of the latter.

A hot-wire ammeter is shown on Pl. XV, with shunts for use with it secured on the under side of the cover, in the upper portion of the figure. It is for use in the open circuit.

When the currents in the aerial are large enough to throw the pointer off the scale, one of the shunts should be connected in parallel with it.

The hot-wire ammeter, as its name indicates, measures comparatively the amount of heat generated in the aerial. The heat in any circuit in which a current is flowing equals $I^2 R$, or the product of the square of the current and the resistance.

A high, as compared with a low, reading of the hot wire ammeter shows that more energy is being dissipated in the *open* circuit, but it does not show whether it is going out in persistent or highly damped oscillations, nor whether the coupling is tight or loose. Since the distribution, as well as the total amount of energy radiated, affects reception, the hot-wire ammeter is useful only to indicate resonance. For any coupling or wave length a maximum reading will be obtained when the two circuits are in resonance, but this maximum will be different for different percentages of coupling.

It is found that when two circuits tuned to resonance are coupled together, that the radiation, as shown by the hot-wire ammeter, varies somewhat with the coupling and is in general greater with a coupling of 15 per cent or more, than with a very loose coupling.

The coupling that gave the highest reading of the hot-wire ammeter was usually found the best when receiving with coherer detectors, but since the introduction of detectors requiring the use of telephone receivers the tendency is toward very loose coupling, which shows but one maximum and gives out more persistent wave trains, i. e., with less damping. However, as previously stated, receiving circuits with the same natural wave length and coupling as the senders should work efficiently on either tight or loose coupling, and there is not sufficient data yet available to determine which is the best.

The close coupling shown in figs. 59a and 60 is partly due to the necessity of adding inductance to the aerial at those stations to bring it into resonance with the closed circuit.

IMPORTANCE OF KEEPING OPEN AND CLOSED SENDING CIRCUITS IN RESONANCE.

181. *In any case* the open and closed circuits should be in *resonance.* This is of the greatest importance.

The removal of a jar from the condenser on account of piercing, blistering of the tin foil, bad connections to tin foil, moisture in jar rack, change of helix connections, 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 sending qualities.

In the same way, change in the amount or arrangement of wire, or lead of the aerial, changes its natural wave length and has the effect of putting the two circuits out of resonance.

When a wave meter is not part of the station equipment the hot-wire ammeter test should be made daily. In making the test care should be taken to have the length of spark gap and strength of current used always the same. The cause of any decrease in maximum reading of the hot-wire ammeter should be sought for first in the condenser and its connections, then in the condition of the spark gap, and finally at the ground and other connections of both circuits.

It is found that the capacity of bare-wire aerials varies very little with widely varying atmospheric conditions, so that, generally speaking, the causes of decreased radiation are found in the closed circuit and nearly always in the change of capacity in the condenser, due to broken or poor contacts, blistering, dead foil, etc.

THE FLEMING CYMOMETER.

182. This type of wave meter is shown in fig. 63. Pl. XVI is a photograph of the complete instrument.

It consists of a sliding tubular condenser formed of two brass tubes, separated by an ebonite tube which forms the dielectric.

The outer tube can be moved by a handle *h*, and an index pointer P (fig. 62) moves with it over a divided scale S S.

Parallel with the condenser is an inductance coil H H, consisting of a bare copper wire wound on an ebonite tube.

From the outer end of the condenser O, a pin 1 projects, which carries a half collar K, resting on the inductance coil.

The circuit of the condenser and inductance (forming a standard oscillating circuit) is completed by a copper bar L_2 L_3 of square section.

With the instrument is supplied a vacuum tube "V," which is attached to two small hooks placed on the ends of copper wires, which are respectively connected with the outer and inner tube of the condenser.

These instruments are made in different sizes for measuring wave lengths up to 2,500 meters. Those for measuring wave lengths up to 700 meters have the following constants:

Wave length 100 meters: Inductance, 24.9 microhenrys; capacity, 0.000119 mf.

Wave length 700 meters: Inductance, 162.3 microhenrys; capacity, 0.000771 mf.

183. To measure the period of any circuit, place the cymometer so that the copper bar L_2 L_3 is parallel with, and close to, any straight portion of the circuit in which electric oscillations are taking place.

Fix the vacuum tube to the two small hooks in connection with the terminals *x* and *y* and screw the ebonite handle into the thick collar *k* of the outer tube of the sliding condenser.

Move the handle, thus sliding the outer tube of the condenser along, until the vacuum tube glows most brightly. Then the end of the index slip P will indicate on the *lowest* of the four scales the number of oscillations in one-millionth of a second.

The *top* scale reading indicates the oscillation constant of the circuit being tested, viz, the square root of the product of the capacity in microfarads and inductance in centimeters of the circuit.

The other two scales give the wave length of the circuit in feet and meters, respectively.

It is generally necessary when using this instrument to connect to the earth the terminal of the vacuum tube which is in connection with the outer tube of the sliding condenser. The copper bar L_2 L_3 should be placed as far from the circuit to be tested as it is possible to obtain a glow in the vacuum tubes. Such a position will give a very sharp scale reading.

Two kinds of vacuum tubes are furnished with the instrument, viz, neon and carbon dioxide tubes. The former is more sensitive and its excitation is more easily distinguishable in daylight.

184. The cymometer differs from the Donitz wave meter in having a variable instead of a fixed inductance. The inductance and capacity are varied simultaneously by the movement of the outer condenser tube, since it carries the pointer and the contact maker on the inductance. It will be noted that the inductance changes one turn at a time.

The wave form, as determined by the heat in the air thermometer, can not be plotted with the cymometer, there being no scale reading for the vacuum tube and no method of recording its relative brightness. The cymometer does, however, show the length of the two waves sent out.

For measuring small inductances and capacities a rectangular circuit of insulated wire, having an inductance of 5,000 centimeters, is furnished with the cymometer. By placing this inductance, whose capacity is too small to be considered, in circuit with an unknown capacity and measuring the wave length of the circuit thus found, the value of the capacity can be determined from the oscillation constant.

By connecting it with a known capacity and an unknown inductance and measuring the wave length of the circuit thus formed, the value of the unknown inductance can be determined in the same manner.

SLABY MEASURING RODS.

185. The wave meters first used were the Slaby measuring rods, a diagram of which is shown in fig. 64 and a photograph in Pl. XVII.

A set for measuring wave lengths up to 1,200 meters consists of three rods, the smallest, measuring wave lengths from 100 to 200 meters, the intermediate, from 200 to 500 meters, and the largest, from 500 to 1,200 meters.

Each rod consists of a glass tube closely covered with a winding of fine, silk-covered wire, forming an open circuit of large inductance.

Inside the glass, at the upper end of the tube, is secured a fluorescent screen, consisting of a small piece of paper covered with conducting particles (preferably gold foil) and crystals of barium platina cyanide.

This screen is attached to the upper end of the wire. The lower end of the wire is brought up inside the glass and ends near the fluorescent screen described above. A metal plate, to be laid on the ground and connected by means of a wire with a metal contact rod, is furnished with the instrument.

When brought near a circuit in which electrical oscillations are taking place, the induced potential at the ends of the wire will cause the screen to fluoresce, if the two circuits are in resonance. By moving the contact maker along the coil its effective length is changed. The wave length corresponding to any point of contact is marked directly in meters on the coil. When in resonance the wave length is read from the scale at the point of contact which gives the brightest light.

The three forms of wave meters described and the hot-wire ammeter are available for tuning sending circuits. The Donitz wave meter is the only one with which receiving circuits can be tuned.

CALIBRATION OF CLOSED RECEIVING CIRCUITS.

186. Closed receiving circuits having fixed inductances and variable condensers, or vice versa, can be provided with a scale on the variable element graduated directly in wave lengths, and by their means the wave length of any station heard can be measured by adjusting until a maximum of sound is obtained and then taking the scale reading of the variable element.

Receiving circuits having both variable condensers and inductances should be provided with a table showing the wave lengths for a number of adjustments of each variable.

PREVENTION OF INTERFERENCE.

187. The importance of careful tuning can not be overestimated. Where a number of vessels and shore stations must be mutually ready to hear each other's calls at any time, they must necessarily *call* in the same tune, and each ship and shore station must keep its receiving circuits adjusted to that tune.

By careful adjustment with the Fessenden interference preventer, it is possible to receive at will one of two incoming signals of the same strength and to exclude the other when the wave lengths differ by 3 per cent, but if the signals which it is desired to exclude are much stronger, on account of proceeding from a near-by station or from any other cause, this percentage of difference must be much greater, and if very strong it may not be possible to exclude the stronger and receive the weaker signals.

It is necessary to call in a particular tune; it is not, however, necessary to communicate in that tune.

The selection of the tune for the communication should be made by the receiving station when it acknowledges the call.

There is a limit in this respect, however, since the range of wave lengths which can be effectively used with any given aerial is much more restricted in sending than in receiving.

Increasing the sending wave length by adding inductance beyond that necessary to receive energy from the closed circuit, rapidly decreases the sending range.

When inductance is added to increase the receiving wave length, no evil effects result, at least, not to such a great extent.

The above may be expressed by saying that a station can not send effectively on a wave more than 25 per cent longer than the natural wave length of its aerial, but it can effectively receive (by adding inductance to the aerial or by shortening it by means of a capacity in series) waves of almost any length.

It is very desirable for the purpose of communicating between shore stations that sending wave lengths be used which are longer than those that can be efficiently used at ship stations.

If a shore station aerial can not send out a ship's wave length and vice versa, it will be necessary to have two receivers at each station, one kept in tune for each of the two wave lengths. This is done at high-power stations, separate aerials being installed for receiving from ships.

It will be seen from the above that the problem of assigning non-interfering tunes to a large number of intercommunicating stations is by no means a simple one, especially when the stations, such as ships, are continually varying their distance from each other. It has not yet been successfully solved.

This problem will be greatly simplified as soon as means for sending and receiving in any desired direction only are perfected.

STATIC.

188. A more serious cause of interference, however, especially at stations in warm climates, is what is commonly called "static."

Every lightning discharge produces powerful electric waves which affect detectors at great distances, and since thunderstorms in warm climates, and especially in the summer, are sometimes almost continuous in the sense of existing somewhere in the area in which waves created by the lightning discharges affect detectors, the interference caused by them is also almost continuous.

These waves vary greatly in length. Those of the same or nearly the same length, as any given aerial, affect that aerial more or less strongly. Those widely different are excluded unless very strong.

Again, at every station the air at the top and foot of any 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 are almost continuous and are described as a continuous roar, through which it is impossible to read signals.

In this respect the *note* of the spark (the frequency of the wave trains) affects reception, a high, clear note being easier to read than any other. Less sensitive detectors can sometimes be successfully used when static disturbances render the more sensitive ones useless.

Whatever tends to selectivity or inertia in receiving circuits, such as large inductances, also tends to decrease static interference.

It is found that closed receiving circuits not directly connected to the open circuit are less affected by static.

The static charges, having a direct path to ground, do not accumulate on the aerial, and the aerial being only inductively connected to the closed circuit, impulses out of tune are much weakened in the transfer.

When the signals it is desired to read are *strong*, static can be largely eliminated by disconnecting the *ground* without destroying the signal.

REGULATION OF SENDING APPARATUS.

189. Fig. 65 is a complete diagram of connections of a Slaby-Arco wireless-telegraph set supplied with current from a mercury-turbine interrupter.

Figs. 66, 67, 68, 69, 70, and 71 are diagrams of connections of complete wireless telegraph sets furnished by Massie, Fessenden, Telefunken, Stone, Shoemaker, and De Forest, respectively. All of these sets are designed to use 60-cycle alternating current instead of interrupted direct current, as used in the Slaby-Arco sets.

On board ship, motor generators are installed in the dynamo room or operating room or outside the latter in its immediate vicinity for transforming the ship's direct current into 110-volt A. C. The A. C. generator leads are connected with the primary of an induction coil or transformer, the secondary of which delivers it at a potential of 25,000 to 30,000 volts to the sending condenser.

Figs. 72, 73, 74, 75, 76, and 77 are diagrams showing the standard methods of installation, control, and protection adopted.

190. 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.

In order to provide for some variations in the resonant frequency due to change of capacity in the sending condenser, the speed of the motor generator is made variable, so as to give any frequency between 50 and 70 cycles.

As previously stated, 60 cycles, normal frequency, are used because this is a commercial type of motor generator. It appears probable that a higher frequency will give better results.

The reading of the frequency indicator when supplied with such sets should be frequently noted while sending and the speed maintained, by adjustment of the motor field rheostat, at the exact frequency shown by experience to be the best.

When running on open circuit practically no work is being done by the motor 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 prevent 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, is placed in the primary circuit. This coil, on account of its inertia, acts as a dead resistance or 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. (See par. 89.)

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 (first introduced with the Shoemaker sets and shown in figs. 70 and 72, etc.) 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.

On account of the small penetrating effect of high-frequency currents (see par. 92), 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.

For the above reason, a safety switch, shown in fig. 72, etc., 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. 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.

Instructions for resuscitation from apparent death from electric shock are given in Appendix F.

PROTECTION OF LOW-POTENTIAL CIRCUITS FROM INDUCED HIGH POTENTIALS.

191. Burnouts and damages to insulation from induced high potentials are referred to in paragraph 130.

The protective devices shown in fig. 74 may consist of Leyden jars or other condensers, straight filament lamps, micrometer spark gaps, or any other form of *high noninductive resistance.*

At shore stations wires leading from power house to operating room should be lead covered or run in conduit, the covering to be grounded in all cases, the object being to afford a *straight path to ground* for all high potentials, and at the same time avoid current losses.

Carbon resistance rods, being a commercial article and not easily destroyed, are generally used for this purpose.

CODES.

192. Any dot and dash code may be used for signaling. For official use between ships of the Navy and between them and naval shore wireless-telegraph stations, the Continental Morse Code has been adopted. Instructions governing its use are issued by the Bureau of Navigation in the pamphlet "Instructions for the Transmission of Messages by Wireless Telegraphy," which is supplied to all operators. The pamphlet also contains the names of all naval ship and shore wireless telegraph stations and their "call letters." Information to the public relating to naval shore stations is issued in "Notices to Mariners." The rules governing communication between shore stations and private vessels are published in the same manner. These, together with the "Regulations for the Government of Shore Stations," will be found in Appendices G, H, and I.

Communication with private shore stations and coasting vessels in the United States is by means of the American Morse code; with all foreign stations, ship and shore, public and private, by means of the Continental Morse Code. It is probable that the call for the International Code of Signals, P. R. B., will soon be adopted by maritime nations for use in wireless telegraphy, so that, by means of the International Signal Book, communication can be carried on between operators not speaking the same language. At the same time the use of the International Signal of Distress, N. C., should be extended to wireless telegraphy.

The Continental and American Morse codes and a list of common abbreviations follow:

A dash is represented as 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.

Telegraph codes.

ALPHABET.

	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.

1	· — — ·	· — — — —
2	· · — · ·	· · — — —
3	· · · — ·	· · · — —
4	· · · · —	· · · · —
5	— — —	· · · · ·
6	· · · · · ·	— · · · ·
7	— — · ·	— · · · (misprint) — — · · ·
8	— · · · ·	— — — · ·
9	— · · —	— — — — ·
0	——	— — — — —

2740—06——8

Telegraph codes—Continued.

PUNCTUATIONS, ETC.

	Morse.	Continental.
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

COMMON ABBREVIATIONS—Continued.

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
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

COMMON ABBREVIATIONS—Continued.

Neg......Negative
Ni........Night
No.......No, and New Orleans
Nun......None
Nv.......Never
Nw.......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
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

COMMON ABBREVIATIONS—Continued.

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
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.

INSTALLATION AND OPERATION.

193. For installation ample room is available at all shore stations. On board ship a room, having about 60 square feet of floor space, with no dimension less than 5 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. Operating rooms below the water line, where long leads to aerial are necessary, are decidedly less efficient than those on the upper deck.

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 between all parts of the sending and receiving instruments should be as direct as possible and in the case of the 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 diagrams of connections and the purpose and use of each connection should be familiar to every operator. They should be well made and kept clean all the time.

194. Wireless-telegraph instruments, like all others, depend for their efficiency on their condition and amply repay good care.

Sending-key contacts should be kept clean and smooth and with faces parallel to each other.

All sliding contacts, especially in receiver tuning coils, should be clean and bright and free from foreign matter.

Detector points should be kept in their most sensitive condition and frequently tested by means of the buzzer furnished for the purpose.

The best adjustment for receiving different stations should be recorded or memorized by all operators.

A sending set worked at low power, with all connections good, closed and open circuits in resonance, no sparking from edges of condenser, jars, or plates, nor glow from aerial and no sparking to rigging, is utilizing its power much more efficiently and will probably be heard farther than the same set pushed to the limit, but out of resonance or with high-resistance connections and sparking at all points.

In any case use only current and gap necessary for good readable signals when sending to stations at known distances.

Tuning curves for open and closed circuits are only correct for the capacity and inductance in each at the time the measurements are taken, and the radiation shown on the hot-wire ammeter after coupling the two circuits is that for the particular period and coupling, as well as for the primary current, frequency, and spark gap then used.

These conditions should be reproduced as nearly as possible and the hot-wire ammeter test made daily. The cause of decreased radiation should be searched for until it is found and then remedied. The condensers should be carefully examined weekly, as well as all contacts on all circuits, special attention being given to the ground connection.

The insulation resistance of the aerial should be tested monthly or more frequently when leaks are suspected, and all insulation aloft should be frequently examined.

Porcelain or glass insulators are preferred. Hard-rubber insulators char on the surface from leaks in wet weather and become less effective as insulators.

Except where a number of tunes are ordered to be used the operators should not alter the capacity nor inductance in either circuit, except when absolutely necessary, and when, while sending, any part of the condenser is injured it should be immediately replaced or repaired, and if this can not be done on account of lack of spare parts the two circuits should be readjusted to *resonance* with the best means available.

Operators must avoid a short or jerky style of sending. Dots and dashes must be firm and of proper relative lengths, as must also the interval between parts of a letter and the spaces between letters and words. The spark must be kept white and crackling and have considerable volume.

Pl. XVIII is a photograph of the *Maryland's* operating room.

Pl. XIX, operating room at Cape Elizabeth, Me.

Pl. XX, operating room at Portsmouth, N. H.

Pl. XXI is a photograph of the Colon station, exterior.

195. The limits of the book will not permit giving detailed descriptions of methods of operating engines and dynamos at shore stations. Instructions for assembling, charging, and discharging storage batteries are given in Appendix K, and fig. 80- is a diagram of connections for the purpose.

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.

APPENDICES.

Note 1.

The following list of metals are 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.	Copper.	Zinc.
Platinum.	Iron.	Magnesium.
Gold.	Tin.	Sodium.
Silver.	Lead.	

The amount of potential difference also depends on the battery solution, and in some instances it may be reversed.

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 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 curcurrent 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.

[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 (in 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

APPENDIX B.

The "flat-top" aerials now used to the exclusion of the "cage" type of the earlier outfits are made of two constructions—"single ended" and "double ended"—the single ended being of the inverted L formation, the double ended being of the T formation. There is also a minor variation applying to either, in which the outer ends of the "horizontal" conductors of the aerial, which might for ordinary purposes be left open, are connected together, as later described in detail, so as to form an inverted U of the Hertzian "loop," which is required by the type of receiver circuits used by the De Forest and Shoemaker companies.

The single conductor from the transmitter runs to one terminal of the anchor spark gap furnished with the outfit of these companies, or to an alternative construction shown on print No. 14831–A attached.

The two legs of the inverted "U" of the aerial attaching to the other two terminals.

The first installation of the flat top double end aerial was made on the U. S. S. *Kentucky* in 1904.

WAVE LENGTHS.

The first standard wave length was 320 meters. This has since been superseded by 425 meters for ship installations

There are other longer wave lengths used in some special cases for shore stations.

In every case it is highly desirable that the length and disposition of the aerial should be such that its natural wave length be that of the standard wave length. This has been found necessary on account of the waste of energy in transmitting, due to the coils of inductance which are inserted to make up for inadequate length.

The dimensions required in the aerial to give a natural wave length of 425 meters varies with the nature and relative location of the adjacent masts, smokestacks, etc., which will affect the values of its inductance and capacity and no exact formula can be assigned.

The length of aerial required for 425 meters natural wave length will, however, in most cases, necessitate the use of the single ended form.

The length of aerial (measured from the outer end of the "horizontal" down through the "vertical" to the transmitter) giving the nearest practicable wave length to 425 meters, for four wire aerials was 219 feet in the case of the *Minneapolis* where the natural wave length was 406 meters for a double end flat top aerial. For a single end flat top aerial, a length of 275 feet measured similarly, gave a natural wave length of 403 meters on the U. S. S. *Charleston.*

In the cases of ships where these lengths are not practicable, it may be necessary to increase the inductance of the aerial by reducing the number of wires from the standard number of four for a part of the length of the aerial.

DRAWINGS.

Examples of aerials installed are shown on blueprints attached as follows:

U. S. S. *New Jersey* and *Rhode Island*, single-ended loop, drawing No. 15301–M.

U. S. S. *Minneapolis*, double-ended loop, drawing No. 15377–M.

SPARS.

The spars forming the aerial are of two lengths, 15½ feet, which have been used on ships of the *Denver* class and larger, and 10½ feet, which have been used on ships smaller than those.

The 15½-foot spars are 3½ inches in diameter in the center and 1½ inches diameter at the ends; the 10½-foot spars are 2½ inches diameter in the center and 1½ inches diameter at the ends.

In the case of double-ended aerials metal spars have been used for the center spar, to avoid the possible damage to wood from the heat from the stacks. These have the following dimensions:

For the larger aerials 15½ feet length, 1½ inches outside diameter, and for the smaller aerials 10½ feet lengths, 1½ inches outside diameter, No. 17 B. & S. gauge.

INSULATORS.

The insulators used in connection with the installation are as shown on blueprints 9244–H and 9899–C and others as specially described in the following:

The uses of those shown on 9244–H are as follows:

The deck-tube insulator 9244–H–4 is used for going through bulkheads and decks in locations where water-tightness is not specially required, but there are liabilities to mechanical injury.

In going through metal decks and bulkheads, it is customary to increase the distance between the conductor and the metal by the use of a deck-tube plate 9244–H–21.

The window tube 9244–H–6 is not ordinarily used. It includes a detachable part which enables the aerial to be disconnected from the apparatus in the case of lightning storms, and be connected direct to ground, thus protecting the apparatus and operator.

The strain insulator 9244–H–20 has ordinarily been used for the ends of the aerial and to secure the halyards which hoist the aerial into place.

The strain clamp and insulator 9244–H–23 is used at the lower part of the aerial and attached usually about 3 feet from the upper end of the rat-tail, and from there guys to another adjacent part of the ship, keeping the aerial in stretch.

The suspending insulator 9244–H–24 is used in guys which supplement the strain clamp and insulator.

Capping 9244–H–25 and molding 9244–H–26 are in some cases run in quarters where it is desired to protect the rat-tails from mechanical injury, and also, to some extent, persons from shock.

The deck tube, protected, type A, 9899–C, has been superseded by an improved modification shown as type B on the same sheet.

This type of insulator is used on decks where the moisture on the deck from washing down, storms, etc., and the mechanical contact with holystones and other objects is to be avoided.

The suspending insulator has been largely superseded by the use of the Locke strain insulator No. 605, especially adapted as shown on print 13993–A and photograph 1644.

Its first application was made on the U. S. S. *Charleston*.

These insulators remove the objection encountered with the use of rubber insulators, i. e., carbonization from sparks, consequent leakage of aerial, and give in their petticoats two dry surfaces of porcelain for effective insulation in rainy weather.

The special form of insulator shown on print 15367-A was used on the *Indiana* for running the rat-tails along the passage to the operating room.

In the particular construction shown, rubber insulators of similar dimensions were used as an expedient, porcelain insulators from the Pass & Seymour Co. not being available at the time.

In drawing 9244-H-30 is shown the rat-tail angle block.

This is used in connection with the rat-tails where guys are taken off, in order to prevent too sudden a nip in the rat-tail.

In the strain insulator and strain clamp and insulator a porcelain insulator No. 20, as shown, is used in connection with the seven No. 20 phosphor-bronze conductor at the wooden and brass spars on the aerials, as will be explained later.

The porcelain tubes which are used in the aerial insulators, drawing 15367-A, are known as "porcelain tubes, glazed, heads 3 inches long, 1-inch hole, 1¾ inches outside diameter, 6 inches under head" for rat-tail, and are made by Pass & Seymour, Incorporated, Dey street, New York.

The aerials are swung from a band with eyes, which are fitted on topgallant mast under truck lights in compliance with the Bureau of Equipment's letter of February 20, 1905.

The runs of the lower part of the aerial to the operating room are either through decks, masts, or ventilators, as the case may require.

The conditions depend upon the protection from mechanical injury which is required, an important feature being the maintenance of as large as possible distance from the rat-tails to the metal part of the ship.

In the case of masts and ventilators, the distance to metal may be as great as 2 or more feet, as compared with 6 inches, which is obtained with the use of the protected deck tube, type B, 9899-C.

Total weights are about 325 pounds.

TYPE.

The aerial to be flat-top single-ended, of *Kentucky* type (12802-L), modified for the Hertz ("loop") circuit, so as to be adapted for the Shoemaker receiver installed.

LOCATION.

The aerial will be swung between the fore and main topgallant masts.

Just below the bottom of the truck lights there will be installed a band with eye and two lignum-vitæ, yacht blocks, No. 9, for the halyards.

YARDS.

Two spruce yards, 15 feet 6 inches long, 3 inches diameter in center, and 1½ inches diameter at ends, to be of clear timber, without knots or checks, and coated with three coats of spar varnish.

The yards to be located 161 feet apart.

INSULATORS.

Four Locke strain insulators, No. 605 (12086-X), with ash plugs as per 13993-A, to be lashed with 10 turns of marline to the inner sides of the wooden yards at 2 feet from ends (as per No. 1686, etc.), and arranged to set vertically when the aerial is in place.

Notch the yards, if required, to fit the bead on the No. 605 insulators.

The ash plugs to be given three coats of spar varnish and fitted with four 3-foot bridles of 18-thread hemp rope, with one-half inch thimbles. The thimbles will be so located that the No. 605 insulators will set vertically when the aerial is swung into place. The bridles and unglazed surfaces of the No. 605 insulators to be given two coats of Armalac.

CONDUCTORS.

On the after yard will be secured, at 59 inches apart, four sets of (2 to set) 7/No. 20 phosphor-bronze wire leads, each 1 foot long, at the 8 ends of which will be No. 20 porcelain insulators, 2 inches diameter, five-eighths inch groove, three-eighths inch hole (requisition No. 1014/05) for insulation from the yard.

Of each set of two, one is to extend on the forward side "horizontally" and one "down."

From the insulators on the four horizontal leads to the forward yard four 160-foot "horizontal" wires will be secured to the other groove of each "horizontal" No. 20 insulator.

Also, from the after-yard four "vertical" wires 7/No. 20 phosphor-bronze, 85 feet long, to extend from the lower four No. 20 porcelain insulators to the rat-tails.

The breaks in the open angles will be closed by a bight of 7/No. 20 phosphor-bronze wire soldered to the "horizontal" and "verticals," with no tension and slightly slack, when aerial is in place, the eight 1-foot leads taking all the strains.

At the forward yard the four wires will be joined together by soldering a cross wire of 7/No. 20 phosphor bronze, without interfering with the Locke insulators, 1 foot from the wood yards.

The leads and wires to be spaced 59 inches apart on all yards.

The sag allowed in center yard is 3 feet from the level of the blocks, or 102 feet to the superstructure deck.

Of the four vertical wires 85 feet long, the two on the starboard side will lead to a rat-tail and the other two on the port side to a second rat-tail.

The stranded conductors in the rat-tails at the upper ends will be thoroughly filled with splicing compound, so as to prevent moisture which runs down the "verticals" from entering inside of the rubber of the rat-tail.

JOINTS IN CONDUCTORS.

In splicing the 7/No. 20 phosphor-bronze wire to make up the necessary lengths use McIntyre twist connections (requisition No. 324).

Where practicable the runs of the 7/No. 20 P. B. wire shall be unbroken and from the same lot of wire.

SECURING OF LOWER ENDS.

To two awning stanchions, outboard, starboard, and port, at frame 73 on the after bridge deck secure two guys of paraffined signal halyard stuff, one at either side to strain clamp and insulator 9244-H-23, which are clamped to the rat-tails at about 3 feet from the upper ends of the rat-tail.

RAT-TAIL LEADS THROUGH MAST AND BULKHEAD.

Two leads 35 feet long, to be run separately through two "long head" glazed, porcelain tubes, head 3 inches long, 1-inch hole, 1¾ inches diameter outside, 6 inches long under head, or, if not available, rubber substitutes 15367-A, cemented into deck tube plates 9244-H-21.

These plates will be softened in hot water and bent to conform to curve of the outside of the mast at 10 feet above the bridge deck.

A similar pair of plates will be fitted to the mast under the superstructure deck, and also to the forward bulkhead of operating room frame 76-77.

In the mast, at distances of 4 feet apart, will be placed five pine sticks 4 by 4 inches by 4 feet long secured to 1½ by 1½-inch angle-iron brackets at each end.

In these sticks will be drilled at the center two 1⅜ inch holes 6 inches c. c., for the porcelain tubes or their rubber substitutes.

The rat-tails will be run from their junction with the "verticals" through these insulators to a lightning switch, type B, 14898-A, to be located overhead in the operating room.

Midway between the mast and the operating room install an aerial insulator 15367-A, to support the runs of rat-tail.

HALYARDS.

From the thimbles in the bridles of the wooden yards, through the blocks secured to the bands on the fore and main topgallant masts, halyards of 21-thread manila rope will be rove and secured to cleats, to be located on the inside of the lower military tops.

GUYS.

From the thimbles in each bridle a guy of 9-thread manila rope will be run to a second thimble at the upper rigging band of topmast, for the purpose of keeping the wooden yards squared up.

WEATHER DRIPS.

In two locations 2 feet apart above the connection to the rat-tail fasten a weather drip of marline to carry off all rain or condensed moisture before it reaches the rat-tail and allow a slight sag to the rat-tails for the same purpose before they enter the mast.

DANGER NAME PLATE.

On the after side of the mast below the deck plate on the superstructure deck secure a danger name plate 15372—A.

Make up complete and furnish all appliances as mentioned above for installation excepting blocks, guys, halyards and cleats.

Spares to be furnished.—One No. 605 Locke strain insulator without plug, 200 feet 7/No. 20 phosphor bronze wire, —— feet 19/No. 25 rat-tail conductor.

Accessories to be furnished.—Lightning switch, type B, 14898—A; print of aerial.

LENGTHS OF CONDUCTORS.

As made:	As fitted in place:
160 feet horizontal.	—— feet horizontal.
85 feet vertical.	—— feet ~~vertical~~.
35 feet rat-tail.	—— feet rat-tail to switch.
——	—— feet switch to antennæ helix.
280 feet total.	—— feet ammeter to jar case.
	——
	—— feet total.

WAVE LENGTH.

Designed for use on wave length, 425 meters. Natural wave length as installed, —— meters. Inductance inserted to increase wave length to 425 meters, —— turns on antennæ inductance. Length on forward end reduced —— feet to reduce the natural wave length to 425 meters.

For adjustment data see curve No. ——.

CONDUCTORS.

The conductors used for aerials are shown on print 15418—A, the 7/No. 20 phosphor bronze wire being used for the "horizontal" and "vertical" parts of the aerial, 19/No. 23 phosphor bronze "rat-tail" wire being used for the lower parts of the aerial where run through decks, masts, ventilators, bulkheads, etc., and of the parts above deck or outside of masts where a person is liable to come in contact with and receive a shock from the aerial.

The No. 26 B. & S. tinned iron wire is not used in connection with aerials, but for serving night-signal cables, truck lights, and rigging, where aerials are installed in compliance with Bureau of Equipment's letter of February 20, 1905.

The McIntyre connectors are used for making splices where necessary to secure the required length in the phosphor bronze and 19 No. 23 rat-tail conductors.

The object of these connectors is to prevent the softening and weakening of the hard drawn wire in soldering as far as may be practicable.

It is customary to paraffin a length of about 10 feet of the upper part of the halyards and an equivalent amount of the signal halyard guys in order to assist in reducing leakage in damp weather.

DANGER NAME PLATE.

In order to give the necessary warning as to possible danger from contact with the rat-tail conductors, it is desirable to install a danger name plate in their immediate vicinity, as shown on print 15372—A.

LIGHTNING SWITCH.

A convenient form of switch for grounding the aerial when not in use or in the case of excessive static charges is shown in print 14898—A, attached..

These are secured to the deck above in the operating room, which grounds the two lugs direct in the case of a metal deck.

If the deck is of wood it will be necessary to lead off a strip of copper to ground.

The two legs of the aerial making the loop connect to the short back ends of the switch blades.

The leads to the receiver connect to the two lower switch contacts.

The aerial from the transmitter connects to the center contact on the crossbar.

The two spark gaps form the equivalent of the "anchor spark gap" used by the Shoemaker and De Forest outfits.

To insure exact similarity in spark length in each side of the loop the gaps should be adjusted by using a piece of ordinary postal card as a gauge.

NOTES ON TUNING.

In tuning aerials a desirable form of record for the readings is E. O., Form No. 291; the readings being later plotted in curves similar to those shown on prints 14826—A, U. S. S. *Maryland;* 15376—A, U. S. S. *Minneapolis;* 14825—A, U. S. S. *West Virginia;* 15440—A. U. S. S. *Charleston.*

In measuring natural wave length of aerials some difficulty is ordinarily encountered from arching instead of an oscillatory spark across the gap in obtaining a sufficient indication on the thermometer of the hot-wire ammeter of the Donitz wave meter.

A convenient method of obtaining the desirable character of spark is by the use of the spark gap for exciting aerials, as shown on print 15368—A.

This is inserted between the single-turn coil of the Donitz wave meter and the aerial.

The other end of the single-turn coil is connected to the ground.

The high-tension terminals of the induction coil connect direct to either side of the spark gap.

APPENDIX C.

Wireless-telegraph specification No. 13936–A.

ALTERATIONS TO NIGHT SIGNAL, TRUCK LIGHT, LIGHTNING CONDUCTOR, RIGGING.

[E. O. No. 1287.]

No. 107688
SSR. ALC.

BUREAU OF EQUIPMENT,
Washington, D. C., February 20, 1905.

SIR: In order to provide suitable elevation for and to minimize induction between aerial conductors for wireless telegraphy and the rigging and other conductors, the following general instructions will be observed:

1. All battle ships, armored cruisers, and other cruisers of and above 4,000 tons displacement should have masts measuring not less than 130 feet from truck to water line.

2. On vessels of and above 2,000 tons but less than 4,000 tons mastheads should not be less than 120 feet and in gunboats and monitors not less than 100 feet from truck to water line.

3. All topmasts and topgallant masts should be of wood.

4. A light band with an eye on forward and after side should be fitted under each truck, to which a block may be attached for hoisting the aerial conductor.

5. Topgallant rigging to be of hemp.

6. Topmast rigging should be of wire, set up with hemp lanyards or approved strain insulators, and if more than 50 feet in length should be served for a distance of 10 feet near the middle of the length with waterproof insulated soft-iron wire, No. 26 B. & S.

7. *Lifts and braces of signal yard.*—Lifts should be made of wire. Braces should be made of wire, with hemp tails on whips below tops of smokestacks. Where braces are within 15 feet of and parallel or nearly parallel to the aerial conductor, they shall be served near the middle of the length with insulated soft-iron wire, as above.

8. *Lower rigging.*—If the aerial conductor passes parallel or nearly parallel to and within 15 feet of the lower rigging, the lower end of the rigging will, if set up with turn-buckles, be served for 10 feet with insulated iron wire as above.

9. *Jacob's ladder.*—If made of wire, will have short hemp pendants or strain insulators at the bottom.

10. *Ladder of night signal set.*—Will have short hemp pendants or strain insulators at the bottom.

11. *Lightning conductor.*—To be fitted with lightning conductor break, type A, No. 10218, at the lower end. The upper section should pass within one-half inch of the metal of the ship if possible.

12. *Truck light conductors.*—To have the equivalent of 6 turns 10 inches in diameter in the lower part of the upper section, (these turns to be taken around the topmast if convenient), or to be served for 10 feet with insulated iron wire about 50 feet from the truck.

13. *Night signal set conductors.*—To be wrapped for 10 feet with insulated iron wire, No. 26 B. & S., about 50 feet from the upper light where most convenient.

14. Where hemp lanyards are used there will be at least 2 feet between dead-eyes when set up.

15. These instructions supersede those already given for vessels now building where the rigging has not already been purchased by the contractor.

Very respectfully,

H. N. MANNEY,
Chief of Bureau of Equipment.

The COMMANDANT, NAVY-YARD, *New York.*

APPENDIX D.

INSTRUCTIONS FOR THE CARE OF SLABY-ARCO RECEIVING INSTRUMENTS.

The relay requires frequent adjustment; it should be tested every morning to see if it is sufficiently sensitive. It should ring readily through 20,000 ohms external resistance on a single-cell circuit, but should not be oversensitive; that is, it must open the local-battery circuit sharply and without chattering when its own circuit is broken. The local-battery contacts in relay and the weak-battery contacts on tongue of decoherer must be kept clean and in good condition. The contacts on coherer and on multiple switch must also be kept clean.

The decoherer must give a sharp, decisive blow against the coherer; care must be taken that this blow is not strong enough to break the coherer. The weak-current contact on tongue should break just before this blow is delivered. A little practice enables the operator to judge when the decoherer is in proper adjustment, and once this is obtained the jam nuts should be screwed down on adjustment screws and the decoherer should remain in adjustment. The same remarks apply to the Morse writer, where the adjustments are still more numerous. This writer works in parallel on the same circuit as the interrupter. Its armature must be somewhat sluggish, since it is required to stay down on an interrupted current while the interrupter makes a series of blows for a dash, and it must rise sharply at end of dots and dashes.

The Morse writer is a clockwork mechanism driven by means of a spring and fitted with an automatic release and stopping device. It contains in all six adjustments, viz., adjustable counter spring, against pull of magnets, top and bottom contacts for adjusting position and movement of armature, adjustable counterbalance of armature, adjustment of lift of printing disk, of point of release of mechanism, and of speed of tape. The normal speed of tape is about 3 feet per minute, and adjustment is effected by altering the tension of spring on fan governor. The downward movement of armature releases driving mechanism and lifts printing disk against tape, so that these two functions must be considered in adjusting limits of armature movement. The speed of movement of armature, and hence the sharpness of the record on tape, is controlled by downward pull of magnets, upward pull of counter spring, and position of counterbalance. The magnet pull on armature is increased by diminishing distance of armature from core and by strengthening battery. As only four cells, 6 volts, are wanted on decoherer, however, and the two have to work in parallel, it is not feasible to change battery strength. The counter spring lifts armature back, after the current is broken in magnet coil, against the pull from residual magnetism and friction. The armature and counterweight should be in equilibrium on point of support of connecting arm, so that counter spring has no weight to lift.

Faulty working and record may be caused by—

1. Failure of releasing mechanism to release.
2. Insufficient lift of writing disk.
3. Insufficient drop of writing disk.
4. Too weak downward pull of magnets.
5. Too weak upward pull of spring.
6. Failure of clockwork to feed tape.
7. Failure of automatic stopping device to act.

1. Take off cover of clockwork and press armature down (take brake off governor) if releasing mechanism is O. K. A little pawl will be lifted out of spring catch by armature-rod extension and drawn back by small spiral spring. This movement will turn a cam and release mechanism. If by downward movement of armature the pawl is not lifted out of catch, increase downward movement of armature slightly. If still not released, lower position of catch by means of the adjusting screw until it will release when armature is pressed down.

2. When not in raised position the writing disk should turn freely with its lower third in the ink well and with the upper edge about 2 millimeters from tape; when raised it should press firmly against the tape. If in normal position disk is fully 2 millimeters from tape and when raised does not press firmly on tape, lower position of armature slightly; if not sufficient, raise disk slightly by means of the adjusting screw on armature from extension on inside of box. (This adjustment affects the automatic starting device, which may have to be readjusted.) The disk should make a smooth continuous line on tape as long as the armature is held down and cease working promptly when the armature is released.

3. If the normal position of disk is too close to tape, dirt in ink or a mechanical jar may make mark on tape when armature is not depressed. The limited movement of disk may also prevent sufficient movement of armature to release starting device. The adjustment is made in the inverse sense of No. 2.

4. Test the battery and see that it is up to voltage—5.5 to 6 volts. Slack off on counter-spring. Move normal position of armature closer to magnet core by screwing down on upper stop. See that armature beam is not jammed in its mountings.

5. Increase tension of spring. Raise lower armature stop so as to lift armature slightly from magnet core. A slip of paper over ends of core so as to prevent armature from coming in actual contact with core will frequently improve the working.

6. If the mechanism runs freely with tape out there is too much tension on tape. If the mechanism is released and wound up and will not run there is too much friction in some of its bearings or gear, and they must be gone over, cleaned, and oiled. The trouble will usually be in some relatively high-speed bearing or gear. If with tape in the mechanism runs but does not feed tape the pressure of rollers on tape must be increased.

7. This is usually due to some overadjustment under heading No. 1 and must be corrected in the inverse sense. It may, however, be caused by spring on catch or cam pawl being too weak or by dirt or excessive friction in cam pawl. If the cam pawl does not fly forward to front position in seat when released by cam the trouble is in it or its spring. One complete revolution of tape pulley is made after last downward movement of armature before automatic stop acts.

Appendex E.

1. The headgear will consist of two watch-case telephone receivers, mounted by universal joints on adjustable covered strap, and arranged so as to be conveniently held on the head of the operator.

2. The receivers are to have a powerful permanent magnet and to be wound with silk or enamel covered copper wire of diameter over copper not less than 0.0015 inch. Diaphragm to measure 1¾ inches by 0.004 inch. The last few turns on the coils will be of heavier silk-covered copper wire. All joints to be rosin soldered. The resistance of each receiver will be between 1,000 and 1,100 ohms.

3. The two receivers will be connected in series with a flexible cord giving a free length of at least 4 feet. The cord will consist of two rubber-insulated conductors, with pin terminals at both ends. The conductors will have seven strands of No. 32 B. & S. copper wire or the equivalent. The cord from each telephone will be joined 15 inches from the receivers and continued for 4 feet 6 inches. Joints to be neatly made. No part of the cord to have more than two conductors. The conductors will be covered and held together with a green silk braid.

4. Strap will be of nickel-plated steel, covered with a thin coating of black hard rubber.

5. Each receiver will be fitted with pneumatic ear cushions of approved type.

6. Weight of set not to exceed 15 ounces.

7. Each set will be supplied with one extra cord, complete.

8. Each telephone will be tested for receiving qualities and must give results equal to standard sample.

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 as shown in fig. 1, 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, as shown in fig. 2. 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 stimulents to the victim in the usual manner by pouring it 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.

APPENDIX G.

SPECIAL NOTICE TO MARINERS.

[Published by the Hydrographic Office, Washington, D. C., November 22, 1904. No. 47a.]

The following regulations governing the use of the United States naval coastwise wireless telegraph stations are hereby established:

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 the rules established herein, 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 ship stations and 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. Messages will not be accepted for transmission to ships whose owners have not agreed to accept unpaid messages, unless a sufficient sum is deposited to cover all charges.

3. The Nantucket Shoal light-ship station will report vessels and transmit messages from them if the signals are made by the international code or any other known to the operators 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 soon be sent to the Nantucket Shoal light-ship by wireless telegraphy and storm signals furnished by the Weather Bureau will be displayed therefrom to warn passing vessels.

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. Arrangements for a time-signal service by wireless telegraphy are now being made.

7. 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 are requested to communicate with the Bureau of Equipment, Navy Department, Washington, D. C.

8. All chambers of commerce, maritime exchanges, newspapers, news agencies, and others desiring to have vessel reports and general marine news forwarded to them regularly are requested to communicate with the Bureau of Equipment 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.

9. Naval wireless telegraph stations are equipped with apparatus of several systems and can communicate with all the principal wireless telegraph systems now in use, if tuned to the same wave length. The Department is desirous of cooperating with all shipowners wishing to avail themselves of its wireless telegraph service, and, judging from its experience with numerous systems, 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.

10. Vessels desiring to make use of this service regularly must agree to transmit and receive all Government messages free.

The following stations are fully manned and will be prepared to receive messages at all hours, except in case of some accidental breakdown, which is not apt to occur because of the precautionary measures which have been taken.

The call letter is given in the column opposite the name of each station:

Station.	Call. letter.	Station.	Call letter.
Navy-yard, Portsmouth, N. H	PC	Cape Henry, Va	QN
Cape Ann (Thatchers Island)	PE	Navy-yard, Norfolk, Va	QL
Highland Light, Cape Cod, Mass	PH	Dry Tortugas, Fla	RF
Nantucket Shoal light-ship	PI	San Juan, P. R	SA
Torpedo station, Newport, R. I	PK	Culebra, West Indies	SD
Montauk Point, L. I	PR	Yerba Buena Island, Cal	TI
Navy-yard, New York	PT	Navy-yard, Mare Island, Cal	TG
Highlands of Navesink, N. J	PV		

It is expected that the following stations will be in operation in a few weeks, fully manned to receive messages at all hours:

Station.	Call letter.	Station.	Call letter.
Cape Elizabeth, Me	PA	Panama Canal Zone	SL
Navy-yard, Boston, Mass	PG	Farallon Islands, Cal	TH
Naval station, Key West, Fla	RD	Naval station, Cavite, P. I	UT
Navy-yard, Pensacola, Fla	RK	Cabra Island, P. I	UY
Naval station, Guantanamo, Cuba	SI		

The following stations are equipped with apparatus but are not yet fully manned; they will receive and transmit messages when operators are on duty:

Station.	Call letter.	Station.	Call letter.
Naval Academy, Annapolis, Md	QG	Navy-yard, Washington, D. C	QI

The Bureau of Equipment expects to erect wireless telegraph stations at the principal points along the coast of the United States and at points in its insular possessions. As fast as they are completed they will be open for public use under the regulations established herein.

Notice will be given in the "Notices to Mariners" when stations are put in operation or withdrawn from the service for any reason.

Messages for the Cape Ann station should be forwarded via the navy-yard, Portsmouth, N. H.

The Nantucket Shoal light-ship will transmit its messages to the torpedo station, Newport, R. I. All messages intended to be sent by this light-ship to ships at sea should be sent to the torpedo station.

Messages for the Montauk Point wireless telegraph station will also be sent via the torpedo station, Newport, R. I.

Arrangements have been made with the Weather Bureau for the transmission of messages between Cape Henry wireless telegraph station and Norfolk. All messages intended for the Cape Henry station should be sent via the Weather Bureau, Norfolk, Va.

All messages intended for Dry Tortugas should be sent via the naval station, Key West, Fla.

The station at Yerba Buena, Cal., can be reached by either the Postal Telegraph or the Western Union system and the one at Mare Island by the Western Union.

The Farallon station will communicate with Yerba Buena Island, California.

INSTRUCTIONS TO GOVERN 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 at a distance not greater than 75 miles from it.

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 lightship, 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 lightship 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 320 meters.

XII. Until further notice the speed of sending should not exceed 12 words per minute.

XIII. 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.

XIV. 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.

XV. In order that the service may be made as good and as useful as possible, it is requested that complaints should be promptly reported to the Bureau of Equipment as soon as possible after the cause therefor, giving date, hour and other details, to enable the Bureau to investigate the case.

XVI. Information regarding the naval wireless telegraph service will be published in "Notices to Mariners."

By order of the Bureau of Equipment:

H. M. HODGES,
Commander, U. S. N., Hydrographer.

NOTE.—Copies of these notices can be obtained by mariners, free of charge, by applying to the Hydrographic Office, to one of the branch offices, or to any of the agencies in seaboard or lake ports. They are also on file in all United States consulates, where every facility will be afforded for their inspection. Shipmasters are especially requested to inform the Hydrographic Office immediately of any newly discovered danger to navigation, or of the establishment or change of any aid to navigation.

APPENDIX II.

REGULATIONS FOR THE GOVERNMENT OF WIRELESS TELEGRAPH STATIONS.

1. The senior electrician will be held accountable for all Government property belonging to the station, and will receipt for all articles invoiced to him. Upon being relieved he will transfer the property to his successor, who will sign an itemized receipt for all supplies on hand in duplicate, one for each party to the transfer.

2. There shall be kept a log book in which shall be recorded the temperature, the direction and force of the wind, and the state of the weather and clouds, by symbols. These records shall be made every four hours during the time the operators are on watch, and if there are not enough operators at the station to permit of night watches being kept, the maximum and minimum temperature during the night shall be recorded on the following morning. All meteorological phenomena, such as lightning, aurora borealis, fog, mist, snow, rain, etc., shall be remarked upon, together with a statement of the character of transmission of signals, if any are made during the period. If there are any atmospheric

signals during the period they shall be noted. Whenever atmospheric signals interfere with transmission, all the circumstances of atmosphere and weather shall be carefully noted. The conditions of the weather which appear to be particularly advantageous and those which appear to be particularly disadvantageous for the transmission of signals shall be carefully observed and noted. Any regular recurrence of atmospheric signals shall be the subject of special report. The log book shall contain a list of stores expended, a record of the number of hours the engine or source of power supply is in use, of all accidents and repairs to any part of the apparatus, of the reporting and detachment of operators, and other matters of interest. The log book shall contain a list of messages sent and received, the number of words and time of transmitting and receiving each message, the distance and wave length, and, for sending, the spark gap and power used for each message.

3. The entries for the log shall be made by the operator on duty on a daily log sheet provided for the purpose. These shall be copied daily, in ink, in the log book, which shall be signed by the electrician in charge.

4. The originals of all official messages sent and copies of all official messages received shall be carefully preserved and filed in a case provided for the purpose. These shall not be open for public inspection.

5. There shall be kept in a book provided for the purpose an inventory of all Government property at the station. Upon being relieved the senior electrician shall inspect the station with his successor, and the latter shall acknowledge the receipt of the property over his signature in the inventory book, making a note of any exceptions as to items or their condition. The daily expenditure of supplies shall be kept in the log book, and a report of supplies on hand and expended made in the log book at the end of each quarter.

6. All official messages received for further transmission shall be transmitted in the most expeditious manner by telegraph, telephone, wigwag, letter, or otherwise, depending on local conditions and circumstances, and a record of the time and method of further transmission made on the original. All telegrams so sent shall be confirmed by mail to the same address as the telegram.

7. A routine shall be made out which shall provide for the efficient care and preservation of all parts of the station and apparatus, including protection from fire, the method and times of relieving operators, smoking regulations, and all other provisions necessary for the proper conduct of the station. A copy of this routine shall be entered in the log book.

8. There shall be no smoking in the vicinity of the gasoline engine or storage tanks for gasoline, nor in the vicinity of any house for the storage of oil.

9. The arrangements for extinguishing fire shall be kept in readiness for instant use.

10. The electrician in charge shall keep a careful watch on all parts of the station and apparatus, such as condition of engine, mast and rigging, storage batteries, etc., and report at once by letter the need of any repairs beyond the facilities of the station.

11. Requisitions for renewal of supplies shall be made not oftener than once a month, except in cases of emergency.

12. All correspondence concerning the Bureau of Equipment shall be conducted through the commandant of the yard having control of the station.

13. Electricians at stations on light-house reservations shall not interfere in any manner with the light keepers.

14. The electrician in charge shall be subordinated to the principal light-house keeper in all matters pertaining to the Light-House Establishment.

15. Electricians at stations on light-ships shall be subordinate to the master of the light-ship in all matters pertaining to the Light-House Establishment and the discipline of the ship.

16. A copy of these regulations shall be posted in each wireless telegraph station.

H. N. Manney, *Chief of Bureau.*

November 15, 1904.

Appendix I.

INSTRUCTIONS FOR KEEPING LOG BOOKS AT WIRELESS TELEGRAPH STATIONS.

A log book will be furnished by the Bureau of Equipment to all naval wireless-telegraph stations except those on vessels in commission.

The entries for the log shall be made by the operator on duty on a daily log sheet provided for the purpose. The log sheet shall be copied daily in ink in the log book, which shall be examined and signed by the electrician in charge.

In the proper column there shall be entered for each message, in the order of sending and receiving, the number of words it contains, the time in minutes taken to send or receive, the distance of sending or receiving station or vessel, if known, the wave length used in sending and receiving (except where standard wave length of station is used, when the letter "S" shall be entered), the spark length and power used in sending, and number of hours the source of power has been in use during the day. When the number of messages sent or received is greater than the number provided for in the column, the record shall be entered on the proper part of a daily log sheet and the same cut out and pasted in the smooth log book. The entries for the wind, weather, and clouds shall be by symbols in accordance with the forms printed herewith, and shall be made every four hours, as indicated in the columns, except when there are not enough operators at the station to permit of night watches being kept, in which case the maximum and minimum temperature during the night shall be recorded on the following morning and the weather conditions at the time of record. The duration and relative intensity (such as continuous, irregular, intermittent, strong, weak, faint) of atmospheric signals shall be noted in the proper column, and the additional information required by the Instructions for Wireless Telegraph Stations given under "Remarks." The daily expenditure and receipt of stores shall be entered, and these shall form the basis of the "Quarterly report of stores," which shall accompany and form part of the log book.

A statement shall be made daily in the proper column as to whether the station routine has been carried out, and if not, in what respect and the reason therefor.

Note in log book when storm warnings are received from Weather Bureau and when sent out.

Under "Remarks" give names of all stations on vessels read or sent to during the day, with distance in sea miles, if known.

Results of experiments of interest to be indicated by a star (*) in upper right-hand corner of page, and if of unusual interest to be reported immediately to the Bureau.

On last page of "Remarks" give greatest distance of exchange of messages and greatest distance received during quarter, with names of stations.

Other entries shall be as indicated under their respective headings and as required by the Instructions for Wireless Telegraph Stations.

The log book shall be forwarded quarterly to the Bureau of Equipment through the commandant.

WIND SYMBOLS.

[Statute miles per hour.]

0. Calm	3	7. Fresh breezes	40
1. Light airs	8	8. Moderate gales	48
2. Light breezes	13	9. Strong gales	56
3. Gentle breezes	18	10. Gale	65
4. Moderate breezes	23	11. Heavy gale	75
5. Stiff breezes	28	12. Hurricane	90 and over.
6. Fresh breezes	34		

WEATHER SYMBOLS.

b. Clear blue sky.
c. Cloudy weather.
d. Drizzling or light rain.
f. Fog or foggy weather.
g. Gloomy, or dark, stormy-looking weather.
h. Hail.
l. Lightning.
m. Misty weather.
o. Overcast.
p. Passing showers or rain.
q. Squally weather.
r. Rainy weather or continuous rain.
s. Snow, snowy weather, or snow falling.
t. Thunder.
u. Ugly appearance or threatening weather.
v. Variable weather.
w. Wet, or heavy dew.
z. Hazy weather.

CLOUD SYMBOLS.

Cirrus (*Ci.*).—Isolated feathery clouds of fine fibrous texture; "Mares tails."

Cirro-Stratus (*Ci-S.*).—Fine whitish veil, giving a whitish appearance to the sky; often produces halos; "Cirrus haze."

Cirro-Cumulus (*Ci-Cu.*).—Small fleecy white balls and wisps, without shades, arranged in groups and often in lines; "Mackerel sky."

Alto-Cumulus (*A-Cu.*).—Larger white or grayish balls, with shaded portions, in flocks or rows, often so close that edges meet.

Alto-Stratus (*A. S.*).—Thick veil of gray or bluish color, brilliant near sun or moon. May produce coronæ.

Strato-Cumulus (*S-Cu.*).—A succession of rolls of dark cloud, which frequently cover the whole sky. The characteristic cloud of storm areas, especially of the fore part of those areas.

Nimbus (*N.*).—Rain cloud; a thick layer of dark clouds without shape, from which continuous rain is falling. Ci-S. or A. S. is seen through the breaks. Low-lying fragments are known as "scud."

Cumulus (*Cu.*).—Thick clouds whose summits are domes with protuberances, but whose bases are flat. "Woolpack" clouds.

Cumulo-Nimbus (*Cu-N.*).—Thundershower clouds. Mountainous clouds surrounded at top by veil of false cirrus and below by nimbus-like masses of clouds.

Stratus (*S.*).—Horizontal sheet of lifted fog.

Appendix K.

INSTRUCTIONS FOR INSTALLING AND OPERATING A "CHLORIDE ACCUMULATOR" BATTERY OF 60 CELLS, TYPE E-9.

[Normal charging and discharging rate, 20 amperes.]

UNPACKING MATERIAL.

1. Great care should be taken in the unpacking and subsequent handling of the various parts of the battery, as many of them are easily broken or bent out of shape by rough handling.

2. Open the crates or packing boxes on the side marked "up" and carefully lift contents out. Never slide out by turning crate on its side.

3. Upon opening crates and boxes, carefully count the contents of each package and check with the shipping list. A number of small parts will usually be found in each shipment, and care should be taken to examine packing materials to determine that no parts have been overlooked.

4. Immediately upon opening the crates the material should be carefully examined for breakage. Cracked jars, whether of glass or rubber, should not be set up, as if put into use leakage of acid may cause annoyance or trouble.

LOCATION OF BATTERY ROOM.

5. *The proper location of the battery is important.* It should be in a separate room, which should be well ventilated, dry, and of moderate temperature.

6. The temperature of the room should be between 50° and 80° F., normal being 70°. Extremes of temperature affect the proper working of a battery. The air should be dry, for if damp there is danger of leakage from grounds.

7. The ventilation should be free, not only to insure dryness, but to prevent chance of an explosion, as the gases given off during charge form an explosive mixture if confined. For this reason *never bring an exposed flame near the battery when it is gassing.*

ASSEMBLING AND PLACING CELLS IN POSITION.

8. Place the jars, after they have been cleaned, in position on the stands, which should be provided for the purpose and which should be so situated in the room that each cell will be easily accessible. If the floor space is available, it is often preferable to install the cells on one tier, in which case the "stand" will be very much simplified, a set of stringers properly fastened together and the insulating bricks being all that is required. The jars are set in the trays, which should previously be filled even with the top with fine dry bar sand, the trays resting on the glass insulators.

9. Place the elements as they come from the packing cases on a convenient stand or table (the elements are packed positive and negative plates together, the positives having plates of a brownish color, the negatives of a light gray. The negative always has one more plate than the positive), cut the strings that bind them together, and carefully pull the positive and negative groups apart, throwing the packing aside. After carefully looking over both groups and removing any dirt, or foreign matter, place two hard-rubber separators on each positive plate about an inch from and parallel with each vertical edge and then slip these plates into position between the negatives, which have been placed crosswise on a board about two-thirds the width of the plates, so as to allow of easy readjustment of the separators, which may become disarranged in handling.

10. To facilitate the lifting of the elements into the jars and to prevent the disarrangement of the separators when doing this, a short strip of webbing should be used. Lay this on the board under the element. When putting into the jars, be careful that the direction of the lugs is relatively the same in each case, thus causing a positive lug of one cell to always connect with a negative of the adjoining one, and vice versa. This insures the proper polarity throughout the battery—bring a positive lug, at one free end and a negative at the other.

11. Before bolting or clamping the lugs together they should be well scraped at the point of contact to insure good conductivity and low resistance of the circuit. This should be done before the elements are taken apart and directly after unpacking if the battery is to be set up at once. The nuts should be gone over and tightened several times after the lugs are first fastened together to insure thoroughly good connection.

CONNECTING UP THE CHARGING CIRCUIT.

12. Before putting the electrolyte into the cells the circuits connecting the battery with the charging source must be complete, care being taken to have the *positive pole of the charging source connected with the positive end of the battery and so with the negative poles.*

ELECTROLYTE.

13. The electrolyte is dilute sulphuric acid of a specific gravity of 1.210 of 25° Beaumé, as shown on the hydrometer at temperature of 70° F. If it is not convenient to procure this from The Electric Storage Battery Company already mixed and ready for use, it may be prepared by diluting *suitable* commercial sulphuric acid or "oil of vitriol," as it is more commonly called, with *pure* water. *The acid as well as the water must be free from impurities, such as iron, arsenic, nitric or hydrochloric acid. This is absolutely essential.* When diluting,

the acid must be poured into the water, not the water into the acid. The proportion of acid (of 1.840 specific gravity or 66° Beaumé) and water are 1 part acid to 5 of water (by volume). The acid must be added to the water slowly and with great caution on account of the heat generated. The final density of the solution (1.210 specific gravity) must be read when the solution has cooled. The vessel used for mixing must be a lead-lined tank or one of wood, which has not been used for other purposes. A new washtub or spirits barrel is recommended.

14. The electrolyte should cover the top of the plates by one-half to three-fourths inch, and must be cool when poured into the cells.

INITIAL CHARGE.

15. The charge should be started at the normal rate (the eight-hour rate of discharge as given in the catalogue) as soon as the electrolyte is in the cells and continued at the same rate, provided the temperature of the electrolyte is well below 100° F., until there is no further rise or increase in either the voltage or specific gravity and gas is being freely given off from *all* the plates. Also the color of the positive plates should be a dark brown or chocolate and the negatives a light slate or gray. The temperature of the electrolyte should be closely watched, and if it approaches 100° F. the charging rate must be reduced or the charge stopped entirely until the temperature stops rising. From forty-five to fifty-five hours at the normal rate will be required to complete the charge: but if the rate is less, the time will be proportionately increased. The specific gravity will fall rapidly after the electrolyte is added to the cells, and then will gradually rise as the charge progresses until it is again up to 1,210 or possibly higher. The voltage for each cell at the end of charge will be between 2.5 and 2.7 volts and for this reason a fixed or definite voltage should not be aimed for. *It is of the utmost importance that this charge be complete in every respect.*

16. At the end of the first charge it is well to discharge the battery about one-half and then immediately recharge it. Repeat this treatment two or three times and the battery will be in proper working condition.

17. After the completion of a charge (initial or with the battery in regular service) and the current off, the voltage will fall immediately to about 2.20 volts per cell, and then to 2 volts when the discharge is started. If the discharge is not begun at once then the pressure will quite rapidly fall to about 2.05 volts per cell and there remain while the battery is on open circuit.

BATTERY IN REGULAR SERVICE.

18. *A battery must not be repeatedly overcharged, undercharged, overdischarged, or allowed to stand completely discharged.* After the initial charge is completed the battery is ready to be put into regular service. A cell should be selected as a "pilot cell," that is, one that is in good condition and representative of the general condition of the battery. The height of the electrolyte in this cell must be kept constant by adding a small quantity of water each day. This cell is to be used particularly in following the charge and indicating when it should be stopped.

19. When the battery is in regular service the discharge should not be carried below 1.75 volts per cell at full load. Standing completely discharged will cause permanent injury; therefore, the battery should be immediately recharged after a heavy discharge.

20. The battery should preferably be charged at the normal rate. *It is important that it should be sufficiently charged, but the charge should not be repeatedly continued beyond that point.* Both from the standpoint of efficiency and life of the plates, the best practice is the method which embraces what may be called a regular charge, to be given when the battery is from one-half to two-thirds discharged, and an overcharge to be given weekly if it is necessary to charge daily, or once every two weeks if the regular charge is not given so often.

21. The regular charge should be continued until the gravity of the pilot cell has risen to within three points of the maximum as shown on the last previous overcharge. For example, if on the previous overcharge the maximum is 1,210 then on the following regular charges

the current should be cut off when the gravity of the pilot cell reaches 1,207, correction being made for temperature change, as noted below.

22. The overcharge should be prolonged until all the cells gas freely and until no rise in the gravity of the pilot cell is shown for five successive fifteen-minute readings.

23. Just before the overcharge, the cells should be carefully examined to see that they are free from short circuits. If any short circuits are found they should be removed with a stick or a piece of hard rubber; *do not use metal*.

24. As the temperature affects the gravity, this must be considered and correction made for any change of temperature. The temperature correction is one point (0.001 sp. gr.) for three degrees change in temperature. For instance, acid which is 1,210 at 70° will be 1,213 at 61° and 1,207 at 70°.

INSPECTION.

25. In order that the battery may continue in the best condition it is essential that gravity and voltage readings be taken on all cells in the battery at least once a week, the gravity readings on the day before the overcharge and the voltage reading near the end: *the voltage readings must always be taken when the current is flowing, open-circuit readings being of no value.* Also at the end of each charge it should be noted that all of the cells are gassing moderately and at the end of the overcharge very freely.

UNEVENNESS OF CELLS; CAUSE AND REMEDY

26. If any of the cells should read low at either time and do not gas freely with the others at the end of charge, examine them carefully for pieces of scale or foreign matter which may have lodged between the plates; if any are noted, remove them by pushing down into the bottom of the jar with a strip of hard rubber. *Never use metal of any kind for this purpose.* If the hard rubber is not easily procured at the moment a piece of hard wood may be used, but it is not advisable as a usual practice.

27. If, after the cause of the trouble has been removed, the readings do not come up at the end of the overcharge, then the cell must be cut out of circuit on the discharge, to be cut in again just before beginning the next charge, during which it should come up all right.

28. Impurities in the electrolyte will also cause a cell to work irregularly. Should it be known that any impurity has gotten into a cell, steps should be taken to remove it at once. In case removal is delayed and any considerable amount of metal becomes dissolved in the solution this solution should be replaced with new immediately, thoroughly flushing the cell with water before putting in the new solution. The change should be made when the battery is discharged and just before charging. If in doubt as to whether the electrolyte contains impurities, a half-pint sample taken at the end of discharge should be submitted for test. The Electric Storage Battery Company will analyze and report on, free of charge, samples received with transportation charges prepaid.

SEDIMENT.

29. The accumulation of sediment in the bottom of the jars must be watched and not allowed under any circumstances to get up to the plates, as, if this occurs, unnecessarily rapid deterioration will result. To remove the sediment, the simplest way, if the cells are small, is to lift the elements out after the battery has been fully charged, draw off the acid, and then dump the sediment, getting the element back and covered with acid as quickly as possible, so that there will be no chance of the plates drying out. Acid, not water, will be required to complete the filling of the cells, the specific gravity being adjusted to standard (1,210 at the end of charge) at the same time.

EVAPORATION.

30. Do not allow the surface of the electrolyte to get down to the top of the plates. Keep it at its regular level (one-half to three-fourths inch above the top of the plates) by the addition of *pure water*, which should be added at the beginning of a charge, preferably the overcharge. It will not be necessary to add acid except at long intervals or when cleaning as noted above.

BATTERY USED BUT OCCASIONALLY.

31. If the battery is to be used at infrequent periods, it should be given a "freshening" charge every two weeks.

PUTTING THE BATTERY OUT OF COMMISSION.

32. If it is thought best to put it out of service for a time, then it must be treated as follows: *After thoroughly charging* siphon off the acid (which may be used again) into convenient receptacles, preferably carboys, which have been previously cleaned and have never been used for other kinds of acid, and as each cell becomes empty immediately fill it with fresh pure water. When water is in all the cells, allow them to stand twelve or fifteen hours, then draw off the water. The battery may then stand without further attention until it is to be again put into service. Then proceed as in the case of the initial charge, as described above. If there is any considerable amount of sediment in the cells advantage should be taken of the out-of-service period to clean them thoroughly.

Appendix L.

To obtain this interval by deduction, let Q be the charge on a Leyden jar whose capacity is C, P the potential to which the jar is charged, L the self-induction, and R the ohmic resistance of the discharging circuit, p the counter electro-motive force due to the induction L. Then J, the intensity of current produced by discharge in time $t=\frac{P-p}{R}$ but $p=\frac{LdJ}{dt}$; therefore $J=\frac{P-\frac{LdJ}{dt}}{R}$. Further, $J=\frac{dQ}{dt}$ and $P=\frac{Q}{C}$; $\therefore$ by substitution and transposing, $\frac{d^2Q}{dt^2}+\frac{RdQ}{Ldt}=\frac{Q}{LC}$. A solution of this equation gives $Q=A_1 e^{x_1 t}+A_2 e^{x_2 t}$ . . . etc., where $x_1 x_2$ are the roots of the equation, $Lx^2+Rx+\frac{1}{C}=O$, hence $x=-\frac{R}{2L}\pm\sqrt{\frac{R^2}{4L^2}-\frac{1}{LC}}$. If the roots are real, $R>2\sqrt{\frac{L}{C}}$, and the discharge is a diminishing one, but if the roots are imaginary, i. e., if $R<2\sqrt{\frac{L}{C}}$, then $Q=_e -\frac{2Lt}{R}$ $[B_1 \; Cos \; Bt+B_2 \; Sin \; Bt,]$ where $B=\sqrt{\frac{1}{LC}-\frac{R^2}{4^2}}$ and the discharge becomes oscillatory with the period $T=\frac{2\pi}{B}$. If $\frac{R^2}{4L^2}$ is small compared with $\frac{1}{LC}$, which in the closed sending circuit *abcd* (fig. 4) is the case, it may be neglected, and hence $T=\frac{2\pi}{B}=\frac{2\pi}{\sqrt{\frac{1}{LC}}}=2\pi\sqrt{LC}$. If V is the velocity of the wave and λ the wave length, then $\lambda=VT=2\pi V\sqrt{LC}$. Now, the induction L and capacity C of the aerial wire varies as the length, hence the wave length λ suited to any aerial wire is proportional to the length l of the wire, and by experiment it has been shown that $\lambda=4l$.

Appendix M.

REPORT ON THE CALCULATION OF THE SELF-INDUCTANCE OF CIRCULAR COILS OF RECTANGULAR SECTION.

DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF STANDARDS,
Washington, ——— —, ——.

1. An approximate formula for the calculation of self-inductance is given by Maxwell, section 706, Volume II, Electricity and Magnetism, as follows:

$$L_0=4\pi n^2 a\left(log_e \frac{8a}{R}-2\right) \qquad (1).$$

where a=mean radius of the coil, n = number of turns of wire, and R is the geometric mean distance of the cross section of the coil. All dimensions are in centimeters, and the logarithm is Naperian. L is then in centimeters, and to convert it to microhenrys, divide by 1,000.

2. The above formula assumes that the current is distributed uniformly over the cross section of the coil, as it would be if the wire were square and insulated by a covering of infinitesimal thickness. For the case of round wire insulated by a thicker covering the self-inductance is greater than that given by the formula, as Maxwell points out, section 693. This correction consists of three parts and is represented by the following expression:

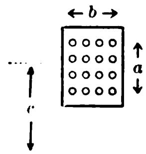
$$\Delta L=4\pi\, na\left(\log_e \frac{D}{d}+0.13806+A\right) \qquad (2).$$

where ΔL is the correction in L (in centimeters), a and n are the radius and number of turns, as before, D and d are the diameters of the covered and bare wire, respectively, and A is a constant depending on the number of turns of wire in the coil. (The correction 0.13806 is the increase in self-inductance of the separate turns because the wire is round instead of square, $\log_e \frac{D}{d}$ is the increase because the wire is smaller than the square wire assumed in the formula, A is the correction due to the difference in the mutual inductances of the separate turns on one another, being more for the round wire than the square.) For a coil of few turns A is about 0.0150. For a coil of many turns it is as much as 0.0180. This part of the correction is small and is not of much importance in coils used for wireless telegraphy.[a]

3. The calculation of R, the geometric mean distance of the section of the coil, is a tedious process for rectangular sections. The formula is given in Maxwell, section 692. If the section is a *square*, $R=0.447\, b$, where b is the length of one side of the square section.

4. Stefan's formula[b] for self-inductance is more exact than Maxwell's approximate formula. It is as follows:

$$L_0=4\pi\, n^2a\left\{\log_e \frac{8a}{\sqrt{b^2+c^2}}\left(1+\frac{3b^2+c^2}{96a^2}\right)-y_1+\frac{b^2}{16a^2}y_2\right\} \qquad (3).$$

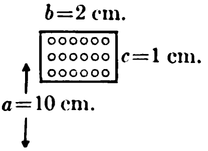


Axis of coil.

Here a and n are the mean radius and number of turns (as in Maxwell's formula), b is the over-all breadth of the coil, c is the depth, and y_1 and y_2 are constants depending on the ratio of the quantities b and c (always dividing the smaller by the larger), this ratio being called x. A copy of these two tables is appended to this report.

This formula is quite exact for the ideal case of square wire insulated by a covering of infinitismal thickness, but requires correction just as formula (1) does for the usual case of insulated round wire.

5. Example 1.



Coil of 18 turns, $a=10$ cm.
$b=2$ cm.
$c=1$ cm.

$x=\frac{c}{b}=\frac{1}{2}$

From Table 1, $y_1=0.79600$
From Table 2, $y_2=0.3066$

Suppose $D=\frac{1}{4}$ cm.
$d=\frac{1}{8}$ cm.
$\frac{D}{d}=2$

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[a] The Bureau will shortly publish a table of values of A for coils of various numbers of turns. No such table has ever been published.

[b] Wied. Annalen, vol. 22, p. 113, 1884.

By formula (3)

$$L_0=4\pi 18^2\times 10\left\{\log_e \frac{80}{\sqrt{4+1}}\left(1+\frac{12+1}{9600}\right)-.7960+\frac{4}{1600}\left(.3066\right)\right\}$$

$$\log_e 80= \quad 4.38203$$
$$\log_e \sqrt{5}= \quad 0.80472$$
$$\log_e \frac{80}{\sqrt{5}}= \quad 3.57731$$
$$\frac{13}{9{,}600}\times \log \frac{80}{\sqrt{5}}= \quad .00484$$
$$\frac{4}{1{,}600}\times .3066= \quad .00077$$
$$3.58292$$
$$y_1=-0.79600$$
$$2.78692$$

$$\therefore L_0=4\pi\times 324\times 10\times 2.78692=113470 \text{ cm.}$$
$$=113.47 \text{ microhenrys.}$$

Then $\Delta L=4\pi na\left\{\log_e 2+.13806-.0150\right\}$

$$=4\pi na\times .8462$$
$$=4\pi\times 180\times .8462=1914 \text{ cm.}=1.914 \text{ microhenrys.}$$
$$\therefore L=L_0+\Delta L=115.38 \text{ microhenrys.}$$

Example 2. Coil of 24 turns, $a=10$ cm.

$b=$ 1.91 cm. $\quad b^2=3.6481$

$c=$ 1.28 cm. $\quad c^2=1.6384$

$x=\frac{c}{b}=$ 0.67 $\quad b^2+c^2=5.2865$

From Table 1, $y_1=0.82932$
From Table 2, $y_2=0.4460$

$$\log_e \frac{80}{\sqrt{b^2+c^2}}= \quad 3.54945$$
$$\frac{3b^2+c^2}{9{,}600}\times \log_e \frac{80}{\sqrt{b^2+c^2}}= \quad .00465$$
$$\frac{b^2}{1{,}600}\times 0.4460= \quad .00102$$
$$3.55512$$
$$y_1=-0.82932$$
$$2.72580$$

$$\therefore L_0=4\pi\times(24)^2\times 10\times 2.72580.$$

For the correction $D=.318$, $d=.109$, $\frac{D}{d}=2.9174$.

$$\log_e \frac{D}{d}=1.0707$$
$$.1381$$
$$.0150$$
$$1.2238$$

$$\therefore \Delta L=4\pi na\times 1.2238$$
$$=4\pi n^2 a\left(\frac{1.2238}{n}\right), \text{ where } n=24$$
$$=4\pi\times(24)^2\,(.0510)$$
$$\therefore L=L_0+\Delta L=40\pi\times(24)^2\,(2.7258+.0510)$$
$$=40\pi\times 576\times 2.7768$$
$$=201{,}000 \text{ cm.}=201.0 \text{ microhenrys.}$$

By varying the size of coil and number of turns any particular value of the self-inductance can be obtained. For accurate work the dimensions must, of course, be taken very carefully.

6. When the section of the coil is square the formula is simpler. Then $b = c$ and

$$L_0 = 4\pi n^2 a\left\{\log_e \frac{8a}{c}\left(1+\frac{c^2}{24a^2}\right)+.0365\frac{c^2}{a^2} - 1.19491\right\} \qquad (4)$$

$L = L_0 + \Delta L$ as before.

7. For a *single* circular turn of round wire, the mean radius being a as before and ρ being the radius of the circular section of the wire,

$$L = 4\pi a\left\{\log_e \frac{8a}{\rho}\left(1+\frac{\rho}{8a^2}\right) - 1.75 - .0083\frac{\rho^2}{a^2}\right\} \qquad (5)$$

This is a very exact formula, and requires no correction. Very approximately this is

$$L = 4\pi a\left(\log_e \frac{8a}{\rho} - 1.75\right) \qquad (6)$$

S. W. STRATTON, *Director.*

TABLE I.

x	y_1	x	y_1
0	0.50000	0.50	0.79600
0.05	0.54899	0.55	0.80815
0.10	0.59243	0.60	0.81823
0.15	0.63102	0.65	0.82648
0.20	0.66520	0.70	0.83311
0.25	0.69532	0.75	0.83831
0.30	0.72172	0.80	0.84225
0.35	0.74469	0.85	0.84509
0.40	0.76454	0.90	0.84697
0.45	0.78155	0.95	0.84801
0.50	0.79600	1.00	0.84834

TABLE II.

x	y_2	x	y_2
0	0.1250	0.50	0.3066
0.05	0.1269	0.55	0.3437
0.10	0.1325	0.60	0.3839
0.15	0.1418	0.65	0.4274
0.20	0.1548	0.70	0.4739
0.25	0.1714	0.75	0.5234
0.30	0.1916	0.80	0.5760
0.35	0.2152	0.85	0.6317
0.40	0.2423	0.90	0.6902
0.45	0.2728	0.95	0.7518
0.50	0.3066	1.00	0.8162

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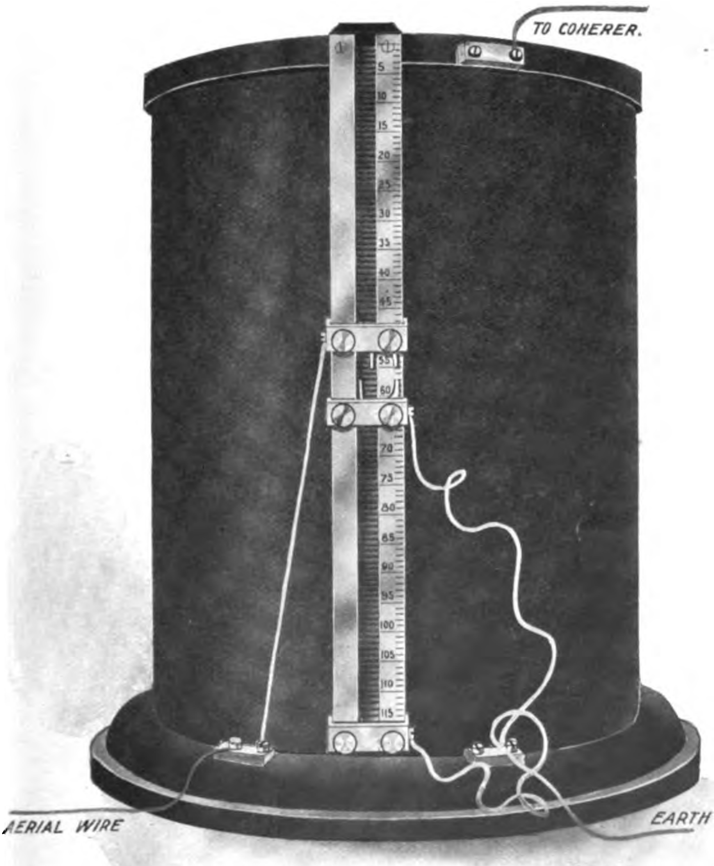
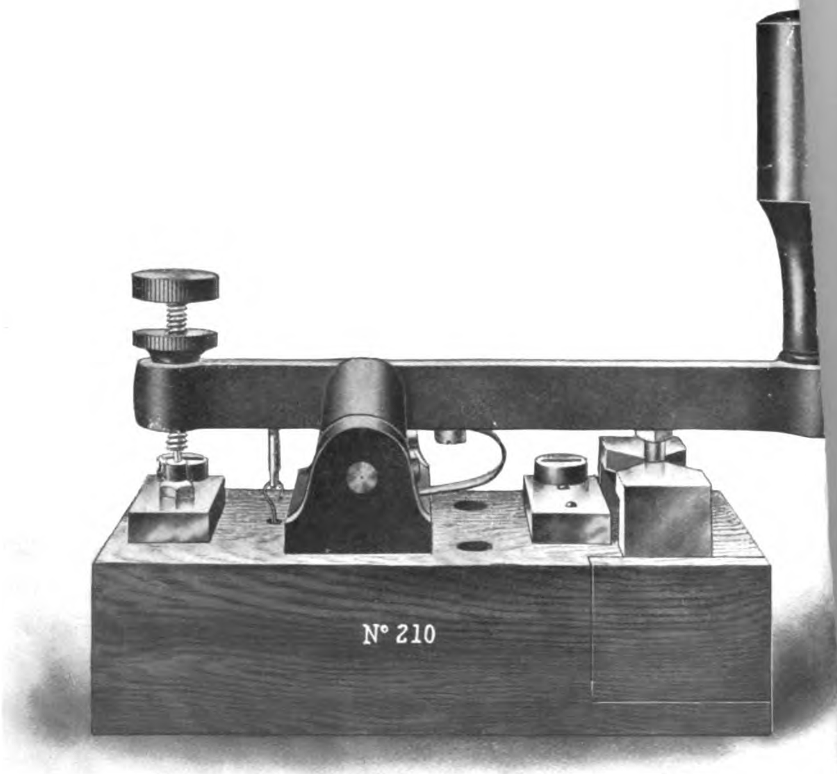
PLATE XIII.



RECEIVER TUNING COIL, SLABY ARCO SYSTEM.



MORSE KEY, SLABY ARCO SYSTEM.

PL