NATIONAL RADIO INSTITUTE

1345 PENNSYLVANIA AVENUE, N. W.

WASHINGTON, D. C.

THE MOTOR GENERATOR

INSTRUCTION BOOK No. 5

SECOND EDITION

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We advise the student to first read the instruction paper thoroughly and then study intensely a few pages at a time.

If possible set apart a certain hour or period of the day for study and allow nothing to distract you.

We will explain by letter any matter at all vague to the student.

Before answering the questions, carefully review the instruction paper.

Write out your answers to the questions and send your work to us for examination and correction.

THE MOTOR GENERATOR

The Motor Generator:—The motor generator is a machine employed to convert direct current to alternating current, alternating current to direct or direct current at one voltage to direct current at another voltage.

In radio telegraphy, we are interested in the type which converts direct current to alternating current, as modern ship transmitters require alternating current for their operation.

The motor generator, although combined as one, really consists of two machines, a direct current motor and an alternating current generator, their armatures being mounted on the same shaft. The motor is treated in detail in Instruction Paper No. 4 and the student is referred to that paper in case he needs to review the subject. The motors used in the construction of motor generators have four poles and range in power from one-half to five horsepower.

The generator has from four to thirty field poles, depending upon the frequency desired and has an armature speed of 1800 to 2400 revolutions per minute.

The student should understand that the two machines operate independently of each other. That is, that the function of the motor is to drive the generator armature.

There are four distinctive types of electric motors used for commercial purposes.

The first type is called the series motor, and has its main field winding in series with the armature and thus the strength of the field will change as the load changes. This motor is a variable speed type of motor and gives maximum torque or pulling power upon starting, and is used for street car service, electric vehicles and for all purposes where a variable speed is desired.

Type two is a shunt wound motor and has the main winding connected across the armature with a rheostat in series to regulate the current in the shunt field. This type of motor is in very common use where nearly a constant speed is desired for driving machinery. For example: a lathe in a machine shop; a saw, or a generator which does not have to maintain a constant voltage.

Type three is called an accumulative compound wound motor, and is a combination of the series and shunt fields, both acting together on the pole pieces of the motor. This gives the motor a very large starting torque or turning power upon starting the machine, and at the same time it maintains a fairly good speed regulation after the load has become constant. This type of motor is used a great deal for elevator and hoisting service.

Type four is known as differential compound motor, and is a combination of the series and shunt wound fields on the pole pieces of the motor, but in this type the series field acts in the opposite direction from that of the shunt and thus has a tendency to weaken the pole pieces as the load increases.

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This type of motor maintains a constant speed, and is used in all cases where a close regulation of the speed is a necessity for the work of the machinery, as, for example, in driving a weaving machine; or we might better say for a wireless generator, where the frequency must be maintained at 500 cycles.

The question might arise as to why alternating current might not be supplied direct to the set without the use of a motor generator. The ship generating plant usually supplies direct current and therefore it is necessary to have some means of conversion. The installations aboard the majority of ships are either the one-half kilowatt or the two kilowatt type of motor generator. These machines provide an alternating current, ranging in voltage from 110 to 500, and in frequency from 60 to 500 cycles. The trend in modern design is for generators of 500 cycles, as this frequency causes a much more efficient wave motion to be radiated from the aerials.

To produce an alternating current it is necessary for the generator to have direct current field excitation. In motor generators, the field coils of both motor and generator are connected to the direct current source, which in ship installations is the ship's generator. In some types of auxiliary or emergency sets aboard ship, the generator is driven by a gasoline engine, a small direct current generator belted to the gasoline engine, supplying the field coils with direct current.

There are three types of alternating current generators (sometimes termed alternators), which are entirely different in their construction.

Type one is called revolving armature alternator, and is illustrated in Figure 41 in this book. This type of machine is very much like the ordinary direct current generator, the armature winding being placed on the rotating part and the pole pieces being located on the frame or stationary part of the machine. Direct current, usually from a separate source of power, is supplied to the field winding, and the alternating current is collected from two or more brushes bearing on collector rings which are placed on the revolving shaft near the generator armature winding.

Type two is called the revolving field alternator, and in this machine the pole pieces and field coils are located on the revolving shaft, while the armature coils are located on the stationary frame of the machine. This type of construction is used a great deal in large machines where the amount of current taken from the armature is large in value and high in pressure, and the collecting of this from a rubbing contact would be a difficult problem. It is also to be noted that the revolving fields can be constructed more rugged and durable than the armature coils which must bear very heavy insulation, and this material is not mechanically strong.

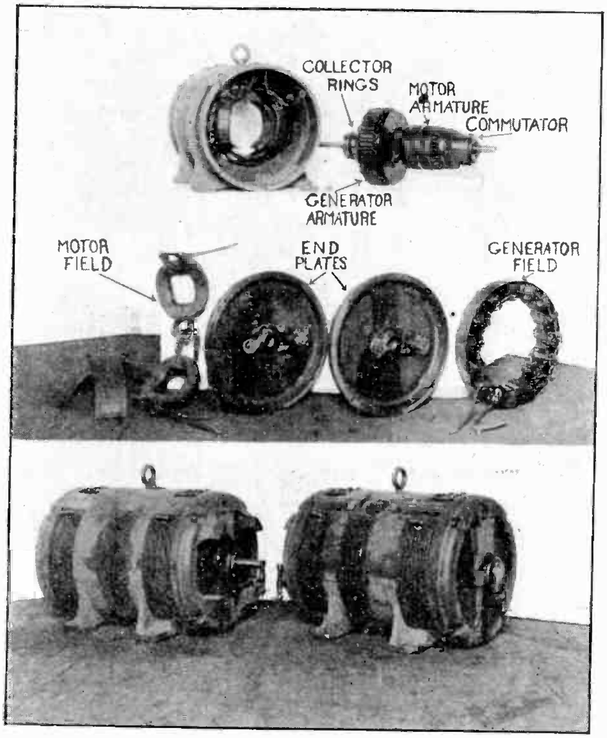


Fig. 41. Exploded and Assembled views of a Two-Kilowatt Five Hundred cycle Motor Generator having Revolving Armature

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

THE MOTOR GENERATOR

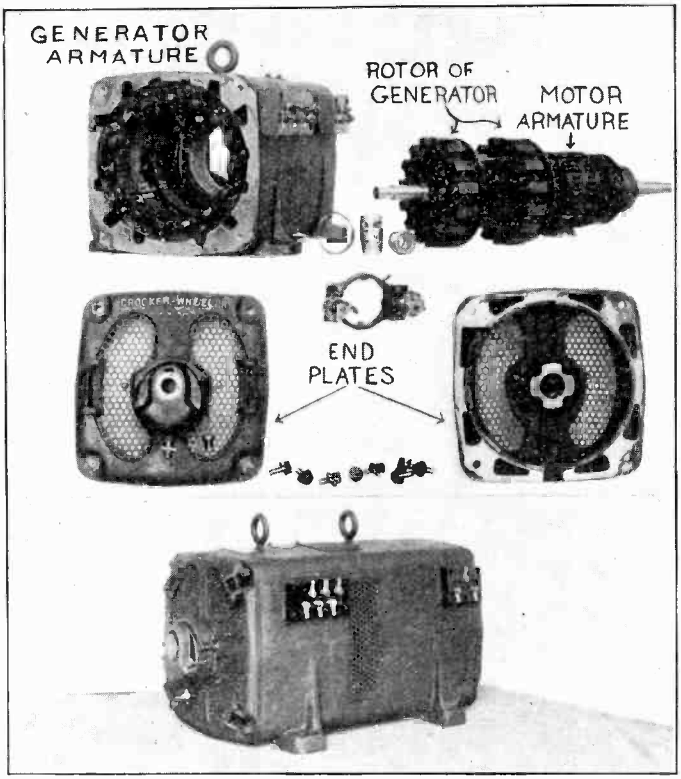


Fig. 42. Exploded and Assembled views of a Two-Kilowatt Five Hundred cycle Motor Generator of the Inductor Type

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

Type three is known as the inductor alternator, and has no revolving coils.

In place of a winding, an iron core, having teeth radiating outward from the center, revolves in the magnetic field produced by the generator field winding. The iron core is laminated in order to prevent eddy currents.

The armature is stationary and consists of a number of coils arranged about the inner surface of the frame as shown in Fig. 42. These coils are built on iron cores and are arranged in two circular rows. Between these two rows a circular field coil of the same diameter as the armature coils is placed and has precisely the same action as a solenoid winding, producing a field parallel with the shaft. The number of stationary armature coils depends upon the frequency desired, and are equal in number to the teeth protruding from the revolving core, as shown in Figure 42 and Figure 42a.

At one instant, the teeth of the core are opposite the stationary armature poles and the lines of force from the field coil pass through the armature cores on one end of the frame through the rotating core and back into the armature cores at the other end of the frame. An instant later, the core teeth are opposite the open space between the armature coils and therefore the lines of force have a more difficult path from the stationary field coil through the revolving core. In other words, owing to the high permeability of the revolving teeth, the number of lines of force are increased in number at the time the teeth are opposite the armature coils, and when the teeth are opposite the open spaces betwen the armature coils, the number of lines of force are greatly reduced, due to the lower permeability of air. This increase and decrease of the strength of the field threading through the armature coils induces an alternating current in them. A machine of the type shown in Fig. 42a produces a 500 cycle current (outside view of Figure 47a).

Field Windings:—Motor generators are divided into three principal types as follows:

(1) Shunt wound motor and simple alternator.

(2) Shunt wound motor and accumulately compounded alternator.

(3) Differentially compounded motor and simple alternator.

A fundamental circuit diagram of the first type is given in Fig 43. The motor field winding is in shunt about the armature; that is, its terminals are connected to the brushes bearing on the commutator. In this diagram, the circular arrangement marked D. C. represents not only the commutator but the armature back of it. A variable resistance called a field rheostat is connected in series with the shunt field winding, and its function is to vary the speed of the motor.

Another field rheostat is connected in series with the generator field winding, its function being to vary the voltage of the generator armature.

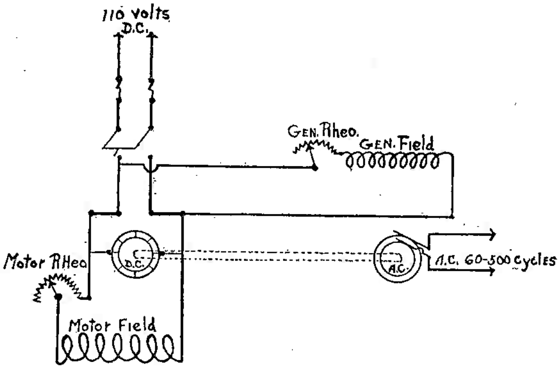


Fig. 43. Simple Shunt Wound Motor Generator

In the second type of motor generator, we have a shunt wound motor and an accumulatively compounded arternator. The motor is wound in the same manner as the first type with the exception that an extra field winding

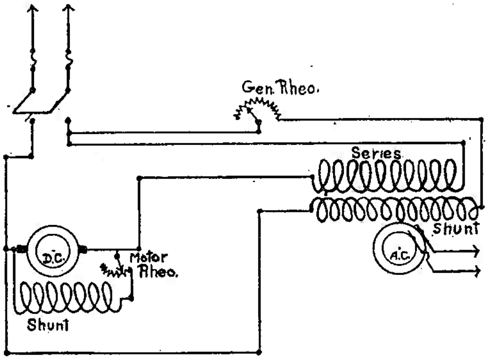
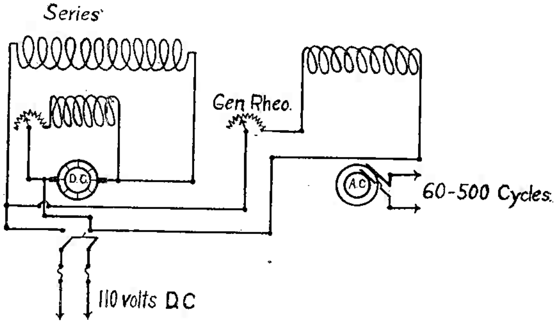


Fig. 44. Motor Generator with Compound Generator Field Windings

for the generator is connected in series with the motor armature. This arrangement, shown in Fig. 44, tends to keep the voltage of the generator constant under varying load. All motor generators used in wireless operate under an extremely variable load and a machine wound in the above manner will give a fairly constant voltage. If a load is thrown suddenly on the generator, the machine slows down under this sudden burden and in consequence the counter e. m. f. of the motor armature is reduced, allowing a heavier current to flow in the armature and through the series winding about the generator field poles. The extra current in the generator field winding strengthens the field and the voltage is kept constant. When the load is removed the speed increases and the counter e. m. f of the motor armature returns to normal, reducing the current flow in the generator field to its former value.

In the third type of winding, illustrated in Fig. 45, the motor has two field windings which are wound in opposite directions. The purpose of this type of winding is to maintain constant speed and therefore a constant frequency of the generator current. If a load is placed on the generator, the motor slows up, thus decreasing the counter e. m. f. of the motor armature. The increasing current in the armature in flowing through the series winding sets up an opposing field which reduces the number of lines of force about the armature. This weak field brings about a still greater drop in counter e. m. f. and hence a decided increase of current in the motor armature. As a result of this increase of current in the armature the motor speeds up.



F(g. 45. Circuits of Motor Generator with Differential Field Winding

The opposing action of the fields acts as a governor or regulator of the frequency of the generator. The generator field winding is identical with that of the first type of motor generator.

The Dynamotor:—The dynamotor is a machine for changing a direct current at one voltage to a direct current at another voltage or to change a direct current to one that is alternating. In wireless, the dynamotor has been used for conversion of direct current to alternating current, but on account of its inefficiency, it has been discarded in favor of the motor generator. The machine is of simple construction and does not require much space.

The machine has one armature, with two windings on it, one being connected to a commutator, the other to collector rings. Direct current is supplied to the armature, driving it as a motor, and the other armature, being wound on the same core, cuts the lines of force set up by the field magnets and has induced in it an alternating current. This current is carried by the collector rings to the external circuit. The frequency of this machine is dependent upon the number of poles and speed of the armature.

This machine is still used in the signal corps sets, but for ship radio is almost obsolete, especially in America.

The Rotary Converter:—The rotary converter has one armature winding, one end of which is connected to a commutator and the opposite end to collector rings. The direct current entering at the commutator causes the armature to revolve as a motor and on account of the armature passing through the field it has an alternating current induced in it which flows out on the collector rings to the external circuit. The machine may be driven by mechanical power and thus generate both a direct and an alternating current. Due to the abnormal number of field poles and commutator segments required, it would be impossible to construct an efficient rotary converter to deliver 500 cycles, and is practically obsolete as far as radio work is concerned.

THE MOTOR STARTER:—The function of the motor starter is to prevent a heavy flow of current through the low resistance armature windings of the motor while starting.

The motor is practically identical in construction with the dynamo and therefore, when the motor is running we have all the necessary qualifications for a dynamo. That is, an armature coil is revolving through a magnetic field and produces a current which is flowing in an opposite direction to the current that drives the motor. When the motor is not running this counter e. m. f. is zero and the armature will have very low resistance, but when the motor is running this current acts as a resistance to the direct current flowing through the armature and thus prevents the burning out of the armature windings.

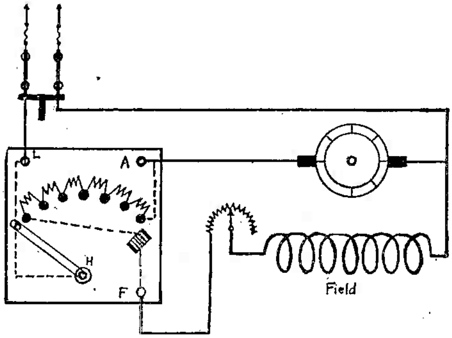


Fig. 47. Cutler Hammer Hand Starter and Connections

Therefore, in starting a motor, some provision must be made to prevent the current from damaging the armature while the motor is developing a counter e. m. f.

If the current should be applied directly to the brushes damage might be done to the commutator and might possibly burn out the armature.

A variable resistance called the motor starter is connected in series with the armature and is so arranged that all the resistance is in series while starting, and which may be gradually reduced until the motor is running at full speed.

At first, the armature current is flowing through all the resistance of the starter and is of a very low value, but small as it is, the armature will turn over slowly and generate a counter e. m. f. of low value. When more of the variable resistance is cut out, the motor revolves faster, generating more counter e. m. f. to oppose the direct current. Thus, the motor starter is a resistance box, all of whose resistance is put in series with the motor armature, when starting, but is gradually reduced over a period of about 15 seconds until the driving current is connected directly to the armature.

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There are various types of motor starters on the market.

The two principal divisions are:

(1) The Hand Starter.

(2) The Automatic Starter.

The Cutler Hammer hand starter is shown in Fig. 48. It consists of several coils of resistance wire, a handle, contact studs and a small electromagnet. The terminals of the resistance coils are soldered to the studs on the back of the panel. As the handle passes over the contacts on the face of the panel, connection is made to the coils. When the handle is on the first contact, all the resistance wire is in series with the armature and the current flow is a minimum, but as the handle moves over each successive contact, the corresponding resistance coil is removed from the circuit. The small magnet holds the handle in the running position. In case the current in the line fails for any reason, this magnet being in series with the field winding, will lose its power and allow the handle to go back to the off position. This release of the handle, when the current ceases to flow, protects the armature from possible damage in case the current should be again turned on. Usually 15 seconds is sufficient time to start most motors and should not be greater than this because of the danger of burning out the resistance wire.

The General Electric Starter is similar to the Cutler Hammer, the principal difference being the connection to the release magnet, which in the General Electric Starter is connected directly across the line.

The resistance wire in any starter is an alloy of several different metals German silver wire and other alloys are used in the different makes of starters.

In case the handle of the starting box flies back and the motor stops, the trouble is probably an open circuit in the field, a short circuit in the release magnet or is due to the current being cut off.

If the release magnet should develop a short circuit, the handle may be fastened temporarily in the running position by means of a cord.

In case a resistance coil in the starting box should burn out, the bad coil may be shunted by means of a piece of wire attached to the two contact studs affected. If two adjacent coils are burned out, it may be necessary to renew the resistance by means of lamps connected in series parallel, but due to the fact that motor generators usually start on no load the resistance coils may be shunted and still cause no great damage to the motor.

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THE AUTOMATIC STARTER:—In recent years automatic starters have been employed extensively in ship wireless sets. By means of an automatic starter the operator merely needs to press a button to start or stop his motor generator, which in some cases is installed in another room, to prevent the noise from its operation to interfere with receiving. The automatic starter usually consists of some form of solenoid operated device.

In Fig. 49 is shown one type of automatic starter used on 2 K. W. sets. A solenoid is arranged so as to cause an arm to move upward and short-circuit the resistance coils. This motion is gradual and serves the same purpose as pulling the handle of the ordinary starter over by hand. To prevent the solenoid from pulling the arm up too quickly, a dash pot is used. A rod attached to the starter arm is fastened to the piston of a small cylinder. As the starter arm moves up, the piston moves also and tends to produce a vacuum in the cylinder, but due to a small leak in one end of the cylinder the arm is allowed to move slowly upward. The cylinder is called a dashpot and in some cases is filled with oil instead of air.

THE FIELD RHEOSTAT:—The function of the field rheostat in the motor field circuit is to vary the speed of the motor and consequently that of the generator. The immediate effect of the field rheostat is the variation of the current flow in the field windings and as a result of this an increase or decrease of the number of lines of force set up about the field poles.

The motor armature in revolving as a motor also acts as a generator and the voltage thus produced causes a current to flow in opposite direction to the current that drives the motor. The voltage of any generator is proportional to the rate of cutting of the lines of force in the field. Hence the counter e. m. f. produced in the motor armature depends upon the change in number of the lines of force brought about by variation of the field rheostat.

The amount of current flowing into the motor armature depends upon the magnitude of this opposing e. m. f., and as the speed of the armature is dependent upon the amount of the driving current that flows into the armature, a weakening of the field by means of the field rheostat will cause the motor to speed up and a strengthening of the field will cause the motor to slow down. To state the matter more briefly: An increase in the value of the resistance in the motor field will increase the speed of the motor, while a decrease in resistance of the rheostat will decrease the speed of the motor.

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A decrease of resistance in the generator field winding will increase the current through the generator field and thus increase the number of lines of force.

The revolving armature will cut through this increase in number of the lines of force and generate a higher voltage. A decrease of current flow in the field has an opposite effect on the voltage.

As the power of a generator depends upon the product of its volts and amperes, the power may be varied by means of the generator—field rheostat.

The power may also be controlled by variation of the speed of the armature, but if a constant frequency is desired it will be necessary to maintain a constant speed of the revolving armature.

As one cycle is produced by the armature passing two adjacent field poles, the number of cycles per second depends on the number of revolutions per second and on the number of field poles. The number of revolutions of the generator is governed by the motor field rheostat.

The frequency of a machine having a revolving armature may be calculated by means of the formula:

$$F = \frac{N \times S}{2}$$

Where:

F equals frequency in cycles per second.
N equals number of field poles.
S equals revolutions per second.

The Marconi 240 cycle type of motor generator is designed to have an armature speed of 2400 revolutions per minute or 40 revolutions per second.

The number of field poles may be calculated by substituting the above data in the formula given above.

$$F = \frac{N \times S}{2}$$

$$240 = \frac{N \times 40}{2} \quad \text{or } N \times 40 = 2 \times 240$$

$$40\ n = 480$$

$$n = 12 \text{ field poles.}$$

THE MOTOR GENERATOR

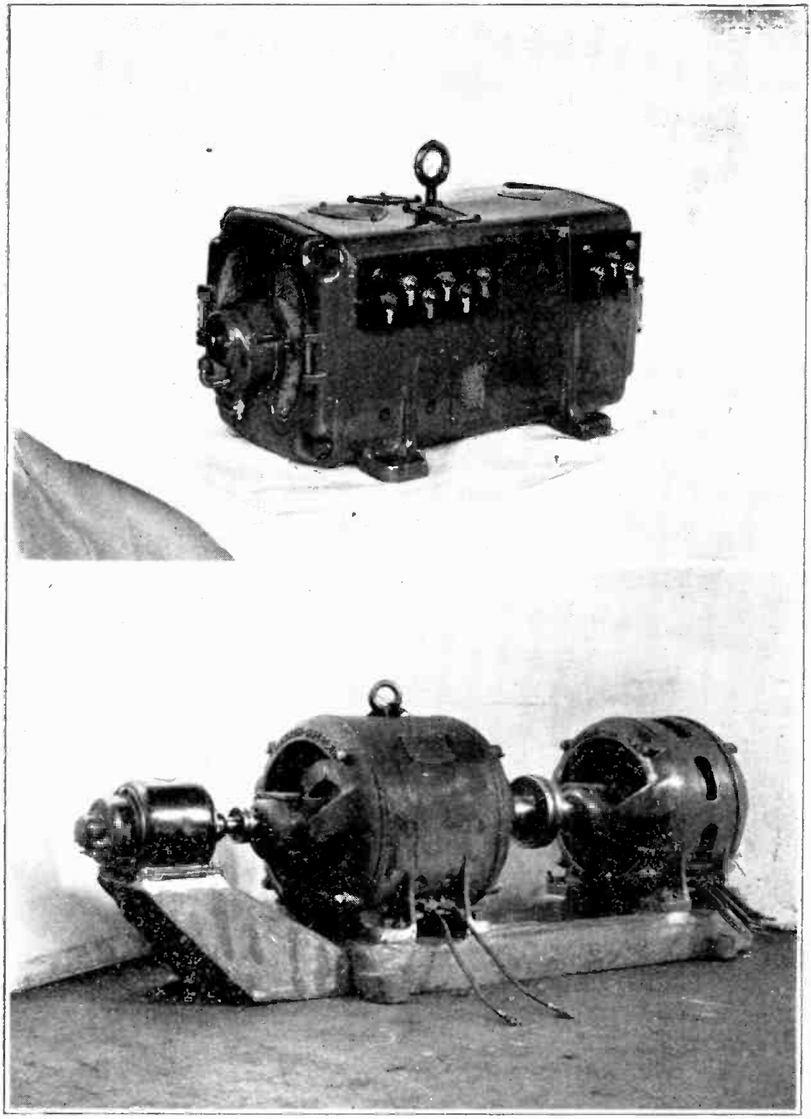

Fig. 47a. Top—Outside view of 500 cycle inductor type Alternator
Bottom—5 K. W. 500 cycles Motor-Generator set with an Exciter mounted on a pedestal at the left-hand end

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

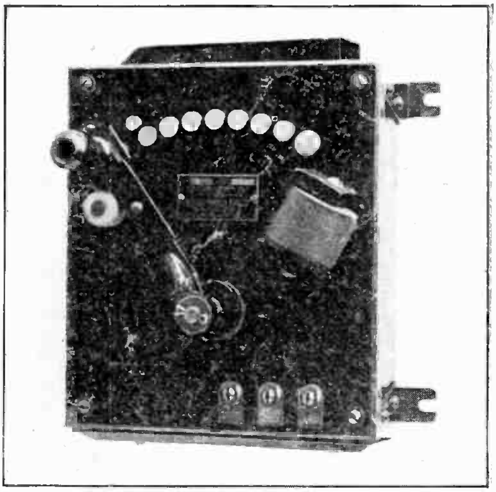

Fig. 48. Cutler-Hammer Hand Motor Starter

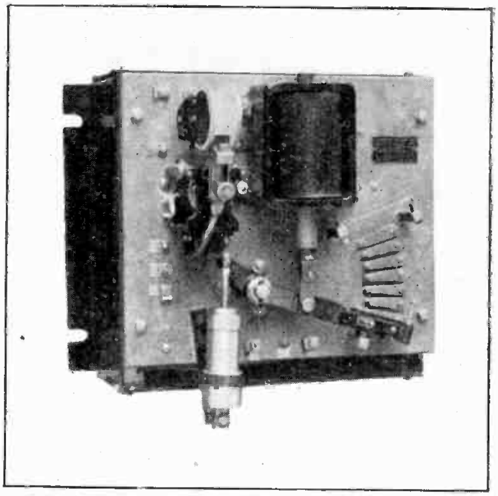

Fig. 49. Cutler-Hammer Automatic Motor Starter

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The student should take note of the fact that there are two principal quantities to be varied in the operation of a motor generator. The **frequency** of the generator is varied by means of the **motor field rheostat** and the **voltage** of the generator by means of the **generator field rheostat.**

The field rheostat is merely a variable resistance wire wrapped on a rectangular piece of slate and a slider arranged so as to make contact with the different turns. When connected in series with the field windings one terminal of the field coil makes connection with the slider and one end of the coil makes connection with the source of direct current. As the slider moves over the coil more or less number of turns are included in the circut, varying the strength of the current flow in proportion.

PROTECTIVE DEVICES:—Whenever a wireless set is in operation, high frequency, high voltage currents flow in certain circuits. On acount of the high voltage circuits being parallel at certain points to the motor generator circuits, dangerous voltages may be induced in the latter. The insulation of the motor generator windings is not designed to carry currents of high voltage and frequency and thus there is constant danger of breakdown unless protective measures are taken.

The stray currents induced in the motor generator windings in seeking the shortest possible path to the ground, may jump from the field windings to the frame, or from the armature to the shaft and in thus puncturing the insulation, a path is made for the low voltage currents which operate the motor generator. A protective measure used to neutralize this induction from the high frequency circuits is to install all wiring in metal conduit. This conduit is grounded and will conduct to earth all stray currents induced in it.

An important device for the protection of the set consists of two one-half microfarad condensers connected in series and is called a protective condenser. The middle connection of the two condensers is connected to earth and the two remaining terminals are connected either (1) across the armature of the motor, (2) across the armature of the generator, (3) across the field and frame of motor, (4) or across the field and frame of generator. This device, shown in Fig. 50, will allow high frequency, high voltage currents to flow through it to the earth, but will not allow the low voltage, low frequency currents to pass. Fuses may be connected in series with the condensers to protect the motor generator in case of a short circuit of a condenser. In case of such short circuit the low voltage current of the motor generator will in passing through the protective condenser, blow the fuse and prevent breakdown of the set.

Another device shown in Fig. 51 that serves the same purpose as the protective condenser is the protective resistance rod. It consists of a graphite rod of about 6000 ohms resistance, having its middle point connected to the ground, and the two end terminals connected to the same points as given above for the protective condenser. The graphite rod will conduct the high voltage, high frequency currents to the ground, but due to its high resistance it will not conduct the low voltage currents flowing in the motor generator.

Upkeep of Motor Generator:—The parts of a motor generator most likely to give trouble are the bearings, commutator and the collector rings. Lack of oil or improperly fitted bearings will cause heating and unless the trouble is corrected will cause the shaft to "freeze" in the bearings. The commutator and collector rings are also a frequent source of trouble due to sparking. The common cause of sparking at the commutator are:

1. Brushes bearing unevenly on the commutator.
2. Grooved commutator.
3. Raised insulating wedges.
4. Brushes not being in neutral field.
5. Open circuit in armature.
6. Dirty brushes or commutator.
7. A partially short circuited field coil.

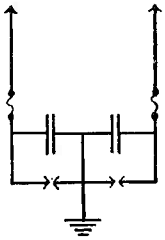

Fig. 50. Protective Condensers.

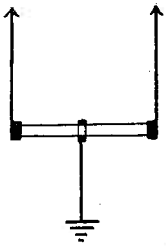

Fig. 51. Protective Resistance Rod.

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The collector rings may also give trouble from sparking, caused by dirt or grease.

The attention required by a motor generator is fully covered by the following list of rules:

1. Keep the motor generator dry and free from dust and grease.

2. Keep all connections tight.

3. See that thrust bearings on the end of the bearings prevents end play of the armature.

4. See that protective condensers or protective resistance rods are properly connected and that they do not come loose from vibration.

5. Keep bearings well oiled and see that rings carry oil properly. The bearings should be inspected every day.

6. Keep a close watch on the valves of the petcocks to see that they do not jar loose and allow the oil to leak out.

7. Keep contacts of automatic starter clean and properly adjusted.

8. See that brushes fit evenly. To make them fit, place a piece of sandpaper between commutator and brush with the rough side up and then pull backward and forward until brush fits the curved surface of the commutator.

9. Keep commutator clean and polished. Clean with fine sandpaper, never with emory cloth. Polish with a coarse piece of canvas.

10. Do not over-speed motor. After operating set for a time, the sound will indicate the proper speed.

11. In case of burn-out of coils in field rheostat or starter, shunt by means of a piece of copper wire.

12. If necessary to remove armature, remove generator end plate, and then in removing armature, be careful of commutator connections.

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QUESTIONS

INSTRUCTION PAPER No. 5

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

101. What is a motor generator?

102. Why is a motor generator required aboard ship?

103. What kind of field excitation is necessary for the generator?

104. What is an inductor alternator?

105. What three principal types of motor generators are in use?

106. Give circuit diagram of the differentially compounded motor and simple alternator type.

107. What is the function of the differential field winding?

108. What is a dynamotor?

109. What is a rotary converter?

110. Explain briefly the action of the motor starter.

111. Give a diagram of the Cutler Hammer Starter.

112. What are the advantages of the automatic starter over the hand starter?

113. What is the function of the motor field rheostat?

114. What is the function of the generator field rheostat?

115. How many poles would be necessary for a generator delivering 120 cycles at 2400 revolutions per minute?

116. In what two ways can the voltage of a generator be controlled?

117. Why is it necessary to use protective devices on the motor generator?

118. Describe the protective condenser.

119. Name five causes of a sparking commutator.

120. How often should the bearings of a motor generator be inspected?

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

1345 PA. Ave., N. W. WASHINGTON, D. C.

Answers to Instruction Book No. 5

101. A motor-generator is two electrical machines, belted or directly connected together for the purpose of changing current into another current with different characteristics.
102. To change 110 D. C. ship power into 500 cycle A. C. current for wireless energy.
103. Direct current field excitation.
104. An inductor alternator is constructed with both field and armature coils on the outer stationary frame, while the motor contains the project steel poles.
105. 1st. Shunt motor with simple alternator.
2nd. Shunt motor with compound wound alternator.
3rd. Differential wound motor and simple alternator.
106. See Figure 45.
107. To reduce the resultant field strength as the load increases, which will increase the speed to counteract the decrease in speed due to this load, finally resulting in a constant speed motor.
108. A dynamotor is a machine with one field, one armature having two windings. One winding receives electrical energy to drive the armature and current with new characteristcs are taken from the other winding.
109. A rotary converter is an electrical machine with one field, one armature with one winding. A. C. or D. C. is supplied to it for operation, and the opposite kind of current, with a fixed ratio of voltage, is drawn from this winding.
110. The handle of the starter is moved onto the first round brass contact, now several coils of resistance wires are in series with the armature; as the handle is moved over the contact points the resistance is removed from the circuit and full voltage is placed on the revolving motor amature. The handle is held in this position by the small field magnet coil which is in series with the motor shunt field. If the power goes off the lines, this field magnet loses its current and releases the handle and a spring pulls this back to the starting position.
111. See Figure 47.
112. The automatic starter works by the simple pushing of a switch button and it causes a smooth, even acceleration of the motor to its full speed.
113. The motor field rheostat regulates the speed of both motor and generator, which in turn determines the generator frequency in cycles which should be maintained constantly at approximately 500 cycles.
114. The generator field rheostat regulates the A. C. voltage of the generator.
115. F=P x R.P.M.-:-120 or 120=P x 2400-:-120 or P=120-:-20=6 poles.
116. The generator voltage can be controlled by the generator field current or by the speed of the generator armature.
117. To protect the motor and generator windings from heavy electrical pressures and surges which might be induced in the wire leading to these machines.
118. The Protective condenser device consists of two condensers joined in series and connected across the motor or generator armature. A ground connection leads from the mid point between these two condensers.
119. Causes for a sparking commutator are brushes out of position, dirty commutator, a raise bar or mica strip, a burnt-out or open armature coil, improper fitting of the brushes.
120. Inspect the bearing whenever the set is operated.

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Lesson No. 5.

No. 101 A motor generator is a machine used to change direct current to alternating, alternating to direct and direct current at one voltage to direct current of another voltage.

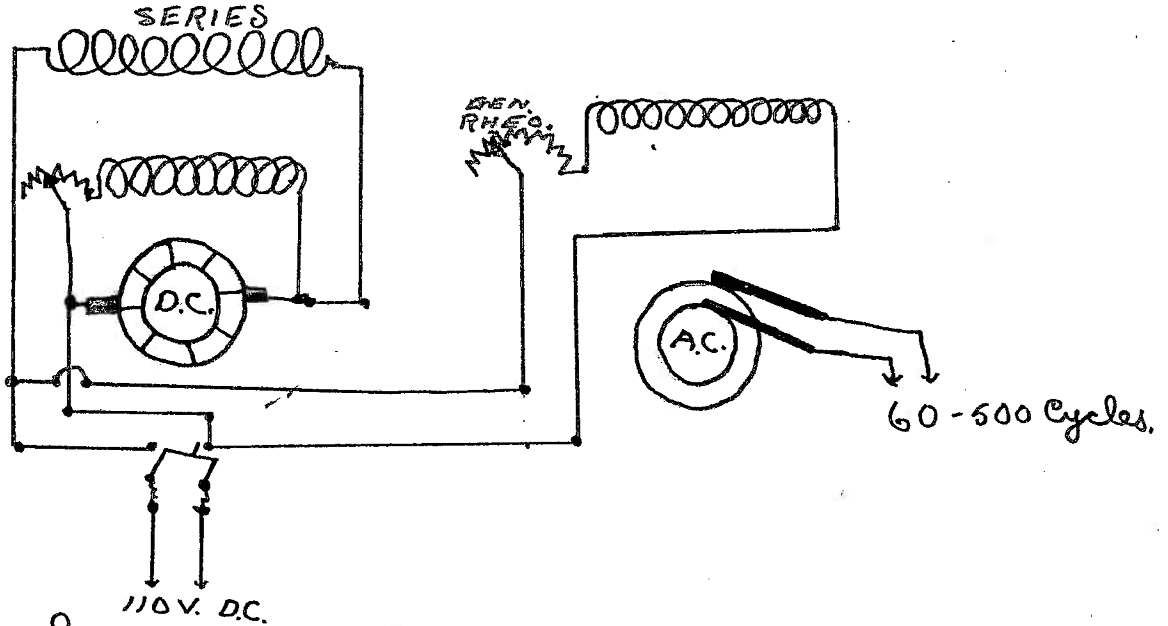
102 Because in most all ships the electrical plants furnish direct current and so some means must be used to change it to alternating current before it will run the wireless transmitter set. For this conversion a motor generator is used.

103 A direct current is necessary for the field excitation of a generator.

104 An inductor alternator is a generator having no revolving coils. The armature coils are arranged around the inner surface of the frame in two circular rows, between these two circular rows the field coil having the same diameter as the armature coils is placed. The revolving core is laminated to prevent eddy currents. The core has teeth radiating outward from the center, when this revolves it alternatingly cuts the lines of force of the field coil and induces a current of electricity in the armature coils. The frequency of this machine depends upon the no. of armature coils. The teeth on the revolving core are equal in No. to the No. of armature coils.

105 1. Shunt wound motor and simple alternator
2. Differentially compounded motor and simple alternator.
3. Shunt wound motor and accumulately compounded alternator

106



107 The function of the differential field windings is to maintain a constant speed and therefore a constant frequency of the generator current.

108 The Dynamotor is a machine for changing a direct current to an alternating current or a direct current at one voltage to a direct current to another voltage. it consists of one armature with two windings on it, one winding is connected to a commutator the other to collector rings. Direct current is supplied to one winding on the armature driving it as a motor, The other winding being wound on the same core cuts the lines of force set up by the field magnets has an alternating current set up in it. this current is carried to the external circuit by the collector rings.

109 The rotary converter has only one armature winding on the core one end of which is connected to a commutator. the other to collector rings. a direct current entering at the commutator causes the armature to revolve as a motor. and on account of the armature passing through the field has an alternating current inducted

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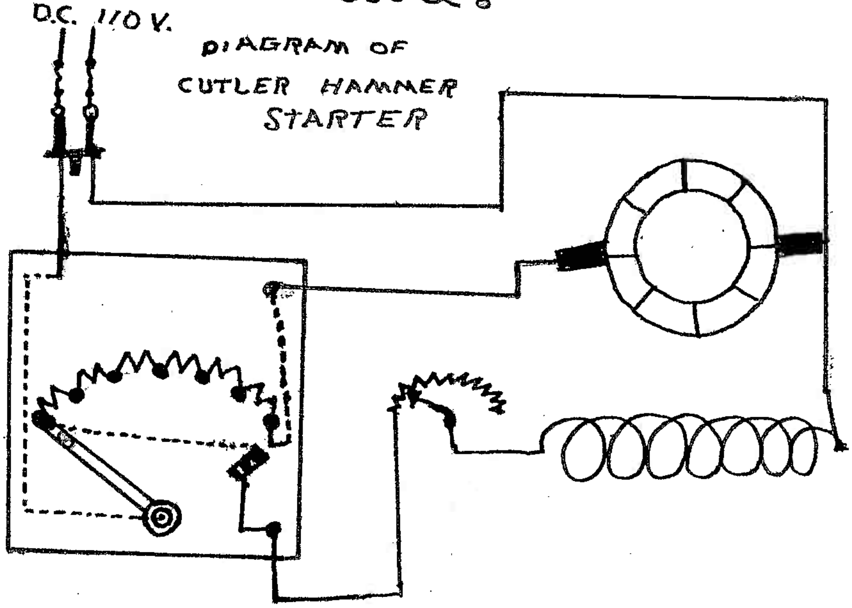
in it. this current is then carried to the external circuit by means of the collector rings.

110 The action of the motor starter is to prevent the burning out of the armature windings this is done by starting the motor slowly with all the resistance in series with the motor. this resistance is successifully cut out as the motor gains speed The faster the motor goes the greater the opposing E.M.F. generated in the windings will be. this counter E.M.F. opposes the direct current preventing the motor burning out. thus a starter is a resistance box, all of whose resistance is in series when starting, but is gradually reduced until the current is directly connected to the armature.

111



112 The advantages of the automatic starter over the hand starter are

The conveniance in operating the starter by a single push of a button.

This starter also allows the exact time necessary for the cutting out of the resistance in series with the motor.

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113 The function of the motor field reostat is to vary the speed of the motor and therefore the speed of the generator. this causes a variation of the current flow in the fieldwindings, this results in an increase or decrease in the No. of lines of force set up about the field poles.

114 The function of the generator field reostat is to vary the voltage of the generator.

115 $F = \frac{n \times S}{2}$

F = frequency in cycles per. second.
n: No of poles
S = revolutions per second.

2400 revolutions per. minute = 40 revolutions per second
120 cycles per. second
{to find the No. of field poles.}

$$120 = \frac{n \times 40}{2} \quad \text{or} \quad n \times 40 = 2 \times 120$$

$$40n = 240$$

$n = 6$ field poles necessary

116 The voltage of a generater may be controlled by means of the generator field reostat.
It may also be controlled by varying the speed of the armature of the generator by means of the motor reostat.

117 Protective devices are necessary on motor generators, on account of the high frequency high voltage currents which flow in certain circuits whenever the wireless set is in operation.
This heavy current is sometimes induced in the motor generator circuit and unless a proper ground has been made before hand will destroy the windings of the motor generator or the insulation, which then allows the low frequency

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currents of the motor generator to jump to the frame putting the machine out of order.

118 The protective condenser consists of two one half microfarad condensers connected in series. The middle connection is then grounded to the earth. The two connections left are then either connected across the armature of the motor, across the field and frame of the generator across the field and frame of the motor or across the armature of the generator. this device allows the induced high frequency, high voltage current to pass to the ground, but will not allow the low frequency, low voltage currents to pass.

119 Five causes of sparking at the commutator are.

1. grooved commutator
2. brushes bearing unevenly on commutator
3. Brushes out of neutral position
4. Dirty commutator or brushes.
5. Open circuit in armature.

120 The bearings of a motor generator should be inspected every day.

LESSON TEXT NO. 2

OF A

Complete Course in Radio Telegraphy

Electrical Units
The Electric Current

REVISED EDITION

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The Electric Current

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THEORY AND CODE LESSON NO. 2

In studying this course, you will find yourself progressing step by step from the simplest principles and problems in electricity to the most intricate ones. Naturally your ability to solve the lessons following will depend largely on the concentration and effort devoted to these.

If you have difficulty, don't get discouraged. It is a common saying that the value of anything is in direct proportion to the difficulty encountered in attaining it. Therefore, if you have trouble in mastering any part of this lesson, or any lesson for that part, you are merely improving yourself and testing your determination to go thru to the finish.

* * *

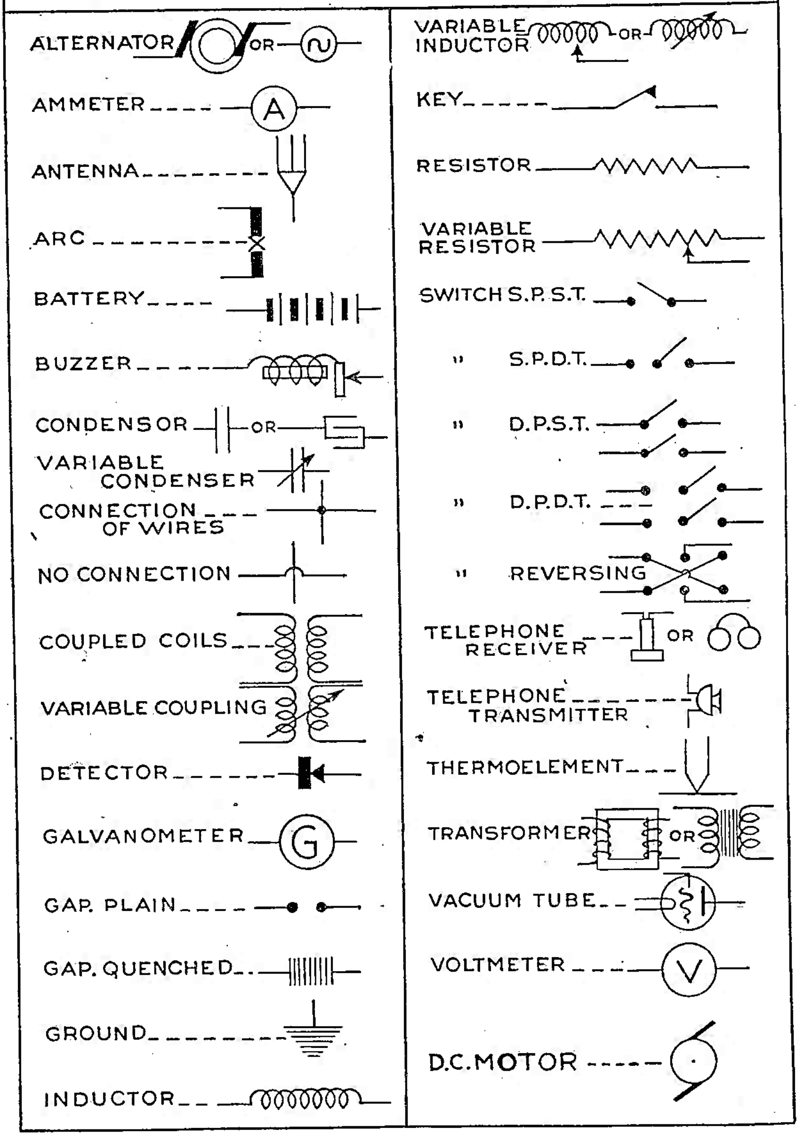
Turn again to the code alphabet in the first assignment of material and practice those symbols until you can repeat from memory the exact symbol which represents any letter of the alphabet regardless of the order in which they come to your mind.

Now practice sending this article on the key and buzzer being careful not to sacrifice speed for accuracy and always making sure that the interval between words is properly proportioned to the length of the dots and dashes you are sending.

> "We live in an age of split seconds. Wireless messages may now be transmitted and received practically between any two points on the surface of the earth in a fraction of a second. This is the amazing progress since the first workable wireless apparatus was invented twenty-five years ago by Marconi. Six years later he sent the first wireless signal across the Atlantic from Cornwall to Newfoundland. On that historic occasion he could transmit nothing except repetitions of the letter S, but in another two years he sent complete messages."

You are now ready to turn to your second theory lesson and learn about electric circuits and how they are formed. Study carefully the matter following:

KEY TO SYMBOLS OF APPARATUS



THEORY LESSON NO. 2

DIAGRAMS OF CONNECTIONS

For convenience in illustrating graphically the connections of an electrical circuit, certain symbols are used to denote the particular predominant property which that part of the circuit possesses. When several of these symbols are used to illustrate certain connections, it is known as a "Diagram of Connections." At the beginning of this lesson text we give a number of these symbols and certain variations of them which are most commonly met with in Radio Telegraphy.

The student should first read the names of the apparatus and satisfy himself that he knows what it is and the purpose for which it is used. He should then write all the names, numbering them numerically, on a sheet of paper. Now take No. 1, which is the alternator or A. C. Generator represented by the symbol, 2 concentric circles with a heavy black line bearing on each circle. This symbol should be drawn several times on paper until it is thoroughly impressed on the student's mind as the symbol for an alternator.

Proceed in this manner with the remaining symbols until they are all committed to memory. Now, in order to test your accuracy in making these symbols, select a certain order of numbers as 1—3—5—7—9, etc., put the name after these numbers as 1—Alternator, 3—Antenna, etc., then draw the symbol for each without referring to the book. Practice the drawing of these symbols until they can be made quickly, neatly and with accuracy.

This is absolutely essential for future progress in executing the diagrams which show the methods of connecting the instruments and apparatus for a complete radio transmitter and receiver. These symbols are also constantly appearing on the pages of the lesson texts.

ELECTRICAL UNITS

The radio operator and also the radio engineer must have a complete and thorough knowledge of the electrical units which are used in the calculation of radio measurements in determination of power, pressure, current and other quantities used in the transmission and receiving of radio messages. All of the fundamental units will be presented in this book and in as simple manner as possible, so that the student may have a clear understanding of quantity and unit used to represent it in the electrical operations which are performed in radio communication.

One may receive a clear understanding of the common electrical terms by referring to terms which apply to material substances such as the flow of water through pipes. We are all familiar with water pressure which is present in our homes and which is being exerted on the faucets in our sinks. We speak of the water pressure in terms of so many pounds per square inch. That is to say forty-five pounds water pressure means to the engineer forty-five pounds force exerted on each square inch area against which it presses. We have an electric pressure which corresponds to our water pressure and it is being exerted on the ends of the wires which lead to our switches for lighting lamps in our homes. This pressure is measured in volts and not in pounds. The common pressures used in our homes are 110 and 220 volts. All our lamps and household appliances are built to operate on 110 volts. It is necessary that a fixed value of pressure should be adopted as a standard throughout the United States so that people living in one city and having electric utensils such as flat irons, fans, vacuum cleaners, etc., should be able to use the same appliances in any other place into which they might move. These electric pressures are produced by an electric generator, sometimes called a dynamo, located in the main power house. Just the same as water pressure is caused by pumps at the pumping stations. We are all familiar with what happens when the faucet is opened. A stream of water runs out and the amount depends upon the pressure and also the degree to which we open the faucet. Just so is it in the case of the electric pressure. If the switch is turned on so that the pressure may exert its force upon the electric lamps a current of electricity will flow through the lamp and cause it to light or if it is an electric motor the current will flow through the motor and cause it to run.

Now in order that we may measure the flow of water we adopt the term so many gallons per minute as a method of computation. In the case of the electric current we speak of the amperes of electricity which means the volume of flow of the electrical energy. The number of amperes of electricity which will flow through a lamp or other piece of apparatus depends upon two quantities. First, the amount of pressure which is forcing the electricity and second, the resistance with which it meets in passing through this piece of apparatus. In the case of a flow of water we do not think in any definite terms of the resistance with which it meets and we have no definite unit to express this opposition but it is always present and is very noticeable if we place a great many bends and other obstructions in the pipe line through which our water is flowing. In the flow of electricity one must consider very carefully this property of resistance which is present in all electrical conductors and is measured by a unit called ohm.

OHMS LAW

The three units just mentioned, volt, ampere, and ohm derive their names from men who devoted their lives to the study of electricity during the early discoveries in this branch of science. Volta was an Italian who invented the first means of furnishing electric pressure in the form of his voltaic cell, which was the first known source of electrical energy by chemical means. Ampere was a Frenchman who studied the flow of electricity through metals and liquids. Ohm was a German who discovered the law which bears his name and is familiar to every electrical engineer. The law is I equals $\frac{E}{R}$. "I" is the electric current in amperes. "E" is the electric pressure in volts and "R" is the resistance in ohms. This equation should be memorized by the student and he should become familiar with its uses in the many ways in which it is applied to problems that arise from time to time. For example: If one wishes to know the electric current which would flow through the coil of wire of 2 ohm resistance when connected to a 6 volt storage battery he may supply these known values; that is to say six volts for the value "E" and two ohms for the value "R" in this equation and solve for "I" which would be three amperes. In another instance we may have the values of pressure given as 110 volts and the flow of current as 5 amperes to solve for the resistance which would be found again from substitution. That is to say "E" equals 110, "I" equals 5, solving for "R" we obtain the value of 22 ohms. The unit of electrical power is the watt and is obtained by multiplying the amperes by the volts; that is to say "W" equals E x I. This is similar to the measurement of mechanical work where a certain force is exerted through a distance thus accomplishing a given amount of work. If one lifts 100 pound weight up a distance of three feet we say he has done 300 foot pounds of work. In the same way if the pressure of 110 volts forces a current of 2 amperes through a fan motor we say that 220 watts of electrical power has been supplied to the fan. In the measurement of a large amount of electrical power for factories and cities are expressed in terms of kilowatts, one kilowatt being equal to one thousand watts. We have the same example in our home life; that is to say, we buy our sugar and flour by the pound, but in buying coal we order a ton which is equivalent to 2000 pounds. We speak of the capacity of our electrical appliances in terms of watts. For example we have 25 watt, 40 watt, and 60 watt lamps, these values being determined from the amount of electric pressure and current which is supplied to them.

THE ELECTRIC CURRENT

Difference of potential, electromotive force, pressure and voltage are all terms having practically the same meaning.

Potential is a term used to denote that which causes a current to move along a conductor.

An electric potential or pressure is necessary before we can have a flow of current in a circuit. The unit of potential is the volt, and may be defined as that electromotive force, which will cause a current of one ampere to flow through a resistance of one ohm. That is, if an electric cell of one volt electromotive force is used to light the filament of an incandescent lamp having a resistance of one ohm, the current through the lamp will be one ampere. The difference of potential between two points A and B on a wire conducting current is shown in figure 6.

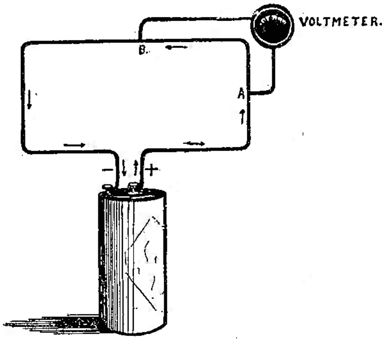


Fig. 6—Difference of Potential

To illustrate electrical potential, we will take the following example: If water will flow from tank A to tank B through a connecting pipe C, we infer that the hydrostatic pressure at A must be greater than that at B, and we attribute the flow directly to this difference in pressure.

Now, if water is not continually supplied to tank A, we know that the pressure at A and B must soon become the same.

Now, take two bodies A and B and connect them by a conducting wire C, it will be found that a charge of positive electricity that passes from A to B or of negative from B to A are of different potential, as we are accustomed to say that the electrical potential is higher at A than at B, and we assign this difference of potential as the cause of the flow. Thus, just as water tends to flow from points of higher hydrostatic pressure to points of lower hydrostatic pressure, so electricity is conceived of as tending to flow from points of higher electrical pressure or potential. Now, if no electricity is supplied to the bodies A and B their potentials very quickly become the same. In other words all points on a system of connected conductors in which the electricity is in a stationary, or static, condition are necessarily at the same potential; for if this were not true, then the electricity which we imagine all conductors to contain would move through the conductor until the potentials of all points were equalized.

Potential depends on:

a. The size and shape of the body.
b. The amount of charge in the body.
c. The presence of nearby charged bodies.

In speaking of the potential of a body we mean the difference of potential which exists between the body and the earth, for the electrical condition of the earth is always taken as zero to which the electrical conditions of all other bodies are referred. Thus a body which was positively charged is regarded as one which has a higher potential than that of the earth, while a body which is charged negatively is looked upon as one which has a potential lower than that of the earth.

MEASUREMENT OF POTENTIAL

Potential is measured by the amount of work necessary to move unit positive charge from the earth to the body.

A simple method of comparing the potential difference which exists between any two charged bodies and the earth, is to connect the charged body successively to the knob of any electroscope which has an outside case of metal connected electrically to earth. (Abbreviated p. d.) If the electroscope is calibrated in volts, its reading gives the p. d. between the body and the earth. Such calibrated electroscopes are called Electrostatic voltmeters. These instruments are the simplest and in many respects the most satisfactory forms of voltmeters to be had. Their use, both in laboratories and in electrical power plants is rapidly increasing. In quadrant form they can measure a p. d. as small as 1/1000 volt and in commercial forms as large as 200,000 volts.

It may be well to say at this time that a large p. d. can be measured without a voltmeter, this can be accomplished by measuring the length of the spark which will pass beteeen the two bodies whose p. d. is sought. The p. d. is about proportional to spark length, each centimeter of spark length representing a p. d. of about 30,000 volts if the electrodes are large compared to their distance apart.

LAWS OF POTENTIAL

a. The presence of opposite charged bodies lowers the potential of the first body.

b. The presence of similarly charged bodies raises the potential of the first body.

The electrical units of measurements are difficult to understand by a single illustration and so they will be presented again in another manner.

22. The electrical unit of current strength or rate of flow is the ampere. The number of amperes in a circuit is a measure of "how big" the current flow is. The student should not confuse this unit with the unit of quantity. Roughly speaking, the amperage of a circuit may be com-

pared to the cross sectional area of a flow of water. The ampere may be defined as that current produced by one volt pressure in a circuit whose resistance is one ohm.

23. The electrical unit of quantity is the coulomb. It may be defined as that quantity of electricity passing a given point in a circuit when the product of amperes and seconds equals one. For instance, if the current in a circuit is one-tenth of an ampere and it flows for ten seconds, the product of amperes and seconds will equal one. That is, a quantity of electricity equal to one coulomb will pass a given point in the circuit. Observe that it requires both amperes and time in seconds to produce coulombs.

24. Resistance may be defined as that property of a conductor by which it opposes the flow of electric current through it.

The unit of resistance is the ohm and may be defined as the resistance of a column of mercury 106.3 centimeters in height, of uniform cross section and weighing 14.4521 grams at a temperature of 32 degrees Fahr. It may be further defined as the resistance of a circuit in which the potential is one volt and the current one ampere.

Resistance depends upon the material, the size and the length of the conductor. For any given conductor the resistance varies inversely as the cross sectional area and directly as its length. In other words, the larger the conductor, the less the resistance; the longer the conductor, the greater the resistance.

Metals usually are of low resistance, liquids of considerable resistance, and pure water of high resistance.

The passage of a current of electricity through a conductor produces heat, the amount of which depends upon the resistance of the conductor and the current strength. In wiring houses for incandescent lighting the size of the wire used will depend upon these two factors. If wire of too small diameter is used, there is danger of the wire melting due to the heat and causing a fire.

ELECTRICAL CIRCUITS

An electrical circuit is a complete path for the flow of electricity as shown in figure 7, sometimes called a closed circuit, and is composed of various conducting substances which may form the parts of electrical apparatus such as an electric lamp, curling iron, vacuum cleaner, flat iron, heater, and many other electrical household appliances which are in daily use. The open circuit and short circuit which were defined in lesson text No. 1 are shown in figures 8 and 9. These electrical appliances and the various wires which are used in connecting them together, may form several different circuits, each of which has its own method of connection and to which there is applied a technical term

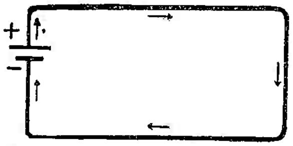


Fig. 7—A Circuit

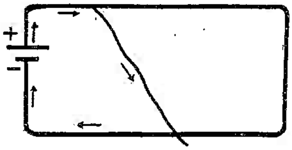


Fig. 8—A Short Circuit

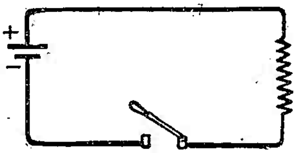


Fig. 9—An Open Circuit

describing the method of its connection. Take for example four coils of wire which may be connected in the following manner:

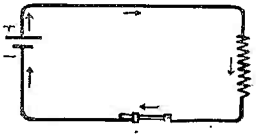


Fig. 10--A Closed Circuit

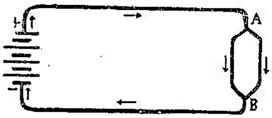


Fig. 11--Divided Circuit

The end of one coil is connected to one terminal of a dry cell, the other end of the coil is connected to one end of the second coil and the other end of the second coil is connected to one end of the third coil, and so on until the three coils are connected together with the end of the last coil joined to the other terminal of the four dry cells as shown in figure 14. These coils are said to be connected in series and the amount of current passing through each coil is the same in amount and direction.

Let us think for a moment of connecting three pieces of pipe in this same manner, that is to say, joining the end of one pipe to the next and so on until the three pieces of pipe form one straight continuous pipe for a flow of water which might be furnished by a tank to which one end of the series group of pipes were joined. Now if there were ten gallons of water flowing out of the tank into the first pipe each minute there would be a flow of ten gallons through the first, second and third pipes and this would be the amount of water which would run out at the end of the last pipe. The flow of current through the coils of wire is exactly like this flow of water and we arrive at the final rule of law for the flow of current in a circuit. That is to say, that the flow of current measured in amperes is the same in all parts of a series circuit.

Now in regard to the pressure or electric force for the entire circuit, we may find this value by adding together the pressures consumed or used up in each one of the coils which will give us the volts of electric power on the entire circuit, or, in other words, the law governing the pressure in a series circuit states that the voltage on the circuit is equal to the sum of the voltages on all its several parts.

Example—In Fig. 12 a divided circuit has two branches, each of 5 ohms resistance. The resultant resistance between A and B is one-half of 5, or 2.5 ohms. In case the divided circuit has unequal resistance this rule will not apply. To calculate the resultant resistance of two or more unequal resistances in parallel it would be necessary to use reciprocals, a branch of mathematics, with which many students are unfamiliar.

Let us now consider another method for connecting these coils. Join one end of all coils together and connect these joined ends to one binding post of four dry cells. Then connect the other ends of the coils together and connect these by a wire to the other binding post of the four dry cells as shown in figure 12. These coils are now said

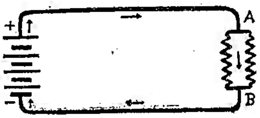


Fig. 12—Resistance in Parallel

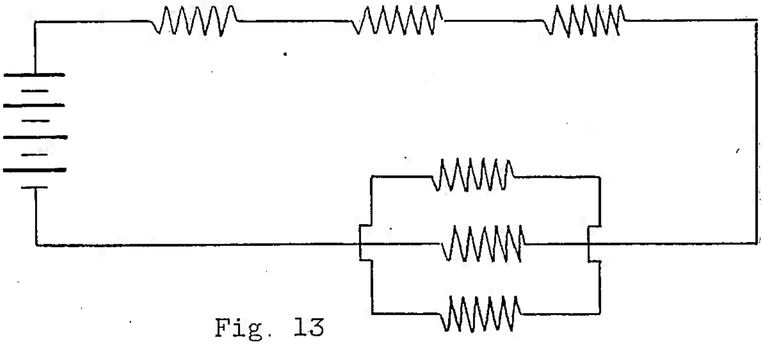


Fig. 13

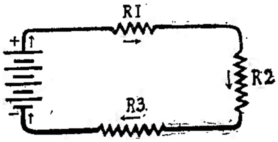


Fig. 14—Resistance in Series

to be connected in parallel. If the student will study for a moment the action that will take place in the flow of electricity, or, if we turn our thought to the case of the coils representing water pipes, one may readily see that the water will divide when it reaches the joining points of the pipes and a small part of the entire water will flow through each one of the pipes. The flow of electricity will be divided in the same manner and a small part of the total current will flow through each of the coils. The total current flowing in a parallel circuit is found by adding together the current flowing in each one of the several branches, while the pressure upon each of the several branches of a parallel circuit is equal in amount as measured in volts. One may make a circuit combining these two arrangements and call it a series-parallel circuit as shown in figure 13.

The three methods of connecting appliances and apparatus in electrical work have been carefully described and illustrated in the above paragraphs and each one of these arrangements has its own particular advantage where a certain result is to be accomplished.

As an illustration. Suppose that we desire to obtain six volts of electric pressure for lighting the lamps on an automobile by the use of dry cells. One dry cell furnishes a pressure of 1 5/10 volts. In order to obtain six volts of pressure it would be necessary to multiply this 1 5/10 by 4, in other words we could use 4 dry cells and connect them in series, thus having a total pressure of the sum of the pressure of the 4 cells added together making the total pressure furnished by this arrangement of six volts. If on the other hand we desired to light a number of electric lamps in a home where each lamp is to receive the same pressure, then it is desirable to connect these lamps, say four or more in parallel across the same two wires which are maintained at a constant pressure of 110 volts. Each lamp will take a certain amount of current say one-half ampere and thus the total amount of current taken by the circuit will be equal to the sum of the current taken by all the lamps. There are other cases where the combination of these two methods are required and the series-parallel connection is used.

27. Ohm's Law—The relation of volts, amperes and ohms in a circuit is expressed very clearly by a law discovered by Dr. S. G. Ohm.

In a given circuit, the strength of the current is equal to the electromotive force divided by the resistance. If we let I equal the current in amperes, E equal the voltage and R equal the resistance in ohms, we may express Ohm's law as follows:

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

In plain language—amperes equals volts divided by ohms. Another form of Ohm's law states that: The resistance of a circuit is equal to voltage divided by number of amperes: That is:

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

Still another form derived from the first states that: The e. m. f. of a circuit equals the product of current in amperes and the resistance in ohms. Symbolically:

$$E = I \times R$$

The following examples illustrate the application of Ohm's law:

Example One—A circuit has a resistance of 10 ohms and a voltage of 110. What is the current in amperes?

Solution—According to the first form of the law—amperes equals volts divided by ohms, therefore, substituting the values of volts and ohms from example one in the formula, we have:

Amperes=110 ÷ 10 or 11 amperes.—Ans.

Example Two—An electrochemical cell gives a voltage of 1 1/2 and is connected to a circuit in which the current is one-half ampere. What is the resistance?

Solution—Resistance equals volts divided by amperes, therefore, 1 1/2 ÷ 1/2 = 3 ohms.—Ans.

Example Three-The resistance of a circuit is 10 ohms, the current is 11 amperes. What is the pressure?

Volts equals ohms times amperes, therefore, 10 × 11 = 110 volts.—Ans.

It may be seen that if two of the quantities used in Ohm's law are known the third may be readily calculated.

In the form $I = E \div R$, we see that to increase current we must decrease resistance or increase voltage.

The volt may be defined as that e. m. f. which will cause a current of one ampere to flow through a resistance of one ohm. Comparing that definition with Ohm's law, $I = E \div R$; if the current is one ampere and the e. m. f. is one volt, the resistance must be one ohm.

Ohm's law forms the basis of many important electrical calculations and therefore the student should thoroughly ground himself in the practical application of this law.

In the form given above, the law is only applicable to direct current circuits.

28. A brief description of primary and secondary cells has already been given in the previous instruction paper. We will describe several of the more prominent primary cells, leaving the secondary cell until later in the course.

The wireless operator seldom has need for detailed knowledge of primary cells, the secondary cell being the most important, in wireless telegraphy.

The Leclanche cell is a primary cell, consisting of a glass jar, small earthenware jar, carbon rod, zinc rod and two solutions. One of the solutions is of salammoniac and is contained in the outer glass jar, while the other solution is a mixture of manganese peroxide and broken gas carbon. The porous earthenware jar contains the latter solution and the carbon plate. The outer jar contains the salammoniac solution and the zinc rod. The function of the porous earthenware jar, surrounding the carbon rod, is to prevent the formation of hydrogen gas on the carbon plate from stopping the current. The cell gives a voltage of 1.48 and will give good service for about 18 months. The cell must then have a renewal of solution and zinc rod.

The Leclanche cell is adapted to a circuit which is only used occasionally, such as an electric door bell circuit. The reason for this is that after the current flows from the cell for a time the carbon element becomes coated with a hydrogen gas, which insulates it, causing the current to drop in value. The porous earthenware jar tends to prevent this film, but is only a partial remedy.

The Edison cell has plates of zinc and black oxide of copper and a solution of caustic potash. The potential of the Edison cell is only .7 volt, but the current output is high.

This type of cell gives better results on closed circuits, that is, on circuits which are closed the greater part of the time.

Dry cells are very important at the present time, due to their use in flashlights and for gas engine ignition. The absence of a fluid gives them many advantages over the fluid type of cell. The dry cell is a form of the Leclanche cell, having zinc and carbon elements and an electrolyte of salammoniac.

The container is a zinc cylinder closed at one end, forming the negative element of the cell. The positive element, of carbon, is in the form of a rod in the center of the zinc shell, but insulated therefrom. Between the zinc and carbon a mixture of carbon, coke and manganese dioxide is placed. The solution of salammoniac forms a paste with the carbon, coke and the manganese dioxide. The term dry cell, applied to this type, is not exactly correct, as it must have a certain proportion of water. To prevent the evaporation of electrolyte the top of the cell is closed with pitch.

29. The term "battery" is used when referring to a number of electrochemical cells connected together. A single dry cell gives about 1.5 volts when new. If two dry cells are connected together by means of a wire, in such a way that the carbon element of one is connected to the zinc element of the other, the potential at the two remaining terminals will be 3 volts, but the amperage will only be that of a single cell.

If the two cells have their carbon elements connected together and their two zinc elements connected together, the potential will be that of one cell alone, but the amperage will equal the sum of the amperage of each cell. That is, if the amperage of one cell is 20, the amperage of two connected as above will be 40.

These two methods of connecting cells are quite important, both in primary and secondary cell circuits. The first method is called the series connection, by which the positive pole of one cell is connected to the negative pole of the next, continuing in this manner until all the cells of the battery are connected. This method is illustrated by Fig. 15. This type of connection gives a potential at the terminals equal to the sum of the potentials of the several cells, while the amperage will be that of one cell only.

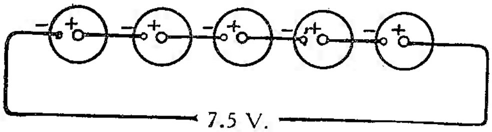


Fig. 15—Dry Cells in Series

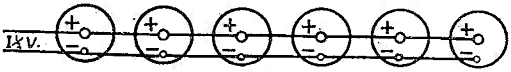


Fig. 16—Dry Cells in Parallel

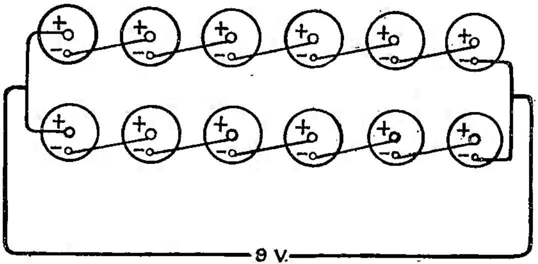


Fig. 17—Dry Cells in Series-parallel

The second method is called the parallel connection and is illustrated by Fig. 16. The voltage, of a battery so connected, is that of one cell alone, while the amperage will equal the sum of the amperage of each cell.

The current output or amperage depends upon the area of the plates in any given type of cell, and that is why the parallel connection gives the increased current. The positive plates being all connected together in the parallel connection, the effect is the same as if the battery were one large cell having a positive plate with a surface area equal to the sum of all the positive plates of the battery.

A third method of connecting cells, illustrated in Fig. 17, is a combination of the first two methods, and is called the series parallel connection. Two or more cells, connected in series, are connected in parallel with another set of an equal number of cells. The two sets in series are called banks, the number of cells in each being equal.

The voltage of a series multiple connection is equal to the voltage of one cell multiplied by the number of cells in one bank, and the amperage is equal to the amperage of one cell multiplied by the number of banks.

Any number of cells may be put in a bank and any number of banks may be placed in parallel.

30. Work may be defined as the overcoming of force or resistance through a distance. If a 10-lb. weight is carried up a ladder, work is done in overcoming the force of gravity. The unit of mechanical work is the foot pound, which is the work done in lifting a pound one foot against the force of gravity.

In electricity, if a current passes through a resistance, work is done and heat is produced.

Power may be defined as the rate of doing work. Thus, one horsepower is that power necessary to raise 33,000 pounds one foot in one minute, or 550 pounds one foot in one second.

The unit of electrical power is the watt which may be defined as the power consumed by a current of one ampere flowing under a potential of one volt. Therefore, to calculate the power consumed in a circuit it is necessary to take the product of the volts and amperes.

Watts = E × I; where I equals current in amperes and E equals voltage.

Example—A current of 10 amperes is flowing in a circuit whose resistance is 10 ohms. Find the power in watts.

Solution—Ohm's law states: I × R = volts.
10 × 10 = 100 volts.

Therefore, substituting in the formula for power: Watts = E × I.
100 × 10 = 1,000 watts.—Ans.

A horsepower is equal to 746 watts, about three-quarters of a kilowatt.

A kilowatt is 1,000 watts.

A watthour may be defined as the work done in a circuit when the product of watts and hours equals one. For instance, if the power is one-fifth watt and the time is five hours, the product of watts and hours will be one—that is, one watthour.

More briefly, it is one watt for one hour. A kilowatt hour is 1,000 watts for one hour. In selling electricity for power or lighting purposes the charge is per kilowatt hour. For instance, the 40 watt tungsten lamp consumes 40 watt hours of current every hour. The number of hours it will burn in consuming one kilowatt hour can be determined by dividing 40 into 1,000, which equals 25 hours.

The product of kilowatts and hours equal kilowatt hours.

In actual practice the number of watt hours or kilowatt hours is measured by an instrument called the watt hour meter.

MEGOHM

PROBLEMS IN POWER AND COST OF POWER

There are many instances in the measurement of resistance when the number of ohms are several millions. The Megohm (1,000,000 ohms) is the unit used to express these large values. For example, 8.25 megohms means 8,250,000 ohms.

The common method of selling electric power is by the unit kilowatt-hour. This value may be found by multiplying the volts times amperes divided by 1,000, then times the number of hours. For example, assume a certain D. C. electric motor requires 2 amperes at 110 volts to operate it and that it runs 8 hours, the kilowatt-hours (K. W. Hrs.) would be

$$2 \times \frac{110}{1000} \times 8 = \frac{220}{1000} \times 8 = \frac{1760}{1000} = 1.76 \text{ K. W. Hrs.}$$

If the price charged for electric power was ten cents per K. W. Hr., the cost of power for running the motor would be 1.76 × .10 = 17.6 cents.

An instrument called the watt-hourmeter is employed to record during the month the total quantity of power in kilowatt-hours which is used in that period. The instrument is constructed very much like a small electric motor with recording dials to indicate the number of revolutions of the armature (or rotating part). The more power that flows through the meter the faster it turns and the number of revolutions also depends on how long the power continues to flow.

The dial reading at the first of one month is subtracted from the dial reading at the first of the next month to obtain the power, in kilowatt-hours, which has passed through it for that period. These kilowatt-hours times the cost per kilowatt-hour is the charge made to the customer.

Answer the following questions on this lesson and also solve the code lesson immediately following and submit your answers to this Institute in the same manner as you did the first lesson. Lessons may be typewritten.

QUESTIONS

Theory Lesson No. 2.

27. What two things are necessary before a current will flow in a circuit?

28. What forms the conducting path of an electric current?

29. What four quantities are used in dealing with electricity?

30. What is a circuit?

31. Define closed circuit, open circuit, and short circuit?

32. Name some common conductors.

33. How are current carrying wires insulated?

34. Name five insulating materials.

35. What is meant by potential?

36. Name the different terms used to represent electromotive force.

37. What is the unit of quantity?

38. How does it differ from the unit of current strength?

39. What is an ohm?

40. What is a divided circuit?

41. A 10 volt battery is connected to a circuit having a 10 ohm, a 12 ohm, and a 15 ohm resistance in series. What is the total value of resistance in the circuit?

42. Explain Ohm's law.

43. Give three ways of expressing Ohm's law.

44. Describe a Leclanche cell.

45. Why is the dry cell of importance?

46. What three methods are used in connecting cells? Explain each.

47. A battery has three cells in series, each cell having an e. m. f. of 1.5 volts. What is the total voltage or e. m. f. of the battery?

48. What is a horsepower?

49. What is the unit of electrical power?

50. How do you calculate the power consumed in an electrical circuit?

51. What is a kilowatt?

CODE LESSON NO. 2

Translate from English into code and submit for correction:

Wire and Wireless Systems Linked.

Conversation between a city home with ordinary telephone equipment, and an airplane in the clouds above it, is forecast by a reported method for connecting wire and wireless systems. The originators do not believe that wireless telephony will ever supplant the present wire system entirely, but they hold that it has its use in communicating with ships, moving trains, islands, and inaccessible places in general.

Correspondence Course

NATIONAL RADIO INSTITUTE

1345 PA. AVE., N. W. WASHINGTON, D. C.

Translation from English into Code

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ANSWERS TO LESSON TEXT No. 2

27. First, there must be a complete path or circuit; and second, an electric pressure applied to this circuit.
28. A copper wire or some metal conductor.
29. The volt, coulomb, ampere and ohm.
30. An electric circuit is a complete conducting path for an electric current.
31. A closed circuit has a source of current with a completed circuit connected to it.

    An open circuit is a path with a break or gap in it.

    A short circuit is one which by some unexpected means conducts current through a much shorter path than is normally done.
32. Gold, silver, platinum, copper, aluminum and most other metals.
33. By covering the wire with rubber or other insulating substances.
34. Rubber, mica, glass, porcelain and slate.
35. Potential is the difference in electric pressure between two points.
36. Difference of potential, electric pressure, voltage and electromotive force.
37. The coulomb is the unit of quantity of electricity.
38. The coulomb is the total amount, while the ampere is the rate of flow or size of stream flowing.
39. The ohm is the unit of electric resistance for an electric circuit or any part of it.
40. A divided circuit is where the current has two or more paths open to the flow of the current.
41. $10+12+15=37$ ohms resistance.
42. Ohms Law says the current I in any circuit equals the volts E divided by the resistance R.
43. (1) $I=\frac{E}{R}$ (2) $E=I\ R$ (3) $R=\frac{E}{I}$
44. Leclanche cell has a carbon plate in a small porous cup with manganese peroxide and broken gas carbon. This porous cup is placed in an outer glass jar containing Sal-ammoniac solution with a zinc rod.
45. The dry cell is very compact, has no liquid to spill and will stand rough treatment without injury.
46. Series, parallel and series-parallel.

    In the series connection the pressure of the cells add together, while the current output is the same as for one cell.

    In the parallel connection the current output equals the sum of the current for each in the parallel group, but the pressure is equal to that of one cell.

    In the series-parallel the pressure equals the sum of the pressure in each series group, and current output equals the amperes for one cell times the number of groups in parallel.
47. $3\times1.5=4.5$ volts. Ans.
48. One horsepower is the rate of doing work and in mechanical work it is doing 33,000 foot pounds of work per minute. In electrical units it is 746 watts.
49. The small unit of electrical power is the watt, while the kilowatt (K. W. = 1,000 watts) is the large unit.
50. Watts = volts × amperes.
51. 1 kilowatt equals 1,000 watts.

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Student No. 13794 Lesson No 2

Ques no.

27 The two things which are necessary before a current will flow in a circuit are first the circuit must be complete or unbroken from the source back to the source and second there must be a difference of potential between the + and - poles.

28 a complete or unbroken circuit from the + to the - pole forms the conducting path through which an electric current may flow.

29 The four quantities which are used in dealing with electricity are Volts, Amperes, Ohms, and Coulombs.

30 a circuit is a complete or unbroken path for the flow of electricity from the source through the circuit and back again to the source.

31 a closed circuit is one where the electricity has an unbroken path

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from the battery or Dynamo through the instruments and back to the source.

Open circuit is defined as when the electricity has not a complete path over which it may flow, as when the switch on an electric light is turned off.

a short cirkuit is when the electricity finds a shorter way back to the source instead of through the instruments, this frequently happens in an accidental way as when one conductor falls accross the other.

32 Some common conductors are copper, iron, phosphor bronze, german silver, mercury, and carbon.

33 Current carrying wires are insulated in many ways, outside wires are insulated only by several layers of cotton braid saturated with water proofing of pitch. inside ires are covered first with rubber en braid is put over this, sometimes he braid is woven of asbestos.

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Ques no.

34 Five insulating materials are Glass, porcelain, rubber, asbestos, and mica.

35 Potential is used as a term to name that pressure which is necessary to cause a current of electricity to flow along a conductor.

36 Different terms used to represent electromotive force are, voltage pressure, Difference of potential and the abbreviations P.D. and E.M.F.

37 The unit of quantity is the Coulomb.

38 The difference between a coulomb and the unit of current strength which is the ampere is, that it requires amperes and time in seconds to produce coulombs while in amperes, time is not required as it is used to denote only how big the current is.

39 An Ohm is that resistance which allows a current of one ampere

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to pass through a conductor under the potential difference of one volt.

another way is the resistance offered to an unvarying electric current by a column of mercury at 32° fahr. 14.4521 grams in mass, of uniform cross sectional area, 106.3 Cm. in length.

40 a divided circuit is one where the conductor coming from the + pole branches off into two or more conductors which again unite into one conductor leading to the − pole.

41 The total value of resistance in the circuit would be 12 ohms + 15 ohms + 10 ohms = 37 ohms.

42 Ohms law may be explained as the relation of amperes, volts and ohms in a circuit, this is clearly shown by the law discovered by Dr Ohm which is "In a given circuit the amount of current is equal to the E.M.F. in volts divided by the resistance in Ohms.

43 Three ways of expressing Ohms law are

$$\text{amperes} = \frac{\text{Volts}}{\text{Ohms}} \qquad \text{Ohms} = \frac{\text{Volts}}{\text{amperes}}$$

$$\text{Volts} = \text{amperes} \times \text{ohms}$$

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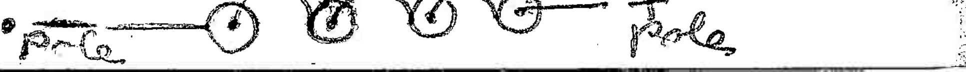
Ques No 44 A Leclanche cell consists of a glass jar, Porous cup, carbon rod, zinc rod 2 solutions and broken carbon into the outer glass jar a solution of Salammoniac is put in, into the porous cup a solution of manganese peroxide and the broken carbun is put the porous cup and its contents are now placed into the solution contained in the glass jar, the zinc rod ~~is~~ now placed in the solution contained in the glass jar while the carbon rod is placed in the porus cup the zinc rod is the − pole, the carbon one the + pole. The use of the porous cup is to stop the formation of hydrogen gas on the carbon rod from stopping the electric current.

45 The dry cell is of importance in that it is portable, non polarizing, and with out a fluid which is easly spilled.

46 The three methods used in connecting cells are series, parallel and series parallel.

The series method is this the + pole of one cell is connected to the − pole of the next and so on as in the drawing.



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The parallel system of connecting cells is all the + poles are connected together and all the − poles.

The series parallel is a combination of the two former methods, two ore more cells are connected in series. they are then connected in parallel with an other set having an equal number of cells as the first, these cells in series are called banks.

47 The total voltage or E.M.F. of the battery of three cells in series, each having a voltage of 1.5 volts would be 4.5 volts.

48 A horse power is that power required to raise 33.000 lbs one foot in one minute or 550 lbs. one foot in 1 second.

49 The unit of electrical power is the Watt.

50 The power consumed in an electrical circuit is found by the unit Kilowatt hour in many cases this method is carried out by multaplying volts X amperes divided by 1000 then times the No. of hours the current was used this gives the no. of kilowatts used, this answer is now multaplyed by the price charged by the company per. K.W. hour

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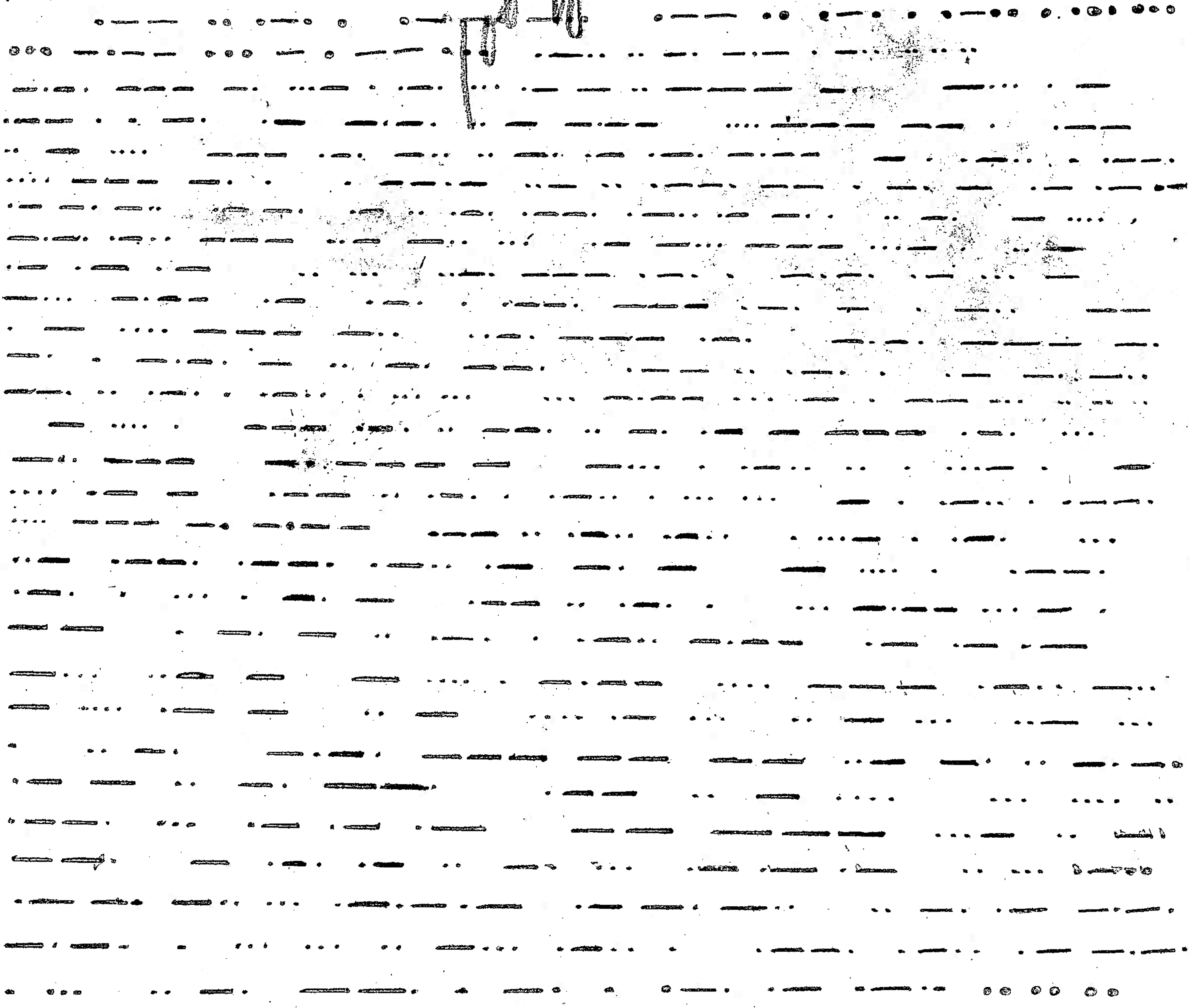
where the amount of current used in a month is to be recorded a watt hour meter is used this consists of a sort of a motor, driving dials on the instrument when more current is used the motor goes faster, when less is used the motor slows up accordingly. The Kilowatt hours are found on this machine by subtracting the last months reading from the present reading the ans. gives the No. of K. W. used that month, this ans. then is multiplyed by the charge the electric light company makes per K. W. H.

51 A Kilowatt is one thousand Watts.

Code Lesson No. 2



LESSON TEXT No. 3

OF A

Complete Course in Radio Telegraphy

Electromagnetic Induction Part 1

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 3

By this time you should know the alphabet well; be able to send the symbol for any letter you may be asked to send without the least hesitation. If you can not do this, turn to lesson one again and practice that alphabet.

You are now ready to take up learning the symbols for the various punctuation marks. Study the symbols as given below and practice them as diligently as you did the alphabet. Continue to practice until you can send the symbol for any punctuation without referring to the text.

Period (.)	●● ●● ●	Apostrophe (')	●▬▬▬▬●
Comma (,)	●▬●▬●▬	Hyphen or Dash (-)	▬●●●●▬
Semicolon (;)	▬●▬●▬●	Bar for Fraction ()	▬●●▬●
Colon (:)	▬▬▬●●●	Parenthesis ( ) Before and after words	▬●▬▬●▬
Interrogation or Repeat(?)	●●▬▬●●	Quotation Marks (" ") Before and after each word or passage quoted	●▬●●▬●
Exclamation Point (!)	▬▬●●▬▬	Underline (_____) Before and after words or part of phrase	●●▬▬●▬

Now practice sending this article and include all the punctuation marks (periods, commas, etc.) When you have completed, repeat the operation.

> "J. Andrew White, Editor, Wireless Age, recently said this: It is my opinion that we have reached but the inception stage of a wireless era. I am convinced that the young man or woman who undertakes the study of the radio art at this time is embracing the one best opportunity to fill a proper niche in the gallery of epochal world events."

You should now study the theory as given below. Study it thoroughly and make sure that you are not skimming over the definitions and principles but try to fix them in your mind by co-relating them to some everyday events or surroundings which you observe.

THEORY LESSON NO. 3

ELECTROMAGNETIC INDUCTION

31. Under the heading of magnetism the lodestone and the artificial magnet were discussed. We learned that magnets are surrounded by lines of force, these lines of force extending from one part of the magnet, called the north pole to another part called the south pole. The process of magnetizing a piece of steel with a lodestone or with an artificial bar magnet is called **magnetic induction.** A current of electricity can be induced in a coil of wire by a moving magnetic field, and also by moving a coil of wire in a stationary magnetic field. The process of inducing currents of electricity by means of a moving magnetic field, or by moving

a coil in a magnetic field is called **electromagnetic induction.** If a compass is brought near a current carrying conductor the needle of the compass will be deflected to a position at right angles to the conductor, thus indicating that there is a magnetic field about a current flowing in a conductor. A graphic illustration of this field is given in Fig. 18. If a current carrying wire is placed in a vertical position through the center of a piece of white cardboard, covered with a thin layer of iron filings, it will be observed that the fillings arrange themselves in circles about the wire.

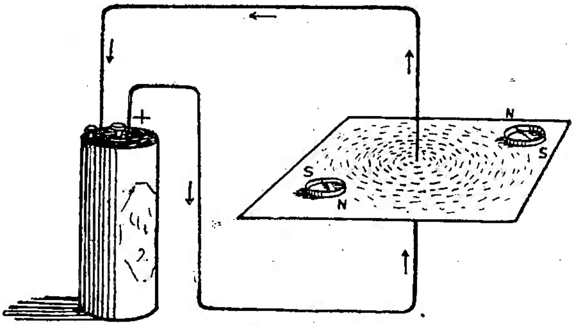

Fig. 18—Lines of Force about a Current-carrying Wire.

These circles are concentric, that is to say, they all have a common center which is the middle point within the conductor producing them, and get larger in size and number according to the increased value of current (measured in amperes) flowing in the wire.

The lines or circles have not only size (length in the circumference) but also have direction. That is to say, the line may be going around the wire to the left (counter clockwise) as shown by the compasses in figure 18, or they may go in the reverse direction, clockwise, in case the current were reversed in the wire by changing the ends where they are connected to the dry cell. In other words, the lines are reverse when the current is reversed and the intensity, or number of lines, change as the current changes in amount.

32. A convenient method of determinating the direction of the lines of force about a current carrying wire may be stated as follows: **If the wire is grasped with the right hand, as shown in Fig. 19, in such a manner that the thumb points in the direction of the current, the figures will then extend about the wire in the same direction as the lines of force.**

3. A **solenoid** is a coil of wire wound in the form of a cylinder. If such a coil has a current flowing through it it will have the same characteristics as a bar magnet. That is, as illustrated in Fig. 20, one end will be a north pole and the other end will be a south pole. **If the coil is grasped with the right hand, with the fingers pointing in the direction of current flow; the thumb will point toward the north pole.**

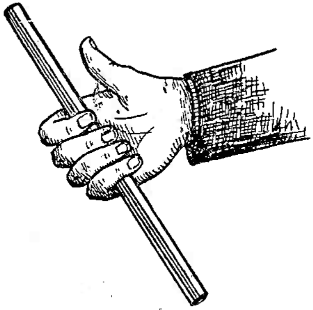

Fig. 19—Right Hand Rule for Direction of Current Flow.

There is another rule which is preferred by some authors and the writer thinks it is less confusing for all cases. It is known as the corkscrew rule and is thus explained. Imagine the point of a screw placed in the end of the wire and now turn this screw so it will move in the direction of the flow of the current. The direction of rotation of the screw will represent the direction of the circular lines of force set up by this current.

Next let us consider what happens when a piece of wire carrying current, as shown in Fig. 19a, is bent into a loop. Let us apply either law and we find the lines are all going away from the observer as we look at the lines on the inside of the loop. If one should insert a round piece of soft iron within the loop, the far end of this iron core would be the north pole of a magnet.

The lines of force about each wire combine to form closed loops extending through the interior and from one end to the other on the outside of the solenoid. The strength of the magnetic field about a solenoid depends upon the value of the current flowing through it, and also upon the number of turns of wire.

34. If an iron core is inserted within the solenoid its magnetizing power will be greatly increased. This increase in power is due to the

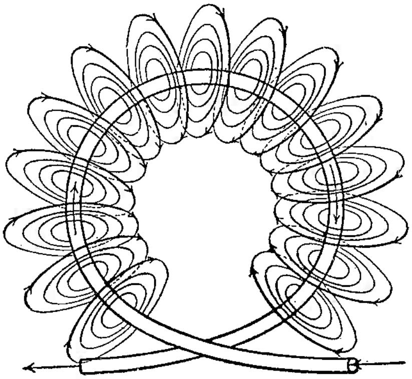

Fig. 19a—Field about a single loop carrying a current.

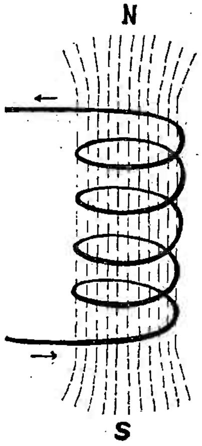

Fig. 20—Lines of Force about a Solenoid.

greater permeability of the iron core as compared with that of air. A solenoid with an iron core is called an **electromagnet,** and may have many turns arranged in one or more layers.

From the preceding paragraphs one may readily conclude the following rule: The strength of an electromagnet depends upon the product of the amperes and number of turns of wire in the coil, termed ampere-turns and also upon the quality of the material making up the magnetic core. For example, an electromagnet with 20 turns of wire carrying 5 amperes would have the same strength if 100 turns carrying one ampere were placed in the iron core. In each case the magnet would have 100 ampere-turns.

Let us turn our attention from the production of magnetic lines by electric currents and consider the effects upon a conductor when it moves upward in front of a north magnetic pole as shown in Fig. 20a. An electric pressure or force called E. M. F. (electric motive force) measured in volts, is induced in the wire. This is the principle of producing electric power in a generator and is called **electric magnetic induction.**

Whenever a conductor cuts magnetic lines or magnetic lines cut an electrical conductor there is induced in the conductor an electric pressure.

35. In 1831 Michael Faraday discovered **the principle of electro-magnetic induction.** In one of his experiments, he wrapped a coil of wire

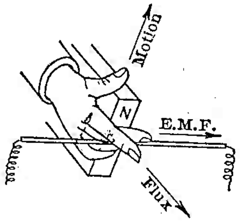

Fig. 20a—Right-hand rule for induced E. M. F.

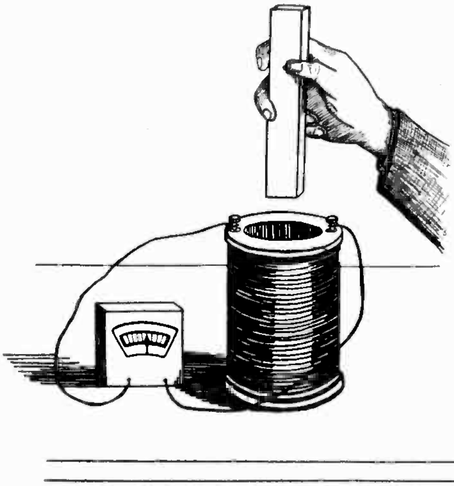

Fig. 21—Electromagnetic Induction.

about a block of wood and connected the terminals to a galvanometer. Another coil was wrapped about the first and connected to a battery. He found, that upon closing the circuit of the coil in series with the battery, that the needle of the galvanometer was momentarily deflected, and upon opening the circuit that the needle was again deflected, but in the opposite direction.

36. This experiment opened up a new field of investigation in electrical science, and the principle deduced from it is of very great importance, due to it being the basic principle of the production of electricity by mechanical motion. One method of demonstrating this principle is illustrated in Fig. 21. If a bar magnet is thrust into a coil of wire, whose terminals are connected to a galvanometer, there will be a slight deflection of the galvanometer needle, and upon removing the magnet an opposite deflection of the needle.

These deflections are due to a flow of current set up in the coil by the action of the lines of force about the bar magnet. If the number of lines of force cutting the turns of the coil are increasing, due to an approaching north pole of a bar magnet, the coil will have a pole of similar polarity induced on the end nearest the approaching pole, but if the magnet is being withdrawn from the coil, the number of lines of force thru the coil will be decreasing. producing a south pole on the end nearest the receding pole. That is, the current induced in the coil by the movement of the magnet, is in such a direction that it will produce an opposing field to an approaching magnet and a field in the same direction as that of a receding magnet.

37. In place of the bar magnet; we may use a coil of wire connected to a battery, as in Faraday's experiment. This experiment is illustrated in Fig. 22. The coil connected to the battery is called the **primary,** while that connected to the galvanometer is called the **secondary.**

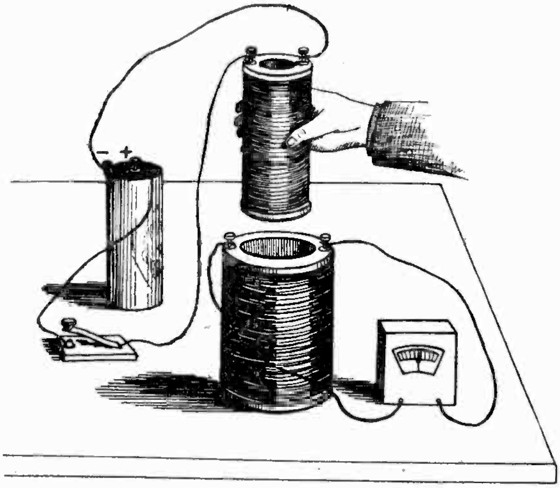

Fig. 22—Electromagnetic Induction.

If the primary is placed within the secondary and allowed to remain stationary, no current will be induced, but if the primary circuit is opened a momentary deflection of the galvanometer will occur. This is due to the current falling from a maximum to a zero value, and consequently a decrease in the number of lines of force about the primary to a zero value.

A similar deflection occurs when the switch is closed, but is not nearly as strong as the deflection resulting from breaking the circuit.

In the experiment described above, the magnetic field has been moving.

38. In a third method, as shown in Fig. 24, the lines of force are stationary and the secondary coil moves. The current is induced by causing the secondary to move through the field in such a manner, that the number of lines of force threading through it are varied. If the coil or conductor passes across the field with a rotary motion, as in Fig. 24, the number of lines of force enclosed by the coil varies, producing a current in it.

39. **Laws of Electromagnetic Induction:**

1. **A current may be induced in a coil by varying the number of lines of force threading through it.**

This is brought about in two ways: By causing a magnetic field to approach or recede from a stationary coil or by causing a coil to be rotated through the field, so as to vary the number of lines of force threading through it.

2. **The voltage induced in the secondary coil will depend upon the number of lines of force cut per second, and upon the number of turns of wire in the coil.**

3. **If the number of lines of force cutting through the coil is increasing in number, the field produced will oppose that of the bar magnet or primary coil.**

4. If the number of lines of force cutting through the coil is decreasing in number, the field produced will have the same direction as that of the bar magnet or primary coil.

40. Self-induction may be defined as that property of a circuit, which tends to prevent any change in the strength of a current flowing through it.

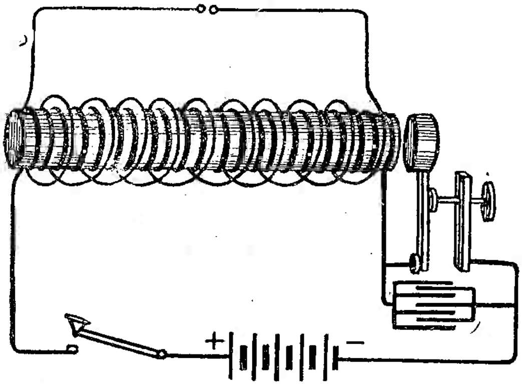

Fig. 23—Secondary Type of Induction Coil.

A solenoid, through which a current is flowing, has a magnetic field about each turn. The field about any one turn cuts through the adjacent turns, inducing a current which is opposite, or the same in direction as the original current, depending respectively upon whether the inducing current is increasing or decreasing in value.

If the circuit of a solenoid, connected in series with a key and battery, is opened suddenly, a spark will occur at the key contacts. This spark is due to what is termed the electromotive force of self-induction. At the instant the key is closed, the current is of course at a zero value, and, due to the opposing current, it does not reach its maximum value at once, but upon opening the key, the current decreases to zero, and the induced current being in the same direction increases the total value of current, thus causing a spark to occur at the key contacts.

The value of this extra current of self-induction depends upon the number of turns of wire in the solenoid, the permeability of the core and the strength of the inducing current.

This property of a coil of wire is made use of in gas engine ignition. The spark occurring when the circuit is broken is used to explode the gaseous mixture in the gas engine cylinder.

41. The principle of self-induction may be stated as follows: **The production of an extra current in a coil is dependent upon a change in the strength of the current flowing through the winding and consequently a change in the number of lines of force cutting the turns of the coil.** As long as the current is steady no extra current will be induced.

42. In the last article we discussed self-induction or the inductive action of a current carrying coil or circuit upon itself.

Under the heading of **mutual induction**, we will discuss the inductive action occurring between two circuits.

Mutual induction may be defined as the induction between two circuits, when the current in one of the circuits is changing in value.

43. If two circuits or coils are placed near together and have no metallic connection, a current flowing in one circuit sets up a magnetic field about the other circuit. The first circuit is called the primary, while the second circuit is called the secondary. If the current in the primary circuit changes in value, the number of lines of force threading or cutting through the secondary will vary proportionately. This change in the strength of field induces a current in the secondary. Fig. 22 illustrates the action of mutual induction between two circuits. The primary circuit consists of a dry cell, key and primary of a few turns of wire, while the secondary consists of a coil of many turns and a galvanometer. If the primary circuit is closed and the primary coil inserted into the secondary, a deflection of the galvanometer will result. If the primary coil is withdrawn an opposite current will result in the secondary with a consequent, opposite deflection of the galvanometer.

44. Another method of inducing currents in the secondary circuit, is to allow the primary to remain stationary within the secondary, making and breaking the primary circuit in order to change the number of lines of force threading through the secondary. We learned that a single coil would have a greater extra current induced in it when the circuit was opened. We have a similar effect on the secondary when the current in the primary is broken. Mutual induction will occur between the two straight wires, if they are parallel, but the greatest induction occurs between two coils.

45. The principle of self-induction is made use of in a device called **a primary induction coil.** It consists of an iron core, upon which is wound one or more layers of fairly large insulated wire. Due to the great permeability of the iron core, the magnetic field about the coil for a given current is much greater than that produced by the same coil having an air core. The purpose of a primary induction coil is to produce a fat, hot spark when the circuit is broken and is used in some types of gasoline engines to ignite the mixture of gas and air in the cylinder. In these engines the point of make and break is located in the cylinder.

46. The principle of mutual induction is used in another device called the **secondary induction coil.** This type of coil consists of an iron core of soft iron wire, a primary of two layers of heavy, insulated wire, and a secondary of many hundreds of turns of small insulated wire. The primary is wound about the iron core, over this a hard rubber tube or other insulating material is placed, and the secondary wound about the tube. The number of turns and the size of the wire used in the secondary are both dependent upon the desired voltage at the secondary terminals. The ratio of the number of turns in the primary to the number of turns in the secondary is the same as the ratio of the primary voltage to the secondary voltage. That is, if the number of turns in the primary is 100, the number of turns in the secondary 10,000 and the voltage of the primary 10, then the voltage of the secondary may be calculated as follows:

$$\frac{10{,}000}{10} = \frac{X}{10}$$

Where 10,000 equals turns in secondary.
100 equals turns in primary.
X equals voltage in secondary.
10 equals voltage in primary.

X must equal 1,000 volts. In other words, 10,000 divided by 100 is equal to 1,000 divided by 10.

47. To make and break the circuit of the primary, a device called the **vibrator** or **interrupter** is used. There are several different kinds of interrupters used with induction coils, but the vibrator is the only type that will be discussed in this course.

As shown in Fig. 23 the vibrator is placed at one end of the iron core. A flat spring fastened at one end has its free end just opposite the core, and has on the side next to the core a small piece of soft iron and on the other side a platinum contact. This contact makes connection with an adjusting screw held by a bracket. As seen in the figure when the circuit is closed the current flows from the battery through the key, primary coil, spring of vibrator, adjusting screw and then back to the battery. When key is depressed, the current magnetizes the core, which attracts spring of vibrator, thus breaking the contact with the adjusting screw. The current, on account of this break in the circuit, dies to zero, and due to the core losing its magnetism, the spring flies back to its normal position, again making contact with the adjusting screw. This completes the circuit once more and the same series of events occur again. This type of vibrator interrupts the circuit about 60 to 100 times per second. On account of the extra current of self-induction in the primary a very hot spark occurs at the vibrator contacts. This extra current not only melts the contact points but reduces the voltage at the secondary terminals. A high voltage at the secondary terminals is dependent on a quick decrease in the value of the current in the primary, when the circuit is broken at the vibrator.

48. If a condenser is connected across the contacts, as shown in Fig. 23, the extra current will be absorbed, preventing fusing of the contacts, and also allowing the current in the primary to die out quickly.

This condenser is usually made of tinfoil and paper. A large number of sheets of tinfoil of the same size are placed one above the other, separated by sheets of paper of larger size than the tinfoil sheets. Alternate sheets of tinfoil are connected to one conductor, while the remaining sheets of tinfoil are connected to the other conductor. These two main conductors are connected across the vibrator contacts.

When the circuit is closed the currents builds up in the primary to its maximum value, inducing a current of high voltage in the secondary, and when the circuit is broken by the vibrator spring, a reverse current is produced in the secondary of much greater value than that produced at instant circuit was closed. The higher voltage induced at the break is due to the quick demagnetization of the core.

49. The induction coil was used very widely in the early days of wireless, but has been superseded by a device called the step-up transformer. The **disadvantages of the induction coil are:..First, that only about one kilowatt of power can be handled efficiently, and second, that it**

gives considerable trouble, on account of contacts of vibrator melting and sticking.

50. In the mechanical production of electricity, the principle of electromagnetic induction is used. Under the heading of principles of electromagnetic induction we learned that there are two principal ways of inducting a current in a coil, in one method the coil remains stationary and the magnetic field about the coil is varied, while in the other method a coil is rotated through a stationary field. The later method, illustrated in Fig. 24, is the one used in the commercial production of electricity.

51. The **alternator** is the most simple form of the mechanical generator of electricity. Such a generator produces a current flowing first in one direction and then in the other, reversing the direction of flow many times per second. Electricity flowing in this manner is termed alternating current. The alternator does not really produce electricity, but merely creates an electromotive force or pressure, which causes electricity to flow against the resistance in a circuit.

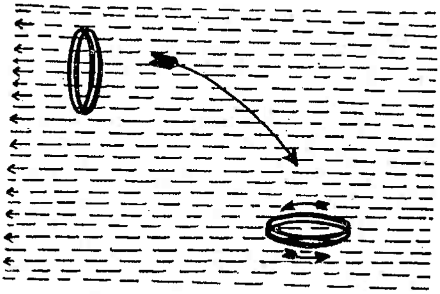

Fig. 24—Electromagnetic Induction.

The earth seems to be a vast reservoir of electricity and the alternator merely creates the pressure necessary to cause electricity to flow in the circuits provided for it.

52. A simple form of alternator consists of a north and south magnetic pole, such as the poles of a horse shoe magnet, between which, a rectangular loop of wire is caused to revolve. Such an arrangement is shown in Fig. 25. **The fundamental principle of the alternator is: If a coil wire is caused to rotate through a magnetic field of uniform strength, so as to cause the number of lines of force enclosed by the coil to increase or diminish uniformly, an e. m. f. will be induced. Fig. 26—Right Hand Rule for Finding Direction of Induced Current in the coil, the magnitude of which will depend upon the rate at which the lines of force are cut.**

In Fig. 25 the loop of wire is in a vertical position, and the lines of force are being cut at a minimum rate. Hence in this position the voltage in the loop will be zero, but in the horizontal position, as shown by the dotted lines in the figure, the rate of cutting will be maximum, the voltage in the loop being also at a maximum value.

53. The two ends of this loop are connected to two metal rings on

the shaft. They are known as **collector rings,** and make an electrical connection with two **brushes** which bear on the rings. The brushes are connected to the outside circuit. **The function of the collector rings is to convey the current from the revolving coil to the external circuit.**

As the loop of wire revolves from the vertical position to the horizontal position, the current rises from a zero to a maximum value, and in the next quarter revolution of the loop, to a second vertical position, the current dies back to a zero value. As the loop continues to revolve, the current reverses, rises to a maximum value and dies back to zero, being again in its original vertical position. Thus in one revolution the current flows first in one and then in the opposite direction. The rise of voltage from zero to a maximum and decrease to zero in the first half revolution is called an alternation, the second half revolution also produces an alternation, and the two taken together are termed a cycle.

54. This simple form of alternator, therefore, consists of **magnets, a revolving coil, collector rings and brushes.** The magnetic field may be produced by permanent magnets or by electromagnets. The number of poles may vary, but are always an even number, there being a north and south pole alternately. The coil in this simple form has only one wire, but in practical machines, consists of many turns in series. The direction of flow in the loop may be determined by the **right hand rule,** illustrated in Fig. 26. **If the thumb points in the direction of the lines of force, and the fingers point in the direction the conductor is moving, the index finger will point in the direction of current flow in the conductor.** It will be seen that as one branch of the loop goes down past one pole, the other branch will be moving upward, and the current induced in each branch will be in such a direction that they will not oppose each other.

55. **Alternating current may be defined as a current that increases**

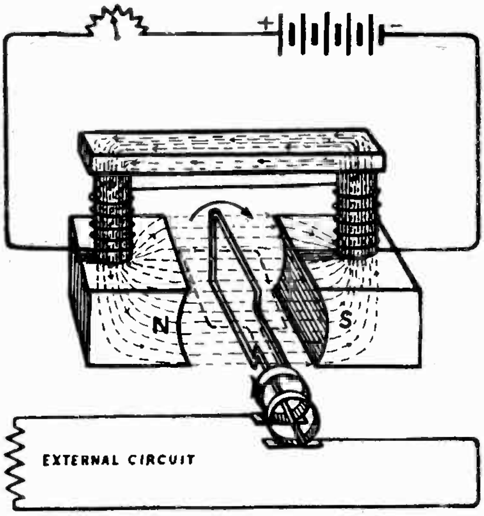

Fig. 25—Simple Alternator.

from zero to a maximum value in one direction, decreases to zero, rises to a maximum in the opposite direction and again decreases to zero.

The fact that alternating current is continuously changing in strength and pressure, with an accompanying change in the electromagnetic induction effects, renders its calculation different and more difficult than that of direct current.

In Fig. 27 we have a diagram of the curve of an alternating current. The straight line represents time, while the greatest height of the curve from this line represents the amplitude, that is, the greatest value attained by the current or voltage during the passage of the loop or coil past a field pole. The complete curve in Fig. 27 represents a cycle or two alternations.

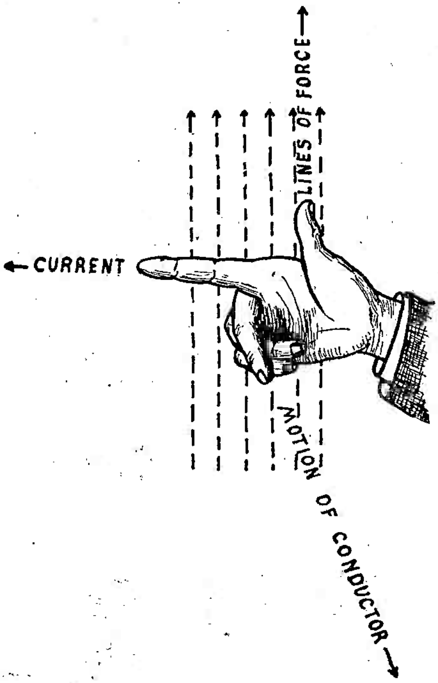

Fig. 26—Right Hand Rule for Determining Direction of Induced Current.

56. The number of cycles produced by the alternator per second is termed frequency. The two-pole alternator described above has one cycle produced per revolution. If the loop were revolved at 2,400 revolutions per minute or 40 per second, the frequency would be 40 cycles.

The frequency used in commercial practice is usually 60 cycles, and in some cases 25 cycles. The simple alternator would need to have its loop or armature revolved 60 times per second or 3,600 revolutions per minute in order to produce a 60 cycle current. Alternators used in commercial practice have more than two poles in order that the speed may not be so high. It is well for the student to remember that a cycle is produced by the revolving armature passing a north and south pole of the field.

57. The number of cycles produced per revolution by an alternator may be found by dividing the number of poles by two. Thus, in the simple alternator described above, the number of poles is two, and hence the frequency per revolution will be one. The rule for determining the frequency of an alternator may be stated as follows:

$$F = \frac{N \times S}{2}$$

Where F equals cycles per second.
N equals number of field poles.
S equals revolutions per second.

The frequencies employed in the generators producing current for wireless apparatus are: 60, 120, 240, 480, 500 and 600 cycles.

Example—An alternator has a speed of 2,000 revolutions per minute, the frequency is 500 cycles. What is the number of poles?

Solution—If the speed is 2,000 per minute, the speed per second is 2,000 divided by 60 or 33 1-3 revolutions per second, therefore, in one revolution there are 500 divided by 33 1-3 or 15 cycles produced per revolution. If two poles are needed to produce one cycle, there must be 2×15 or 30 poles in such a generator, instead of two as in the simple alternator.

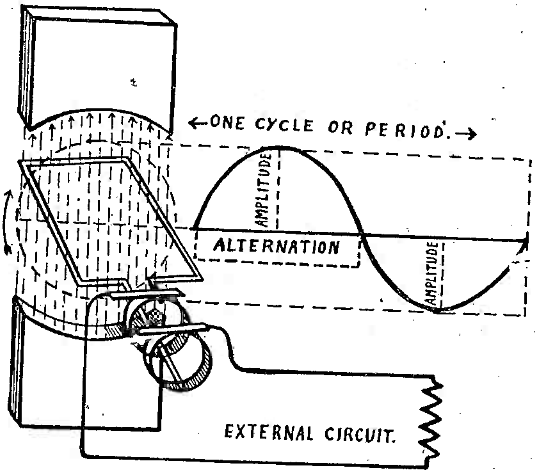

Fig. 27—Production of One Cycle of Current in an Alternator.

58. The frequency of an alternator may be varied by regulation of the speed of the armature.

59. **Inductance may be defined as that property of an electrical circuit by which energy may be stored up in electromagnetic form.**

Inductance, or the co-efficient of self-induction, may also be defined as the property of an electric circuit by which it produces induction within itself.

ELECTROMAGNETIC INDUCTION

Inductance and self inductance are practically synonomous.

The **unit of inductance** is the **henry** and **is** that **inductance possessed by a circuit which has an induced e. m. f.** of one volt, **when the current is changing at the rate** of one **ampere per second.**

That is, if the current increases from zero to a value of one ampere through a coil of wire having an inductance of one henry during one second of time, the change in the number of lines of force set up about it will cause an induced pressure of one volt.

The henry is too large a unit for practical use, except in special cases, so a smaller unit called the millihenry is used. The millihenry is one thousandth of a henry. Another subdivision is the centimeter which is one billionth of a henry.

CAPACITY.

Capacity is a very important subject in connection with wireless apparatus and a very thorough grounding in its principles is essential. We will give only a brief discussion in this instruction paper, touching principally on those parts of the subject which affect the flow of alternating current.

Capacity may be defined as that property of a circuit by which energy is stored up in electrostatic form.

Every circuit has more or less capacity, depending upon its dimensions, its form and the nature of the surrounding medium.

A device having concentrated capacity is termed a condenser. The Leyden Jar is an example of the type used in wireless circuits.

Another form of condenser is made of sheets of tinfoil separated and insulated from each other by paper. The construction of such a condenser may be described as follows: Sheets of paper 8 inches by 12 inches of tinfoil, 6 inches by 10 inches are piled alternately one above the other.

Suppose that 100 sheets of tinfoil and 100 sheets of paper are used. The sheets of tinfoil are considered as numbered one to a hundred. All even numbers are connected to one terminal and the odd numbers to the other terminal.

In the discussion of electromagnetic induction we learned that, when a circuit composed of a coil of wire and battery is closed, that is takes considerable time for the current to reach its maximum valve, due to the inductance of the circuit. The inductance of a circuit prevents the current from reaching its maximum valve as quickly as it would otherwise.

The effect of a condenser on alternating current is just the opposite to that of inductance. If the inductance and the capacity of the circuit are in the correct proportions, the one will neutralize the other, and the current flowing in the circuit will behave the same as if the circuit had no capacity of inductance. The unit of capacity is the farad. A condenser has a capacity of one farad if one volt potential will place a charge of one coulomb (one ampere for one second) within it.

The farad is a very large unit and a smaller unit called the microfarad is used. The microfarad is one millionth of a farad.

The material insulating the plates from each other is called the dielectric and may be paper, glass, mica, air or other insulator.

ELECTROMAGNETIC INDUCTION

The capacity of a condenser depends upon the dielectric material, the thickness of the dielectric and the size of the plates. By the dielectric is meant the material used to insulate the condenser plates.

Some dielectrics conduct static lines of force with greater ease than others. The ability of the air to conduct the lines of force is taken as one and that of castor oil is 4.8. That is, a condenser with castor oil as a dielectric will have 4.8 times the capacity of a like condenser having air as the dielectric. The number representing the ability of a substance to carry these lines of force is called its specific inductance capacity, or dielectric constant.

A very simple and familiar illustration which will form a deep and lasting impression is the case of a common rubber balloon such as one buys at the circus. Its ability for holding air depends upon three things: First, the size of the rubber sheet used to make it; second, the quality of the rubber and third, upon the thinness of the rubber provided it is not so thin as to break. These same things are true regarding the capacity or holding power of a condenser. The quality of the dielectric which might be rubber, mica, glass, oil, etc., will effect its capacity. The capacity will increase if the dielectric is made thinner but it must not be so thin that it will not withstand the electric pressure put upon it. Should the dielectric be too thin or too poor in quality the electric force (in volts) or strain will break down or rupture the substance as in the case with the rubber balloon.

60. Mutual induction has been discussed in a previous article. **It may be further defined as that induction between two circuits when the current through one of the circuits varies in strength.**

The inductance of a circuit depends on the size of the coil.

61. Due to the property of inductance, if an alternating current of a certain value is desired it will be necessary to have a higher voltage than would be required for a direct current of the same value. That is, inductance acts as a resistence in the circuit and must always be taken into consideration when calculating the dimensions of a circuit which is to carry a certain given current.

This opposing action of inductance in a circuit is called the spurious resistance and does not cause heat in the conductor.

The inductance of a circuit is termed reactance, and a coil having large self-induction used to regulate the flow of current by reason of its spurious resistance is known as a reactance coil.

The reactance of a circuit is measured in ohms.

Impedance is the sum of the true ohmic resistance and that due to the reactance.

A condenser also possesses a reactance, which is opposite in its effect to that of inductance.

That reactance due to induction is known as positive reactance, while that due to a condenser as negative reactance. If these two reactances are of the proper values they neutralize each other, the circuit behaving the same as it would in carrying direct current.

*Answer the questions immediately following and send your answers to this Institute for grading. There is no code work to be submitted with this lesson.

QUESTIONS

THEORY LESSON NO. 3

52. How do we know that a current is accomplished by a magnetic field?
53. How may the polarity of a solenoid be determined?
54. What effect does an iron core have on a solenoid?
55. Give three methods of inducing a current in a coil of wire.
56. Define self-induction.
57. What causes the spark at contact when key is opened?
58. State the principle of self-induction.
59. Define mutual induction.
60. How does mutual induction differ from self-induction?
61. Name and describe briefly each of the two types of induction coils.
62. What is the purpose of the condenser connected across the vibrator contacts?
63. What is the function of the collector rings in an alternator?
64. Name the principal parts of an alternator.
65. Define alternating current.
66. Define frequency, alternation and cycle.
67. Give the rule for determining the frequency of an alternator.
68. Define inductance.
69. What is the unit of inductance?
70. What does the inductance of a coil depend upon?
71. Define capacity.
72. What is the unit of capacity?
73. What is meant by dielectric constant?
74. What does the capacity of a condenser depend upon?
75. Define reactance.
76. What effect does capacity reactance and inductance reactance have upon a circuit?

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West Salem, Ohio.

Student No. 13794 Lesson No. 3

Ques no.

52 We know that a current is accompanied by a magnetic field by this simple experiment, a compass is placed in a north and south position, The wire of the circuit with the current turned off is now placed accross the compass, also in a north and south position, when the current is turned on the needle will be deflected if the current is strong enough, at right angles to the current carrying conductor.

53 The polarity of a solenoid is determined by grasping the coil in the right hand with the fingers pointing in the direction of the current flow, the thumb will then point to the North pole.

54 The effect of an iron core on a solenoid is to greatly increase its power of magnetism, this is due to the greater permeability of iron than of air.

55 Three methods of inducing a current in a coil of wire are,

1st. a bar magnet is thrust into a coil of wire which is connected to a galvanometer a deflection of the galvanometer needle will be seen. no deflection of the needle will be shown if the magnet is held stationary but when the bar is pulled out a deflection again will be noted but in the opposite direction of the first.

2nd a current is induced in a coil also by mooving the coil through stationary lines of force, the current is induced by causing the coils to move through the field in such a manner that the lines of force cutting through it are varied.

3rd. Another way is to place a primary coil connected to a battery and key within a secondary connected to a galvanometer, no current is induced into the secondary if the primary becomes stationary, but when the key is opened the current falls from maximum to zero inducing a current into the secondary a current is also induced when the key is closed.

56 Self induction is that property of a circuit which tends to stop any change in the strength of a current flowing through it.

57 The spark at contact when key is opened is caused by the electromotive force of self induction that is, when the key is closed the current due to the opposing current does not reach the maximum value at once. but when the key is opened the current decreases from maximum to zero, the induced current being then in the same direction increases the current flow and causes the spark at contacts.

58 The principle of self induction is The production of an extra current in a coil is dependent upon a change in the strength of the current flowing through the windings, and therefore a change in the number of lines of force cutting through the turns of the coil.

59 Mutual induction is defined as the induction between two circuits,

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when the current in one is changed in value.

60 Mutual induction differs from self induction in that it is the inductive action which occours between two circuits while self induction is the inductive action of a current carrying circuit upon its self.

61 The two types of induction coils are primary and secondary.

A primary coil is made up of an iron core around which many layers of fairly heavy wire is wound, the iron due to its great permeability the field about the coil is much greater for a given current than an air core, this device makes use of the principle of self induction.

A secondary coil is made up of a core of iron, a primary wound with one or more layers of heavy wire according to the strength of the current to be used, and a secondary made up of many hundreds of turns of fine wire. The secondary is wound on an insulated tube which is slipped over the primary, this device makes use of the principle of mutual induction.

62 The purpose of the condensor connected accross the vibrator contacts is to absorb the extra current and stop the spark and to prevent sticking of the contacts it also helps the current in the primary to die out quickly.

63 The function of the collector rings in an alternator is to carry the current from the revolving coil to the external circuit.

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64 The principle parts of an alternator are magnets (either permenant or electro magnets) collector rings, revolving coil and brushes

65 Alternating current may be defined as current which increases from zero to maximum in one direction, decreases to zero, rises to maximum in the opposite direction and again decreases to zero.

66 Frequency is defined as the term applied to express the number of complete cycles taking place per second of time.

Alternation of a current is one half cycle or the rise and fall of a current in one direction.

A cycle is a complete reversal of current or two alternations.

67 The rule for determining the frequency of an alternator is.

$$F = \frac{n X S}{2}$$

F = No. of cycles per. second
n = No. of field poles
S = No. of revolutions per. second.

68 Inductance is defined as that property of an electrical circuit by which energy may be stored up in an electromagnetic form.

69 The unit of inductance is the henry

It is that inductance of a circuit which has an induced voltage of one volt when the current is changing at the rate of 1 ampere per. second.

70 The inductance of a coil depends upon the rise of the current from zero to maximum and from maximum back to zero, or the rise and fall of the current in the coil

(Over)

The inductance of a coil also depends upon the number of layers or turns of wire on the coil. or the induction varies as the square of the turns. The inductance of a coil varies also in respect to the core such as. with air it is least but with an iron core it is increased in proportion to the permeability of the iron.

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West Salem O.

71 Capacity may be defined as that property of a circuit by which energy may be stored up in electrostatic form.

72 The unit of capacity is the farad, this unit is very large so a unit called the micro farad is often used, this unit is one millionth of a farad.

73 Dielectric constant means the ability of a substance to carry the lines of force, since some Dielectrics carry the lines of force with greater ease than others, air is taken as the standard and is rated as one.

74 The capacity of a condenser depends upon the size of the plates and the thickness of the dielectric material

75 Reactance is the term applied to express the resistance of a wire to changes of current established in it.

76 The effect of capacity reactance and inductance reactance upon a circuit is when the two reactances are of proper values they neutralize each other, that is the circuit would be the same as it would be in carrying direct current.

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Answers to Lesson Test No. 3

52. If a wire carrying current has a cardboard at right angles about it and iron filings are scattered on it, they will arrange themselves in concentric circles about the wire.
53. Grasp the coil with the right hand so the fingers point in the direction of current flow and the thumb points in the direction of flow of the lines.
54. An iron core greatly increases the number of lines produced and makes it an electro-magnet.
55. First, by moving a magnet in the coil; second, by moving one coil, carrying a current in another coil; third, by changing the current in one coil which is surrounded by another coil.
56. Self induction is the inducing of a pressure within the coil of wire itself which opposes any change of current.
57. A current due to self-induction.
58. A change of current in a coil will change the number of lines linked with the coil and thus induce a new current (called self-induction).
59. Mutual induction is the inducing of current in one wire from the changing current in another wire close to it.
60. Self-induction occurs within the wire itself, while with mutual induction it is within another wire.
61. A spark or primary induction coil consists of one coil which has a high potential induced in it due to self-induction, while the regulation induction coil with a vibrator has two coils—a primary and secondary. A make or break in primary induces a high potential in the secondary due to mutual induction.
62. The condenser absorbs the current due to self-induction and reduces the sparking on the vibrator contacts.
63. The collector rings form a rubbing contact with the brushes to convey the current from the armature coil to the external circuit.
64. Magnets or poles, the armature with its coils, the collector rings and brushes.
65. An alternating current is one which goes thru periodic changes, starting with zero value, increasing to a maximum value in one direction; decreasing to zero and increasing to a maximum in the opposite direction, then decreasing to zero; repeating this change many times each second.
66. A cycle is one complete change in current, an alternation is one-half a cycle, and frequency is the number of cycles per second of time.
67. Frequency in cycles equals the number of pairs of poles passed per second by the armature coils.

$$F = \frac{N \times S}{2} \quad F = \text{frequency}, \quad \frac{N}{2} = \text{no pairs of poles} \quad S = \text{Rev. per sec.}$$

68. Inductance is that property of a circuit which objects to a change in the current.
69. The Henry is the unit of inductance.
70. The inductance of a coil depends on the size of the coil and number of turns.
71. Capacity is the property for storing electricity.
72. The Farad is the unit, and for practical use the Micro-farad.
73. The Dielectric constant is a number which indicates how much better dielectric a certain substance is than air.
74. Size of plates, quality of dielectric (dielectric constant of substance) and the thinness of the dielectric.
75. Reactance is the property of a piece of electrical apparatus which reacts on the circuit, causing the electric pressure and current to be placed out of phase relations.
76. There are two reactance effects. First, Capacity reactance, causing the current to lead the pressure. Second, Inductance reactance, which causes the current to lag behind the pressure.

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LESSON TEXT No. 4

OF A

Complete Course in Radio Telegraphy

Electromagnetic Induction
Part II

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 4

Do you know the International Code symbols for the alphabet?

Do you know the symbols for the punctuation marks?

In the first assignment we emphasized that frequent reviews were quite beneficial to the thorough mastery of wireless. Although we leave to you the advisability of doing so, we would suggest that you read through the first three theory lessons right now and compare our model answers with your answers, which no doubt you have received. Also practice the code work once more.

Now you are ready to learn the numerals. Practice these symbols until they are firmly fixed in your mind.

1 ● ▬ ▬ ▬ ▬ 2 ● ● ▬ ▬ ▬ 3 ● ● ● ▬ ▬ 4 ● ● ● ● ▬
5 ● ● ● ● ● 6 ▬ ● ● ● ● 7 ▬ ▬ ● ● ● 8 ▬ ▬ ▬ ● ●
9 ▬ ▬ ▬ ▬ ● 0 ▬ ▬ ▬ ▬ ▬

The bar indicating a fraction (/) is sent after the whole number and after the numerator of the fraction; i. e., 2½ would be sent thus:

● ● ▬ ▬ ▬ ▬ ● ● ▬ ● ● ▬ ▬ ▬ ▬ ▬ ● ● ▬ ● ● ● ▬ ▬ ▬

Try these numbers without referring to the symbols for the numerals given above:

1456	9383	13,678.25	6234 1/2	76.51 2/3	.0020	1/2
7210	6899	2/3	4976 3/4	13.05 1/4	.1027	5/8
3/4	7/8	34,678 1/10	1/10	6.5	.0001	5/6

For additional practice in sending numbers, turn to your telephone directory, an arithmetic, the stock columns of your newspaper, etc.

It is a good idea to send from newspapers, including the words, punctuation marks and numerals. You may now turn to the following theory discussion.

THEORY LESSON NO. 4

62. **Transformers:**—In the early days of wireless, the necessary high voltage currents for the production of electromagnetic waves were produced by the induction coil. This coil, described in the last instruction paper, makes use of low voltage direct current in the primary, producing a potential of 50,000 volts or more at the secondary terminals.

As the interrupter used to make and break the primary current cannot handle large powers, and is a source of continual trouble, on account of sticking of contacts, the induction coil is now obsolete in wireless work.

The transformer, a device operating on the same principle as the induction coil, has been adopted almost universally and has numerous advantages over the latter. The amount of power, that the transformers can handle is unlimited. Traisformers handling 500 K. W. are not uncommon in high power wireless transmission.

The transformer operates on either pulsating or alternating current, We learned under the heading of Principles of Electromagnetic Induction, that a current flowing in one circuit, would induce a current in a neighboring circuit, provided, the current in the first circuit was changing in value.

ELECTROMAGNETIC INDUCTION

In the operation of an induction coil, this change in current strength is brought about by the making and breaking of the current at the vibrator contacts. The current through the primary rises from zero to maximum when the circuit is closed, and drops from a maximum to zero when the circuit is broken.

If the transformer is operated by alternating current, the current is continually rising and falling, and also reversing its direction of flow periodically. In modern wireless sets, the frequency of the alternating current used to operate the transformer varies from 60 to 600 cycles. A frequency of 500 cycles has found favor among wireless engineers and most sets now put on the market are of that frequency.

The alternator giving the required frequency is driven by an electric motor, the combination of the two being called a motor generator.

The transformer consists of an iron core, a primary winding and a secondary winding. An induction coil and an open core transformer are identical in their construction, except that the transformer does not need an interrupter.

The current from the alternator, periodically increasing and decreasing in value, flows through the primary of the transformer, first in one direction and then in the other. This change in current value causes a varying magnetic flux to flow through the secondary windings, inducing either a low or a high voltage current depending upon the ratio of the turns in the secondary to the turns in the primary. The greater the number of turns in the secondary, the higher the voltage. This process of transformation may be expressed by the following:

$$\frac{V}{V1} = \frac{T}{T1}$$

Where V. equals voltage of primary current.
V1. equals voltage of secondary current.
T. equals number of turns in primary.
T1. equals number of turns in Sec. winding.

That is, if the voltage in the primary is 10, the voltage in the secondary 10,000 and the number of turns in the primary 100, then the number of turns in the secondary may be found by substituting the above values in the formula. Substituting:

$$\frac{10}{10{,}000} = \frac{100}{T\text{-}1}$$

Therefore, T1 would need to be 1000 times 100 or 100,000 turns in the secondary.

$$\frac{10}{10{,}000} = \frac{100}{100{,}000}$$

If the current in the primary is 10 amperes, and the voltage 10, the power would be 10x10 or 100 watts. (See formula for Power, paper Number 2.)

The power at the secondary terminals will be less than 100 watts, depending upon the percentage of efficiency, and would be equal to the product of secondary voltage and amperage.

The current at the secondary would be about 1-100 ampere, because as the voltage increases, the amperage must decrease proportionately.

63. Types of Transformers:—Many types of transformers are in use in electrical installations.

The two main types are the step-up and the step-down transformer.

The first type raises the voltage from a low value to a high and is much used in wireless transmitters.

The step-down type lowers the voltage from a high to a low value, being of very little interest to the student of wireless.

Transformers may be classified as to construction as follows:

Open core, closed core, air core and auto transformer.

In the open core type of transformer we have the same construction as in the induction coil. This type gives practically constant current at all times, whether the secondary is short circuited or open.

The secondary winding is divided into sections in order to make easy any repair, due to short or open circuit. In case of a burnout in one of the sections or pancakes, all that is necessary to effect a repair, is to short circuit the section or replace it with a spare.

This type of transformer is illustrated in Fig. 28.

The closed core transformer, shown in Fig. 29, is so constructed that there is a complete path through the secondary for the magnetic lines of force set up by the primary, and is more efficient than the open core type.

The core is made of rectangular strips of soft iron, built up to the proper thickness and then wrapped with empire cloth.

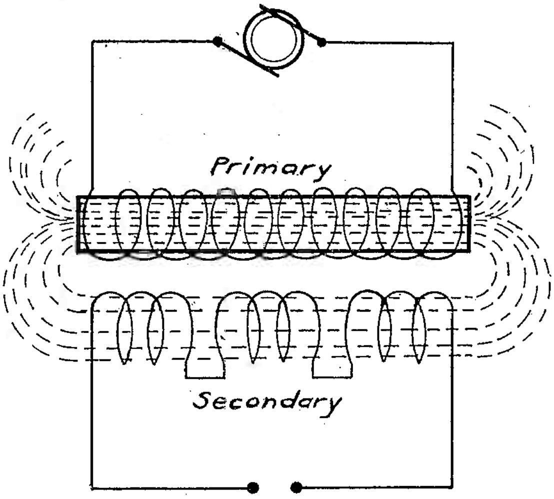


Fig 28. Diagram of Open Core Transformer

The primary winding consists of one or two layers of coarse wire, such as No. 10 or No. 12 gauge, wound on one leg of the core, while the secondary consists of hundreds of turns of No. 28 to 32, wound in sections on the opposite leg of the core.

This transformer will give constant current if an adjustable magnetic leakage gap is provided, as shown in Fig. 29.

This gap allows the magnetic reaction set up by the secondary to dissipate itself and not affect the primary winding. The induction from the secondary if allowed to flow through the primary core would neutralize the self induction of the primary and allow more current to flow.

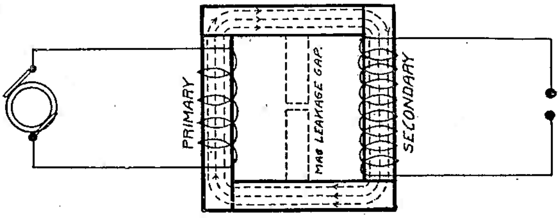


Fig. 29. Diagram of Closed Core Transformer.

The magnetic leakage gap prevents this and consequently the change of load on the secondary will cause no change in current flow.

In building the core of a closed core transformer, the sheets of iron are insulated from each other by shellac, in order to reduce the eddy currents. These eddy or Foucault currents are set up in the iron by induction, causing heating of the core and represent a considerable loss of energy.

The open and closed core transformers used in wireless telegraphy are designed to raise the voltage from 110 or more to various voltages ranging from 10,000 to 30,000 volts. The tendency at the present time is to make use of low voltage transformers.

The air core transformer is used extensively in radio circuits, both in sending and receiving. This type will be discussed in another instruction paper.

The auto transformer is a single winding having either an air or iron core. It is used to reduce alternating current to lower voltages. It was employed to a considerable extent in wireless apparatus of past years but is now practically obsolete. This type of transformer is illustrated in Fig. 30.

64. The Dynamo:—In Instruction paper No. 3, the principle of the alternating current generator is explained. All mechanical generators produce an alternative or pulsating current and to obtain direct current it is necessary to attach a device called a commutator to the alternator.

This commutator takes the place of collector rings, and a machine so equipped is called a dynamo.

The function of the commutator of a dynamo is to so vary the connection of the brushes to the armature coils that the flow of current in the external circuit is in a constant direction.

The action of the commutator will be better understood, by studying the action of a simple two pole machine having a two segment commutator connected to a single loop, as illustrated in Fig. 31.

The principal parts of the dynamo are:—

1. The field magnets.
2. The armature.
3. The commutator.

The field magnets may be either permanent magnets or electro-magnets and their function is to create a magnetic field about the armature. The armature loop revolving through this field, has an alternating electric current induced in it, which is converted into a direct current by the action of the commutator.

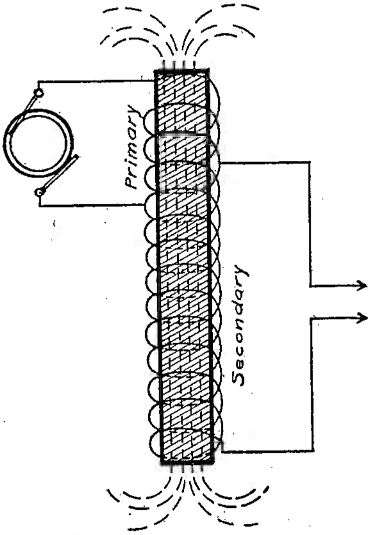


Fig. 30. Diagram of Auto Transformer

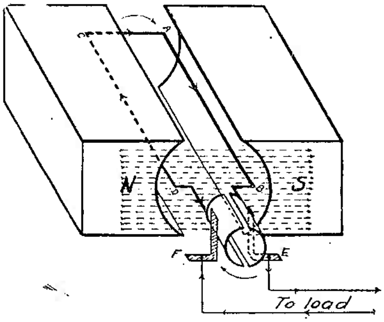


Fig. 31. Diagram Showing Function of Simple Commutator

As shown in Fig. 31, the machine has two field poles of opposite polarity, between which the loop of wire revolves. This loop has its ends connected to the two semi-cylindrical segments. These two segments are insulated from each other, and are located on one end of the revolving shaft. Two brushes are so arranged, that one brush makes contact with one segment, and the other with the other segment. Hence there is a complete path from one brush through the loop and back through the remaining segment to the other. The two brushes are also connected to the external circuit. According to the right hand dynamo rule, as the upper branch AB of the loop revolves down past the south pole the direction of current will be toward the segment of the commutator connected to this branch. As the branch AB goes down past the south pole, the branch CD revolves up past the north pole, causing a current to flow away from the segment connected to that branch. Therefore, the current during this half revolution flows out on the brush marked E, through the external circuit and back through the brush marked F.

The student should observe that the current is flowing to the external circuit through the brush E and to the loop through the brush F. During the next half revolution which brings the loop back to its original position, the branch AB will have the current reversed in it. That is, it is now moving up past the north pole and having a current induced in it, which flows away from the segment, and the branch CD is moving down past the south pole, having a current induced which flows to the remaining segment. Take note, however, that the current is still flowing from brush E to the external circuit and back to the loop through brush F.

Therefore, the commutator switches the brushes from one branch of the loop to the other in this simple type of machine. The current flow in the external circuit, when using a commutator of few segments will be direct, but of varying strength, or in other words, a pulsating current.

It will be observed that the brushes change segments at the position of zero current flow in the armature loop, that is, when the loop is at right angles to the direction of the lines of force.

In practical machines, the armature consists of many loops or coils wound over an iron core, the ends of the loop being connected to a commutator having many segments. Such machines are called multipolar dynamos, as they have more than two field poles.

In large machines the commutator has 150 or more segments, but in small machines, commutators having 20 or 30 segments are common. In the construction of a commutator, many copper bars or segments, separated by strips of mica are arranged in the form of a cylinder. This cylinder is placed on one end of the shaft, the two terminals of each armature coil being soldered to the ends of two segments. The commutator is insulated from the shaft of the armature by some insulating material.

65. Armatures.—Armatures for dynamos are made in two principal types, the ring-wound and the drum-wound.

The ring-wound armature is used very little in generators designed for wireless work. It consists of a ring of iron about which is wound the coils of the armature winding. Owing to this type of armature being practically obsolete, it will not be further discussed.

The drum-wound type is used in most modern dynamos and motors. In this type of armature all the wire is placed in slots cut into the outer surface of the iron core. The magnetic field of the dynamo is produced by two or more field poles arranged so that adjacent poles are of opposite polarity. The outstanding feature of the drum winding is that the two branches of each turn of wire lie under adjacent field poles. The iron core is made usually of many sheets of soft iron insulated from each other by shellac. These sheets are bolted together very tightly so that they form practically one piece of metal. A core of this type is said to be laminated.

The size of wire used on the armature of a motor or generator is determined from the current value for which the machine is designed. Large enough wire must be employed to prevent heating of the wire to a point where the temperature will melt the fiber insulation and ruin the windings.

66. **Brushes.**—The brushes which rest on the commutator and lead the current from the revolving armature to the external circuit are usually made of carbon. They usually bear at a slight angle or in the case of some types of small dynamos, directly against the face of the commutator. These brushes must be of proper hardness and bear against the commutator with proper pressure to prevent undue wear of the surface of the commutator. In many dynamos, the brushes are held by a rocker-arm. This device is merely a holder which allows shifting of the brushes from one point to another on the surface of the commutator. The position of the brushes must be adjusted to a critical position called the neutral point. In this position there is a minimum of sparking, due to the fact that the coils connected to the segments on which the brush is bearing, at this point in their revolution, have little or no current induced in them. That is, the coils are cutting the lines of force at a minimum rate.

67. **Types of Dynamos.**—Dynamos are divided into three main types:

1. The shunt wound.
2. The series wound.
3. The compond wound.

The shunt wound type of dynamo, shown in Fig. 32, has a field winding in shunt to the armature winding. The wire wound about the field poles has its terminals connected to the brushes bearing on the commutator. Therefore, part of the current flowing from the armature will pass through the field windings and keep the magnetic field at the proper strength.

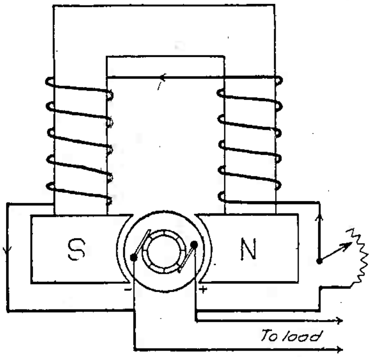


Fig. 32. Diagram of Shunt Wound Generator.

In starting a dynamo, the magnetic field is of very low value, being merely that due to the residual magnetism remaining in the field poles after being magnetized. However weak this field may be, the coils of the armature in passing through it have a small current induced in them, which flowing through the shunt field windings, gradually strengthens and builds up the field between the poles. This increase in the number of lines of force induces a stronger current in the armature and finally the dynamo is supplying full voltage.

The shunt field windings are made of fairly high resistance wire which prevents too great a flow of current, and allows the greater part of the current from the armature to flow out on the external circuit. A variable resistance, called a field rheostat is usually connected in series with the shunt winding to regulate the strength of the field and consequently the voltage of the current delivered to the external circuit. It is well to remember that the voltage induced in the armature depends upon the rate of cutting of the lines of force. Hence, if we vary the current through the field windings, we vary the number of lines of force cut by the armature coils.

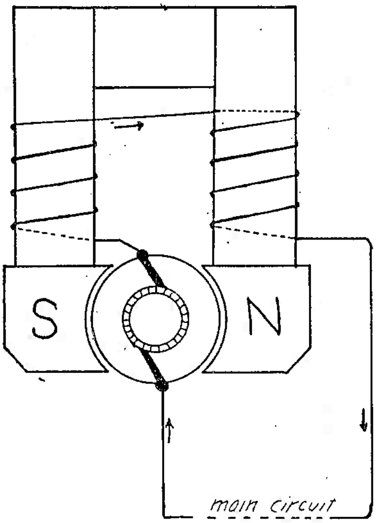


Fig. 33. Diagrams Showing Connections of Series Wound Generator

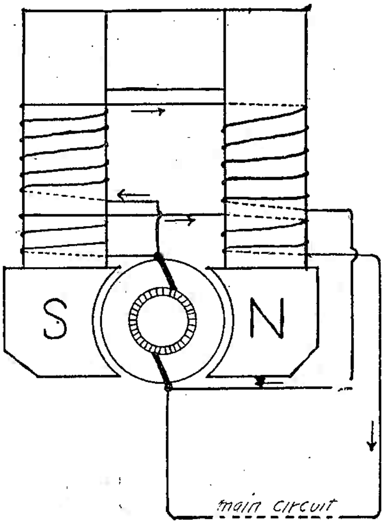


Fig. 34. Diagram Showing Connections of Compound Wound Generator.

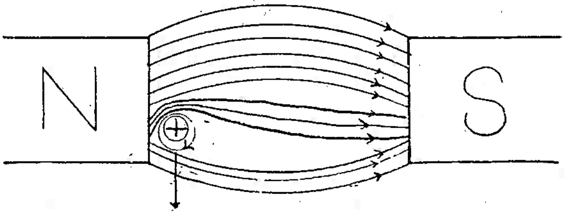


Fig. 35. Diagram Showing Effect of Magnetic Field on Current Carrying Conductor

In the **series wound dynamo**, illustrated in Fig. 33, the field magnets are in series with the armature, and consequently all the current induced in the armature must flow through the field windings. In order that this heavy current may not be held back, the field coils are wound with heavy wire. This winding will then carry the full output of the dynamo without heating. The series wound machine is practically obsolete.

In the **compound wound dynamo,** shown in Fig. 34, there is a shunt winding and also one in series with the armature. The series coil is of large wire, its function being to increase the magnetic field when the load varies. That is, in case a heavier load is put on the dynamo the increased flow of current will, in flowing through this series winding, increase the number of lines of force cut by the armature and thus maintain the voltage.

The **voltage** of dynamos may be regulated either by means of the field rheostat or by varying the speed. The former is the practical method used in controlling the voltage of all types of dyanmos.

68. **The Electric Motor.**—The direct current electric motor is almost identical in construction with the dynamo. In fact, most dynamos will act as motors if supplied with direct current. The electric motor converts electrical energy into mechanical energy and takes a very important part in modern industry.

The principle of the electric motor is: If a conductor free to move in a stationary magnetic field, has a current flowing through it, it will have a magnetic field of its own. The reaction of these two fields causes the conductor to move in a certain direction, depending upon the direction of current flow.

This principle is illustrated in Fig. 35. The direction of the lines of force about the conductor is found by means of the thumb rule. If the conductor is grasped by the right hand, so that the thumb points in the direction of current flow, the lines of force will be about the wire in the same direction as the fingers.

As shown in Fig. 35, due to the field about the wire, the lines of force are more dense on one side of the conductor, thus causing a distortion of the lines of force extending between the north and south poles. The lines of force in trying to straighten exert a pressure on the conductor, causing it to move in a certain direction.

The left hand or motor rule can be used to determine the relation between the field, the conductor, and the current flowing. This rule may be stated as follows: **If the forefinger of the left hand points in the direction of current flow in the conductor, and the thumb points in the direction of the lines of force, then the middle finger at right angles to the thumb and forefinger, will point in the direction of motion of the conductor.**

If we supply current to a simple machine, such as shown in Fig. 31, it will act as a motor. According to the left hand rule, the current flowing in the branch AB, if near the south pole, will cause this branch to go down, while the branch CD near the north pole will have a tendency to move upward. When the loop has reached a vertical position the brushes move from one segment to the other, reversing the direction of current flow in the loop. This causes another semi-revolution again placing the loop in a vertical position. The segments exchange brushes and the loop makes another half revolution. This action continues indefinitely as long as current is supplied to the motor.

The commutator of two segments plays a very important part in the action of this simple type of motor.

The function of the commutator of any type of direct current motor is to maintain the polarity of the armature (loop) in such relation to the field poles, that there will be a constant attraction and repulsion, and therefore rotation.

That is, the function of the commutator is to maintain the current flow through the coils of the armature in such a direction, that the lines of force between the field poles will exert a pressure on the armature windings, thus causing rotation.

Practical motors have more than two poles. Four and six pole motors are quite common. The armatures have many coils and the commutator many segments like the dynamo. We learned that for generation of current in a dynamo it was necessary to cause coils of wire to rotate through a magnetic field. In a motor, we have this same situation, as the motor, at the same time it is a motor, has also the action of a dynamo.

Since the direct current motor is identical in construction with the dynamo, it has coils of wire revolving in a magnetic field. Therefore, while the armature is revolving and delivering mechanical power, it also has an electromotive force or voltage induced in its turns. This voltage will flow in an opposite direction to that of the current which drives the motor. This back or counter electromotive force has a decided effect on the action of the motor. It can never be as great as the applied voltage since in that case the motor would stop, but it does act as a resistance to the current entering the motor and proper control of the back e. m. f. will influence the speed.

In the dynamo, a series variable resistance may be inserted in the field windings and used to vary the voltage at the terminals. A variable resistance is also used in the motor field windings and used to regulate the value of the back e. m. f. If the e. m. f. is increased by allowing more current to flow through the field windings, the current entering the armature will be reduced in value, and the motor will slow down. When a larger current flows through the fields the number of lines of force cut by the armature is greater, inducing a larger e. m. f. This e. m. f. will oppose the applied e. m. f. from the source of power, thus reducing the speed.

The variable resistance connected in series with the motor field windings is called a motor field rheostat and its function is to control the speed of the motor.

60. **The Starting Box:**—The winding of the armature is made of large insulated wire. The large wire has very low resistance and if, in starting the current is connected directly to the motor, the current through the armature will be of great value. This will cause heavy sparking at the commutator and may cause the armature to burn out.

To prevent such an action a device, such as shown in Fig. 36, called a starting box, is employed. It is a variable resistance mounted in such a way, that when starting, the current will flow through all of the resistance. A low value of current flows through the armature causing it to revolve slowly, generating a slight counter e. m. f. The handle of the starter is pulled over slowly, cutting out resistance and allowing more and more current to flow through the windings of the armature. As the motor gains speed, the counter electromotive force increases in value and offers resistance to the applied voltage. Hence, at full speed the resistance of the starter is unnecessary. In the next instruction paper, the actual construction of the starting box will be fully explained and illustrated.

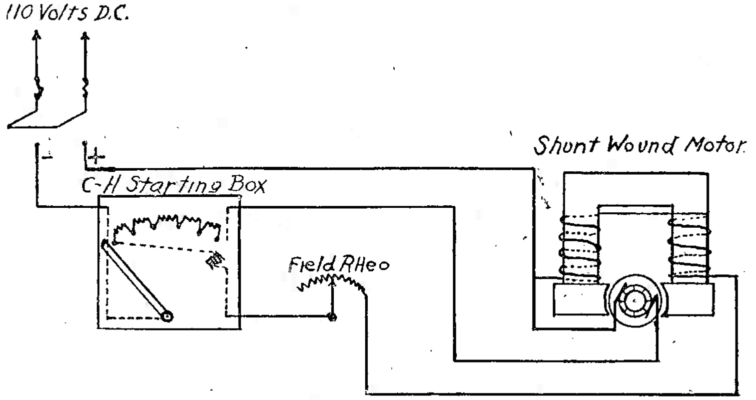


Fig. 36. Diagram of Cutler Hammer Starting Box with Connections to Motor

70. **Measuring Instruments.**—In order to control the action of electrical machinery, it is necessary to know the strength and pressure of the electric currents used in their operation. Instruments employed to indicate potential, current strength, power and frequency are called meters. These instruments take various forms and are based on different principles. The presence of an electric current is made known by the production of heat, magnetic action and chemical changes. The construction of almost all meters are based either on heating or magnetic effects.

The **galvanometer** is a very sensitive indicator of the presence of electric currents, being capable in some types of measuring as small a current as one-millionth ampere.

A galvanometer of the magnetic type takes the form of a permanent horseshoe magnet, between which a rectangular coil of wire is suspended in such a way that it may revolve and enclose the magnetic lines of force extending between the north and south poles.

As illustrated in Fig. 37, if a current flows through the coil of wire, it acts similar to a motor armature, in that the field of the permanent magnet reacts on the field of the coil, causing the coil to move. A pointer fastened to the moving element, passes over a scale which is marked in degrees or some other convenient unit. The extent of the rotation of this coil of wire will depend upon the strength of current and upon the sensibility of the instrument. In very sensitive instruments, the moving coil is supported in jewel bearings and held to the zero position by spiral springs. As shown in Fig. 37, a stationary cylindrical iron core is placed in the center of the moving coil. The function of this core is to increase

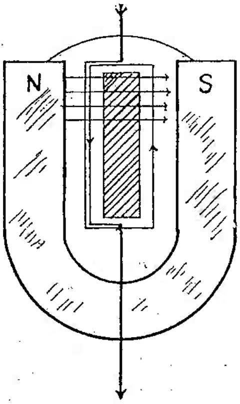


Fig. 37. Diagram of Simple Galvanometer

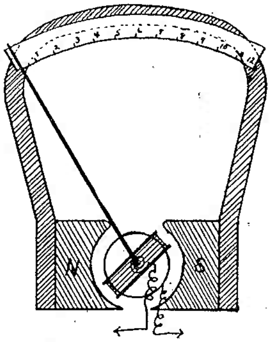


Fig. 38. Diagram of Voltmeter or Ammeter

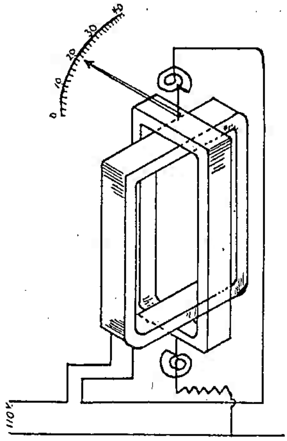


Fig. 39. Diagram of Wattmeter

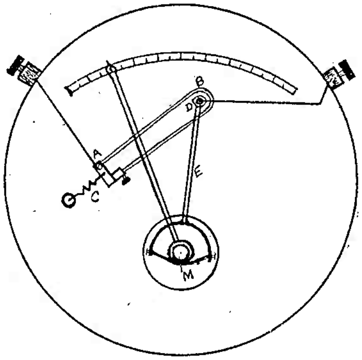


Fig. 40. Diagram of Hotwire Ammeter

the permeability of the path, which the lines of force take from the north to the south pole.

Taking the direction of the lines of force as being from the north to the south pole and the direction of the current as shown by the arrows, the left hand motor rule indicates that the direction of the part of the coil next to the north pole would be up, out of the paper.

The **voltmeter** for measuring direct current is merely a magnetic galvanometer, such as shown in Fig. 38, arranged in a certain way. As the voltmeter measures the pressure or potential difference between two points of a circuit, it is not connected in series but in shunt to a circuit, such as across the terminals of an armature. A high resistance coil is placed in series with the coil of the voltmeter to keep the current flow at a very low value.

The **ammeter** is an instrument for measuring the value of the current flow in a circuit. It is merely a galvanometer of special construction placed in series with the circuit, and is illustrated by Fig. 38. It has a low resistance moving coil connected in shunt to a path of low resistance. It only takes a small current to actuate the instrument, so a shunt is placed about the moving coil to carry the greater portion of the current.

The voltmeter and ammeter just described can only be used for direct current measurements.

The **wattmeter** is an instrument for measuring the power flowing in a circuit. The product of volts and amperes in direct current circuits equals the watts, but in alternating current circuits this it not always true, due to the fact that the amplitude of the current may lag behind the amplitude of the potential.

As alternating current is used in modern wireless transmitting sets, a wattmeter is necessary in order to know what power is being absorbed by the apparatus.

In Fig. 39, one type of wattmeter is illustrated. It consists of two coils, one of which is connected in series with the line, while the other in series with a high resistance connected across the line. The wattmeter is practically an ammeter and a voltmeter combined, the voltage coil being movable while the current coil is stationary. As shown in the figure a spiral spring is used on the voltmeter coil to keep the needle at zero when no power is being used. When current is flowing, the magnetic fields set up in the two coils react on each other in such a manner that the movable coil tends to move into a parallel position with the stationary coil. The pointer on the voltage coil moves over a scale calibrated so as to measure either watts of kilowatts.

The **hot wire ammeter** is an instrument designed to utilize the heating effect of the current to be measured. This type of ammeter is employed in measuring the currents flowing in the wires leading to the aerial of a transmitting or sending set. The currents flowing in certain portions of a transmitter are of high frequency and high voltage, and the ordinary ammeter will not give true readings.

The principle of the Roller-Smith hot wire ammeter is, that a wire expands when a current flows through it. That is, a given length of wire will increase in length if a current flows through it. This increase in length of the wire is employed in causing a pointer to move over a scale. The more current flowing in this wire the greater the deflection of the needle. As shown in Fig. 40, the current flows on the wire from A to B. The resistance of this wire causes it to heat and therefore expand. The spring at C puts a tension on the two wires extending over the pulley D. If a current flows and expands the wire from A to B, due to the increase in length of the one branch the pulley D must rotate to make both branches the same length. This causes the arm E attached to the pulley to move to the left. Between the prongs of this arm a silk thread, which passes around the shaft M, is stretched. As the arm E moves, the silk thread must move the shaft, carrying the pointer over the scale.

Another type of hot wire ammeter uses a thermo couple as the essential element.

A thermo couple is shown in Fig. 3, of instruction paper No. 1. If a junction of two dissimilar metals are heated by some means, a direct current will be produced. This current, while weak, will actuate a sensitive ammeter.

In this hot wire ammeter, the current to be measured is allowed to flow through several wires stretched between two copper blocks. On one of the wires a thermo couple is fastened, which is heated by the current flowing between the copper blocks. The direct current set up by this thermo couple flows to a magnetic ammeter. The necessity for the other wires between the copper blocks is to carry part of the heavy current flowing in the circuit. It acts as a shunt to the thermo couple junction.

This instrument is used by the Marconi Company and is manufactured by the Roller-Smith Company.

The **Frequency Meter** is an instrument used to indicate the frequency of an alternating current. In one common type a number of reeds having various vibration frequencies are arranged in such a manner that an alternating current flowing through it will cause the reed having a corresponding frequency to vibrate. The frequency in cycles per second will be indicated on a dial. This instrument is very little used in modern equipments.

QUESTIONS

INSTRUCTION PAPER No. 4

We suggest that you study this lesson over twice before attempting to answer the following questions. Send your answers to the Institute for grading. No code translation is included.

77. What is one advantage of the transformer over the induction coil?

78. What is the frequency of the alternating current employed in modern wireless sets?

79. What two main types of transformers are in use?

80. Name four other kinds of transformers.

81. Which is the more efficient, the open or closed core type of transformer?

82. What is the function of the magnetic leakage gap?

83. What is the function of the commutator of a dynamo?

84. Name the principal parts of a dynamo.

85. With what type of armature are most dynamos equipped?

86. Describe the type of brushes used on dynamos.

87. Give diagrams of three types of dynamos.

88. What is the principle of the electric motor?

89. Give the left hand or motor rule.

90. What is the function of the commutator of a motor?

91. What is the cause of the back or counter e. m. f. of a motor?

92. How is the speed of a motor controlled?

93. Explain the use of a starting box.

94. Upon what two effects of a current of electricity is the design of measuring instruments based?

95. Why is the voltmeter connected across the circuit rather than in series?

96. What is the wattmeter?

97. Upon what principle does the hot wire ammeter operate?

98. Describe the thermo-couple.

99. What is a frequency meter?

100. What size of wire is used on the armature of a motor or generator?

Student No
13794

George J. Guderjahn
West Salem, Ohio.

Lesson No 4.

Ques No.

77 One advantage of the transformer over the induction coil is the absence of an interrupter, whose contacts frequently become fused together, shorting the primary the inductance coil cannot handle very high voltage.

78 The frequency of the alternating current used in wireless sets ranges from 60 to 600 cycles. 500 cycles is much used at present on account of its high clear note it produces.

79 Step up and Step down.

80 Four others used are auto transformer, air core, closed core and open core.

81 The most efficient of the two is the closed core type of transformer

82 The function of the magnetic leakage gap is to prevent the magnetic reaction set up by the secondary from neutralizing the self induction of the primary and allowing more current to flow in the primary.

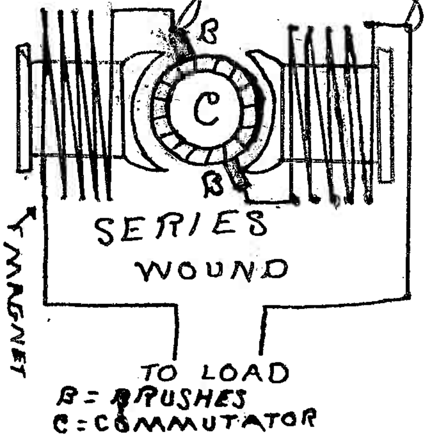
83 The function of the commutator of a dynamo is to so vary the connection of the brushes to the armature coils that the current flowing in the external circuit is in a constant direction.

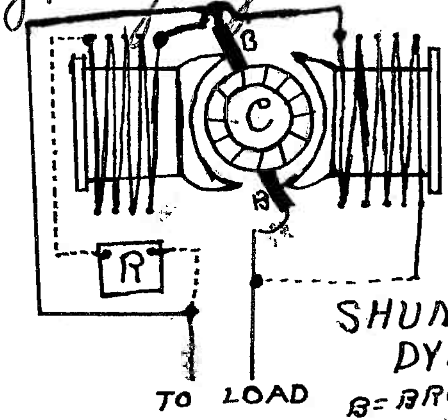
84 The principal parts of a dynamo are armature, commutator and field coils or magnets.

85 most dynams are equipped with the drum wound type of armature.

86 The brushes used on a dynamo are made of carbon set in a holder in such a position that they either bear at an angle or directly against the commutator, the brushes must be of the right hardness to prevent ruining the commutator by excessive wear

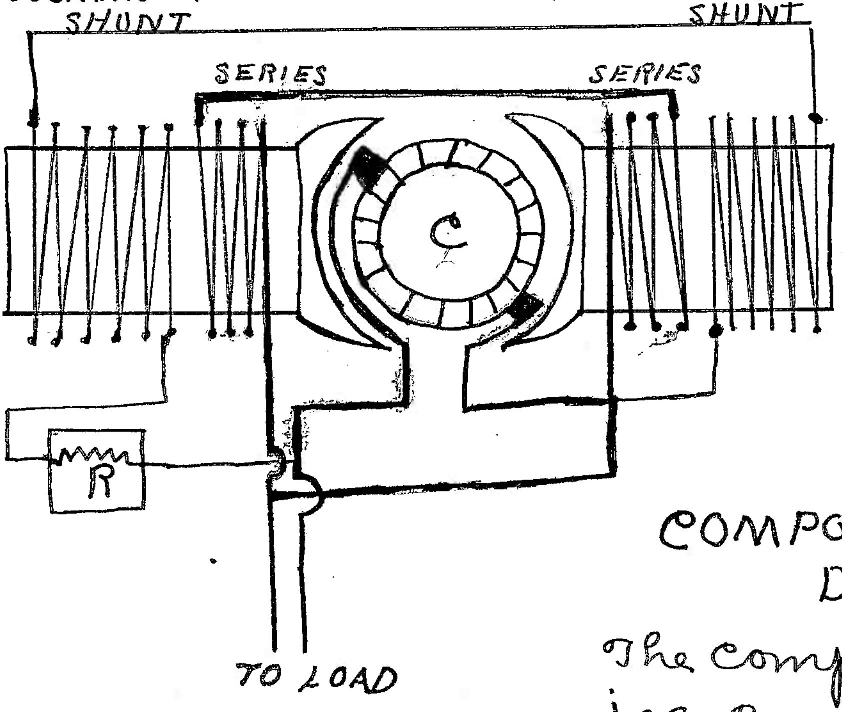
87 Diagrams of three types of dynamos are.





SHUNT WOUND DYNAMO

B = BRUSHES
C = COMMUTATOR
R = REOSTAT



COMPOUND WOUND DYNAMO

The compound dynamo is a combination of the series and shunt types.

Student No. 13794

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West Salem Ohio

88 The principle of the electric motor is: if a conductor is freed to move in a stationary magnetic field, and has a current flowing through it. it has a magnetic field of its own, these two fields reacting upon each other causes the conductor to move in a certain direction, depending upon the direction of the current flow.

89 The left hand motor rule is.
If the forefinger of the left hand points in the direction of the current flow in the conductor, and the thumb points in the direction of the lines of force, then the middle finger at right angles to the thumb and forefinger. will point in the direction of motion of the conductor.

90 The function of the commutator in a motor using direct current is to maintain the polarity of the armature in such relation to the field coils that there will be a constant attraction and repulsion, which causes the rotation of the armature.

91 The back or counter E.M.F. of a motor is caused by the armatur revolving in a magnetic field which causes an electromotive force to be induced in its windings, this current flows in the opposite direction to the current which drives the motor, it is never as strong as the current used to drive the motor because if it was the motor would stop, however it does act as a resistance to the applied current and therefore the speed is influenced by it.

92 The speed of a motor is controlled by a reostat of variable resistances inserted in series with the field windings of the motor.

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93 The use of the starter box on a motor is to prevent the armatur from burning out and the motor ruined due to the very low resistance of the wire on the armatur, that is: if the current was connected directly to the motor the current in the armatur would be very great and causes the brushes to spark at the commutator, and may also burn the armatur out. The starting box prevents this, it is similar to a reostat and is placed in such a way that when the motor is started all the resistances are in series, the value of current in the armatur is cut down causing it to turn over slowly, generating a counter E. M. F. in the windings as the resistances are successifully cut out this back E. M. F. increases in value and offers a resistance to the applied current, so that when the motor is running at full speed the resistance of the starter is not needed.

94 The two effects of a current of electricity which are used in the designing of measuring instruments are heat and magnetism.

95 The voltmeter is connected across the circuit because it has to measure the pressure or P. D. between two points of a circuit, therefore it is equipped with a high resistance coil placed in series with the voltmeter coil to keep the current flow at a low value.

96 A wattmeter is an instrument to measure the current value flowing in a circuit

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97 The principle upon which the hot wire ammeter operates is. It is known that heat causes expansion and cold contraction, so it was found that a current flowing through a circuit causes the circuit to heat up, and in turn the circuit expanded. this expansion was then carefully measured and made to actuate a pointer over a scale, it was then possible to measure the amperage of a circuit by the heat imparted to the wire by the current flowing through it.

98 The thermo-couple is described as the production of direct current by the junction of two dissimilar metals when heated

This principle is made use of in a hot wire meter for measuring the amperage of a circuit

The current is allowed to flow through several wires stretched between two copper blocks. the thermo couple is connected to one of the wires, when the current is flowing in the circuit the wires heat up setting up a direct current in the thermo couple, which in turn is connected to a magnetic ammeter

99 A frequency meter is an instrument used to tell the frequency of an alternating current

100 The size of wire used on the armatur of a motor or generator is determined from the strength of the current for which the machine was designed. that is wire must be used that is large enough to prevent heating of the wire to a temperature high enough to destroy the insulation and ruin the coils

Correspondence Course
NATIONAL RADIO INSTITUTE
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Answers to Lesson Test No. 4

77. The transformer has the advantage of being able to handle large amount of power.
78. 500 cycles.
79. The step-up and the step-down transformer.
80. Air core, open core, closed core and auto-transformer.
81. The closed core transformer.
82. The leakage gap allows the secondary increased current to react thru it and tends to maintain a constant current in the primary.
83. The commutator of a dynamo rectifies the A. C. current generated in its armature coils as it passes out thru the brush to the external circuit, and thus delivers direct current to the load.
84. Field magnets, armature and commutator.
85. Most generators have a drum-wound armature.
86. Carbon brushes of the proper hardness bearing on the commutator at right angles to the surface or slanted a bit toward the direction of rotation.
87. See Figures 32, 33 and 34.
88. Electric current is supplied to the armature conductors which set up a field of their own and react on the lines of the field to cause a movement of the conductors.
89. Let the forefinger of the left hand point in the direction of the current and the thumb indicate the direction of field lines, then the middle finger at right angles to the thumb and forefinger will show the direction of motion.
90. The motor commutator changes the polarity of the armature coils so as to form a constant attraction and repulsion with the pole pieces, causing a rotation.
91. The counter E. M. F. of a motor is the pressure generated within the armature coils which react against the incoming or impressed voltage. It acts as a resistance to cut down the flow of current.
92. The motor speed is controlled by a field rheostat connected in series with the shunt field.
93. The starting box is a variable resistance put in series with the armature to prevent excessive currents on starting the motor. The counter E. M. F. takes its place when the armature comes up to speed.
94. Electrical instruments are designed to operate on the heating or magnetic effects of the electric currents.
95. A voltmeter measures the pressure between two points or wires, and must therefore be connected to these points. It contains a high resistance which cuts the current thru it to a small value, just enough to move the pointer to the correct value on the scale.
96. A wattmeter is an instrument for measuring the electric power in watts or kilowatts.
97. The hot-wire ammeter operates on the principle of the current causing an expansion or elongation of a special wire in the instrument. This elongation moves the pointer over a scale.
98. A thermo couple is formed by the junction of two different metals. When this junction becomes heated a direct current will be set up in a circuit connected across these two wires.
99. A frequency meter is an instrument to indicate the frequency in cycles for the current flowing in it. Some instruments have a pointer while another type has vibrating reeds. The reed corresponding to the frequency will vibrate and indicate, by a scale over it, the cycles per second.
100. The size of wire used on the armature of a motor or generator is determined from the current value for which the machine is designed. Large enough wire must be employed to prevent heating of the wire to a point where the temperature will melt the rubber insulation and ruin the windings.

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LESSON TEXT No. 6

OF A

Complete Course in Radio Telegraphy

Production of Electromagnetic Waves

REVISED EDITION

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Washington, D. C.

RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 6

We submit the following exercise for sending practice. By this time you have cultivated an even "sending hand" and you may time yourself and advise us how long it takes you to complete this exercise.

1	2	3	4	5
E I S H	T M O E H	A N E O T	U D A N E	V B D U N
S E H I	S O M E T	H A M E N	N O M E U	D O U B A
H I S E	M E T O S	T H E N A	U H M A N	N T E H B
I S E H	H O T S M	R S T O N	T H E N U	M U R O B
E H I S	E T O M H	A E I H M	D O N U T	D B S A V

6	7	8	9	10
R K A N B	W G R N K	P C W K G	F L E C K	Z X P C W
H T R U K	H A W K G	H R C S P	P R O W L	S W Z P X
M E K A R	N W K G R	M E P R U	S F R G H	W Z P X K
K V D R N	B E W R O	I P D C K	L W K V C	Z G X N C
T R S K O	G M R W K	W N P R C	B F C R L	P C R Z X

11	12	13	14	15
G Y C W X	J G W R S	1 2 3 4 5	6 7 8 9 0	2 V 7 H 5
K Z F Q L	C Y Q Z J	3 1 H V 4	8 0 6 7 9	9 0 3 B 6
Y P Z G Q	K H J P L	2 5 U 3 1	1 4 B H 6	1 4 8 K 7
C F Y Q W	F G W J X	S H 5 2 V	V 5 9 0 7	2 8 0 3 6
Y L Z P H	U V Y C P	4 D 1 3 5	0 2 8 6 3	4 1 9 7 0

16	17	18
3 6 1 9 V	1 9 7 4 8	H 3 9 1 4
8 H 5 2 0	3 6 2 0 1	2 5 G 3 7
V 7 B 4 3	7 4 3 5 9	8 V 4 B 9
2 0 9 Y 1	1 0 7 6 3	J 7 H 5 1
6 U 3 0 5	4 8 9 4 2	0 Q 3 8 6

Up to this time we have said little, if anything, about the art of good receiving. This art consists principally in possessing a fairly accurate knowledge of just what an entire word sounds like taken as one combination.

In other words, one should be able to understand a word spoken in the wireless telegraph language by means of the International Morse Code symbols as readily as he does the same word uttered by mouth in the language of any national tongue with which he may be familiar.

One of the most important tendencies the beginner should try to avoid is striving for speed in sending and receiving until he has learned to make and understand all the symbols correctly and without hesitancy. Speed will come natural as you progress.

PRODUCTION OF ELECTROMAGNETIC WAVES.

Complete instructions for operating the Natrometer are sent with the machine. You should note how you can get many different combinations from one set of dials; how you can set the dial shifting device so that the entire dial will be sent to you through the phones in one continuous message.

Remember the privilege you have of exchanging dials is free. All we ask is that you take particular care to pack the dials so that no damage will occur en route and to inclose **with your dials** name, address and student number and sufficient postage to cover return charges. New sets of dials are not sent upon request except when our records show that you have returned one set. Always return your set when you desire a new one.

You know the conditions which must be complied with before the machine is sent. You may not have the Natrometer at this time, but these words should be carefully noted just the same. Proficient and accurate sending can easily be acquired by imitating the dot and dash messages which are sent to you through the phones. Remember, hundreds of wireless operators all over the country are going to hear you send when you are working, so do not neglect to acquire a distinctive and accurate hand in this art. It is very common to hear operators remark that the operator at ——— (mentioning the call letters) is the clearest they ever heard. Take pride in your sending.

This assignment is also devoted entirely to one topic—the production of electromagnetic waves. You are now ready to begin the study of this assignment.

No doubt you have noted already how some of the principles you learned are applied to things with which you come in contact almost every day. If you will recall in your mind the principles and definitions upon which these things are being operated, this course will prove doubly interesting and fascinating. Continue to do that and the matter of memorizing some of them will be easy.

In the preceding instruction papers the subjects of elementary electricity and magnetism is treated in a very brief manner. A student makes better progress when he is not required to read a mass of unnecessary detail, and for that reason only the essential facts have been covered. After he has obtained a grasp of the subject, the student should read other books on radio in order to get a broader understanding of the theory and practice.

Paper No. 5 treats of the motor generator in detail, as it is advisible that the student have a thorough understanding of this important part of the radio set. The rules given for the proper upkeep of the motor generator should be committed to memory, as the operator is required to give the machine daily attention.

PRODUCTION OF ELECTROMAGNETIC WAVES.

Wave Motion:—This article treats of the principles of wave motion and the methods by which waves are produced. The art of wireless telegraphy is based on the fact that a wave motion can be set up which will travel to great dstances. The use of waves for purposes of communication is not entirely confined to wireless telegraphy, the heliograph, the transmission of sound through water and through air, being common examples of the transmssion of ntelligence by means of waves.

The most common example of wave formation is that produced by casting a stone into a pool of water. Surface waves of circular form radiate from the point where the stone strikes the surface and travel outward. The stone as it strikes the water gives it an up and down motion and we see alternate crests and hollows.

Another example of wave formation is that of a rope, one end of which is fastened to a hook in a wall and the other end given an up and down motion. A wave travels from the hand to the wall and then is reflected back again to the hand. The difference between this type and the first is that this wave travels in a straight line while the other radiates in all directions in a horizontal plane.

Still another type of wave motion is that seen on a windy day on a field of grain. The wind striking the stalks, bends them over, thus displacing other stalks, which in turn displace more stalks until finally the displacement travels over the entire field of grain.

In any type of wave motion, two things are necessary—first, a disturbance, and second, a medium through which a displacement may travel. In the case of the stone thrown into the water, the stone is the disturbance and the water is the medium. In the case of the human voice the vocal cords supply the disturbance while the air is the medium through which the sound waves travel.

A point not always understood is that a wave travels but the medium does not. If a chip is placed on the surface of a pond and a wave motion is set up, it will be seen that as the wave passes, the chip is raised up and down but is not carried with the wave. The particles making up the medium move only a very short distance when a wave motion travels through it, vibrating a short distance to either side of their normal position of rest. A piano wire when struck vibrates back and forth alternately, compressing and rarifying the air adjacent to it. This compression of the particles close to the wire is communicated to the particles nearby and thus the compression will travel through the air at a certain velocity until its energy is exhausted. The rarification of the air occurring after a compression is also transmitted alternately with the compression. This type of wave moton is termed a **pressure wave.**

The type produced on the surface of a substance as when a stone is thrown into a pool is called a **height wave,** as the particles forming the medium have an up and down vibration.

PRODUCTION OF ELECTROMAGNETIC WAVES.

The velocity of any wave motion is the distance it will travel in one second and depends upon the nature of the medium. In air the velocity of a sound wave is 1090 feet per second, in water the velocity is 4700 feet per second, while in steel the wave travels at the rate of 16,400 feet per second.

The length of a wave is the distance from the crest of one wave to the crest of another or from the trough or hollow of one wave to the trough or hollow of the next.

The amplitude of a wave is the highest point reached in a positive or negative direction. It is measured from the normal level or base line. As a wave travels away from its source its amplitude ceases, until finally it dies out entirely.

The frequency of a wave motion is the number of waves occurring per second.

The relation between the frequency, wavelength and the velocity is given by the following formula:

$$\text{W. L.}=\frac{V}{F}\text{ where}$$

F. equals frequency.

$$\text{W. L.}=\frac{300{,}000{,}000}{F}$$

V. equals velocity.
W. L. equals wavelength.

The ether is an invisible medium through which wave motions of various lengths are propagated. The most common wave motion in the ether is light. Light waves are about 15 millionths of an inch in length, x-rays have a still shorter wave length, while heat waves have about the same length as light. Electric waves, as used in wireless telegraphy range from 100 to 20,000 meters in length. The velocity of all forms of waves in the ether is 300,000,000 meters or 186,000 miles per second.

The Condenser:—In the production of electric waves we make use of high voltage, high frequency currents. The frequency employed in most stations ranges from 1,500,000, down to 15,000 cycles or oscillations. As a general rule, ship stations employ a frequency of 500,000, while amateur stations employ currents whose frequency is of the order of 1,500,000 cycles. To designate currents whose frequency is above 10,000 cycles, the term radio frequency is used, while for those frequencies below 10,000 we use the term audio frequency.

There are several methods for the production of currents of radio frequency, the most important being:

1. The discharge of a condenser.
2. The high frequency alternator.
3. The Poulsen arc.
4. Vacuum tube generator.

PRODUCTION OF ELECTROMAGNETIC WAVES.

The first method is employed on most ship stations and in the greater proportion of coast stations. In the high power stations the second and third methods are in use, but the fourth method is only in the experimental stage at the present time.

In this paper we will consider the condenser method of producing radio frequency currents. The condenser is a device consisting of two metallic plates separated by a non-conductor called a dielectric, and has the ability to store up energy in electrostatic form. A common type, shown in Fig. 52, the condenser consists of a glass jar coated inside and out with tinfoil or copper to about three-quarters of its height. If the condenser is connected to a source of current, a charge or quantity of electricity will be placed on the plates. Upon removal of the charging source and the substitution of a wire which touches one of the coatings and almost touches the other, a discharge in the form of a spark will occur at the gap. This discharge appears to be but one spark, but actually consists of a series of sparks.

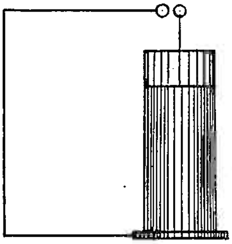

Fig. 52. Leyden jar.

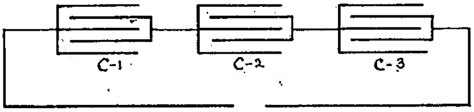

Fig. 53. Series Connection of Condensers.

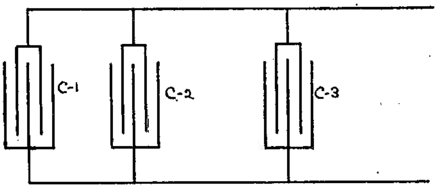

Fig. 54. Parallel Connection of Condensers.

PRODUCTION OF ELECTROMAGNETIC WAVES.

In 1838, Prof. Henry, of Princeton, discovered that this discharge of a condenser was oscillatory, or in other words that the current passed from one coating to the other across a gap and then back again, and that this back and forth discharge would continue until the energy of the charge was dissipated. The discovery of this fundamental fact marked the beginning of the development of radio telegraphy.

The two plates of the condenser appear to have unequal charges and when the connection between the two plates is close enough a discharge from the positive side to the negative side takes place. This discharge appears to produce a heavy charge on the negative plate, making it positive and the other plate negative. Owing to resistance and other losses some of the energy of the charge is lost and the succeeding oscillations are not so strong, having less and less amplitude, until finally equilibrium is restored. The energy of the charge is converted into heat and into ether waves. The frequency of the oscillations of a condenser are exceedingly rapid and are not under control.

The capacity of a condenser is dependent upon:

1. The size of the plates.
2. The number of the plates.
3. The dielectric material.
4. The thickness of the dielectric.

The farad is the unit by which capacity is measured, but on account of its size, a smaller value, called a microfarad, equal to one millionth of the larger unit is employed. The standard Leyden jar used by the radio companies and the navy has a capacity of about .002 microfarad. This condenser is used in a large percentage of the ship installation, and in many of the land stations.

In addition to the Leyden jar condenser, we have:

1. The oil plate.
2. The compressed air.
3. The Dubilier or mica condenser.
4. The moulded condenser.

The oil plate condenser consists of plates of glass coated with tinfoil or copper and immersed in a tank of oil. Alternate layers are connected to one main lead and the remaining layers to the other lead. The oil prevents brush discharge (leakage around the edges of plates).

The compressed air condenser consists of two sets of metallic plates insulated from each other and placed in a tank in which there is an air pressure of 250 pounds. Air at this pressure is a very good dielectric.

The **mica condenser** as developed by Dubilier is composed of several sections sealed in an aluminum case. Each section consists of over a thousand alternate pieces of mica and tinfoil. The sheets of mica are of larger size than the sheets of tinfoil. Several sections are piled one on top of the other and an adhesive substance is forced through the condenser to fill up all pockets or cavities and cover the tinfoil with a tin coating. If a puncture should occur, the adhesive flows into the hole and heals it. The special construction of this condenser reduces the brush discharge about the edges of the condenser plates to a very low degree.

The moulded condenser is made of sheets of tinfoil or copper embedded in an insulating compound which hardens when cold. This compound forms the dielectric and at the same time keeps moisture away from the plates.

The dielectric between the metallic plates affects the capacity of the condenser. The term used to denote the ability of a material to conduct the electrostatic lines of force is called the specific inductive capacity or the **dielectric constant.** Air is said to have a dielectric constant of one, while castor oil has a constant of 4.8. The best grade of glass has a constant of 9 and a condenser having glass as the dielectric would have 9 times the capacity of the same condenser having air as the dielectric. Therefore the **dielectric constant** of a substance may be defined as the ratio of the capacity of a condenser having it for a dielectric to the capacity of a like condenser having air as the dielectric.

A condenser is said to have a capacity of one farad when one coulomb will charge it to one volt potential.

The formula for the capacity of a condenser may be given as follows:

$$C = \frac{2248KA}{10^{10}T}$$

where A equals area of opposed surfaces in sq. inches.
K equals the dielectric constant.
T equals the thickness of the dielectric in inches.
C equals the capacity in microfarads.

In order to get various values, condensers may be connected in several different ways, such as series, parallel or series parallel. In the **series** connection the outside coating of one condenser is connected to the inside coating of a second, the outside coating of the second to the inside coating of the third and so on until all the jars are connected.

When condensers are connected in series, the resultant capacity is found by the formula:

$$C = \frac{1}{\frac{1}{C\text{-}1} + \frac{1}{C\text{-}2} + \frac{1}{C\text{-}3}}$$

where C is resultant capacity.
C-1 is capacity of one condenser.
C-2 is capacity of second condenser.
C-3 is capacity of third container.

It will be seen that the capacity of several condensers in series is less than the capacity of the smaller condenser. For instance, take three condensers of the following capacities: .001, .002 and .003 microfarad—

$$C = \frac{1}{\frac{1}{.001} + \frac{1}{.002} + \frac{1}{.003}} = \frac{1}{\frac{6}{.006} + \frac{3}{.006} + \frac{2}{.006}} = \frac{1}{\frac{11}{.006}}$$

$$\therefore \frac{1}{\frac{11}{.006}} = \frac{1}{1} \times \frac{.006}{11} = .00054 \text{ microfarad.}$$

Thus the resultant capacity is less than the least of the three.

If the three condensers are connected in parallel, however, the resultant capacity will be the sum of the three. Such a connection is shown in Fig. 54. The following formula is used to calculate the capacity of condensers in parallel:

$$C = C\text{-}1 + C\text{-}2 + C\text{-}3$$

Substituting:

$$C = .001 + .002 + .003 = .006 \text{ microfarad.}$$

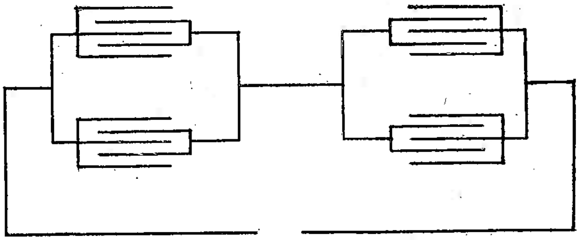

Fig. 55. Series-parallel Connection of Condensers

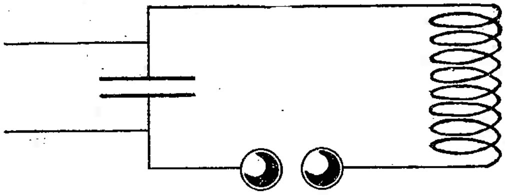

Fig. 56. Closed Oscillation Circuit.

A third method of connecting condensers is called the series parallel connection, and is shown in Fig. 55. If two banks of condensers connected in parallel are connected in series we have a condenser of the series parallel type. It has the advantage of having a greater dielectric strength. Instead of having one thickness of dielectric to withstand the high voltage, the two banks in series have a double thickness of dielectric.

PRODUCTION OF ELECTROMAGNETIC WAVES.

Oscillatory Circuits:—We have already considered the discharge of a condenser across a gap and have learned that it is oscillatory and of very high frequency. If we insert a coil in series with the condenser and spark gap, we reduce the frequency of the oscillations. To understand this, let us consider what is meant by frequency.

Frequency may be defined as the rate at which the oscillations occur per second. Then, if a certain number occur in one second the length of time necessary for one oscillation to be produced will be **one** divided by the **frequency.** We call this quotient the **period.** In other words, **period** is the time necessary for one oscillation to occur. If we insert a coil of wire in series with the spark gap and condenser, we have obviously increased the length of wire necessary for the discharge to travel over, hence it will take a longer time for the oscillation to pass from one coating to the other and back again. If it takes a longer time for one oscillation to occur, evidently there will not be as many oscillations per second in the circuit. We can vary the frequency then by making a change in the number of turns of the coil in series with the condenser and spark gap. By an increase or decrease of the size of the condenser we may also vary the frequency. The reason for this is, that it takes longer for a charge to be placed over a large condenser than it does for a small one.

A circuit, containing inductance and capacity, in which oscillations may occur is called an oscillatory circuit. An example of such a circuit is shown in Fig. 56. If the resistance of an oscillatory circuit is too high, no oscillations will occur. It is necessary, therefore, in order to have oscillations in a circuit, to have the resistance below a certain critical value.

To obtain a low resistance for high frequency currents such as we encounter in radio circuits, we must use conductors of a large surface area, such as large wire, stranded wire, copper ribbon or copper tubing. High frequency currents travel on the outer surface penetrating but a very short distance into the conductor. The resistance of a conductor will be different for a high frequency current than for direct current. The number of oscillations in a circuit, for each charge of the condenser depends to a great extent upon the high frequency resistance.

The Spark Discharge:—If the condenser is given a charge by some source of high voltage current, such as an induction coil or transformer, all the energy is, at the instant, in electrostatic form being stored up in the coatings of the condenser. If the spark gap made of two rods of brass or zinc, in series with the condenser and inductance has the proper separation, the strain in the condenser will cause a discharge to occur from the positive to the negative side of the condenser. During the time the condenser is discharging across the gap and passing through the inductance coil, the energy is electromagnetic in form and lines of force are produced about the coil, but as long as the energy is in the condensers, it is electrostatic. This change from one form to another continues until all the energy is dissipated. When a discharge occurs across the gap, the inductance of the coil opposes the flow of current, but the instant the current starts to die down, an induced current in the same direction as the dying current is set up and due to this extra current a positive charge is placed on the plate that an instant before had a negative charge, but is not so great as the first positive charge, due to resistance losses, brush discharge, and to loss of energy by radiation. This discharge across the gap continues, first in one direction and then in the other until the energy is dissipated. The amplitude decreases in proportion to the charges on the plates, finally dying out entirely, as illustrated in Fig. 58.

Damped Oscillations:—The decrease in the amplitude of the oscillations mentioned above is called damping or decrement. The number of oscillations occurring before the charge in the condensers is entirely dissipated is dependent upon the resistance of the gap and circuit as well as to the loss due to radiation. If the resistance is too great, there will be no oscillations in the circuit, the discharge being in one direction only. Hence, the actual number of oscillations produced by one charge in the condenser depends upon the resistance and other losses in the circuit.

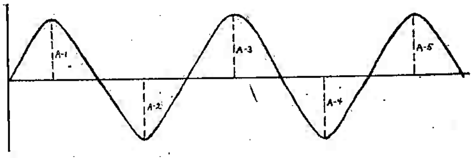

Fig. 57. Undamped wave.

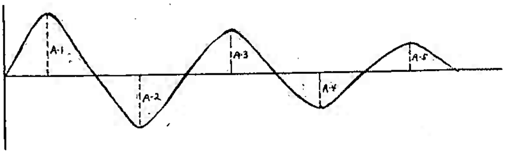

Fig. 58. Damped wave.

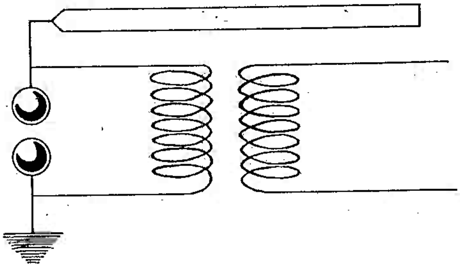

Fig. 59. Direct Excitation of Aerial.

PRODUCTION OF ELECTROMAGNETIC WAVES.

Frequency has been defined as the number of cycles or oscillations occurring per second. This definition will apply to alternating current as supplied by a generator of continuous oscillations or cycles, but will not apply to damped oscillations as generated by the charge and discharge of a condenser. It is rather the rate at which the oscillations occur. It is well for the student to remember that an oscillation and a cycle are identical, the first term being applied to high frequency currents, while the latter is applied to low frequency currents.

In oscillatory circuits the frequency depends upon the size of the condenser and the inductance. Capacity is measured in microfarads and the inductance in centimeters or millihenries.

This frequency will be the rate at which the oscillations occur, but the actual number will depend upon the damping of the trains of oscillations. Such a circuit as we have described above is called a **closed oscillatory circuit** and is shown in Fig. 56.

Open Oscillatory Circuit:—In the closed type of oscillatory circuit, we have a condenser and a coil of wire in shunt to each other. The coil of wire has the property of inductance and is of very low resistance. In the open oscillatory circuit one or more wires are suspended in the air, either in a vertical or horizontal position, and have their lower terminal grounded. The capacity of such a circuit is supplied not by an artificial condenser, but lies between the wires as one plate and the earth as the other side of a condenser. The inductance is located in the wires, lead-in and in the coils in series with the elevated wires. If a spark gap is placed in series with the wires and the ground, and a spark coil or transformer has its terminals connected to either side of the gap, a discharge can be made to occur across the gap. In this circuit a charge has been given to the aerial and ground. The action is identical with the closed circuit, with the exception **that this type of circuit will radiate a large proportion of its energy in the form of electromagnetic waves.**

The relation between the oscillations in the open oscillatory circuits and the electromagnetic waves will now be considered.

If a charge is given to the aerial by means of a transformer or other source of high voltage alternating current, oscillations occur up and down the aerial circuit, each oscillation causing a wave to be radiated from the aerial. For each charge given to the aerial and ground, a series of waves will be radiated, equal in number to the number of oscillations in the discharge. The number, length and height above the earth of the elevated wires will determine the frequency of the waves radiated.

The wave length of an open oscillatory circuit is calculated by the following formula:

where W. L. equals wave length,
W. L. = 38 V L C L. equals inductance in centimeters.
C. equals capacity in microfarads.

When we speak of the wave length of an oscillatory circuit, we have reference to the length of wave which will be radiated by such a circuit. The frequency of the waves radiated will equal the frequency of the oscillations in the circuit.

Most ships and shore stations handling commercial business operate on the following wave lengths: 300, 450, and 600 meters. The high power commercial stations use much longer wave lengths, while naval stations range in wave length from 150 to 20,000 meters.

If a charge is given to the aerial and ground, the energy is in electrostatic form and there are lines of static force between the aerial and the earth. When the discharge occurs across the gap the energy is converted into electromagnetic form and the lines of magnetic force are at right angles to the static lines of force. These static and magnetic lines represent a strained condition of the ether about the aerial circuit and as the currents oscillate up and down the aerial circuit, this strained condition radiates in every direction with the velocity of light.

Logarithmic Decrement:—In the article on damped oscillations, we considered the decrease in amplitude of the high frequency oscillations produced by the charge and discharge of a condenser. The series of oscillations produced by the discharge of a condenser is called a **train of oscillations.** The condenser is charged 200 to 1000 times per second, giving an equal number of trains of oscillations. Each train of oscillations consist of a number of oscillations of decreasing amplitude. This discharge of the condenser may be compared to the action of a pendulum. If the pendulum bob is pulled to one side and released, it will swing back and forth. The distance the bob will swing from the vertical line through its bearing will be less and less each swing, until the friction at the bearing and air resistance bring it to rest. The friction and air resistance correspond to the resistance and other losses in the oscillatory circuit and as the former causes the decrease in amplitude of the pendulum bob, so do the losses of the oscillatory circuit cause the oscillations to decrease in amplitude. Damping or decrement are synonymous and mean decrease in amplitude. If the oscillation train in the open radiated circuit of a transmitter is highly damped, the wave motion radiated from the aerial will be scattered over a wide range of wave lengths. Modern sets are tuned to radiate and receive on specific wave lengths and if a transmitter sends signals on many wave lengths at the same time interference is caused. To prevent such an interfering wave, the radio laws state that the logarithmic decrement shall not be over .2. To understand this it will be necessary to explain briefly what is meant by logarithms.

A logarithm of a number may be defined as the exponent of the power to which the base must be raised to equal the number. In the Briggs system the base is ten. The logarithm of 100 is 2, that is 10 must be raised to the 2nd power to equal 100. The logarithm of 1000 is 3, because 10 must be raised to the 3rd power to equal 1000. The **logarithmic decrement** of a train of oscillations is the Naperian logarithm of the ratio of the amplitude of one oscillation to the amplitude of the succeeding oscillation in the same direction. The Naperian system of logarithms is different from the Briggs system in that 2.718 is the base instead of 10. In this system the logarithm of a number is the exponent of the power to which 2.718 must be raised to equal the number. In Fig. 58 the amplitudes are indicated by a, a-1, a-2, a-3, a-4, a-5 and a-6. When the condenser discharges, the first alternation is the largest and therefore the ratio would be:

$$\frac{a}{a-2} = \frac{a-2}{a-4} = \frac{a-4}{a-6}$$

The ratio of (a) to (a-2), (a-2) to (a-4), (a-4) to (a-6) is constant. The logarithm of the ratio (a) to (a-2) to the base of 2.718 is the logarithmic decrement. In other words, the logarithmic decrement is the exponent of the power to which 2.718 must be raised to equal the ratio of (a) to (a-2). The law states that this exponent must not be greater than .2. If an oscillation train has a logarithmic decrement of 12, the number of

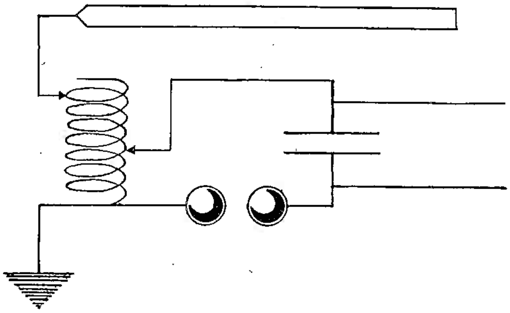

Fig. 60. Conductively Coupled Set.

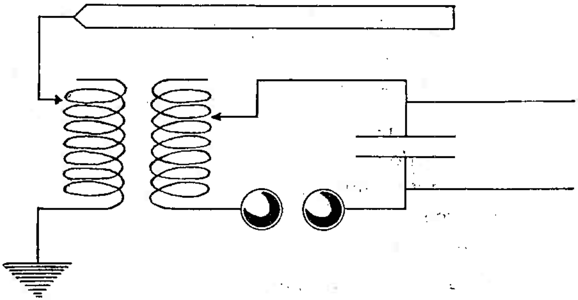

Fig. 61. Inductively Coupled Set.

oscillations will be 24. The formula for computing the number of oscillations in an oscillation train, when the log. decrement is given is:

$$\text{Oscillations} = \frac{4.605 + \text{decrement}}{\text{decrement}}$$

Substituting the log. decrement of .2,

$$\text{Oscillations} = \frac{4.605 + .2}{.2} = 24 \text{ oscillations}$$

A logarithmic decrement of .3, greater than the law allows will give 16 oscillations per train of oscillations, while a log. decrement of .1 will give 47 oscillations to the train. The greater the number of oscillations per train in an aerial the less will be the interference, as the energy will be confined to one wave length.

An increase in the log. decrement above .2 will decrease the number of oscillations in the train, while a decrease in the log. decrement will result in an increase of the number of oscillations per train. **A sharp wave** may be defined as the wave motion radiated by a transmitter when the energy is confined to one frequency or wave length. **A broad wave** may be defined as the wave motion radiated by a transmitter when the energy is spread over a wide range of wave lengths.

Resonance:—The open oscillatory circuit is a very good radiator of electromagnetic waves and the aerial circuits of the majority of stations are built on that principle. A high frequency current may be produced by the discharge of a condenser through a coil of wire and a spark gap. This type of circuit is called a closed oscillatory circuit and is a good oscillator but not a good radiator. In the transmitter we make use of both types, the closed circuit is used in generating the high frequency currents and the open circuit for the radiation of the waves. In order to transfer the energy from one to the other, it is necessary for the two to be in **resonance,** and to be in inductive relation with each other. We say two circuits are in resonance when the product of the inductance and capacity of each are equal. The frequency of the two circuits will be the same and consequently the wave length will be the same. If two tuning forks are placed near together, and one of them is vibrating, the second one will be set into vibration by the first, provided they have the same frequency. To have a maximum transfer of energy from the closed to the open oscillatory circuits of a wireless transmitter, it is necessary that the two have the same wave length.

Aerial Excitation:—The most simple method of producing electromagnetic waves in the ether is by **direct excitation** of the open oscillatory circuit. A spark gap is placed in series with the elevated or aerial wires and the ground. The terminals of the secondary of the transformer or induction coil are connected to either side of the spark gap, as shown in

Fig. 59. The capacity of an aerial circuit is supplied by the aerial and ground and the inductance by the aerial wires and lead-in. If the aerial is charged by the transformer, a spark will occur across the gap and oscillations will flow in the aerial circuit. These oscillations will set up electromagnetic and electrostatic strains in the ether, which will travel from the aerial with the speed of light. The disadvantages of this type of excitation is that the aerial is subjected to a very high potential from the secondary of the step-up transformer, and unless considerable inductance is added in the form of coils in the aerial circuit, the wave radiated is highly damped and causes much interference to other stations.

Conductively Coupled Sets are connected as shown in Fig. 60. One inductance coil is employed for both the aerial and closed circuits. A clip connection represented by the arrows is employed for variation of inductance. The efficiency of the conductively coupled set is fairly high and has the advantage of simplicity. When the condenser discharges across the gap, oscillations flow through the turns of the closed circuit, setting up lines of force about the coil and inducing a current in the aerial circuit. Part of the current actually flows by conduction into the aerial circuit.

The **Inductively Coupled Set** is the most widely employed of the three different methods of excitation and although it is very little, if any, more efficient than the conductively coupled, the coupling of this type is more easily adjusted than is the conductively coupled transformer. This method is illustrated in Fig. 61.

The two circuits have no metallic connection with each other, the energy being transferred by means of electromagnetic induction. The two circuits must be tuned to resonance in order that a maximum transfer of energy will occur. The advantage of the inductively coupled set over the conductively coupled or direct excited set is that a sharper wave can be radiated—that is, a wave whose energy is all sent out at one frequency. If the two inductance coils are placed too near each other a broad wave will be radiated, but if the two coils are at the proper distance apart, a sharp wave is produced. The reason for this action is due both to the gap used, and to the mutual induction between the two coils. If a straight gap is used it does not immediately return to its state of high resistance, when the discharge of the condenser is complete. The condenser discharges, oscillations flow in the closed circuit, producing lines of force about the primary coil and induce a current in the secondary coil of the aerial circuit. The current in the secondary sets up lines of force which cut the primary and tends to induce a current back in the closed circuit. If the spark gap has not returned to its state of high resistance, there will be a considerable transfer of energy back into the closed circuit. This transfer of energy back into the closed circuit causes a change in the inductance of the aerial circuit and consequently a variation of the wave length radiated. This variation of wave length is usually such that two wave lengths are radiated, one longer and one shorter than the wave length to which the aerial circuit is tuned. The disadvantages of this double wave radiation are first, that a receiver can only be tuned to one of the waves, the energy in the other being lost, and second, the double wave creates unnecessary interference. The remedy for this condition is to separate the two coils until but one wave is radiated.

QUESTIONS

THEORY LESSON No. 6.

(Answer the following questions and submit your answers to the Institute for grading.)

These questions should be answered in ink on the standard size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer immediately after it.

Leave a one and a half inch margin (for correction purposes) and write only on one side of the paper.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

121. What is meant by the amplitude of a wave?

122. What is the velocity of electromagnetic waves?

123. If the frequency of a wave is 500,000, what is the wave length?

124. Define radio frequency; audio frequency.

125. Name four methods of producing high frequency oscillations.

126. What does the capacity of a condenser depend upon?

127. Name five high potential condensers.

128. Explain what is meant by dielectric constant.

129. Explain the three methods of connecting condensers.

130. What is meant by the frequency of an oscillatory circuit?

131. What is an oscillatory circuit?

132. What two forms does the energy of an oscillatory circuit take?

133. Why does the amplitude of the train of oscillations decrease?

134. What is meant by damping or decrement?

135. By the frequency of an oscillatory circuit, do we mean the actual number of oscillations occurring in the circuit?

136. What is the difference between an oscillation and a cycle?

137. What does a closed oscillatory circuit consist of?

138. Describe an open oscillatory circuit.

139. What is the formula for the wave length of an open oscillatory circuit?

140. If the oscillation frequency is 500,000 in the aerial circuit, what is the frequency of the radiated waves?

141. What is meant by logarithmic decrement?

142. How many oscillations will occur in a train of oscillations whose decrement is .2?

143. Explain resonance.

144. Name and explain brefly the three methods of aerial excitation.

145. Which method is the one employed by the majority of stations?

LESSON TEXT No. 7

OF A

Complete Course in Radio Telegraphy

The Transmitting Set

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 7

Summary of Previous Instruction Papers.—The first four instruction papers present the elementary principles upon which the science of radio telegraphy is based. These first four papers are very important and should be reviewed by the student from time to time until he understands and can apply the principles taught therein. Among these principles, a knowledge of Ohm's law is very essential to a proper understanding of the operation of a radio set. In preparing this course of lessons, only the essential facts bearing on the theory and operation of radio apparatus have been given. Supplementary reading on the art may be found in any library. Among numerous textbooks on the art of radio communication the following are especially valuable to the student preparing for the operator's license: "Wireless Telegraphy," by Rupert Stanley, and "Practical Wireless Telegraphy," by E. E. Bucher.

The student should make sure that he understands each instruction paper before starting the next, and in case he does not understand certain statements made in the lessons, he should ask the school for further explanation.

In instruction paper No. 7 a practical discussion and explanation of the actual instruments employed in a transmitting set is given. The different instruments will be taken up in the order of their connection in the set.

A fundamental circuit diagram of a marine type of transmitter is shown in Fig. 62. This type of sets produces damped waves.

The following instruments are shown in the diagram:

1. The direct current line switch.
2. The starting box.
3. The motor generator.
4. The field rheostats.
5. Protective devices.
6. The alternating current line switch.
7. Measuring instruments.
8. Reactance regulator.
9. Key.
10. Step-up transformer.

11. Safety gap.
12. Choke coils.
13. Condensers.
14. Spark gap.
15. Oscillation transformer.
16. Aerial tuning inductance.
17. Short wave condenser.
18. Hot wire ammeter.
19. Ground.

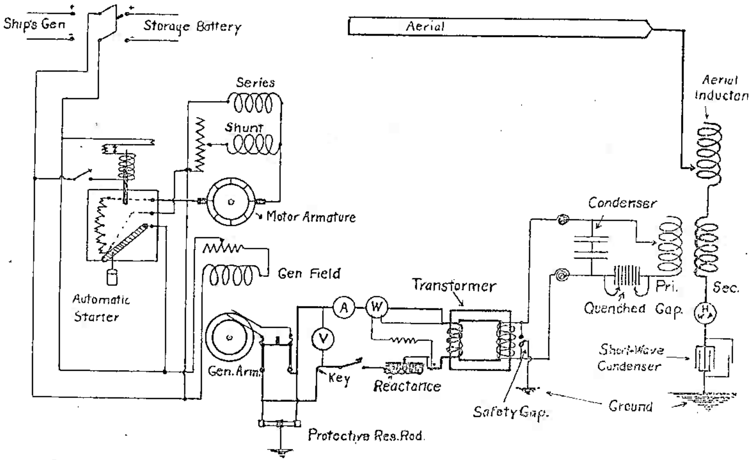

Fig. 62 Fundamental Circuit Diagram of Transmitter.

The direct current line switch connects the motor to the source of direct current, whether it be storage battery or ship's generator. It is equipped with fuses capable of carrying a current somewhat heavier than that which the motor requires. In case the current becomes too heavy, the fuses melt and break the circuit.

The starting box is a device used in starting a motor. Due to the winding on the motor armature being of very low resistance wire, if the current should be allowed to flow directly into the motor armature, a burnout of the winding would probably occur. When the motor is running, it generates a current whose strength is proportioned to the speed and which flows opposite in direction to the current which drives the motor. This opposing current offers resistance to the driving current.

To prevent any damage being done to the motor, a device called a starting box is employed. It is a variable resistance and is so arranged that when the direct current switch is closed the current must flow through all the resistance of the starting box. That is, when the motor is first started all the resistance of the starting box is connected in series with the motor armature, thus preventing any damage being done to the windings. As the handle of the starting box is moved over the contacts, the resistance is gradually cut out and the motor speeds up in proportion. As the motor speeds up the counter e. m. f. produced in the motor armature increases in value and acts as a resistance to the incoming current and prevents any damage to the armature windings when the motor is running at full speed. This is the reason why the resistance of the starter is only needed at the time of starting. A description of the starter has been given in the paper on motor generators.

The motor generator consists of a motor and generator on the same shaft and frame. The motor is driven from a source of direct current having a potential of 110 volts and delivers about 4.3 horsepower in the two kilowatt type. The generator is rated at two kilowatt and delivers current at a frequency of 60 to 600 cycles. The modern motor generator is of the 500 cycle type, while another type of motor generator recently placed on freighters and small passenger ships produces a current at 120 cycles and has a power of one-half kilowatt.

Two field rheostats are employed to control the motor and generator. The *The motor field rheostat regulates the speed of the motor generator and consequently controls the frequency,* while *the generator field rheostat controls the voltage of the generator, and consequently the power delivered.*

The alternating current line switch enables the generator armature to be disconnected from the primary of the step-up transformer.

The protective device may be either the resistance rod or condenser type. The device has three leads, two are connected to the parts to be protected and the remaining one to the ground. The function of the protective condenser or resistance rod is to conduct to the ground those high frequency, high voltage currents induced in the motor or generator circuits from the closed or open oscillatory circuits. These high frequency, high voltage currents, in seeking the easiest path to the earth, may puncture the insulation of the windings, unless above devices are employed.

The measuring instruments employed in the circuit connected to the armature of the generator are: the voltmeter connected across the leads from the collector rings; the ammeter in series with the circuit; the wattmeter in series and in shunt to the circuit; and the frequency meter in series with the circuit.

The reactance regulator is a device placed in series with the primary of the tranfsormer for regulation of the current flowing therein. It consists of one or more layers of heavy insulated wire wound over an iron core. By means of taps leading out from a number of turns, the inductance may be varied. In another type the iron core is so constructed that it can be pulled in or out, and thus allow variation of the inductance of the coil. The flow of an alternating current through a reactance reglator is accompanied by a rise and fall of the lines of force about the coil. This rise and fall induces what is termed an electromotive force of self induction, which acts as a resistance to the flow of alternating current through the coil, and for this reason can be used to regulate the flow of current in the primary of the step-up transformer. By thus regulating the current flow, the power delivered at the secondary of the transformer is also under control. As explained above, the action of this reactance is regulated by means of the tap switch or by withdrawal of the iron core from the winding.

The inductance is at maximum when all the turns are in circuit and therefore the current is a minimum. By reducing the number of turns the current flow will increase. In the other type of reactance regulator, the current is a minimum when the iron core is completely within the coil. By removing the core partially the inductance can be reduced proportionately and thus increase the flow of current. One type of reactance regulator is shown in Fig. 63.

The transmitting key is employed to make and break the current flowing in the primary circuit of the step-up transformer into long or short-pulsations. This key is of the same type as the regular telegraph key, with the exception that it is of heavier construction. The contact points are made of silver and are much larger than those of the ordinary telegraph key. A large percentage of the ship sets are operated with a current in the primary circuit of 25 amperes or less, but in large stations much greater currents must be broken, and the use of the hand operated

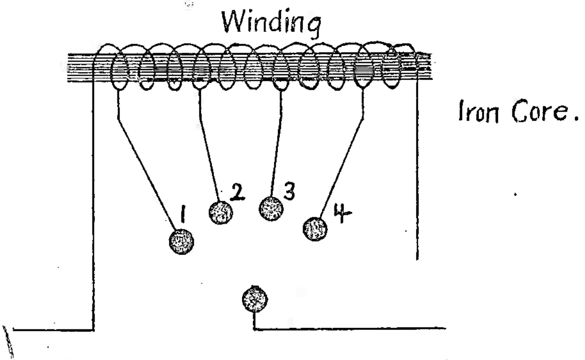

Fig. 63. Reactance Coil.

key is not feasible because of the heavy arcing at the contacts. A relay key is employed to break these heavy currents and consists of an electromagnet and a bar. The bar takes the place of the lever of the ordinary key and has a contact of silver which makes connection with a stationary silver contact. The current from a small battery or other source flows through the electromagnet, giving the bar an up and down motion. The local current is controlled by a small telegraph key and can be thus broken into dots and dashes of the code. A stiff spring is attached to the bar to keep it under tension, and to pull the two contacts apart when the circuit is broken by the small key. This spring breaks the circuit so rapidly that there is very little arcing at the contacts.

In the case of the hand operated key, arcing may be minimized by shunting the contacts with a condenser, inductance or a resistance.

In some stations a break key is employed which operates as follows: When the key is pressed to make a dash or dot, two extra contacts on the key are closed, short-circuiting the receiving set so as to prevent damage to it by the high voltages flowing in the sending circuit. This key enables the operator to listen in, in the intervals between the dots and dashes.

The primary of the step-up transformer is connected in series with the key reactance regulator and generator armature. It consists of two layers of heavily insulated wire about an iron core. If this primary is properly designed no reactance regulator is needed.

The key circuit is the term applied to the circuit containing the alternator armature, the reactance regulator, measuring instruments, primary of step-up transformer and the key. This is a circuit of low voltage and low frequency, having currents of a frequency of 60 to 600 cycles and a voltage of 110 to 500.

The secondary of the step-up transformer is a winding of many hundreds of turns which in the case of the open core is wound over the primary winding, and in the closed core transformer is wound over one of the legs of the reactangular core.

The number of turns in the secondary depends upon the voltage desired at its terminals. The size of the wire ranges from No. 28 to 32, and is cotton, silk or enamel covered. The potential at the secondary terminals of step-up transformers in low power radio sets ranges from 7,500 to 30,000 volts.

The safety gap is a spark gap placed across the terminals of the secondary of the step-up transformer and acts as a protection to the secondary and to the condenser in case the oscillation circuit spark gap is lengthened abnormally. A spark occurs at the safety gap whenever the strain becomes abnormal, preventing puncture of the condensers or of the insulation of the secondary winding.

THE TRANSMITTING SET.

The choke coil is a term applied to a form of reactance connected in the leads from the secondary of the step-up transformer. The function of the choke coil is to prevent the passage of the high frequency, high potential energy of the closed oscillatory circuit back into the secondary. The resistance which a reactance offers to the passage of an alternating current depends directly on the frequency. If the frequency is high the resistance to the current offered by the counter e. m. f. will be high; but if a low frequency current is flowing the resistance will be low. Hence, the low frequency, high potential current from the secondary may pass to the condenser, but the high frequency, high potential current of the closed circuit cannot pass back into the secondary of the step-up transformer. If the current produced by the discharge of the condenser is allowed to pass back into the secondary, it is liable to puncture the insulation of the windings.

The condenser in many ship sets consists of a battery of copper-plated Leyden jars. The oil plate condenser is rapidly becoming obsolete, and is found only on ships equipped several years ago. The condenser is difficult to repair in case of puncture of the dieletric, while the Leyden jar can be replaced instantantously. The compressed air condenser is employed in several large stations, but is very seldom found in low power sets. A new type of condenser which promises to replace practically all the old types of transmitting condensers is the *Dubilier mica condenser.* It has the advantage of being self-healing in case of puncture and of being economical in space. The function of any condenser is to produce high frequency oscillations.

The charging circuit includes the secondary of the step-up transformer, the choke coils, the safety gap and the condenser. It is traversed by a low frequency, high potential current ranging in voltage from 7,500 to 30,000 volts.

The spark gap. *The function of the spark gap is to prevent the discharge of the condenser until the latter is charged to the proper potential and then to form an easy path for the discharge, after which it returns to its former state of high resistance.* For many years the straight gap shown in Fig. 64 was used, but due to its inefficient action has become obsolete. It consists of two rods of zinc about ⅜-inch in diameter and separated a distance of ¼ to 1½ inches, depending upon the power employed. Radiating fins are sometimes placed on the rods in order to cool the gap quickly. The great disadvantage of this gap is that it does not regain its state of high resistance quickly enough after a discharge, and therefore the next discharge of the condenser will occur too quickly. The ideal closed circuit stops oscillating as soon as the oscillations have been built up in the aerial circuit.

There are two types of *rotary gap,* the *non-synchronous* and the *synchronous.*

One type of non-synchronous gap is shown in Fig. 65. In another form, a disc having a number of electrodes arranged about its outer edge is placed on the shaft of a small motor. Two stationary electrodes are placed on opposite sides of the disc so that the spark occurs from one electrode to one of the disc electrodes and then to the other stationary electrode. In another form a number of electrodes are placed in the shape of a circle on two semi-circular frames in such a way that the electrodes face the center of a circle. One terminal of the condenesr is connected to one of the semi-circular frames, and the other terminal of the closed circuit is connected to the other frame. A metallic bar is placed on the shaft of a small motor and revolves within the circle of stationary elec-

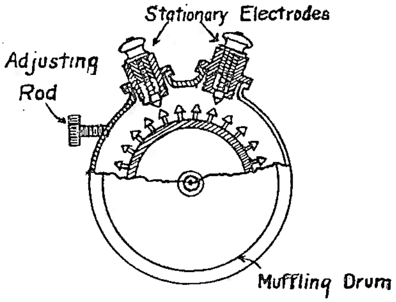

Fig. 66. Synchronous Rotary Gap.

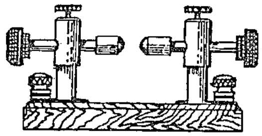

Fig. 64. Straight Gap.

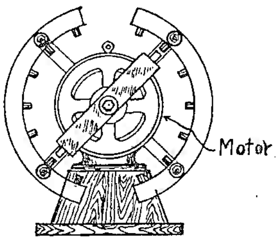

Fig. 65. Non-Synchronous Gap.

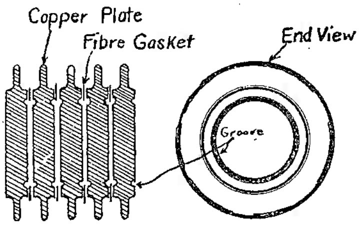

Fig. 67 Cross-section of Quenched Gap.

trodes. The metallic bar has an electrode on either end, and when the condenser discharges, the spark occurs from one of the electrodes on one of the frames to the revolving bar and thence to the corresponding electrode on the other frame. This type is shown in Fig. 65. Either type of gap has a speed of 1800 to 2500 revolutions, and due to the large number of dischargings of the condenser *a more musical note* is obtained with the non-synchronous gap than with the straight. Every time the revolving electrodes come opposite the stationary electrodes a discharge occurs, and the spark frequency will be equal to the number of electrodes multiplied by the revolutions per second. In the case of the non-synchronous gap having ten electrodes and a speed of 40 revolutions per second, the spark frequency would be 400 per second. Hence, the *spark frequency may be defined as the number of discharges of the condenser occurring per second. An advantage of the non-synchronous gap is that it produces a musical note from a 60 cycle source of supply.* It also has the *advantage of cooling itself* and thus quenching the oscillations in the closed circuit after the aerial is set into oscillation. The motor of a non-synchronous gap is usually driven at such a speed that 300 to 400 discharges occur per second.

The synchronous gap consists of a disc placed on the shaft of the motor generator and a number of electrodes equal to the number of field poles of the generator. The disc being on the shaft must revolve at the same speed as the generator armature. Two stationary electrodes are placed as shown in Fig. 66, being separated from the revolving electrodes a distance of about .005 of an inch. In a previous instruction paper we learned that one alternation occurs each time the armature winding passes a field pole. *Hence, if at the instant an alternation is produced, two electrodes on the disc are brought opposite the stationary electrodes, the condenser being charged by the alternation will discharge across the gaps.* The alternation places a charge on the condenser and the condenser discharges almost instantaneously. *The reason that this type of gap is called synchronous is that the discharge occurs at the same instant as the alternation.* The *advantage* of this gap over the others is that it gives a *uniform discharge and each discharge has the same power as another.* This gap is used on many of the high power damped wave stations, and is the only type that can be used for very high powers. When used with the 500 cycle generator, 1000 discharges occur per second and a *high, clear note* in the phones of the receiving station is the result. This is the only frequency that can be used to any advantage in the tropical regions, where the atmospherics are bad. *A third advantage* is that it tends to prevent the oscillations in the aerial circuit from being transferred to the closed circuit and therefore brings about better radiation. *A fourth advantage* is that this gap can handle very large powers. As seen in the figure, the gaps are surrounded by a muffling drum which deadens the sound of the spark and at the same time produces a blast of air for cooling of a quenched gap. The synchronous gap illustrated in an example of the type used on the Marconi Panel sets. An adjusting handle is shown in the figure, which allows the most suitable sparking point to be found. It allows a rotation of the stationary electrodes through a small arc. The distance between the stationary and movable electrodes is actually greater than the value of .005 inch stated above, because the condenser will begin to discharge before the disc electrode reaches its closest position to the stationary and will continue to discharge until the electrode has passed the stationary electrode a certain distance.

The quenched gap is the most efficient spark gap in use. As shown in Fig. 67, it consists of a number of copper discs from three to six inches in diameter and separated by insulating washers of micanite, treated paper, fibre, or other insulating material. This type is merely a series gap with a space of about .01 inch between the discs. The sparking surfaces in the case of the six-inch size of disc are about two and one-half inches in diameter. At the outer edge of the sparking surface a circular groove is cut in the disc so as to prevent the spark from carbonizing the insulating washer and thus shortcircuiting the gap. The space between the copper discs is airtight which helps to quench the oscillations at the end of a discharge and at the same time renders the discharge noiseless. In the Marconi type, 1,200 volts per gap are required for efficient operation.

The advantages of this type of gap are:

1. *It quenches the oscillations in the closed oscillation circuit at the completion of the discharge and thus allows the aerial circuit to oscillate at its own frequency and damping.*

2. *Due to the above, the secondary and primary may be placed in very close inductive relation to each other, thus insuring a maximum transfer of energy to the aerial and hence a large radiation of energy.*

3. *It has no moving parts.*

4. *It is noiseless.*

5. *It is synchronous if adjusted properly.*

6. *It allows the employment of the low voltage transformers.*

By quenching of the oscillations we mean that the oscillations in a circuit are brought to an end. All that is required of the closed oscillation circuit when the condenser discharges across the gap is that it oscillate only long enough to set up oscillation in the aerial circuit of the proper amplitude. Thus, the condenser is charged by one alternation, a discharge of the condenser occurs across the quenched gap and oscillations occur in the closed circuit. As soon as these oscillations die down to a very low value, the resistance of the gap becomes very great and prevents the induced oscillations in the aerial from setting up oscillations back in the closed circuit. With the straight gap, as soon as the spark discharge occurs, the air between the electrodes becomes heated and ionized and hence reduces the resistance to a very low rate. Oscillations are induced in the aerial circuit, which by setting up lines of force about the primary induces a current back into the closed circuit. This transfer and retransfer causes alternately an increase and decrease of the inductance of the aerial circuit with a consequent increase and decrease of the wave length. This causes the simultaneous radiation of two waves of different length and consequently a division of the energy between the two. As it is impossible for a receiving set to receive the energy of two waves at the same time, part of the energy of the transmitter is wasted, and interference is caused.

This action of a straight gap is one of its great disadvantages. To prevent a straight gap from causing the radiation of two waves or a *broad wave* as it is sometimes called, the primary and secondary must be placed considerable distance apart. This separation necessarily reduces the transfer of energy, so a reduced range is the result of the radiation of a strictly sharp wave. With the quenched gap, however, this retransfer of energy is reduced to a very small value, and enables us to place the primary and secondary in very close inductive relation, with the result that there is a large transfer of energy to the aerial circuit.

The primary of the oscillation transformer may consist of a coil of copper wire or tubing wound in the form of a cylinder. In another type it consists of copper ribbon wound in the form of a spiral. In either the inductance may be varied by means of plugs or clips. The *function* of the primary is to *transfer* the energy of the closed circuit to the secondary of the aerial circuit and also to *provide* the inductance of the closed circuit.

The closed oscillation circuit consists of the condenser, the spark gap and the primary of the oscillation transformer. This circuit is the source of the high frequency oscillations that produce electromagnetic waves about the aerial. The condenser discharge is only one of several methods used to produce high frequency oscillations. It is the most common method in use, but is rapidly becoming obsolete in high power radio transmission.

The secondary of the open or radiating circuit may be a coil of heavily insulated wire wound on an insulated cylindrical frame, or may consist of copper ribbon wound in the form of a spiral. This secondary coil is placed in inductive relation to the primary and in series with the aerial and ground. Its function is to absorb the energy of the closed circuit.

The oscillation transformer consists of the primary of the closed circuit and the secondary of the aerial circuit. It is so constructed as to allow a close or loose coupling of the two coils. That is, the secondary may be placed close to the primary or may be placed at various distances from the primary. The helix type is shown in Fig. 68, while the spiral type is shown in Fig. 69.

The aerial changeover switch is a device employed to switch the aerial from the sending to the receiving set or vice versa. When sending, owing to the delicate nature of the receiving apparatus, it ns necessary to disconnect the receiving instruments from the aerial. Upon pressing the key, very high voltages are present in the circuits of the transmitter and aerial, and thus makes necessary the employment of a switch that places a wide gap between the connections of the aerial and the receiver when the switch is in a sending position. The connections of one type are shown in Fig. 70. This switch is so arranged that when in the receiving position, the generator field circuit, the key circuit and the motor blower circuit are open, the aerial and ground being connected to the receiver. When in the sending position the three transmitting circuits are closed, the aerial and ground are connected to the transmitting set and certain delicate parts of the receiver are protected from the high voltages by

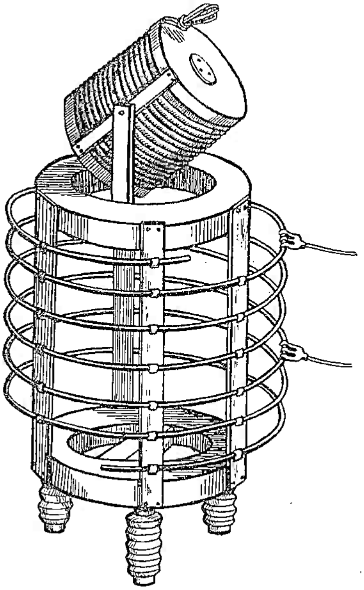

Fig. 68 Helix Type Oscillation Transformer

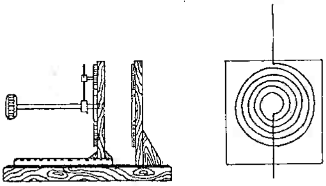

Fig. 69. Spiral Oscillation Transformer

short-circuiting devices on the switch. The reason for opening the generator field circuit while receiving is to reduce the induction from the current flowing in the motor circuits. The key circuit is opened to prevent accidental discharge of condenser while receiving and consequent damage to the receiver. The motor blower, used to keep quenched gap cool, is opened in order to reduce noise while receving faint signals.

This article will be referred to when receiving apparatus is taken up. After studying receiving sets, the student will understand how the aerial changeover switch affects the receiver.

The aerial tuning inductance may consist of a coil of stranded copper wire wound in the form of a cylinder. Another type is made by winding copper strip in the form of a spiral. The inductance may be varied by connecting more or less turns in circuit by means of a clip. *The function of the aerial tuning inductance is to tune the aerial circuit to a wave-length longer than the natural wave-length. (By natural wave-length we mean the wave-length radiated by the aerial and ground alone with no added inductance or capacity.)* In the modern panel type of set this inductance is continuously variable and allows very sharp tuning of the aerial circuit. Due to the high voltages encountered in the aerial circuit the turns of the inductance are separated a half-inch or more and are wound on a hard rubber or procelain support.

The aerial of most ship sets consists of two or more wires stretched between the masts and separated by wooden spreaders. The *function of the aerial of the transmitting set is to radiate energy in the form of electromagnetic waves.* The aerial will be treated very fully in a following instruction paper.

The short wave condenser. We learned that the aerial tuning inductance enables the aerial circuit to be tuned to a wave-length longer than the natural wave-length. *In order to tune the circuit to a wave-length shorter than the natural wave-length, it is necessary to use a short wave condenser.* We learned in a previous paper that the resultant capacity of two condensers in series is *less than* the capacity of either. *The aerial and ground form a condenser* and this capacity combined with the inductance of the aerial gives the aerial circuit a natural wave-length. If this capacity is reduced by placing a condenser in series with the aerial a decrease in wave-length will be the result. In one form of this short wave condenser, two Leyden jars are placed in series with the aerial and in another form several plates of glass coated with tinfoil or copper are placed in series with the aerial. *The reason for having the jars or plates in series is that such a connection increases the dielectric strength of the condenser.*

The aerial ammeter is an instrument connected in series with the aerial and ground, its function being to measure the strength of the current in amperes. This enables the operator to determine whether he is *getting proper radiation from the set and also allows the placing of the aerial and closed circuits in resonance.*

It is usually of the hot wire type, the expansion of a wire from the heating effect of the current being utilized to move a pointer over a calibrated scale. This instrument is fully described in Instruction Paper No. 4.

The ground forms an important part of the aerial circuit and is merely a metallic connection with the moist earth or body of water. In airplanes the ground is replaced by a counter-poise. The counterpoise in most cases is merely the metallic parts of the airplane, such as the engine and guy wires. The aerial consists of a suspended wire or perhaps of a number of wires stretched above the planes. In dry countries, where it is difficult to find moist earth, a counter-poise is made by constructing a network of wires three or four feet above the ground. On shipboard the ground connection is made to the steel hull, except in the case of wooden ships, where connection is made to a sheet of copper or brass fastened to the hull of the ship below the water line. The ground appears to form one plate of a condenser, with the aerial as the other plate.

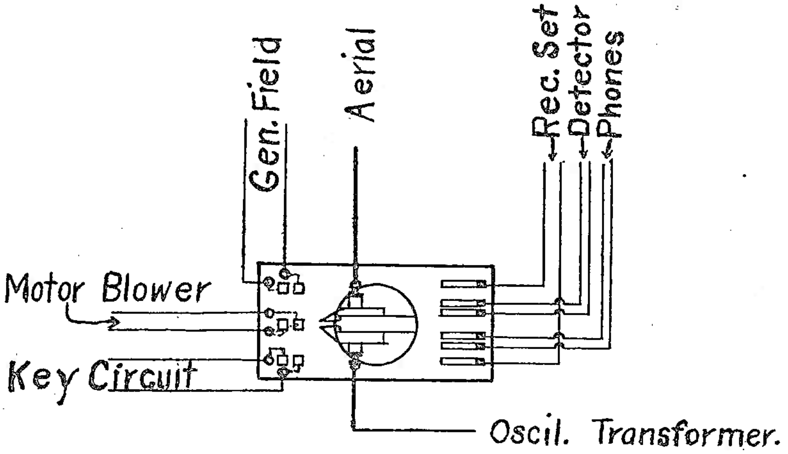

Fig. 70. Aerial Changeover Switch.

The open or radiating circuit consists of the aeriel, aerial switch, aerial tuning inductance, secondary, the aerial ammeter, the short wave condenser and the ground. *This circuit is traversed by high frequency, high potential currents which set up electrostatic* and magnetic strains about the aerial. These strains in the ether radiate in every direction with the same velocity as light.

A Brief Description of the Action of a Transmitting Set.—The generator produces alternating current at a frequency depending upon the speed of the armature and the number of field poles. This frequency in modern panel sets is usually 500 cycles. As the armature passes a field pole one alternation is produced, and as it passes the next field pole of opposite polarity, an alternation of current in the opposite direction is produced. These two alternations constitute a cycle, *and in one revolution of the generator armature the number of cycles will equal the number of field poles divided by two.* This alternating current flows through the key circuit and is broken up into dots and dashes by the key. Each dot has a length of about one-fifteenth second, and therefore in the case of a current having a frequency of 500 cycles per second each dot made by the key will allow 33 cycles or 66 alternations pass through the primary of the transformer. A dash will be about three times as long as a dot, so a total of 99 cycles or 198 alternations will pass each time the key makes a dash.

In passing through the transfomer, the alternating current is raised in voltage from 110-500 to 7,500-30,000, but the frequency remains unchanged. In the charging circuit the high voltage from the secondary charges the condensers, each alternation placing a charge on the condenser when a synchronous gap is used. The condenser immediately discharges across the gap and through the primary of the oscillation transformer. For each dot made by the key there will be 33 cycles or 66 alternations and therefore 66 charges and discharges of the condenser. When the condenser discharges across the gap, a number of oscillations occur in the closed oscillation circuit. *The discharges of the condenser are equal in number to the alternations of the generator, and the number of discharges per second is termed the spark frequency.* The train of oscillations produced by each discharge of the condenser do not have a constant amplitude. That is, each oscillation of the train has a lower amplitude than the oscillation preceding it. *The currents produced by the discharge of a condenser are termed "damped oscillations."* This damping or decrement varies with different circuits. The train of damped oscillations in the closed circuit in flowing through the primary, induces a train of oscillations in the secondary of the aerial circuit. The damping of this train is not necessarily the same as the train in the closed circuit. Usually there are a great many more oscillations in the aerial circuit trains that in the closed circuit trains. When a good spark gap is employed, the resistance of the closed circuit is very high until a discharge occurs, then the resistance drops to a very low value, due to ionization of the air. As soon as the train of oscillations has been set up in the aerial circuit the closed circuit has served its purpose, and hence there is need of only a few oscillations in each train of the closed circuit. The quenched gap regains its state of high resistance as soon as the train dies to zero and thus prevents any retransfer of energy from the open to the closed circuit. The advantage of this action of the quenched gap is that it allows the aerial circuit to oscillate at its own frequency and damping. It is very desirable that the trains in the aerial circuit have as many oscillations as possible because this makes for sharp tuning and prevents interference.

The reason for the quenching of the gap is that when the oscillations die out, the gap immediately cools and thus becomes of very high resistance. The resistance of a gap when no current is passing is several thousand ohms, but when the condenser discharges this drops to about one ohm.

Each train of oscillations in the aerial circuit causes a train of waves to be radiated, each oscillation setting up a wave. *The frequency of the oscillations produced by the discharge of a condenser may be defined as the rate at which they occur, and not the actual number really present in the circuit.*

Nearly every standard marine type of transmitter is provided with means for shifting to wave lengths of 300—450—600 meters by the movement of a handle. This handle operates three contact arms which move in unison and changes the turns of inductance in the closed and open oscillatory circuits, also cuts in and out the short-wave condenser.

The complete wiring diagram and details of these changes will be given in later books.

QUESTIONS

INSTRUCTION PAPER No. 7

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

146. Draw from memory a fundamental circuit diagram of a transmitting set. (Before answering this question, be able to draw from memory).

147. Name the instruments which make up the complete transmitting set.

148. Of what does the key circuit consist?

149. Of what voltage and frequency is the current which flows in the key circuit?

150. Explain the two types of reactance regulator.

151. What is the voltage and frequency of the current which flows in the charging circuit?

152. What instruments are included in the charging circuit?

153. What is the function of the spark gap?

154. Name the different gaps in use.

155. What determines the frequency of the closed circuit?

156. If a synchronous gap is employed, what is the spark frequency when using a 500 cycle motor generator?

157. What are the advantages of the rotary gap over the straight gap?

158. Name the advantages of the quenched gap over the other gaps.

159. What is meant by "quenching of the oscillations?"

160. What is the function of the primary of the oscillation transformer?

161. What is the purpose of the aerial changeover switch?

162. What is the function of the aerial tuning inductance?

163. What is the function of the short wave condenser?

164. Why is the short wave condenser made by placing jars or plates in series?

165. Of what does the aerial circuit consist?

CODE LESSON No. 7

Commercial Form for Recording Radio Messages

Send on Practice Set and Memorize Form:

POZ DE KGJ
P NR 4 WDS 35 RDO FLD 5:02 PM
TO:

The Confection Shop,
22nd and Broadway,
New York City.

Ship at once COD all available supply of candy such as your last shipment Very satisfactory Customers very much pleased with this style of confection
Hybob Confectionery Company

TRANSMISSION OF MESSAGES No. 7

The form consists of:

1. Prefix:
    a. Prefix for any commercial radiogram is the word radio.
2. Office of origin:
    a. This designation shall be transmitted by NAME.
3. Number of message:
    a. Each message shall be numbered in sequence.
4. Check:
    a. Consists of number of words included in the address, text and signature.
5. Date and hour of filing:
    a. Shall always be transmitted to the coastal station.
6. Address and route:
    a. Must consist of at least two words, name of address and destination (ship or city).
7. Text:
    a. Must be sent exactly as received.
8. Signature.
9. End of message:
    a. Message is terminated by ●▬●▬● followed by the call letters of the sending station and by the signal ▬●▬●

Acknowledging or received signal.

1. Send call letters of the station which sent the message.
2. The received signal ●▬●
3. Number of message, or numbers of first and last messages of a series.
4. Call letters of the receiving station.
    Examples:

    NMO ●▬● 1 NAM ▬●▬
    NAR ●▬● 14 NWQ ▬●▬

Ship kmo sending to nar a plain commercial message filed on board at 4 P. M. of the twelfth after receiving "K."
▬●▬●▬ radio Kingwilliam 2 S twelfth 4 P. M. ▬●●●▬ to Brown 175 King Street New Orleans ▬●●●▬ Arrive tomorrow ▬●●●▬ Jones ●▬●▬● KMO ▬●▬

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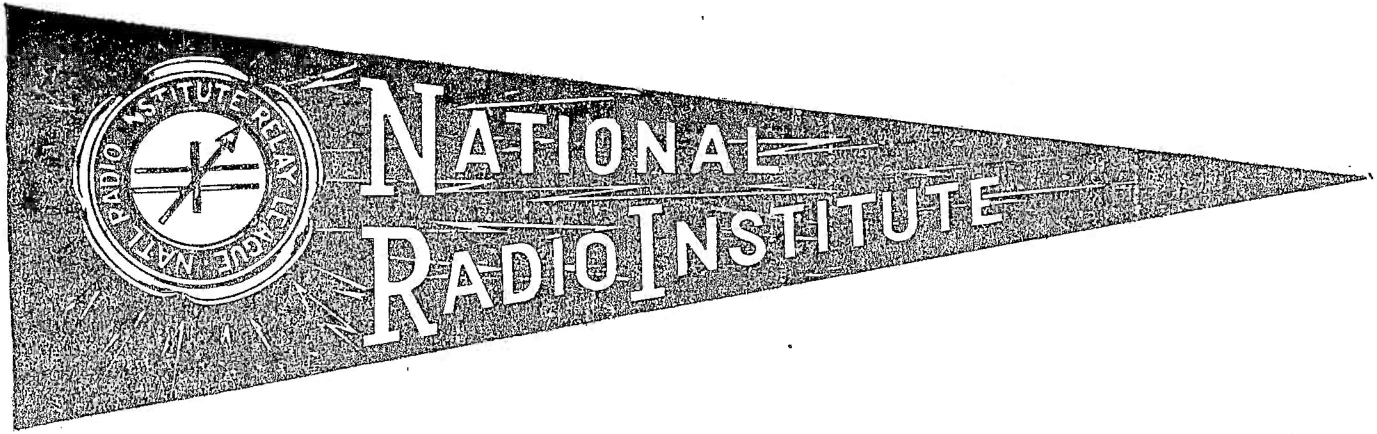
SHOW YOUR COLORS

There's nothing like having a pennant tacked on the wall of your room to show the colors of your school--your colors.

This Institute has just received a supply of beautiful pennants--blue and gold--as the illustration below shows.



Not one student will want to pass up this chance to get a life-long remembrance of the N. R. I. Pennants are used more today than any other emblem to signify enthusiasm and allegiance. A finer emblem can not be had.

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CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

1345 PA. Ave., N. W. WASHINGTON, D. C.

Answers to Instruction Book No. 7

146. See Figure 64.
147. Main line switch, starter, motor generator, field rheostats, protective devices, generator line switch, measuring instruments, power regulator, key, step-up transformer, safety gap, choke coils, transmitting condensers, spark gap, oscillation transformer, aerial tuning inductance, short wave condenser, hot wire ammeter and ground.
148. The key circuit contains the A. C. generator armature, line switch, protective device, voltmeter, ammeter, wattmeter, key, power regulator, and primary or low tension side of the step-up transformer.
149. 110 volts and 500 cycles.
150. There are two types of power or reactance regulators. First type has taps brought on from a coil, wound on an iron core to contact points so the number of turns of inductance can be varied. The second type has a fixed number of turns on an iron core which is movable, and drawing the iron core out of the coil the inductance is lessened, or reduced.
151. 500 cycles at voltages from 7,500 to 30,000.
152. The charging or high tension power circuit contains the secondary or high tension side of the step up transformer, safety gap, choke coil, and transmitting condensers.
153. The spark gap allows the transmitting condensers to charge to the proper amount and then discharge thru the closed oscillatory circuit, offering a small resistance.
154. Plain or straight gap, synchronous rotary gap, non-synchronous gap and quenched gap.
155. The frequency of the closed oscillatory circuit depends on the product of the capacity and inductance in this circuit.
156. The spark frequency would be 1,000 per second.
157. It gives a better note, offers less resistance during discharge, better insulation discharges, and keeps much cooler.
158. The advantages of the quenched gap are: The quenching of the oscilltions near the end of each wave train when the energy becomes small; a closer coupling which allows a transfer of maximum energy to the aerial circuit; noiseless; no moving parts; it is a synchronous when properly adjusted, and the use of a lower voltage transformer.
159. Quenching of the oscillations means that the oscillations are stopped by the action of the gap when the amplitude of wave is built up in the open circuit and becomes very small in the closed circuit. This allows time for gap to cool off and prevents energy working back from the open into the closed circuit.
160. The primary of the oscillation transformer serves two purposes. First, to act as a variable induction to adjust the closed circuit to a given wave length; and second, it acts to transfer this energy from the closed to the open circuit.
161. The aerial change-over switch is to change the electrical connections from the sending to the receiving apparatus and vice versa as desired.
162. The aerial tuning inductance is used to adjust the radiating (or aerial) circuit to a wave length longer than that obtainable by the secondary coil of the oscillation transformer.
163. The short wave condenser is placed in series with the open circuit to obtain wave lengths shorter than those obtained otherwise.
164. Placing the jars in series, causing them to stand a greater dielectric strain and also decrease the capacity which is desired.
165. The open or radiating circuit consists of the aerial, aerial switch, loading coil (or aerial tuning inductance), secondary of oscillation transformer, hot wire ammeter, short wave condenser and ground.

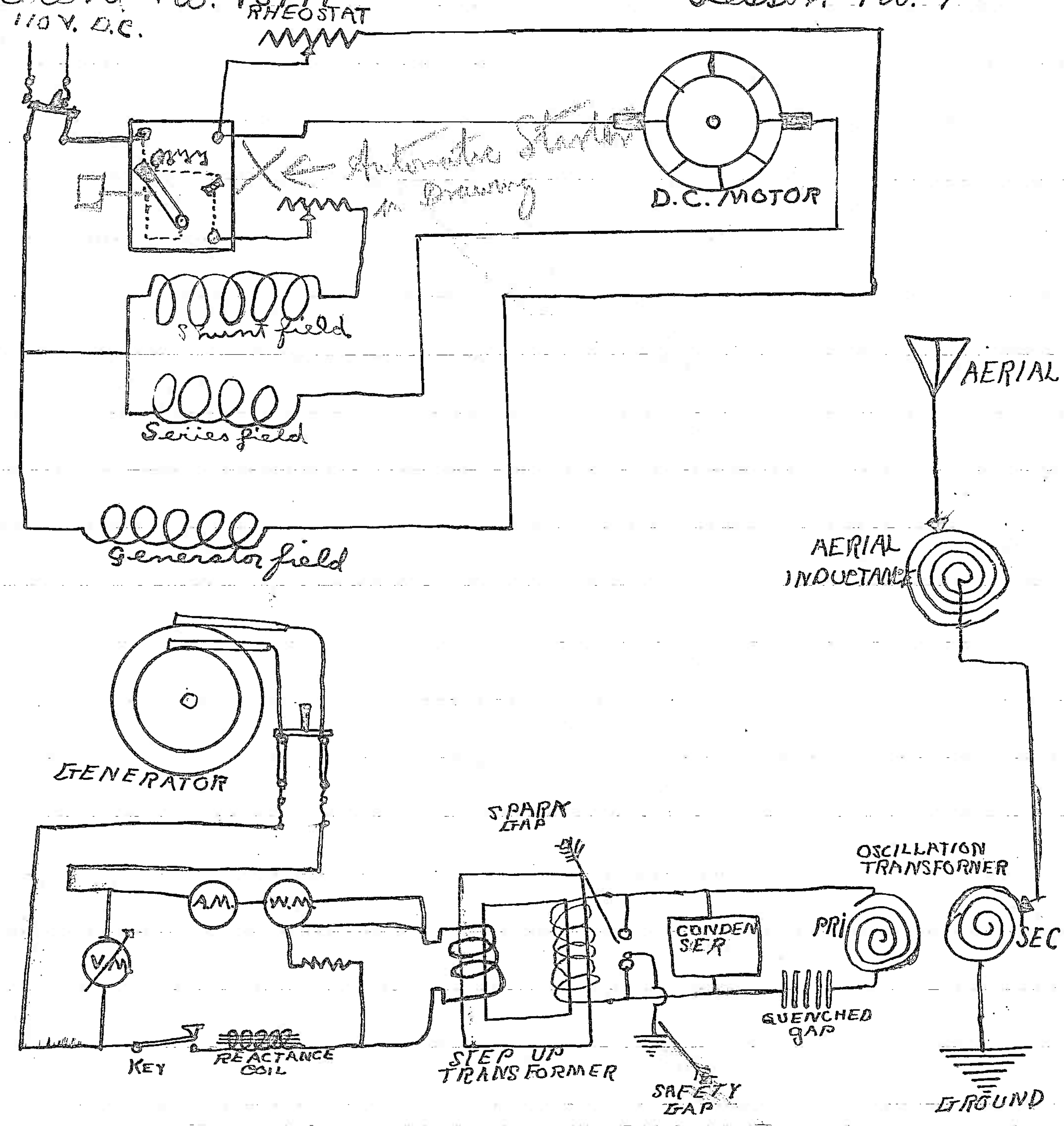
93%

George J. Guderjahn

Student No. 13794

Lesson No. 7

146



Automatic Starter in Drawing

Student No. 13794

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West Salem Ohio

147 1 D.C. Line switch
2 starting box
3 Motor generator
4 A.C. Line switch
5 Volt meter
6 Ammeter
7 Wattmeter
8 Reactance coil
9 Key
10 step up transformer
11 spark gap
12 safety gap
13 condenser
14 quenched gap
15 oscillation transformer
16 Aerial inductance
17 Aerial

148 The key circuit consists of a A.C. Line switch, voltmeter ammeter, wattmeter, reactance coil, key, and the primary of the stepup transformer. and

George J. Gudejahn

Student No 13797

ature of the A.C. Generator.

tage ranges from 110 to 500 volts

quency . . . . 60 to 600 cycles

eactance regulator is a device used to regulate the current flow to the primary of the transformer, it is placed in series with the transformer. The first type consists of one or more layers of heavy insulated wire wound on an iron core. this wire is then tapped in several different turns and then by means of a variable switch the reactance is varied.

The second is also a coil of heavy wire wound on an iron core which is moveable. By pulling the iron core in or out the reactance is varied.

151 The voltage ranges from 7000 to 30.000 volts in low power Radio sets.

The frequency is low and ranges from about 60 to 500 cycles in commercial sets.

152 The charging circuit consists of the secondary of the step up transformer, spark gap

Student No. 13794 George J. Gudeijahn

safety gap. Condenser, quenched gap and primary of oscillation transformer.

153 The function of the spark gap is to prevent the discharge of the condenser until it is charged to the proper potential and then to form an easy path for the discharge, after which it returns to its former state of high resistance.

154 The different gaps in use are straight gap, quenched gap. Non synchronous rotary gap, and the synchronous gap.

155 The frequency of a closed circuit is determined by the no. of poles of the a.c. generator and the rate at which the armature revolves.

156 The spark frequency would be 1000

157 The advantage of the Rotary gap over the straight gap is it produces a clear sharp note from a 60 cycle current, cuts down damping, and unlike the straight gap, uses nearly all of the energy in one wave instead of dividing it into two waves of

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different lengths as in the straight gap. It has the advantage of cooling itself.

158 The advantages of the quenched gap over the rest of the gaps are, it is noiseless, no mooving parts to adjust, It quenches the oscillations as soon as the discharge takes place and allows the aerial circuit to oscillate at its own frequency. and also low voltage transformers may be used

159 We mean by quenching of the oscillations of a circuit, that they are brought to an end. That is the oscillations need only to oscillate long enough to set up oscillations in the aerial circuit of the proper amplitude. if then a quenched gap is used these oscillations will be put an end to or stopped. before the condenser again discharges setting up other oscillations. therefore the two will not run together and cause two distinct waves of different

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lengths to be radiated from the aerial.

#160 The function of the primary of the oscillation transformer is to transfer the energy of the closed circuit to the secondary of the aerial circuit and also to give inductance to the closed circuit.

161 The purpose of the aerial change over switch is to provide means of changing from sending to receiving or vice versa.

162 The function of the aerial tuning inductance is to tune the aerial circuit to a wave length longer than the natural wave length or that wave length radiated by the aerial and ground alone.

163 The function of the short wave condenser is to radiate a wave shorter than the natural wave length of the aerial and ground.

164 a short wave condenser is made by placing jars or plates in series because in that way the dielectric strength of the condenser is strengthened

-(OVER)-

165 The Aerial circuit consists of.

1. Secondary of step up transformer.
2. spark gap
3. safety gap
4. Condensers.
5. Primary of oscillation transformer
6. Secondary . . . .
7. Ground
8 short wave condenser
9 Aerial inductance
10 Aerial .

LESSON TEXT No. 8

OF A

Complete Course in Radio Telegraphy

The Antenna

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 8

In General. In the previous instruction paper, in the discussion of a transmitting set, we explained the function of the apparatus employed in the oscillatory circuit. In this paper, we will discuss in detail those parts of the open circuit which actually produce the electro-magnetic waves in the ether. These parts are known as the aerial and ground. Some writers use the term antenna in place of aerial. The report of the standardization committee of the Institute of Radio Engineers defines the term antenna as follows: **Antenna.—A system of conductors designed for radiating or absorbing the energy of electromagnetic waves.** Dr. Zenneck in his book "Wireless Telegraphy" defines **"Antenna" as the open oscillatory circuit" and "aerial" as that part of the antenna which is elevated.** A majority of the radio engineers use the term interchangeably. The function of an aerial is twofold:

1. **To radiate energy in the form of electromagnetic waves.**

2. **To absorb energy from passing electromagnetc waves.**

Previous to 1888, Heinrich Hertz had set up electromagnetic waves by using two metallic plates in place of an aerial and ground. Hertz found that, if a spark gap was energized by an induction coil and the two metallic plates were connected to either side of the gap, oscillations would occur in the circuit made by the two plates and spark gap. The apparatus was termed the Hertzian oscillator and the waves set up by it were called Hertzian waves. The ether (the invisible medium supposed to permeate all space) in the vicinity of the metallic plates is alternately electrically and magnetically strained. That is, as the current flows to or from the metallic plates, the ether is magnetically strained, but during the time the electricity resides in the plates, the ether is electrically or electrostatically strained. These experiments of Hertz were the first to be made using an open oscillatory circuit.

Professor Popoff of Kronstadt, Russia, seems to have been the first to use an elevated wire as one terminal of the open oscillating circuit.

In 1895, Marconi employed a wire raised high in the air as one terminal of the oscillating circuit and the ground as the other terminal.

In 1897, Marconi, by the use of an elevated wire, was able to communicate a distance of about 45 miles, and had discovered that by increasing the height of the elevated wire, the distance of transmission could be increased.

In 1901, he communicated a distance of 200 miles, using an aerial 300 feet high. It was formerly the belief that electric waves were propagated in straight lines, similar to light waves, but after this notable experiment by Marconi, it was disclosed that electric waves seem to follow the curvature of the earth, and that the range increased in proportion to the height of the aerial.

The open oscillating circuit, open radiating circuit, aerial circuit and the antenna circuit all refer to the circuit consisting of the aerial, inductance coils, series condenser, ammeter and ground. While this paper deals with the subject of antenna, it should be understood that this includes the action of the ground. When oscillating currents flow in the aerial circuit, the ground and aerial are charged alternately, neither being more important than the other in the radiation of waves. Recent radio developments lead modern radio engineers to believe, that for receiving purposes at least, there is no necessity for an elaborate and costly aerial system. The invention of the underground and loop aerials give promise of very simple and compact aerials in the future. Air craft radio sets make use of an aerial wire and in place of a ground, use the metallic parts of the airplane or dirigible, such as the engine, guy wires, etc.

The student should understand that **the aerial and ground form a condenser, the aerial wires being one plate and the ground the other with air as the dielectric.** The two important properties of radio circuits, inductance and capacity, are possessed by the aerial circuit. The length, number, and height of the aerial wires determine the capacity and inductance possessed by the aerial. If we increase the size of the aerial, we increase its capacity and this will change the length of the radiated wave. The wave length of an open oscillatory circuit may be calculated from the formula:

$$\text{Wave length}=38\sqrt{LC}.$$

where L=Inductance in centimeters.
C=Capacity in mfds

This formula only holds true with those aerial circuits having no coils in series with the aerial and ground. Hence, it can be seen that the size of an aerial depends upon the length of the wave to be radiated. The selection of the wavelength to be employed depends upon two factors:

1. **The power of the transmitter.**

2. **Space available for erection.**

It can be shown that the power, a given aerial can handle depends upon the capacity of the aerial, and upon the voltage of the charging current. Hence, in order that power sufficient to transmit messages a given distance may be efficiently handled it is necessary to have an aerial of the proper dimensions.

The space available for erection of an aerial determines the type of aerial and to a certain extent the power employed.

THE ANTENNA

The length of wave radiated by an oscillatory circuit, consisting merely of aerial and ground is called the natural wavelength. To increase the length of the waves radiated it is necessary to add inductance in the form of a coil and to decrease the wave length, it is necessary to employ a short wave condenser. A coil of wire used for increasing the radiated wavelength is called a concentrated inductance. To calculate the length of wave radiated with such a coil in the aerial circuit a new formula must be employed.

$$\text{Wave length} = 59.6\sqrt{LC}.$$

The reason for this is, that, in the first case the inductance was distributed over the whole circuit, while in the latter, concentrated inductance is present in the coil. An aerial will not be efficient with a radiated wave length greater than four times the natural wave length of the aerial circuit. Hence, there is a limit to the size of the concentrated inductance in the circuit. The student should remember that the natural wavelength of an aerial depends upon the height, length and number of wires in the air. The natural wavelength of a simple horizontal aerial may be determined in an approximate manner by multiplying the total length of aerial and lead-in by 4.5.

Types of Aerial. Modern types of aerials may be classified as follows:

1. Vertical aerials.
2. Inverted L.
3. T type.
4. Umbrella type.
5. Triangular aerials.
6. Rogers underground aerial.
7. Loop aerials.
8. Weagant.

The most simple form of aerial is the vertical wire suspended by an insulator from a mast. This is the type used by Marconi in 1896. A later development of the **vertical aerial** consists of a number of vertical wires arranged in the form of a fan, being connected to one conductor at the lower end and then connected to apparatus. The upper ends of the wires, in such an aerial, should be well insulated. The vertical aerial radiates as well in one direction as in another, but equally as good results may be obtained with a less expensive type of aerial. It is not suitable for ship sets due to the fact that the ship's smokestack and derricks would not permit its erection. The vertical aerial is not used at the present time except for airplanes, balloons and dirigibles.

The inverted L flat top aerial is merely a horizontal continuation of a vertical aerial, as shown in Fig. 71. It was invented by Marconi in 1905 and proved very efficient for long range communication, due to the fact that it is directional. That is, it radiates energy in a direction opposite to the free end, better than in any other direction. The action of the horizontal directional aerial in receiving, is to absorb energy from a direction opposite to the free end. Thus, a directional aerial on the Atlantic coast for reception from Europe would have its free end pointing west from the receiving station. In high power stations, this hori-

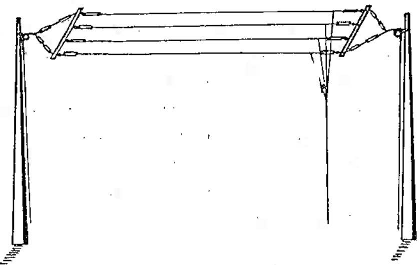

Fig. 71. Inverted L Aerial.

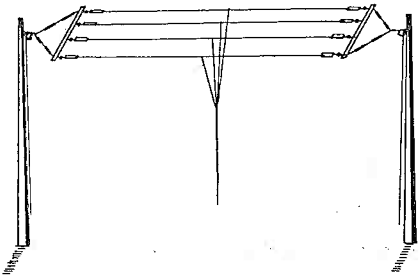

Fig. 72. T Aerial.

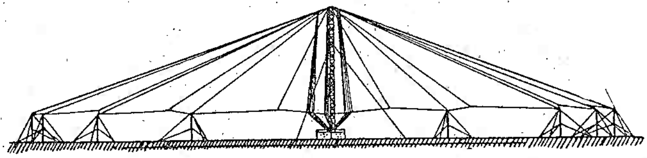

Fig. 73. Umbrella Type of Aerial.

zontal aerial may be over a mile in length, consisting in the case of a transmitting station of a large number of wires spaced three or more feet apart and in the receiving aerial of two wires. This is the type used in the high power stations of the Marconi Company. This type is also used on a majority of ships equipped with wireless. It is especially adapted to ships, the wires being strung up between the masts above all of the ship equipment. The lead-in to the instruments can usually be connected so as to cause but little inconvenience in the operation of the ship.

The "T" type aerial is very similar to the inverted L, the only difference being that the aerial lead-in is connected at or near the middle of the horizontal stretch of wires, instead of at the end. The T type, shown in Fig. 72, is used on those ships whose horizontal stretch is so very long that with the inverted connection, the natural wave length depends upon the distance from the apparatus to the free end of the aerial, we can see that the T type would have a smaller natural wave-length. The T type aerial merely reduces the inductance and not the capacity of an aerial.

The Umbrella Type Aerial. This aerial derives its name from its form. It consists as shown in Fig. 73 of a tall mast from the top of which many wires radiate to shorter masts arranged in a circle about the larger mast. The lead-in extends from the station to the ends of wires meeting at the top of the large mast. This type of aerial is employed in German high-power stations and in a number of army stations of the United States built several years ago. It is also employed in some portable sets, but is becoming obsolete, due to the greater efficiency of more modern types. It is not as good a radiator as the horizontal aerial, but the waves which it sets up possess good tuning qualities. That is, the signals from a station employing an umbrella aerial are confined practically to one wavelength and do not cause much interference to stations receiving other wavelengths.

The triangular or V type of aerial is supported by three masts and may be horizontal or inclined. It has directional characteristics.

The Underground Aerial. This aerial is a development made by Dr. Rogers during the world war. It is a radical departure from old methods and has given very striking results, but is still in an experimental stage. Its possibilities for transmitting are apparently slight, but future experiments may cause it to be adapted for both sending and receiving purposes. At the present time it is used to some extent for receiving long distance stations.

One method of construction of the underground aerial is as follows: Wires either bare or insulated are buried to a depth of three feet in trenches radiating from the receiving apparatus. The length of these wires depends upon the wavelengths of the stations to be received. This aerial gives better signals in the receiver when in fresh water or very wet ground.

The advantages of the underground aerial are, that it enables a transmitting station to be received without interference from others, that it reduces to a considerable extent the interference caused by static, and that the cost of construction is comparatively small. It has been stated that this aerial is far superior to the raised or elevated aerial when receiving from long wave stations. The reason the underground aerial allows reception without interference is due to its directional effect. It receives best in the direction in which the aerial wires are laid. In Fig. 74 is shown a diagram of the underground aerial. As shown in the figure the receiving sets is connected in series with two buried conductors. In the discussion of the elevated aerial, we mentioned the fact that the aerial and ground form a condenser. In the case of the underground aerial the wires form a condenser with the ground, the difference being that the dielectric is very much thinner. The second advantage, that of reduction of static interference, is due probably to the fact that the earth shields the wires and prevents the picking up of all stray waves.

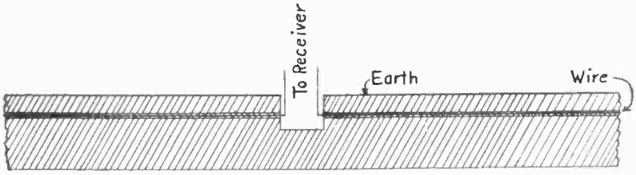

Fig. 74 Roger's Underground Aerial.

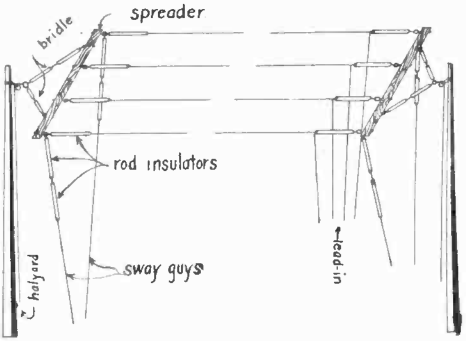

Fig. 75. Marconi Ship Aerial

(By static interference, we have reference to the stray waves set up in the ether by lightning and by other unknown causes. These strays, as they are sometimes termed, in certain regions and at certain seasons reduce the efficiency of a receiving set by being louder than the signals.) This reduction of static is not total and at certain times the static seems as bad on the underground aerial as on the elevated, but the former allows reception even during the most severe electrical storms, when receivers using the elevated aerial find it necessary to suspend work.

The Loop Aerial. This is another development brought out during war times, and which possesses certain advantages over both the elevated and the underground. It might be stated here, that the development of the underground areial and the loop aerial are the result of the wonderful increase in sensitiveness of detecting instruments. It can be proved, that the underground aerial, the loop and the tree wireless were tried years ago, but owing to the insensitiveness of detectors at that time very poor results were obtained.

The loop aerial consists of either a frame several feet square, having many turns of wire wound on it or of a spiral coil wound on a flat frame. The terminals of the loop are connected to the receiving apparatus in the same manner as an aerial and ground in the old type of receiver. It does not give the intensity of signals that the elevated or underground aerial does, but has the advantage of compactness and economy of space. It was used in the trenches during the world war to some extent, having the double advantage of secrecy and safety. If a loop 4 to 8 feet square with 50 or more turns of wire is employed in conjunction with suitable receiving apparatus, the signals from European stations may be copied.

The Weagant Anti-static Aerial. This is an invention recently made by Mr. Roy Weagant, Chief Engineer of the American Marconi Company. This aerial consists of two low horizontal loops extending out from the receiving aerial, one pointing in one direction and the other in the opposite direction. In one arrangement the space between the wires of each loop was 15 feet, each loop being about 3 miles in length and suspended by masts 30 feet in height. Special receiving apparatus is used with this type of aerial to bring about the elimination of static. This invention, although it gives very good results at the present time, is still in the experimental stage. Hitherto, at certain seasons of the year, it was impossible to do continuous receiving owing to the effects of static, but according to the claims of the inventor, with the new invention, such reception is now possible not only with lesser amounts of power, but with a much less expensive antenna structure at the receiving station. He also states that the great barrier in the way of high speed telegraphy as well as satisfactory radio telephony has been removed by his invention.

Type I Aerial Switch. The wiring connections for type I aerial change over switch is shown in fig. 75-A. The binding posts 2, 4 and 5 short-circuit the crystal detector and the head telephones during transmission. Binding post No. I connect to aerial binding post No. I of the type 106 tuner. Contacts 11 and 12 close the circuit to the primary winding of the transformer. Binding posts 7 and 8 close circuit to Automatic Starter. Binding posts 9 and 10 close circuit to Generator Field. The binding posts 6, 7, 8 and 9 of the type 106 tuner are connected to the four binding posts of the battery box as shown.

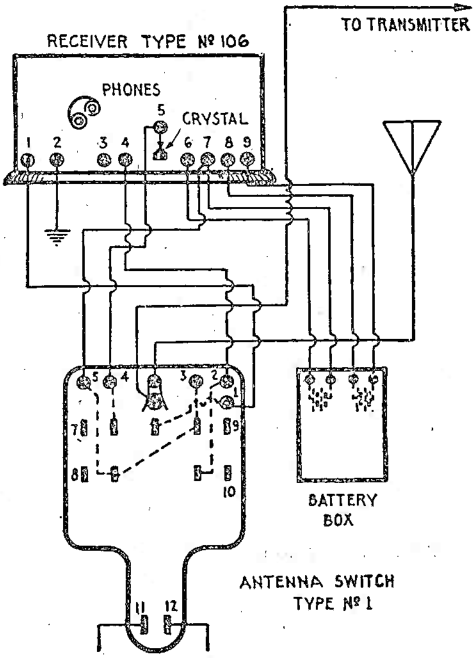

Fig. 75A.

The Ship's Aerial. The aerial in which the student of this course is especially interested, is that used aboard ships. In the majority of vessels, especially of the passenger or freight type, the "Inverted L" or "T" type is being employed. The length of the horizontal portion of the ship's aerial depends upon the distance between the ship's masts. This ranges from 75 to 250 feet and the height above the water from 50 to 150 feet.

The number of wires varies from 2 to 8, the majority of ship aerials having from 4 to 6 wires. Large vessels usually employ 2 wires, while small vessels may have from 4 to 8. These wires are spaced from 2½ to 4 feet apart. Silicon bronze or phosphor bronze stranded wire is used, each cable consisting of 7 strands of No. 21 bare wire. Hard drawn copper or aluminum wire may be used but have less elasticity and tensile strength than silicon or phosphor bronze wire. Stranded wire is used because such construction reduces the resistance of the conductor to high frequency currents.

Ships sets employ wavelengths ranging from 300 to 600 with corresponding frequencies ranging from 1,000,000 to 500,000 oscillations per second. Currents of the above frequencies oscillate in the aerial circuits and as they travel on the outer layers of a conductor, it is necessary to provide aerial wires having proper surface area. Unless low resistance conductors are provided, much energy will be converted into heat. The resistance of many ship aerials is as low as 2 ohms. Not only is energy lost by high resistance of the aerial circuit but the trains of oscillations are damped out with the result that a broad wave is radiated. (By broad wave, we mean a wave which can be heard over a wide range of wave lengths and consequently cause interference to other stations.)

In erecting an aerial, spreaders are used to keep the wires spaced the correct distance apart. They are usually of spruce and range from 12 to 20 feet in length. To attach the spreader to the supporting halyard, an arrangement called a bridle is attached to the ends of the spreader, as shown in Fig. 75. This bridle is of marlin rope threaded through hollow hard rubber tubes. The space between the tubes and the rope is filled with melted sulphur, which after hardening serves to keep moisture out of the rope. The middle portion of the bridle is fastened by a shackle to the galvanized steel cable called a halyard. The halyard passes through the pulley or block at the top of the mast, and is fastened to a cleat at the bottom. The aerial wires are insulated from the spreader by hard rubber rod, electrose or by porcelain insulators. In some installations the only insulation is that between the spreader and the halyard.

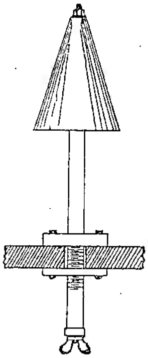

Fig. 76. Bradfield Deck Tube.

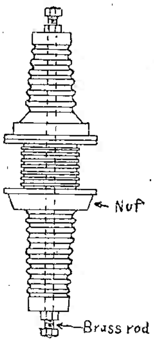

Fig. 77. Electrose Deck Insulator.

To prevent the aerial from being twisted by the wind, guy ropes are attached to the ends of the spreaders and fastened to a lower part of the mast. Two hard rubber rods are connected between the spreader and the rope to prevent leakage in wet weather.

In the inverted L type the lead-in wires are attached to the end of the stretch wires. The lead-in consists of as many wires as are in the aerial wires. These wires converge at the lower end where the lead-in is attached to the apparatus.

The International regulations require that a ship be equipped to send and receive waves of 300 and 600 meters and the United States regulations give the standard ship wave lengths as 300, 450 and 600 meters.

In designing an aerial for a ship it is necessary to take into consideration what dimensions will cause a maximum radiation on all three of the standard wavelengths. In order to get efficient radiation on the principal wavelengths of 600 meters it is necessary to have a natural wavelength less than 600 meters. As stated in another part of this instruction paper, the natural wavelength depends upon the length of the aerial and lead-in, the number of wires, their height above the water and the spacing between them. It is also somewhat affected by the proximity of metallic structures near the aerial, such as masts, smokestacks and guy wires. An approximate value of the natural wavelength may be calculated by multiplying the length of the aerial and lead-in by 4.5. Most ships have a natural wavelength ranging between 300 and 500 meters. With such natural wavelengths, to radiate a 600-meter wave it is necessary to add inductance in series with the aeral. To get a 300-meter and 450-meter wave, it is necessary to use a short wave condenser in series with the aerial to reduce its effective capacity. In case the natural wavelength is less than 450 but greater than 300 meters it will be necessary to use the short wave condenser, only for the latter wavelength. The capacity of ship aerials range from .0009 to .0015 microfarads as a general rule.

The Deck Insulator. Many different forms of deck insulators are in use. This device is employed to connect the apparatus in the radio cabin with the aerial lead-in. Owing to the high voltage produced by the transmitter the deck insulator must withstand 30,000 volts potential. The American Marconi Company employs two types, called the Bradfield Tube and the Electrose deck insulator. The first type, shown in Fig. 76, is a hard rubber tube about 2 inches in outside diameter and several feet in length. A brass rod extends through the hard rubber tube and is threaded on both ends. A funnel-shaped metal hood is placed over the top of the tube and serves to protect it from moisture. The brass rod extends through this hood, and is connected to the lead-in by means of a nut. At the point where the tube goes through the deck, it is threaded and is held in place by two wooden blocks screwed on the threaded tube, one above and the other below deck.

The electrose deck insulator, shown in Fig. 77, is moulded about a brass rod and has a corrugated surface. It is held to the deck in a similar manner to the Bradfield Tube, a threaded electrose nut being used instead of wood to clamp it to the deck. On account of the extensive surface supplied by the corrugations, it is difficult for leakage to occur over the surface of the insulator to the deck.

The Ground Connection. The necessity for a ground has been discussed quite fully in preceding papers as well as in the early part of this paper. Some parts of the earth's surface are much more conductive than others. Moist earth or sea water form the most conductive ground obtainable, but wherever the soil is dry or rocky, it is difficult to get a suitable ground connection. It is very necessary that the ground be of high conductivity if efficient results are to be obtained.

The lead from the apparatus to the ground connection should be short and of very high conductivity. The flow of current in the aerial circuit is greater at the ground connection than at any other part of the aerial circuit, while the voltage is of less value at this point than at any other part of the circuit.

In the case of steel ships, the ground is obtained by connecting the apparatus directly to the steel deck of the radio room.

In wooden ships it is necessary to place a copper plate on the hull of the ship below the waterline and have as short a lead as possible connecting it with the apparatus. In some wooden steamers, the ground lead is connected to the propeller shaft, making contact with water by means of the propeller.

In land stations, zinc or copper plates are buried to a depth which will insure connection to moist earth.

In high-power land stations, a very elaborate ground arrangement is employed. A number of large zinc plates are buried in the ground in the form of a circle, making connection with the station in the center of the circle by means of large copper conductors. From the large plates other conductors lead outward radially from the station to other plates buried in the earth. Where the station is located near a body of water metallic plates may be placed in the water and thus make a very good ground connection.

In dry countries or where the soil is rocky and of poor conductivity a counterpoise may be employed. This consists of a wire network placed at various distances above the ground, usually not more than ten feet and insulated from the ground. This counterpoise forms a condenser with the earth and by covering a greater area than the aerial, it reduces the density of the aerial lines of force and thereby allows them to enter the earth with less difficulty.

Aircraft make use of counterpoise grounds. The aerial usually consists of a wire having a weight at its end, and arranged so that it may be suspended at the proper distance by means of a reel. The counterpoise consists of the metallic parts of the airplane, such as the engine, tanks, guy wires, etc. In some cases a horizontal aerial is stretched between two parts of the airship.

Proper Care of the Aerial. The aerial and aerial lead-in should be kept taut at all times to prevent swinging with the roll of the ship, and hence probable grounding to guy wires or other metallic structures.

On account of the high voltages employed the hard rubber rod insulators may in time have their insulation destroyed. The current leaking over the surface finally carbonizes it, making it more and more conductive, until finally a great percentage of energy is led directly to the ground.

To test an aerial for leakage, a gap may be inserted directly in series with the aerial and ground and energized by an induction coil or transformer. If a good spark occurs at the gap, the insulation of the aerial is good, but if a weak straggling spark or no spark at all is obtained, there is probably a bad leak present at some portion of the aerial. The aerial should be inspected, and if an insulator is found which has a charred surface, it may be temporarily repaired by scraping the surface and painting with varnish or vaseline.

The result of poor insulation of the aerial is poor radiation. That is, the range is reduced if part of the current leaks to the earth. What would be poor insulation for the transmtiting set may be very good insulation for the receiving set.

All joints in the aerial should be soldered to prevent corrosion and keep resistance low. Low resistance at the joints is not so important with the sending as with the receiving. In receivng, very weak currents are present in the aerial circuits, and therefore any resistance tends to weaken the strength of the signals.

QUESTIONS

Instruction Paper No. 8.

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

THE ANTENNA

The questions should not be written out, but the number written down and the answer written immediately after it.

Leave a one and a half inch margin (for correction purposes) and write only on one side of the paper.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

166. What is the function of an aerial?

167. Name the various types of aerials and describe briefly the four most important types.

168. In selecting a wavelength, what factors must be considered?

169. Define natural wavelength.

170. What types of aerials are used on ships?

171. How many wires are used in the average ship aerial?

172. How is the aerial insulated?

173. On what wavelengths do ships of the merchant marine operate?

174. How do you obtain wavelengths above and below the natural wavelength?

175. Does the capacity of the aerial have anything to do with the power it can handle efficiently?

176. Name two different types of deck insulator.

177. Describe the ground connection used aboard ships.

178. Describe the ground connection used in land stations.

179. Is the current or voltage greater, at the ground connection?

180. What is a counterpoise? Describe it.

181. What care should be taken of the aerial and lead-in?

182. Why should all joints in an aerial be soldered?

183. What is the effect on the radiation if the insulation of the aerial is poor?

184. What effect has the height of the antenna on the range?

185. How would you test the insulation of an aerial?

ABBREVIATIONS USED IN RADIO COMMUNICATION.

Memorize the Following Abbreviations:

Abbreviation.	Questions.	Answer of Notice.
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?	This is ....
QRB	What is your distance?	My distance is ....
QRC	What is your true bearing?	My true bearing is .... degrees.
QRD	Where are you bound for?	I am bound for ....
QRF	Where are you bound from?	I am bround from ....
QRG	What line do you belong to?	I belong to the .... Line.
QRH	What is your wave length in meters?	My wave length is .... meters.
QRJ	How many words have you to send?	I have .... words to send.
QRK	How do you receive me?	I am receiving well.
QRL	Are you receiving badly? Shall I send 20?	I am receiving badly. Please send 20.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are the atmospherics strong?	Atmospherics are very strong.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready. All right now.
QRW	Are you busy?	I am busy (or: I am busy with ....). Please do not interfere.

Examples of How Two Stations Would Use These Abbreviations:

Station A. QRA? [What is the name of your station?]

Station B. QRA Campania [This is the Campania.]

Station A. QRG? [To what line do you belong?]

Station B. QRG Cunard QRZ [I belong to the Cunard Line. Your signals are weak.]

(Station A then increases the power of its transmitter and sends:)

Station A. QRK? [How are you receiving?]

Station B. QRK [I am receiving well.]

QRB 80 [The distance between our stations is 80 nautical miles.]

QRC 62 [My true bearing is 62 degrees.] Etc.

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

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Answers to Instruction Book No. 6

121. The amplitude of a wave is the maximum height or depth from a plane midway between these two points.
122. The velocity of electro-magnet waves is 300,000,000 meters, or 186,000 miles per second.
123. Wave length (1) = $\frac{V}{F}$ or $\frac{300,000.000}{500,000}$ = 600 meters.
124. Radio frequency is a frequency above 10,000 oscillations per second, while audio frequency is 10,000 or less oscillations per second and can be heard by the ear. Radio frequency cannot be detected by the ear.
125. First, discharge of a condenser through a gap and inductance.
     Second, by the Arc Transmitter.
     Third, by the high frequency alternator.
     Fourth, by the vacuum tube transmitter.
126. The capacity of a condenser depends on:
     First, Size of plates.
     Second, Number of plates.
     Third, Quality of the dielectric.
     Fourth, Thinness of the dielectric.
127. First. The Leyden jar or glass plate condenser.
     Second. The mica or Dubilier condenser.
     Third. Compressed air condenser.
     Fourth. The oil plate condenser.
     Fifth. The moulded condenser.
128. Dielectric constant of a substance is a number which indicates how much larger capacity is possessed by a condenser with this substance used in the place of air.
129. The three methods of connecting condenser are: series, parallel and series parallel.
130. The frequency of an oscillatory circuit is the number of oscillations (back and forward motion of the current) occurring per second.
131. An oscillatory circuit is one containing inductance and capacity of such values as to allow oscillation to take place.
132. First, the electro-static form where the energy is stored in the condenser plates, then the electro-magnetic, when it is in the form of a current flows with magnetic lines linked with it.
133. The energy is used up as the current oscillates and this causes a decrease of the strength or amplitude between two successive waves in a train.
134. The damping or decrement is the decrease in strength or amplitude between two successive waves in the same wave-train. The law says that all transmitters shall emit a sharp wave. A sharp wave is one in which the logarithmic decrement per complete oscillation shall not exceed .2.
135. No, we mean the rate of occurrence or the number per second if they should endure for that time.
136. Cycles and oscillations are the same, but cycles refer to frequencies of 1,000 or less, while oscillations refer to high frequencies as used in wireless wave and usually above 20,000 per second.

(OVER)

137. The closed oscillatory circuit consists of the transmitting condenser, spark gap and primary coil (or inductance) of the oscillation transformer.

138. The open oscillatory circuit is made up of the aerial, an inductance (variable number of turns in a coil) and the ground connection.

139. W. L. = 38 $\sqrt{LC}$ -- L=inductance in centimeters.
C=capacity in microfarads (in f)

140. The frequency of the wave sent out is the same or 500,000 waves per second.

141. The logarithmic decrement is the logarithm of the decrease in amplitude between two successive waves in a train.

142. There will be 24 oscillations in the train which has a decrement of .2.

143. Two circuits are said to be in resonance when the product of capacity times inductance is the same in each or the number of oscillations in each circuit is the same.

144. Direct excitation is where a gap is put in the plain aerial and a high potential connected across the gap conductively coupled where one coil or helix is put in the aerial circuit and the power wire connected to this helix. Inductively coupled where two coils are used, one coil in the aerial circuit and another in the power circuit, and the energy is transferred by mutal induction.

145. The Inductive coupling is almost universally used.

CORRESPONDENCE COURSE

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Answers to Instruction Book No. 8

166. The aerial serves two purposes. First, a radiator of electro-magnetic waves; and second, as a receiver of current from waves as they pass the aerial.
167. Vertical, inverted L, T type, umbrella, Triangular, Roger's undergound, Loop and Weagants aerial. The inverted L and T aerials mostly used on ships, while the umbrella type is employed for portable use and the loop aerial for direction, finding station, and portable inside aerials.
168. The wave length of a transmitting station depends on the power of the transmitter and the space available for the erection of the aerial.
169. The natural wave length is the wave length which the aerial and ground alone, without any added inductance or capacity, will send out.
170. The flat-top T or inverted L.
171. 4 to 6 wires are used in ships' aerials.
172. Each wire is insulated from the spreaders at each of the ends by 4-inch to 9-inch electrose insulators, and the two spreaders are further insulated from the pole or mast by large 10 to 16 insulators.
173. Ships use wave lengths of from 300 to 600 meters.
174. Wave lengths above the natural are obtained by adding a loading coil in the open circuit, and shorter waves are obtained by putting a short wave condenser in the open or aerial circuit.
175. The greater the capacity of an aerial the larger the amount of power it can use.
176. The Bradfield and the Electrose deck insulators.
177. The ground on board a ship is made to the steel hull of the vessel.
178. For high-power land stations a very elaborate and expensive ground is made by burying in the ground, zinc or copper plates with copper wires radiating from these. In some cases a network of copper wire with soldered joints is put 1 to 2 feet underground by plowing deep furrows. Where the land is dry or rocky a counterpoise (a network of copper wire) is supported and insulated about a foot above the ground on wooden pegs.
179. The current flow is greatest at the ground lead connection.
180. A counterpoise is a large amount off sheet metal or wires spread out in space and insulated from the ground and acts as a ground to form one plate of the condenser, with the aerial as the other.
181. The wires making up the aerial and its lead-in should be kept taut at all times to prevent grounding by their swinging against something as the wind blows or the ship rocks.
182. The joints in an aerial and all parts of a receiver should be soldered to insure a low resistance path and allow maximum current and energy for the receiver and also a small waste of power in transmitting.
183. The radiation is greatly reduced and may become reduced to point where transmission is impossible if aerial insulation is poor.
184. The higher the aerial the greater the range for the amount of power sent out.
185. By connecting a high voltage across a small gap in the aerial circuit, and if a spark jumps the gap it shows the insulation to be good.

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166 The function of the aerial is for two things
1st To radiate energy in the form of electromagnetic waves
2nd To absorb energy from the passing electromagnetic waves.

167 The various types of aerials are, inverted L, T, verticle, umbrella, underground, Loop and triangular aerials.

The four most important are inverted L, T type, umbrella and verticle.

168 1st the place and the space where the aerial is to be erected.

2nd The power which is to be used in transmitting.

169 Natural wavelength is defined as the wavelength radiated by an oscillatory circuit, consisting only of aerial and ground

170 The types of aerials used on ships are the inverted L and the T type.

171 4 or 6

172 The aerial wires are insulated from the spreaders by electrose or porcelain insulators of sufficient size to stand the strain

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of the swaying wires and also to prevent the high frequency current from leaking from the aerial to the water or ground.

Some aerials are not insulated from the spreaders but is insulated by means of an insulator made of marlin rope run through a hard rubber tube and the surrounding space filled with melted sulphur to keep out the moisture this arrangement is placed between the spreaders and the supporting halyard.

173 300, 450, and 600 meters wavelength.

174 To obtain a wavelength above the natural wavelength it is necessary to add inductance in series with the aerial.

To obtain a wavelength below the natural wavelength it is necessary to use a short wave condenser in series with the aerial

175 Yes, the lower the capacity of the aerial the less power it can handle efficiently and the greater the capacity the more power it can handle efficiently.

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176 The Bradfield Deck tube and the Electrose Deck insulator.

177 In case of wooden ships the ground is made through the shortest possible cable from the operating room to a large copper plate fastened to the ships hull below the waterline.

On steel ships the ground is made directly to the steel deck of the operating room.

178 In the large high powered land stations the ground is made by burying large copper or zinc plates in the form of a large circle from the large plates other conductors are buried and on their ends other plates are fastened, The station is placed in the center of the circle and the conductors and plates radiating from it are connected with the station by a large copper conductor.

179 The flow of current is greater at the ground connection than in any other part of the circuit and the voltage at this point is the least.

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180 A counterpoise is a ground for a wireless set used in Rocky country or aircraft

A counterpoise used in rocky country is made by suspending a wire network at various distances from the earth or at the height that it can be used most efficently this network must be very well insulated from the earth. this counterpoise forms a condenser with the earth, and when it covers a greater area than the aerial it cuts down the density of the aerial lines of force and allows them to enter the earth with greater ease.

181 The aerial and aerial lead in should be kept taut to prevent them being grounded to guy wires or to other metal objects by the roll of the ship.

The insulators must be looked after to see that they are not broken, thus allowing the energy to be led to the earth.

182 All joints should be soldered in the aerial to prevent corrosion and therefore keep the resistance low, for if the resistance is high

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in receiving the very weak currents which are present in the aerial are made still weaker by the resistance and therefore the strength of the signals are made weaker.

153 If the aerial insulation is poor, it results in poor radiation, that is the range of the set is reduced on account of part of the energy escaping from the aerial to the earth.

184 Marconi in his experiments found that electric waves tend to follow the curvature of the earth and that the range increased in proportion to the height of the aerial.

185 I would test the insulation of an aerial by inserting a spark gap directly in series with the aerial and earth this I would energise by a transformer or spark coil if a good heavy spark occours in the gap the insulation may be pronounced O.K. but if a weak or no spark at all occours at the gap the insulation of some part of the aerial has broken down.

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Lesson No. 6 Student No 13794

121 The amplitude of a wave is the highest point reached in either a negative or positive position

122 The velocity is 186,000 miles per. second

123 $W.L. = \frac{V}{F}$ or $W.L. = \frac{300.000.000}{500,000} = 600$ W.L. Ans

F = frequency
V = velocity
W.L. = wave length

124 Radio frequency is defined as that frequency which is over 10.000 cycles.

Audio frequency is defined as that frequency which is between 1 and 10.000 cycles.

125
1. Discharge of a condenser.
2. The Poulsen arc.
3. high frequency alternator.
4. Vacuum tube generator.

126 The capacity of a condenser depends upon. the size and number of plates and also the dielectric used and its thickness

127
1. The Leyden jar.
2. mica condenser.
3. The oil plate.
4. moulded condenser.
5. compressed air condenser.

128 Dielectric constant is defined as the ratio of the capacity of a condenser using some substance as a dielectric to the capacity of a like condenser using air as a dielectric.

129 The series connection, parallel and series parallel connection.

In the series connection the outside of one jar is connected to the inside of the next and so on until all the jars are connected.

In the parallel connection all the outsides of the jars are connected together and all the insides are connected together.

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In the series parallel connection two or more banks of condensers are connected in parallel and then in series.

130 What is meant by the frequency of an oscillatory circuit, is the number of discharges taking place back and forth between the inner and outer coatings of a condenser for a period of one second.

131 An oscillatory circuit is defined as a circuit having inductance and capacity, in which oscillations take place.

132 The two forms that the energy of an oscillatory circuits takes are Electrostatic and Electromagnetic energy.

133 The amplitude of a train of oscillations decreases, because of the great loss due to radiation and also the resistance of the gap.

134 Damping or Decrement means the decrease in the amplitude of the oscillations.

135 No. it means the rate at which these oscillations take place.

136 No difference, only oscillations is used to denote high frequency and cycle low frequency current.

137 a closed oscillatory circuit consists of a condenser and a coil of wire having the property of inductance in shunt to each other.

138 An open oscillatory circuit has one or more wires suspended in the air and its lead in grounded to the earth, an artificial condenser is not used for the capacity. for this lies between the wires as one plate and the ground as the other side of the [redacted] condenser, the inductance is in the elevated wires and the coils in series with the wires, a charge may now be given

to the elevated wires and the earth by inserting a spark gap in series with the aerial and ground and shunting this with a transformer or spark coil.

139 $W.L = 38\sqrt{L.C}$

L. = inductance in cm.
C = capacity in microfarads.
W.L. = wavelength.

140 The frequency of the radiated waves would be 500,000 the same number as in the aerial circuit.

141 Logrothmic decrement means the Naperian lograthim of the ratio of the amplitude of one oscillation to that of the next oscillation in the same direction in a train of decreasing oscillations.

142 About 24

$$\text{oscillations} = \frac{4.605+.02}{.02} = 28+ \text{ oscillations}$$

143 Resonance means that when a closed circuit is used to generate the high frequency currents and an open circuit is used to radiate the waves they must be in inductive relation to each other that is the inductance and capacity will be of the same value in each circuit and therefore the frequencies will be the same.

144 The three methods of aerial excitation are inductively, conductively and direct excitation

In the inductively coupled set there are two complete circuits with no metal connection between them. the energy is transferred from one circuit to the other by means of induction. The two circuits are ajusted until they are in resonance with each other. this gives a very sharp wave.

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In the conductively coupled set only one coil or circuit is used for the closed and aerial circuits, the inductance is varied by means of clips. When the condenser is discharged across a gap a current is induced in the aerial circuit and also a part of the current is conducted to the aerial circuit since both circuits are joined together.

In direct excitation a gap is placed in series with the aerial and ground, the secondary of the transformer has its terminals connected to the gap, one being on each side. When the spark leaps the gap it sets up oscillations in the aerial circuit causing waves of energy in the ether.

145 The inductively coupled, method is used in most of the stations today.

It took me 5¼ minuts to complete the exercise in the front of the book.

LESSON TEXT No. 9

OF A

Complete Course in Radio Telegraphy

The Damped Wave Receiving Set

REVISED EDITION

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RADIO TELEGRAPHY

NATIONAL RADIO INSTITUTE - - WASHINGTON, D. C.

THEORY AND CODE LESSON NO. 9

CODE LESSON NO. 9.

Abbreviations Used in Radio Communication

Memorize the Following Abbreviations:

Abbreviation	Question	Answer or Notice
QRX	Shall I stand by?	Stand by. I will call you when required.
QRY	When will be my turn?	Your turn will be No. ....
QRZ	Are my signals weak?	Your signals are weak.
QSA	Are my signals strong	Your signas are strong.
QSB	{Is my spark bad? {Is my tone bad? Is my spacing bad?	The tone is bad. The spark is bad. Your spacing is bad.
QSC	What is your time?	My time is ....
QSD	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSF		
QSG	....	Transmission will be in series of 5 messages.
QSH	....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for?	Collect ....
QSK	Is the last radiogram canceled?	The last radiogram is canceled.
QSL	Did you get my receipt?	Please acknowledge.
QSM	What is your true course?	My true course is .... degrees.
QSN	Are you in communication with land?	I am not in communication with land.
QSO	Are you in communication with any ship or station (or; with........)?	I am in communication with .... (through ....).
QSP	Shall I inform......that you are calling him?	Inform .... that I am calling him.
QSQ	Is ...... calling me?	You are being called by ....
QSR	Will you forward the radiogram?	I will forward the radiogram.
QRT	Have you received the general call?	General call to all stations.
QSU	Please call me when you have finished (or: at .... o'clock).	Will call when I have finished.
[1] QSV	Is public correspondence being handled?	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency??	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?	Decrease your spark frequency.
QSY	Shall I send a wave length of .... meters?	Let us change to the wave length of ...... meters.
QSZ	....	Send each word twice. I have difficulty in receiving you.
QTA	....	Repeat the last radiogram.

---

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

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

THE RECEIVING SET.

In General: In the two previous instruction papers the transmitting set and the aerial were the subjects of discussion, and the following may be considered a summary of what the student should know regarding the production of electromagnetic waves: In marine installations:

THE DAMPED WAVE RECEIVING SET

1. Direct current from the ship's generator is converted into an alternating current of proper voltage and frequency by the motor generator.

2. The alternating current from the armature of the generator flows in the key circuit where it is broken up into the dots and dashes of the International Morse Code.

3. This current, whose voltage is raised to a high value by the step-up transformer flows into the condenser, charging it to the proper potential.

4. After a charge is placed in the condenser, a discharge immediately occurs across the gap and through the primary of the oscillation transformer. This discharge consists of a series of oscillations and is termed a train or group of oscillations. The number of groups or trains occurring per second is determined by the number of complete discharges of the condenser, the latter being dependent on the type of spark gap and frequency of the generator.

5. The energy of the trains of oscillations produced in the closed circuit of the inductively coupled set is transferred to the aerial circuit by electromagnetic induction in the oscillation transformer. The trains in the aerial circuit alternately produce a magnetic and a static strain in the ether adjacent to the transmitting aerial, which travels from the aerial with the velocity of light. At the present time the damped wave transmitter is found in the majority of installations. The wavelengths employed by ship and coast stations range from 200 to 10,000 meters, and the frequencies corresponding to the above wavelengths from 1,500,000 to 30,000.

The student should understand that the transmitter is a source of high frequency oscillations, each oscillation in the transmitting aerial producing a wave, and therefore the frequency of the oscillations in the aerial circuit must be equal to the wave frequency. In damped oscillation circuits, by the term frequency, we mean the rate at which oscillations are produced, not the actual number really present.

The transmission of signals between a sending and receiving station may be compared to the transfer of energy between the closed and aerial circuits. The principal difference being that in the former the distance between the circuits is very great, and the energy induced in the receiving aerial is of very low value.

The problem involved in designing an efficient receiver is to utilize the minute currents induced in the receiving aerial in such manner that suitable audible or visible indication is given to the operator.

The energy of the radiated waves appears to decrease as the square of the distance; that is, the energy received at a distance of ten miles from a transmitter compared to the energy received at a distance of 20 miles would be as 20 squared is to 10 squared, or 400 is to 100. Therefore, at 20 miles the energy received would only be ¼ of that at 10 miles.

The flow of an oscillating current in the aerial of the transmitter produces a moving train in the ether which upon reaching the vicinity of the receiving aerial induces an oscillating current of the same frequency in the aerial circuit, provided it has the same wavelength as the transmitting aerial. This instruction paper deals with the apparatus employed to make an audible or visible indication of the currents induced in a receiving aerial by passing waves.

There are two general types of receivers, those for damped and those for undamped waves. This paper will be confined to the treatment of the damped wave receiver.

Early Methods: The first device used to give an indication of the passage of electric waves was the resonator of Heinrich Hertz and Sir Oliver Lodge. It consisted of a loop in which was inserted a very small gap. If this device is placed in the vicinity of an oscillator and is of the correct dimensions a spark will occur across the gap when the oscillator is in action.

It was never more than a laboratory arrangement, being sensitive only when very close to the source of waves.

The **coherer,** a device invented in 1890 by Prof. Branley, was made into a practical detector of electromagnetic waves by both Lodge and Marconi. A glass tube, a fraction of an inch in diameter, has within it two silver plugs, between which is placed a mixture of nickel and silver filings. The above arrangement is called a coherer and is placed in series with the aerial and ground. If an electric wave from a distant station strikes the aerial, an oscillating current will be induced in the aerial circuit, which in passing through the coherer causes the filings to place themselves end to end, and lowers the resistance to a very low value. Connected to the ends of the coherer is a circuit consisting of a battery, relay and a tapper. As the aerial current passes through the coherer, the lowered resistance allows the local current to flow through and actuate the relay. The tapper jars the tube and rearranges the filings, which are again placed end to end by the next train of oscillations. This device is used with a Morse register, which prints the dots and dashes on a strip of paper. It is not particularly sensitive and is unreliable. Marconi discarded the coherer in 1901, in which year he invented the magnetic detector.

The **magnetic detector** is a simple, reliable device consisting of a bundle of soft iron wires passing over two small wooden pulleys, each about four inches in diameter. One of the pulleys is rotated by clock-work, causing the iron band to move slowly in front of two small permanent magnets. The iron band passes through a small glass tube on which two coils of wire, in inductive relation to each other, are wound. The iron band is magnetized as it slowly moves past the permanent magnets, this magnetized condition remaining in the band for some time.

The aerial and ground are connected in series with one of the coils on the tube, while the telephone receiver is connected in series with the other coil. If a train of oscillations, induced by a passing wave train is flowing through one of the coils, the lines of force from the magnetized iron band will be partially neutralized or destroyed. This reduction of the number of lines of force flowing through the telephone circuit will cause a current to flow through the phones. Each of the following wave trains set up this momentary current, with the result that a buzz is heard in the phone.

It is much more sensitive and reliable than the coherer and was in use for many years in stations equipped by the Marconi company.

In both the coherer and magnetic detector arrangements it may be seen that a direct aerial connection is used. That is, these two devices are connected in series with the aerial and ground. It is well to observe that no provision is made for tuning the circuit, and in consequence these detectors will receive stations, transmitting on various wavelengths. The natural wavelength of the aerial would have a tendency to confine the received signals to the same length, but for the resistance of the detector itself. If too much resistance is placed in series with any oscillatory circuit, the oscillations induced in it will not be confined to any one wavelength.

In 1904 Dr. J. A. Fleming invented the Fleming valve detector. It is a reliable and very sensitive device, much superior to both of the earlier types of detector. The theory of its action will be taken up later in the section on detectors.

The electrolytic detector is very sensitive and reliable, although difficult to adjust. It consists of a small glass cup, in the bottom of which the end of a small platinum wire is exposed. A few drops of a solution of one part nitric acid to five parts water covers the exposed platinum wire in the cup. A piece of wollaston wire (a platinum wire, one thousandth of an inch in diameter and silver plated) is caused to just touch the solution in the cup, by means of a screw adjustment. This detector is used in conjunction with a local battery current, and the action is as follows:

A local battery current flows through the detector as connected, in Fig. 81, and, according to one theory, forms hydrogen gas bubbles which collect about the platinum electrode and insulate it, thus causing the current to cease flowing. As soon as a train of oscillations passes through the detector the bubbles are destroyed and the current flows again. Immediately after the oscillation train ceases, the bubbles again insulate the platinum wire. Therefore, a momentary flow of current occurs through the telephone receiver, once for each wave train passing the aerial. This detector is obsolete at the present time.

Receiver Circuits:

Modern receiving circuits may be classified as follods:

(1) Simple receiver.

(2) Conductively coupled receiver.

(3) Inductively coupled receiver.

(4) Capacitatively coupled receiver.

The **coherer and magnetic** detector are placed directly in the aerial circuit, and as a result the signals received will not be confined strictly to one frequency. If many transmitting stations are in the vicinity, a receiver of either of the above types will receive the signals from any or all of them, and consequently it will be difficult for the operator to do efficient receiving. The reason for such action of the coherer and magnetic detector is that, being in series with the aerial and ground, the resistance is increased and the result is that the trains of oscillations are damped.

To understand the action involved in modern receiving apparatus it will probably be best to explain a simple type of receiver.

The essential elements of a *simple receiver* are: *Aerial, detector. indicating device and ground.* The detector may be of the crystal rectified type, such as galena. Galena is an ore, its chemical composition being lead and sulphur, and has the property of "unilateral conductivity;" or, in other words, it will allow electricity to flow through it in one direction but not in the other. In a common form it consists of a piece of galena held in a cup and a fine wire, which makes light contact with it.

The telephone receiver is used in modern sets to make the signals audible to the operator, and is a very sensitive device, being almost as sensitive to weak currents as the delicate galvanometers used in laboratories. Further on in this paper a complete discussion will be given of the action of the telephone. A modern telephone receiver as used in wireless crcuits is most sensitive to currents whose frequencies range between 300 and 600 cycles. When we consider the fact that the frequencies of the oscillatory currnts flowing in radio circuits usually range between 15,000 and 3,000,000 cycles, we can understand the futility of connecting a receiver directly in the aerial circuits for reception of signals. Some means must be employed to alter the incoming currents, so that they will give an indication in the phones. At this point it may be well to remark that the detector does not detect, but merely alters the incoming radio currents.

As explained in an earlier instruction paper, the oscillations produced in the transmitting aerial are damped. That is, each discharge of the condenser produces a train of oscillations of decreasing amplitude; and as the number of discharges range between 200 and 1,200, the number of trains will be the same. There is an interval of time between each group as shown in Fig. 78. (a). Each of these trains or groups sets up a corresponding wave train which, upon passing the receiving aerial, induces a train of oscillations in the aerial circuit. For instance, in Fig. 79 (a) we have a circuit consisting of aerial, crystal detector, telephones and ground. The action in such a circuit is as follows: Each passing wave train induces a train of oscillations in the aerial circuit. The galena detector, such as was described above, will allow half of each train to flow through. This action causes a charge to be placed on the condenser formed by the aerial and ground, and after a wave train has passed, this charge passes through phones to the earth, creating a single click. The student should take note that the sound in the phones is not due to the oscillations, but to the group or train of oscillations. The tone in the telephone receiver will be dependent upon the wave train frequency, and as the latter depends upon the spark frequency, we may say that the tone depends upon the type of spark gap at the transmitter. The simple receiver is broadly tuned, due to the resistance which the detector offers to the circuit, and it will receive loudest those signals sent on waves, whose length is nearest the natural wavelength of the aerial.

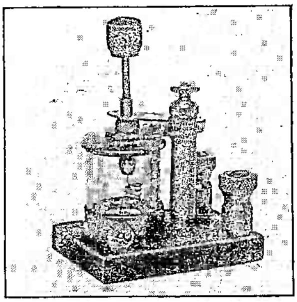

Fig. 80. The Galena Detector

Courtesy of DeForest Radio Telephone and Telegraph Co.

The **conductively coupled receiving circuit** is shown in Fig 79 (b). In this circuit a variable inductance is in series with the aerial, variable condenser and ground. The detector is shunted about the coil and the phones about the detector. This arrangements enables the aerial circuit to be tuned to wavelengths greater or less than the natural wavelength of the aerial. It allows a greater wavelength than the natural, due to the increase of inductance that is possible with the coil. We know that the wavelength is greater if the inductance is increased and that the same is true with respect to an increase of capacity. The variable condenser may be employed to reduce the effective capacity and thus allow a reduction of the wavelength below the natural wavelength of the aerial.

The circuit can be made more efficient by inserting a varable condenser across the two leads to the detector. The type of condenser used in both the aerial circuit and across the detector is shown in Fig. 83.

The variable inductance is sometimes referred to as a two slide tuner. One slide is connected to the aerial and the other to one side of the detector. With this hookup the circuit consisting of the turns in shunt to the condenser and the condenser itself form an oscillating circuit. When this circuit has the same product of inductance and capacity as the circuit consisting of the aerial, the turns of the coil and the ground, the two circuits are in resonance and the loudest signals will be obtained from a given station. The turns of the coil in series with the aerial form the primary winding, while the turns in shunt to the variable condenser form the secondary winding. The current flowing in the aerial circuit in flowing through the primary winding, sets up lines of force in the space about the coil, inducing a similar current in the secondary winding. Part of the current flows directly to the detector by conduction and for that reason it is called a conductively coupled circuit.

The **inductively coupled receiver,** shown in Fig. 82, is the most common receiver in use at the present time. An arrangement shown in Fig. 86, called a receiving transformer or loose coupler is employed in this circuit. It consists of two cylindrical coils of wire; one coil called the secondary telescopes into the larger coil, known as the primary. The primary is in series with the aerial loading coil, variable condenser and ground; while the secondary is in shunt to a variable condenser. The detector and phones are connected in series. The inductance variation in the loose coupler is usually by tap switch, but in some types the primary winding is varied by means of a slider. The tap switch consists of a handle which makes connection with a series of contacts, these being connected by short pieces of wire to different turns of the coil. By adjusting the handle any number of turns may be included in the circuit. The action occurring in this type of circuit will be taken up in another part of this instruction paper.

The **capacitively coupled circuit** is shown in Fig. 83. This type of circuit differs from the inductively coupled receiver in that the energy in the aerial circuit is transferred by condenser coupling. As shown in the figure, two condensers, C-1 and C-2, control the energy transfer from the aerial circuit to the secondary circuit. They do not have any effect on the tuning of the two circuits, merely acting as an "energy controller." There is no magnetic action between the two inductance coils, as they are constructed at right angles to each other.

Many advantages are claimed for this arrangement. In the inductive type of set the adjustment of the coupling between the primary and secondary required considerable space, while in the capacitative receiver the coils are fixed and very compact. The adjustment for coupling merely

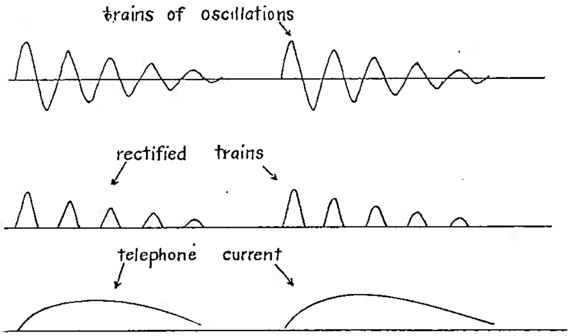

Fig. 78. A. B. C.—Rectification of Incoming Train of Oscillations.

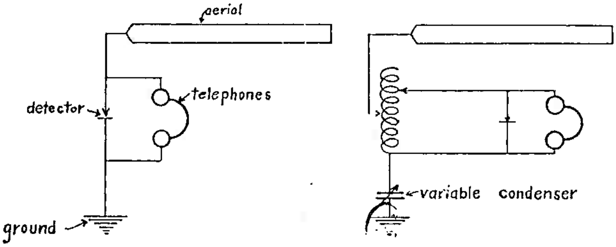

Fig. 79. A. B.—Simple Receiving Circuits.

consists in turning the knob of the coupling condensers, which is much easier than changing the coupling of the inductively coupled set.

The secondary circuit may be calibrated, allowing the circuit to be adjusted instantly to any given wavelength. The advantages of this circuit may be summarized as follows:

(1) Compactness.

(2) Ease of operation.

(3) Calibration of secondary circuit.

Functioning of Receiving Set:

In order that the student may have a thorough grasp of the action of the most common form of the receiving set, the function of each part will be explained.

The principal parts of the inductively coupled set shown in Fig 82 are:
The Aerial Circuit:

(1) Aerial.
(2) Aerial tuning inductance.
(3) The variometer.
(4) Primary of receiving transformer.
(5) Variable condenser.
(6) Ground.

The Secondary Circuit:

(1) Secondary of receiving transformer.
(2) Variable condenser.
(3) Detector.
(4) Potentiometer and battery.
(5) Telephones.
(6) Fixed condenser.
(7) Buzzer tester.

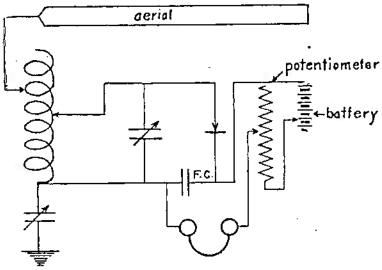

Fig. 81. Conductively Coupled Set.

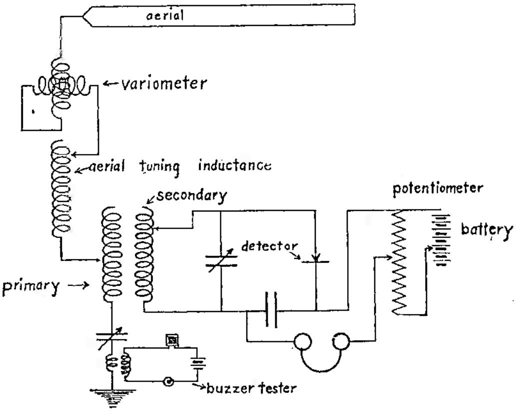

Fig. 82. Inductively Coupled Receiving Set.

THE DAMPED WAVE RECEIVING SET

The electromagnetic waves from a distant station strike the aerial of the receiving station and by the action of the electric and magnetic fields of the wave, an oscillating current is induced in the aerial circuit. If the aerial circuit of the receiver has the same wave length as the aerial circuit of the transmitter, the frequency of this induced current will be the same as that flowing in the transmitter circuits.

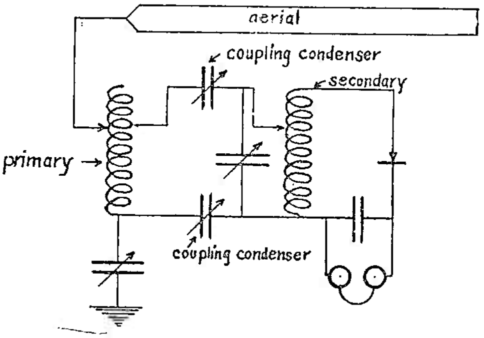

Fig. 83. Capacitatively Coupled Receiver.

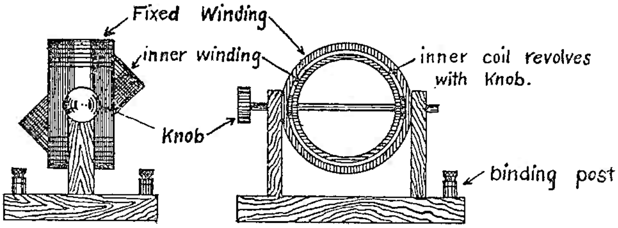

Fig. 85. Variometer.

The function, therefore, of the receiving aerial is to absorb the energy of passing waves.

The *aerial tuning inductance, sometimes called the loading coil, allows the aerial circuit to be tuned to a wavelength greater than the natural wavelength of the aerial.* It may consist of a single layered solenoid winding, the turns of which are varied by means of a tap switch, or the multilayered coil made by winding many turns of wire on a spool. The latter has the advantage of compactness and if wound by modern methods will be superior to the solenoid type of coil.

The variometer is a device used to obtain close or continuous variation of the inductance in a circuit. It is used in the aerial circuit of some forms of receiving sets in order to tune sharply to a given wavelength.

In the form used for receiving purposes it may consist of two coils of insulated wire wound on two cylinders, so arranged that one cylinder may revolve within the other as shown in Fig. 85. If the coils are connected in series and are in such a position that the direction of winding is the same in each, the inductance of the two coils will be a maximum. In other words, if the magnetic fields of the two coils coincide, then the inductance will be a maximum; but on the other hand, if the inner coil is revolved one-half revolution, then the two fields will oppose and the inductance will be a minimum. Intermediate positions of the inner coil with respect to the outer will give corresponding values of inductance.

The primary of the receiving transformer transfers the energy of advancing wave trains to the secondary by electromagnetic induction. In a simple type of receiving transformer the primary is a single layer of insulated wire wound on a cylinder of cardboard or other insulator. The cylinder may be 3 to 8 inches in diameter and up to 16 inches in length. A tap switch or slider allows variation of the number of turns in the circuit. The secondary coil is of similar construction, but is of smaller diameter, in order to allow it to slide in or out of the primary.

A tap switch allows variation of the inductance of the secondary winding, and as shown in Fig. 86, the secondary is mounted on two rods which support it and allow a variation of its position with respect to the primary coil. When the two coils are close to each other, the secondary being within the primary, the mutual induction will be a maximum and alarge percentage of the energy flowing in the primary will be transferred to the secondary. When the primary and secondary are in such a position, they are said to be closely coupled; but if the two coils are placed some distance apart, they are said to be loosely coupled.

The **variable condenser** employed in practically all receiving sets consists of two sets of semi-circular plates, one set of which revolves within the other. In Fig. 84 is shown a common type of variable condenser. When the movable set of plates are entirely within the stationary set, the condenser has a maximum capacity; but when the movable set is entirely outside of the stationary, the capacity is a minimum. Intermediate positions give values of capacity in proportion.

The variable condenser in series with the aerial and ground allows the aerial circuit to be tuned to wavelengths less than the natural wavelength of the aerail. This can be understood when we consider the action of two condensers in series. The resultant capacity of two condensers in series is less than the least of the two.

The aerial and ground form a condenser and a variable condenser in series with the above will enable the effective value of capacity to be reduced, consequently we may reduce the wavelength of the aerial circuit to values less than the natural wavelength.

The ground or earth has been explained quite fully in the paper on aerials.

The *secondary of the receiving transformer absorbs the energy from the aerial circuit.* By placing the secondary coil in close or loose inductive relation to the primary, the transfer of energy may be controlled. If a close coupling is employed, there will be a maximum transfer of energy and this will cause damping of the incoming oscillations. The result of this action is the reception of a broad range of wavelengths, while in the event that loose coupling is employed, if the two circuits are in resonance, only the wavelength to which the set is tuned will be received.

The variable condenser employed in the secondary circuit supplies the capacity necessary to allow adjustment to various wavelengths, and also allows a very sharp adjustment of the wavelength.

The secondary winding of the receiving transformer usually is equipped with a tap switch and will allow adjustment in steps; but to enable the circuit to be tuned to wavelengths between steps, the condenser is used. That is, one tap on the switch may enable a given length of wave to be received, but the next tap will give a larger value; and for adjustment to wavelengths between these two value we may use the variable condenser. In order to absorb a maximum amount of energy from the trains of oscillations in the aerial circuit, it is necessary that the circuit consisting of the secondary winding and the variable condenser be in resonance with the aeral circuit.

Detectors:

Under the heading of "Receiving Circuits" the galena type of detector was discussed in a superficial manner.

Devices such as the galena arrangement do not "detect" but merely alter the incoming trains, so that they will give an audible indication in the telephone receiver.

The so-called detector has been defined by the standardization committee of the Institute of Radio Engineers as "that portion of the receiving apparatus which is connected to a circuit carrying currents of radio frequency and in conjunction with a self-contained or separate indicator translates the radio frequency into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency energy or by means of the control of local energy by the received energy."

The two principal modern detectors are the crystal rectifier and the vacuum valve.

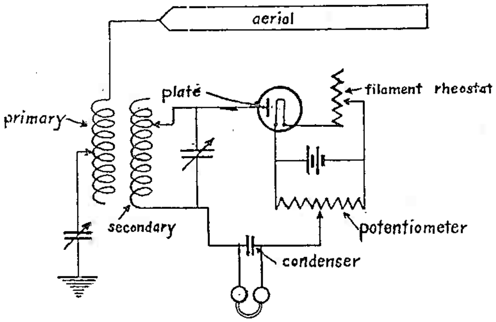

Fig. 88. Receiving Circuit for Fleming Valve.

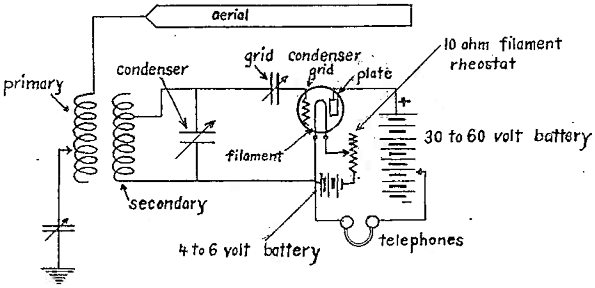

Fig. 89. Receiving Circuit for Three Electrode Valve.

The former in most cases converts the incoming radio frequency current into a current that will give audible indication, while the latter, in its modern form, controls the local energy by a relay action.

The crystal rectifier converts the incoming trains of oscillations into a pulsating direct current, each rectified train combining in the condenser and then discharging through the telephone receiver. Thus the current of possibly 500,000 cycles per second is converted into a pulsating current whose frequency is equal to the spark frequency of the transmitter and is therefore probably less than 1,200.

The **potentiometer** is used with some types of detector, the most common type being the carborundum crystal. The chemical name for this crystal is silicon carbide. The potentometer is a variable resistance of about 400 ohms. It is connected in shunt to a battery of two dry cells, and as shown in Fig. 82, the two leads from the potentiometer are connected to the telephone receiver and one side of the fixed condenser. By variation of the movable contact on the potentiometer we may vary the voltage of the local current which flows through the detector and telephones. If the slider is at one end, the voltage will be a minimum; but as the slider approaches the opposite end the voltage will increase to a maximum.

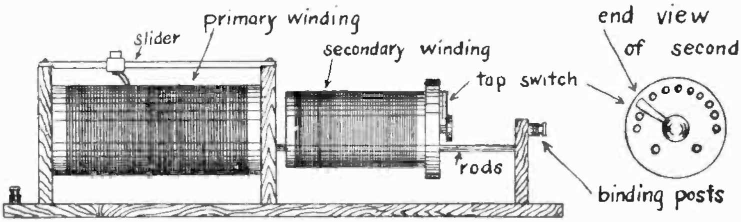

Fig. 86. Receiving Transformer.

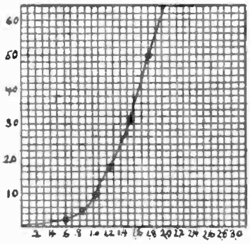

Fig. Characteristic Curve of Carborundum.

The carborundum detector gives the loudest response in the telephone at a certain critical adjustment of the potentiometer. That is, when the voltage flowing through the detector is of the correct value, the detector is most sensitive. An arrangement such as shown in Fig 87 is called a characteristic curve of a carborundum crystal and illustrates the fact that the crystal does not obey Ohm's law. Ohm's law states that as the voltage increases the amperage will increase. If we vary the voltage applied to the carborundum detector from a low to a high value by means of the potentiometer and if we measure the flow of current through the crystal by means of an ammeter we will find that the flow of current is not proportional to the voltage. We may plot the results of such an experiment on a sheet of cross section paper, as shown in Fig. 87. The values of the voltage applied are found on the lower edge of the paper, while the current in millionths of an ampere is found on the left-hand edge of the paper.

As the voltage increases the current increases more and more rapidly. At the lower voltages on the curve the current increases slowly, while later the curve bends sharply upward, showing that the current is increasing more rapidly. As the voltage increases from one to two volts the increase in currents is not near so much as when the voltage increases from two to three.

Suppose the voltage applied to the crystal was adjusted to the voltage just below the point at which the curve bends sharply upward. If incoming oscillations of certain voltage, due to the passing wave, flow through the detector, the total voltage applied to the crystal will be the sum of the two. Therefore, if a train of oscillations is rectified by the crystal, the pulsations of current that pass through the detector will cause an increase of current flow in the phones, with the result that louder signals are produced than if the potentiometer and battery were not used. The alternations flowing through the detector in the opposite direction, in addition to being weak, oppose the applied voltage and reduce the current flowing through the telephone.

To get the best results with a carborundum detector it is necessary to vary potentiometer adjustment until the critical voltage is found, which, added to the voltage of the incoming oscillations, will cause a large increase of current in the telephone. Carborundum crystals require a heavier pressure from the opposing contact than other crystals. Different points on the crystal may possess different degrees of sensitiveness, and it is also well to remember that the two-cell battery must be so connected to the potentiometer that the current will flow through the crystal in the right direction.

The **telephone receiver** is a very important part of the receiving set. Its adoption brought about a great increase in the range of radio stations. It consists essentially of a permanent magnet, a coil of wire, and an iron diaphragm. These three are held in their proper relation to each other by a hard rubber or aluminum shell. The permanent magnet in the ordinary type of telephone receiver is of the bar type, and is placed very close to the diaphragm, but far enough away to allow it to vibrate. The permanent magnet attracts the iron diaphragm and therefore places it under a constant tension.

A coil of small insulated wire of many hundreds of turns is placed about the end of the bar magnet, near the diaphragm. If a current flows through this coil, the magnetic field produced will either assist or oppose the field of the permanent magnet. Hence, if it assists, the diaphragm moves closer to the magnet; if it opposes, the field of the permanent magnet will be partially neutralized and a diaphragm will move away from the magnet. These vibrations will set up sound waves. Even if very weak currents flow, the very minute vibrations will cause a sound, as only a few millionths of a watt are required to produce a sound in a sensitive receiver.

The receiver employed in radio is of the watch case type. Its construction is similar to the other and perates on the same principle.

The sensitiveness of any telephone receiver depends upon the frequency of the current, the construction, the number of turns and the size of the wire used. For a given receiver the sensitiveness will depend upon the frequency of the incoming current. The receiver will be the most sensitive to currents whose frequency is the same as the natural frequency of vibration of the diaphragm. Modern receivers are more sensitive to currents whose frequency is about 500 cycles, which frequency has the same effect as a pulsating current whose frequency is 1,000.

The natural frequency of vibration of the diaphragm will depend upon its weight and thickness; therefore, a transmitter whose spark frequency is about 1,000 will give a louder signal in the telephone receiver than one of lower frequency. A current of 500 cycles would consist of 1,000 alternations and therefore would produce 1,000 vibrations of the telephone.

The magnetizing force of any current carrying coil of wire depends upon the product of amperes and turns of wire. This is termed "ampere turns." That is, one ampere through 100 turns would have the same magnetizing power as 100 amperes through one turn.

Hence, to get the loudest response in a telephone from very weak currents, it is necessary to use many hundreds of turns of wire, and due to the limited space we must use very small insulated wire. The smaller the wire the greater the resistance, which accounts for the fact that all sensitive telephones are of fairly high resistance. Low resistance telephones may be used with some types of detector and give very good response; but for the crystal detector, telephones having 1,500 to 2,000 ohms resistance are best.

Another type of telephone receiver is that developed by T. Baldwin. This receiver has a mica diaphragm, a permanent magnet, a coil of wire and an armature. It is much more sensitive than any of the iron diphragm type. It operates on the principle of the polarized relay.

The function of the telephone receiver in the receiving set is to render audible the rectified trains of oscillations.

The fixed condenser usually connected across the telephones stores up the pulsations of the rectified train of oscillations and then discharges through the telephone receiver, giving one sound or click per train. In Fig. 78 (a), (b), and (c) is shown the action occurring in the detector circuit. In Fig. 78 (a) we have the trains of damped oscillations, in Fig. 78 (b) the rectified trains, and in Fig. 78 (c) we find the rectified trains combined by the fixed condenser into one charge for each train of oscillations. It can be seen that no matter how high the frequency of the individual oscillations, the frequency of the trains of oscillations determines the note heard in the telephones.

Detectors: In the preceding papers the detector has been defined as a device which alters the incoming oscillation trains in order that they may cause an audible sound in the telephones. Detectors for damped oscillations may be divided into two general classes; those that rectify and those that vary a local source of current.

According to construction, practically all detectors belong to the crystal or vacuum valve type. The vacuum valve detector has been so highly developed in recent years that it promises to render obsolete all other forms of detectors. All crystal detectors operate on the principle of rectfication.

The crystal detectors operating without local battery are: galena, silicon, zincite-bornite and iron pyrites.

Those that require local battery are: Carborundum and zincite-bornite.

The carborundum detector is very reliable, is fairly senstive, and has been employed on marine installations of the Marconi Company for several years.

The galena is considered one of the most sensitive crystal detectors but is very easily thrown out of adjustment by mechanical vibration, by dscharges of atmospheric electricity or by strong signals. The Telefunken Company of Germany employed the galena detector to a considerable extent until recent years. The galena crystal is mounted in a cup and is so arranged that it makes light contact with a fine copper wire.

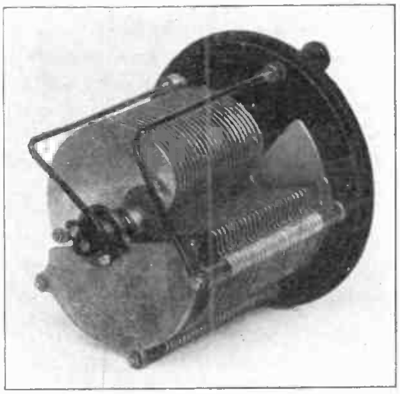

Fig. 84. **Variable Receiving Condenser**

Courtesy of the DeForest Radio Telephone & Telegraph Co.

The iron pyrites are also mounted in a cup and make contact with a gold point or crystal of antimony.

The **vacuum valve** is known by a number of names, such as audion, audiotion, electron relay, etc.

The first type of vacuum valve was invented by Dr. J. A. Fleming in 1904, and is called the Fleming valve. It consists of a small electric lamp with a small filament, about which there is a cylinder of sheet copper connected to the outside of the lamp by a platinum wire.

The lamp is lighted by a 4 to 8 volt battery, the brilliancy of filament being controlled by a 10-ohm rheostat. In Fig. 88 is a drawing of a receiving set connected to a Fleming valve. One side of secondary variable condenser is connected to the copper cylinder about the filament and the other side is connected to the telephone receiver. The other side of the telephone receiver is connected to another resistance which is shunted about the filament battery.

The action of such a detector is as follows:

When a filament is lighted, small negative particles of electricity called electrons are thrown off from filament. If trains of oscillations are flowing in the receiver circuits due to passing waves, the copper cylinder will be given a positive and negative charge alternately. When charged positively, the electrons from the filament will be attracted to the plate and there will be a passage of negative electricity to the cylinder. The next charge of the train of oscillations will be negative, and as "like charges repel," the electrons will not be attracted. Hence, the detector acts as a rectifier, allowing current to flow through the phones only at the times the cylinder is charged positvely. The pulsations of each rectified train appear to combine and then discharge across the telephone receiver as a single click. This detector is sensitive and very reliable, but has been superseded by the more sensitive three electrode vacuum valve.

In 1904 Dr. Lee de Forest invented the first form of the three electrode vacuum tube. Dr. de Forest, in developing this detector, had in mind a relay and not a rectifier, such as the Fleming valve. In Fig. 89 is shown a diagram of a receiving circuit using the audion, as it is called by the inventor.

It differs from the Fleming valve, in that an electrode made of a coiled wire or perforated cylinder is placed between the filament and the plate. This grid, as it is called, makes a relay of this detector instead of a rectifier.

As shown in Fig. 89, the grid is connected to one side of a condenser, and the other side of the condenser to the secondary winding of transformer. The plate is connected to the positive side of a 30 to 60 volt battery, the battery being in series with the telephone receivers. The other terminal of the telephone is connected to the filament terminal, the remaining terminal of the secondary winding being also connected at this point. When the filament is burning, electrons are thrown off which are attracted to the plate, due to the fact that it is charged positively by the battery. A flow of negative electricity is said to flow from the filament to the plate; but as we usually consider the current as flowing from the positive pole of a battery to the negative pole, we consider the current as flowing from the plate to the filament and thence through the phones back to the battery. Therefore, as long as filament is burning, there will be a flow of current through the phones; but owing to the fact that it is steady, no vibration of the diaphragms will occur.

If oscillations are flowing in the receiver circuits, alternate positive and negative charges will be given to the grid. When the grid is charged negatively no current flows from the grid to the filament, but when the grid is charged positively current passes from the grid to the filament. In other words, when the grid is charged negatively, the electrons will be repelled and no negative flow of electricity will occur; but when the grid is charged positively the electrons will be attracted and a negative flow to grid will occur. This latter is identical to a flow of current from the grid to the filament. The student should take note that during the times that the grid is charged negatively no current passes; therefore, a negative charge piles up in the grid condenser on the side next to the grid. This negative charge causes a decrease in the flow of electrons to the plate and consequently the flow of current from plate to filament is reduced. After a train of oscillations has passed, the negative charge leaks off and the plate current returns to normal. Thus, each train of oscillations reduces momentarily the flow of current through the plate circuit. This reduction of current causes a click in the telephone receivers, the number of clicks per second being dependent upon the number of trains of oscillations.

Hence, it can be seen that if each of the trains of oscillations is produced by a train of waves, and each train of waves by a train of oscillations in the distant transmitter circuits, the number of clicks in the telephone depends upon the spark frequency of the transmitter.

The subject of vacuum valves will be continued in the following instruction paper:

Static: Static, also known as "atmospherics" or "strays," is a form of disturbance which interferes with the reception of signals. It is manifested by discharges through the receiving set, which cause crackling noises in the telephone receivers. One form of static is due to electrical storms, whose approach is made known to the radio operator by an increasing number of irregular clicks in the telephone receiver. The origin of other forms of static has not been satisfactorily explained, many theories being advanced as to their source. The interference due to static is more serious during the summer months in temperate zones than at any other time, while in the torrid zone this interference is a serious problem at all times. In the Pacific Ocean, north of 34 degrees north latitude, static is very light, and due to this fact exceptonal ranges are attained by radio stations operating in this part of the world.

Radio transmitters using a spark frequency of about 1,000 have less difficulty in transmitting through static interference than do stations having lower frequences. The reason for this is that the signals are of higher pitch than the static, and therefore easier to copy. A station using a 120 cycle synchronous set is almost impossible to copy through bad static interference due to the similarity of the sounds produced in the telephone receivers. Static interference may be reduced somewhat by loose coupling of the receiving transformer and by the use of a detector whose sensitiveness is just sufficient to render the signals readable.

Buzzer Tester: Some types of detectors, such as the crystal, may have varying degrees of sensitiveness, certain points on the face of the crystal being more sensitive than others. To determine when a detector is in the most sensitive condition, a buzzer tester is employed. The buzzer tester is merely a combination of a buzzer, battery, push button and a small inductance. This arrangement is shown in Fig. 82, connected in inductive relation to a part of the aerial circuit. In some cases no inductance is used, the buzzer circuit being connected by a wire to the aerial circuit. If the button is pressed, the interrupter on the buzzer will break up the current, causing the current strength to rise and fall. This interrupted current will induce another current in the circuits of the receiver. If the detector is properly adjusted, this current will be rectified, producing a note in the phones identical with that of the buzzer itself. In the case of a crystal detector, the contact is varied until a sensitive spot is found on the face of the crystal, at the same time varying the potentiometer (if used) until signals are a maximum. When using the vacuum valve, the buzzer tester is not so necessary, but may be employed, as it tests the circuits of the receiver as well as the detector itself.

Adjustment and Care of Apparatus: The student should now have a fairly comprehensive grasp of the function of the different parts of the receiving set.

In order to assist the new operator in placing a receiving set in operation, the following suggestions may be followed:

1. Trace out connections of receiver from the aerial to the ground, comparing with schematic wiring diagram of the set.

2. It is well for the new operator to inspect the interior of the receiver box and note the method of varying coupling, inductance and capacity.

(a) When listening for signals, use close coupling of primary and secondary.

(b) Use a large value of inductance in the primary and a small value of inductance in the secondary.

(c) Adjust detector and potentiometer, using test buzzer as an exciting medium.

(d) Vary the series condenser in the aerial circuit and also the secondary condenser.

(e) If secondary circuit is calibrated, it can be set instantly to the wavelength desired, and then it is only necessary to vary the aerial circuit.

(f) It is well to remember that different aerials require different adjustments of the primary circuit of the receiving set.

4. A loose coupling and very close adjustment of the two circuits to resonance may reduce interference from static or from stations to a minimum.

QUESTIONS

THEORY LESSON No. 9

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

186. Into what four types may receiving circuits be classified?

187. Why is it necessary that a detector be used in receiving circuits?

188. What is the advantage of varying the coupling of the receiving tuner?

189. What coupling is used when it is desired to receive on a wide range of wavelengths?

190. Describe a buzzer tester. What is the use of a buzzer tester?

191. What are the least number of pieces of apparatus necessary to receive signals? Give diagram.

192. Describe fully a direct or conductively coupled receiving circuit.

193. Draw a diagram of a modern type of inductively coupled receiver, showing all apparatus used, including the buzzer tester.

194. Describe the capacitatively coupled receiver.

195. Name the principal parts of a receiver of the inductively coupled type.

196. Give diagram of a set employing a carborundum detector.

197. What is the function of a potentiometer?

198. What is the function of a variable condenser in shunt to the secondary winding of a receiving tuner?

199. What is the function of a detector?

200. Explain briefly the function of a telephone receiver.

201. Why should the coupling be reduced when receiving to the point where signals are just readable?

202. How do you protect the receiving set from the local transmitter?

203. Explain the action of a vacuum valve detector.

204. Name some of the crystal detectors.

205. Give diagram of a receiver circuit employing a vacuum valve detector.

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

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Answers to Instruction Book No. 9

186. Receiver circuits may be divided into four types. (1) Simple plain receiver, inductively coupled, conductively coupled and statically or capacity coupled receivers.

187. The detector is necessary to stop one-half of each wave in the train so that the telephone receiver will respond to the incoming waves. The detector with stopping condenser causes one discharge of current thru the phones of each wave train.

188. The advantages of the varying couplings are: 1st, to tune broadly so as to pick up a number of messages; 2nd, by loose coupling to get selective tuning and elimiate the undesirable waves.

189. A tight or close coupling is used for receiving on a wide range length.

190. A buzzer tester consists of a small buzzer, a dry cell, key or switch and a small coil of wire for coupling it to another circuit. The buzzer serves as feeble transmitter to excite the receiver so the operator may test his detector for sensitiveness.

191. An aerial, crystal detector with phone across it and a ground. See Figure 79a.

192. A direct or conductively coupled receiving circuit consists of a coil or helix in series between aerial and ground and connected across this same coil is the secondary receiving circuit with a detector and stopping condenser in series and the phone shunt around the condenser.

193. See Figure 82.

194. In the statically or capacity coupled set two wires are brought off the turns of the primary tuning inductance, one wire being connected to one set of the plates of a variable condenser and the other wire to a set of plates of another variable condenser which has its movable plates mounted on the same shaft. The other set of plates for each two condensers has the two wires leading off to secondary receiving circuit, as shown in Figure 83. The energy is transferred by static induction thru the two coupling condensers to the secondary or detector circuit.

195. The parts of a receiver are: aerial, loading inductance, primary of receiving transformer, short-wave condenser and ground for the primary circuit. The secondary circuit has secondary coil of receiving transformer, variable tuning condenser, detector, stopping condenser, phones and buzzer tester.

196. See Figure 82 and put carborundum crystal in the detector.

197. To place an initial pressure on the crystal, thus making it more sensitive to responding to the incoming waves.

198. The secondary tuning condenser is for very fine tuning which cannot be obtained by turn variation on the secondary coil of the receiving transformer.

199. The function of a detector is to receive the energy in the form of radio oscillations and effect a change so the impulses on the phone will be in one direction and at an audio frequency.

200. The telephone receiver changes the electrical impulses made upon it into sound waves for the ear by the vibratory motion of the diaphram.

201. The coupling is reduced to eliminate all interfering waves.

202. The receiving circuit is protected from damage due to nearby transmitters by the short circuiting of the detector with a switch.

203. The secondary is connected between the filament and grid, while the phone circuit is in series with a high voltage battery and connected across plate and filament, the positive pole of the battery being connected to the plate. When the filament is lighted negative electrons flow outward from the filament to the plate, uniting with positive charges from the battery which causes a steady flow of current thru the phones. When the oscillations from the incoming waves are impressed on the grid condenser the negative charges repel the negative charges from the filament and stop the flow of current. When the wave train is over the negative charge leaks off the grid condenser and the current increases its flow; thus each train of waves changes the current and makes a click.

204. Galena, silicon, carborundum and perikon crystals are used as detectors.

205. See Figure 89.

100%

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Student No. 13794 Lesson No. 9

186 (1) Simple (2) Inductively (3) Capacitively coupled (4) conductively coupled.

187 A detector is a device connected in a circuit carrying currents of radio frequency this transforms these currents into a form sutable for the operation of the receivers in other words it changes Radio frequenky into Audio frequency.

188 The advantage is that when receiving from a certain station the coupling may be set exactly on his wavelength and interferance from other stations of other wave lengths are eliminated.

189 A close coupling.

190 A buzzer tester is a combination of a buzzer battery, push button and a small inductance which is placed in an inductive relation to a part of the receiving circuit.
The use of a buzzer tester is to help the operator in finding the most sensative spot on the crystal in the absence of incoming signals It is also used in testing out the receiving circuit

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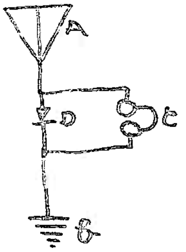
#91 The least number of apparatus necessary are detector and receiver attached to the aerial and ground.



A aerial
b ground
C receiver
D detector

192 a conductively coupled receiving set consists of a variable inductance in series with the aerial, variable condenser and grounds, the detector on one side is connected to the ground wire at the end of the coil. the other side is fastened to a coil upon which there is a slider, the slider makes contact with the different turns of wire. The receiver is then shunted around the detector

By varying the number of turns on the aerial slider and also the number on the secondary or detector side a great range of wave lengths are obtainable above the natural wave length, to go below this the variable condenser is used to vary the capacity.

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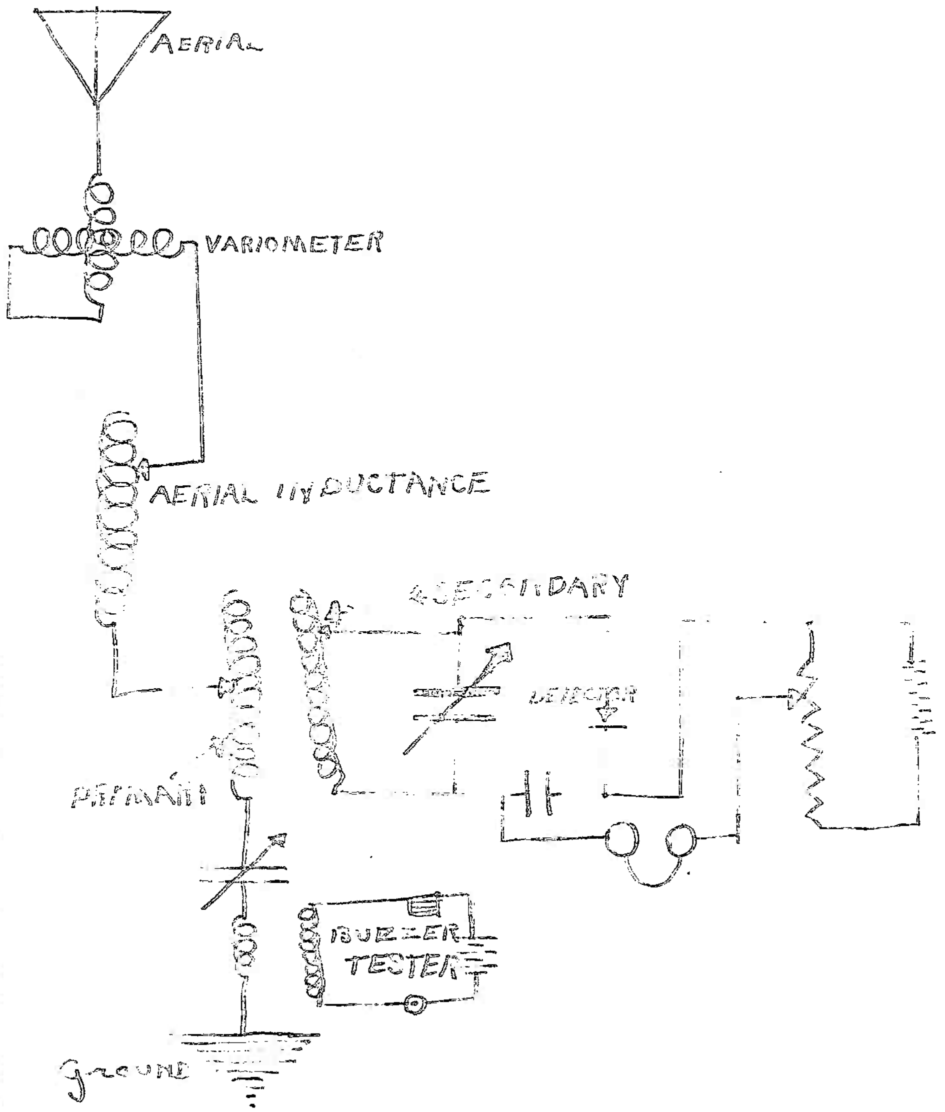
193



194 The capacitively coupled circuit consists of a primary and secondary, unlike other circuits there is no magnetic action between the two inductances as they are placed at right angles to each other. The energy is transferred from the primary to the secondary by means of two coupling condensers.

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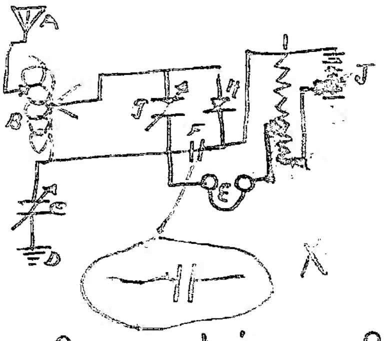
These coupling condensers have nothing to do with the tuning of the set. The phones and detector are shunted around the secondary.

175 Aerial, aerial tuning inductance, primary, Variable condensers, Secondary, detector, fixed condenser, phones, potentiometer and battery and ground, buzzer tester.

196 a circuit using a carborundum detector.



A aerial
B tuning coil
C variable condenser
D ground
E phones
F fixed condenser
G variable condenser
H carborundum detector
I potentiometer
J battery

197 The function of a potentiometer is to vary the voltage of a battery passing through a detector to give maximum strength or loudness to the incoming signals.

198 The function of a variable condenser in shunt to the secondary of a receiving transformer is, On the secondary there are switch~~es~~ points connected to every few turns of the secondary. By turning the switch a station is tuned in. The variable condenser is then used to tune

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Lesson No 7

in the exact wavelength which may lie within the different turns of wire between the switch points.

199 The function of the detector is to transform the incoming signal from radio frequency to Audio frequency.

200 The function of the telephone receiver in a receiving set is to render audible the rectified trains of oscillations.

201 When receiving to a point where the signals are just readable the coupling should be reduced in order to allow more energy to be induced from the primary to the secondary since, When the two coils are close together the mutual induction will be greatest and a large part of the energy from the primary will be transferred to the secondary but when the coils are far apart a minimum amount of current is transferred and therefore the set becomes very selective.

202 By moving the coupling so the transformer is slightly out of tune with the local transmitter the minimum amount of current will

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Lesson No. 9

Student No 13797

be induced from the primary to the secondary, and therefore the strength of the incoming signals will be reduced and the detector will not be put out of order.

203 The action of a Vacuum valve detector is thus Negative particles of electricity called Electrons are thrown off from the filament when it is lighted, if passing waves of oscillations are flowing in the receiving circuit, the copper cylinder will be alternately charged positive and negative, when the cylinder is positive, the negative electrons thrown off from the filament will be attracted to the cylinder, The next charge of the oscillations will be negative, and as like charges repel each other the electrons will not flow to the plate, therefore the valve acts as a rectifier, and allows current to flow through the phones only when the plate is positive charged. It is this pulsation of current through the telephone receivers that makes the audible sound in them.

204 Silicon, galena, carborundum, zincite -- bornite, iron pyrites, Radiocite

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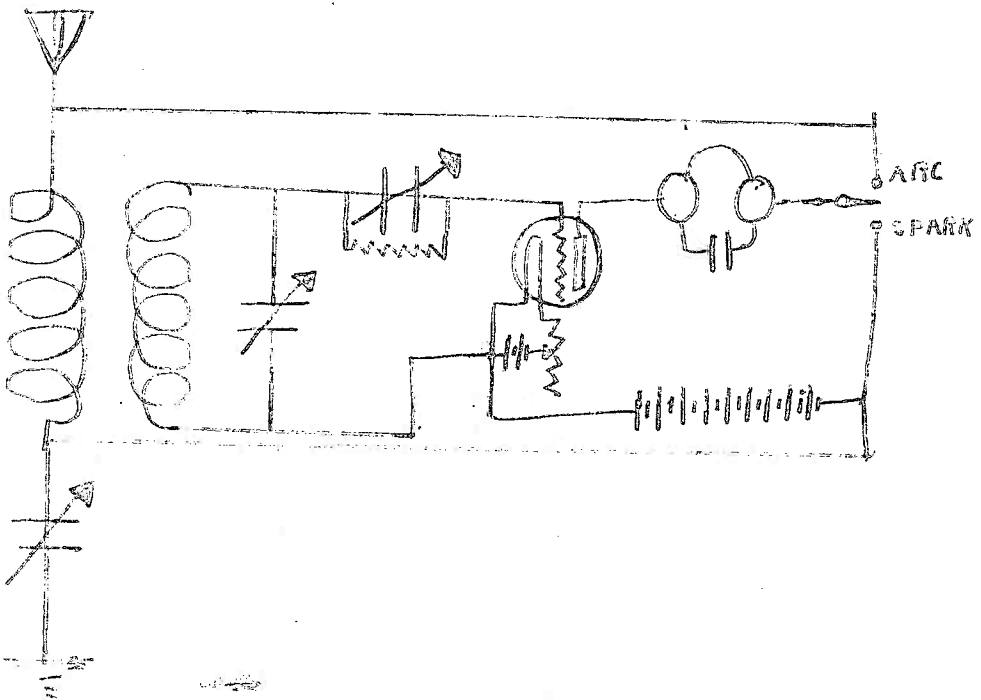
Student No. 13777 Lesson No. 7

205 Diagram of a receiving circuit using a Vacuum valve detector.



LESSON TEXT No. 10

OF A

Complete Course in Radio Telegraphy

The Receiving Set for Undamped Waves

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 10

WARNING MESSAGES

QST QST QST de NAA NAA NAA

S. S. Merrimack reports water-logged hull N. Long. forty-six eight W. Lat. thirty-nine six. Stump of mast projecting ten feet out of water. Dangerous to navigation.

QST de NAA

Derelict three masted schooner Mabeldavis in position N. Long. thirty-nine ten W. Lat. forty-three twenty-six.

METHOD OF CALLING THE NEAREST STATION

Stations desiring to enter into communication with ships, without, however, knowing the names of the ships within their radius of action, may employ the signal ▬ ● ▬ ● ▬ ▬ ● ▬ [signal of inquiry.] After a station in that locality has answered the call, communications are transmitted by the regular method.

Practice on Sending Key

SAQN
DOLTZ
CANDZ

DAKM
NOQAL
POZXQ

QNLOR
PZBOJ
NOLQY

PAZYD
RIVOM
KYQOB

KKNYO
QOLYM
YZLER

DOZEQPAMEL
DPZQKNOTUE
PODUMQOZYL

NOQEZRAZEL
MAKOKTUBEZ
JUYOWPENOK

HYFOWQALPO
YOZEHJOKYQ
KIWEFMAREW

1259078296
0095843210
6802645210

4102617901
6102859021
5102148739

3708529071
5820634821
5762093845

QAZPN
KYCYO
GOHJK

NOLYJ
PAZOM
AOYKN

PETER
NOLUJ
AEYOJ

JOHNZ
JIWQO
QELYU

KQKYK
KAMPY
PANZA

WEATHER REPORTS

QST QST QST de NAA NAA NAA

USWB. District of Columbia and Virginia. Partly cloudy with occasional showers probably tonight and Sunday. No material change in temperature. Gentle to moderate south winds.

THE RECEIVING SET FOR UNDAMPED WAVES.

CODE TEST

RHUAZ BWCLX SVTND OKFYE PIQJG
UBLVD FPJHZ CSNKE QRAWX TOYIG
HABCX VNOFE IJGRU ZWLST DKYPQ
ACYOE JUWSD YQHBX NFINZ LTKPG
ZXDEG RBSOP HWVKI UCTFQ ALNYJ

PIQJG MKFYE SVTND BWCLX RHUAZ
TMYIG QRAWX EKNSC FPJHZ UBLVD
DKYPQ ZWLST URGJI VNMFE HABCX
LTKPG NFINZ YQHBX JUWSD ACYME
ALNYJ UCTFQ HWIKV PMSRB GEDXZ

19328 47650
34691 08725
82543 70169
52187 63904
06714 35892

25439 86017
73150 92486
68902 14573
97065 21348
40876 59231

PRESS SCHEDULES OF SPARK STATIONS.

Call	Station	Metres Length Wave	Time
NAA	Washington, D. C.	2500	10.00 P.M. 75th Meridian
NAR	Key West, Fla.	1500	10.00 P.M. 75th Meridian
NAX	Colon, Panama	2400	10.00 P.M. 75th Meridian
NPG	San Francisco, Cal.	600	1.15 A.M. Local Time
KHK	Honolulu, Hawaii	600	11.30 P.M. Local Time
NAH	New York, N. Y.	1500	9.00 P.M. 5 A.M. Local Time
NPL	San Diego, Cal.	2400	.....
BZM	St. Johns, N. F.	1500	7.30 A.M. (GMT)
VCU	Barrington Passage, N. F. .	1500	8.00 A.M. (GMT)
BZL	Demerara, British Guiana . .	1300	6.00 A.M. (GMT)
BZN	Falklands	4300	3.30 A.M. (GMT)
BYZ	Malta (Rinella)	2650	9.00 A.M. 7.00 P.M. (GMT)
OAZ	San Cristobal, Peru	1500	2.00 A.M. 3.30 P.M. (GMT)
BXY	Hong Kong, China	2000	9.45 P.M. (GMT)
BXW	Singapore	2000	9.15 P.M. (GMT)

BZE	Matara, Ceylon...........	2000	8.45 P.M. (GMT)
BZF	Aden, British Somaliland..	2000	7.30 P.M. (GMT)
BZH	Seychelles	2000	9.45 P.M. (GMT)
BZG	Mauritius	2000	10.30 P.M. (GMT)
BZI	Durban, South Africa.....	2000	3.15 P.M. (GMT)
VMG	Apia, Samoa	2000	11.30 A.M. (GMT)
VLA	Awanui	2000	7.15 A.M. (GMT)
VLB	Awarua, Australia	2000	10.45 A.M. (GMT)
VID	Darwin, Australia	850	6.30 P.M. (GMT)
VKT	Naura, Australia	2200	7.00 P.M. (GMT)
VIP	Perth, Australia	1500	4.30 P.M. (GMT)
VJZ	Rabaul, Australia	2900	6.00 P.M. (GMT)
VIS	Sydney, Australia	2000	3.30 P.M. (GMT)
VIT	Tounsville, Australia	1000	4.30 P.M. (GMT)
VIF	Woodlark, Isl., Australia..	1000	5.00 P.M. (GMT)
UA	Nantes, France	2400	3.30 A.M. 3.45 P.M. (GMT)
FL	Paris, France	2500	3.00 P.M. (GMT)
YN	Lyons, France	5000	8.00 A.M. (GMT)

TIME SIGNALS BY ARC STATIONS

Call	Station	Wave Length Metres	Time
NSS	Annapolis	17000	11.55 A.M. to Noon
			9.55 to 10 P. M.
NBA	Balboa Panama	7000	4.55 to 5 A.M.
			12.55 to 1 P.M.
NPO	Cavite, P. I.............	5000	10.55 to 11 A.M.
			9.55 to 10 P. M.
NPL	San Diego, Calif........	2400	11.55 A.M. to Noon
NPH	San Francisco, Calif....	4800	11.55 A.M. to Noon
NPM	Pearl Harbor, Hawaii...	11200	Daily at 180th Meridian Noon Time

Undamped Waves: In the preceding papers we have been dealing with damped electromagnetic waves. Such waves are produced by damped oscillations and occur in groups.

Damped oscillations are the result of a condenser discharging through a spark gap and a coil of wire. We learned that if the key of a damped wave transmitter were depressed a number of groups waves equal to the spark frequency (the number of complete discharges of condenser per second) would be radiated. As the velocity of electromagnetic wages is about 300,000,000 meters per second, one wave train will have traveled a certain distance from the aerial before the next one leaves. Hence, there is a considerable space between consecutive groups. The student should bear in mind that each *train* or group of waves is produced or set up by a *train* of oscillations.

In this paper we are dealing with undamped or continuous waves.

Undamped waves may be defined as those of constant amplitude and continuous formation. A comparison of the two types of waves is given in Fig. 90. It can be seen that the number of waves radiated per second will be far greater with the undamped than with the damped, owing to the continuity of the former. If we take as an example two transmitting stations, one of the stations being undamped and the other of the damped type, each radiating waves 6000 meters in length, the number of waves radiated by the damped wave station will depend upon the wave train frequency and the number of waves per train, while the number of waves radiated by the undamped set may be determined by dividing 6000 into 300,000,000. The latter is true, for the reason that if waves travel 300,000,000 meters per second, the number leaving the aerial per second must be equal to 300,000,000 divided by the wavelength. If the logarithmic decrement of the damped transmitter is .2, there will be 24 waves per train; and if a synchronous gap is used with a 500 cycle source of supply the spark frequency will be equal to the number of alternations of the source (1000).

The actual number of waves radiated will be 1000x24 or 24000 by the damped transmitter, while the undamped station will radiate 300,000,000 divided by 6,000 or 50,000 waves. *Undamped or continuous waves have also been defined as those radiated from a conductor in which an alternating current flows.*

That is, undamped waves are radiated from an aerial in which undamped oscillations are flowing. The oscillations are generated at the present time by any one of the three following methods: The high frequency alternator, the vacuum valve generator and the Poulsen arc generator.

A description of these three methods will be given in the latter part of the course.

The undamped wave system of communication is rapidly replacing the older method, due to the following reasons:

THE RECEIVING SET FOR UNDAMPED WAVES.

1. As the waves are of constant amplitude there is no decrement and consequently they are confined to one wavelength or frequency.

2. Being continuous, the amplitude need not be so great, and therefore lower potentials may be employed.

3. Radio telephony is made possible.

4. The tone of the received signals can be controlled by the receiving operator.

5. The efficiency of the undamped system is far greater than that of the damped.

The Undamped Wave Receiver—In the preceding paper the apparatus employed in damped wave reception is the subject of

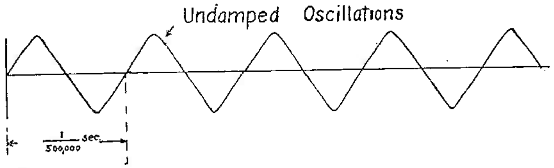

Fig. 89

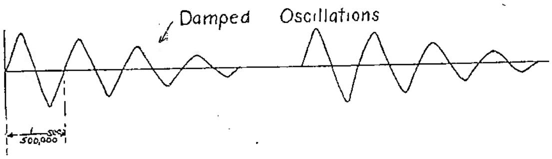

Fig. 90. Damped and Undamped Oscillations.

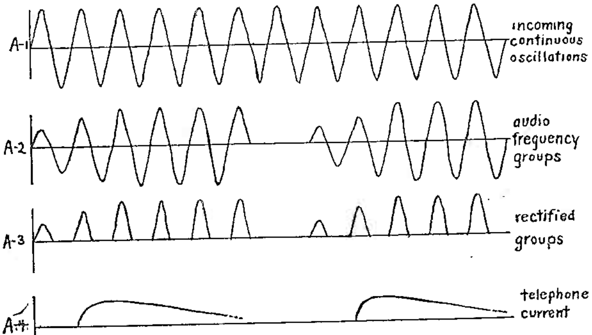

Fig. 91. Curves showing action of tikker or slipping contact detector.

discussion. We learned that the note in the telephones is dependent on the number of wave trains cutting the receiving aerial per second and that the function of the detector is to so alter the trains of oscillations induced in the aerial by the trains of waves that one sound for each train is heard in the phones. The student should be very careful to get the distinction between the terms *"wave frequency"* and *"spark frequency."* The "wave frequency" of modern radio stations ranges between 15,000 for the large stations to 3,000,000 for the small short wave stations, and consequently is of too high a frequency for indication in the telephone. (By wave frequency we mean the rate at which the waves are produced and not the actual number of waves.)

As stated before, the human ear will not respond to vibrations above 20,000 per second and the telephone is most sensitive to vibrations in the neighborhood of 1,000 per second.

The **"spark frequency"** of modern sets usually ranges between 120 and 1,200, and as each spark is the source of a wave train, we have a frequency which will give response in the telephone. (By spark frequency is meant the number of discharges of condenser per second.)

The detector of damped waves merely rectifies the trains of oscillations induced in the aerial by passing wave trains, each rectified train flowing into the condenser connected across the phones and in the interval between train discharges through the phones as one click; hence the spark frequency, the oscillation frequency of transmitter, the wave train frequency, the oscillation train frequency in the receiver and the vibration frequency of the telephone diaphragm are equal in number.

Owing to the fact that undamped waves do not occur in groups but are of continuous formation, we can not use the damped wave detector for continuous wave reception. If by some means we chop up the continuous flow of oscillations either in the transmitter circuit or in the receiving circuit into an audio frequency succession of trains or groups we may then use the rectifying detector for reception.

The means used in making continuous or undamped waves audible may be listed as follows:

1. By means of a chopper in either the transmitting or the receiving set.
2. The tikker.
3. The slipping contact detector.
4. The rotating plate condenser.
5. The Goldschmidt tone wheel.
6. The heterodyne receiver.
7. The regenerative vacuum valve.

The first four methods actually break up the continuous waves into groups of audio frequency while the last three employ other means for obtaining the same result.

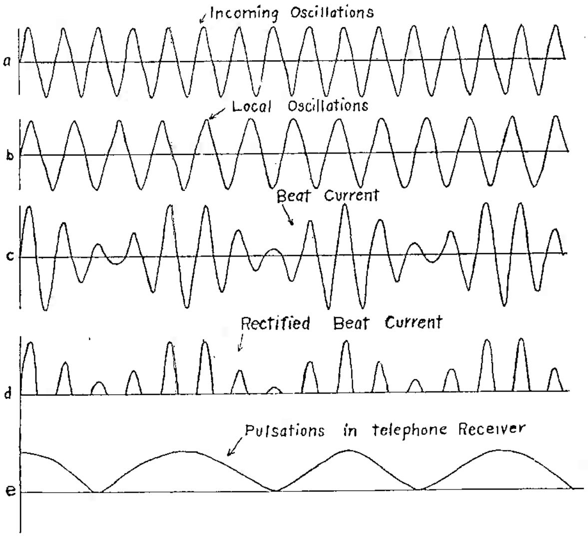

Fig. 92. a, b, c, d, e. Curves showing action of heterodyne (beat) receiver.

The Chopper: This is a device for making and breaking the circuit in either the transmitter or the receiver. It is an interrupter and derives its name from the fact that it chops up the continuous flow of oscillations into groups of audio frequency. If the chopper is employed in the aerial circuit of the transmitter, the groups of oscillations cause groups of waves to be radiated which travel to the distant receiving stations, where groups of oscillations are produced in the receiver circuits. With this arrangement the damped wave receiver will rceive from the undamped station, but the transmitter when equipped with a chopper ceases to be an undamped wave station. The great disadvantage of the chopper as connected in the transmitter is that it reduces the range to a considerable extent. A better method is to place a chopper in the receiving circuit and break up the oscillations there, the detector rectifying the groups.

The Tikker: This is identical with chopper as described above except that this device is employed in receiving sets. It interrupts the circuit at various frequencies between 400 and 1,000. This device is usually connected as in Fig. 93, the secondary circuit consisting of the secondary coil, the secondary variable condenser, the tikker, telephone condenser and telephones. A small metal disc having teeth cut in its periphery is mounted on the shaft of a small electric motor, the spaces between the teeth being filled with insulating material. A spring brush bears on the edge of the disc, alternately making and breaking contact with the disc. A second brush makes continuous contact with the side of the disc. As the motor revolves the circuit is made and broken at a rate depending upon the speed and the number of segments on the disc.

The action is as follows: The brush at one instant makes contact with the metal disc, and if signals are being received the secondary condenser will discharge through the disc into the telephone condenser. The next instant the brush rests on insulation and the circuit is broken. During this interval in which the circuit is broken the condenser discharges through the telephones. The secondary condenser discharges at a regular rate into the telephone condenser but will not be charged to the same potential each time, and for this reason a rough note is produced in the telephone. This rough note is the principal disadvantage of the tikker detector, while is simplicity and sensitiveness may be given as its advantages. It is a current operated device, giving best results in a circuit where there is a maximum of current rather than voltage. It is rapidly being superseded by a more modern detector called the regenerative vacuum valve.

The Slipping Contact Detector: This instrument operates on practically the same principle as the tikker but is of different construction. A plain brass pulley is mounted on the shaft of a small electric motor. A spring wire is mounted on a standard in such a manner as to bear in the groove of the pulley. A second brush makes a sliding contact with the side of the pulley. This detector is connected in the circuit as shown in Fig. 93. As the motor revolves the spring wire makes a contact of varying resistance; one instant there is good contact and the next a poor contact. The result of this action is that when a good contact is made, the secondary condenser discharges into the telephone condenser; and at the times of poor contact or high resistance, the charge is not strong enough to pass to the telephone condenser. In the intervals between the low resistance contacts the condenser discharges through the phones. This detector is also a current operated device. Both the tikker and the "slipping contact" detector will make *damped* waves audible, but due to the low note of the signals are not usually employed for that purpose. The capacity across the phones for either detector should be about one microfarad.

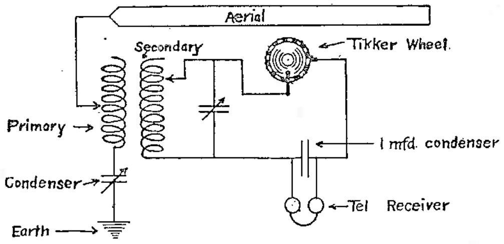

Fig. 93. Diagram of Connections for Tikker.

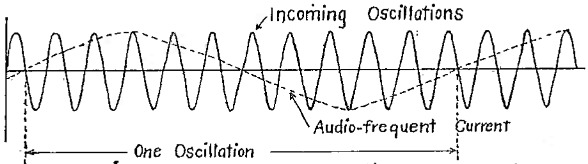

Fig. 94. Production of an Audio-frequency by the action of a Tone Wheel.

The Rotating Plate Condenser: Suppose that the secondary condenser in Fig. 97 is shunted by a small air condenser, the movable plates of which are fastened to the shaft of a small electric motor. If the large condenser is adjusted to such a value that the addition of the maximum value of the rotating condenser will place the secondary circuit in resonance with the incoming signals, each time the shaft of the motor revolves there will be an impulse of the telephone diaphragm. The tone depends on the speed of the condenser motor. The rotary condenser method is not used to any great extent.

The Goldschmidt Tone Wheel: In the discussion of the tikker we spoke of the irregular note produced in the phones and explained that this was due to the fact that the secondary condenser does not always have the same potential when the circuit is closed. A detector called the tone wheel operates on a similar principle to the tikker, but with this difference: the tone wheel has as many as 800 segments and revolves at a very high speed, interrupting the circuit many thousands of times per second. It may be adjusted so that it will interrupt the circuit in synchronism with the incoming oscillations. If oscillations were flowing through the receiver circuits at a frequency of 50,000 cycles, and the tone wheel interrupted the circuit at 50,000 times per second, the result would be a rectification of the current, and 50,000 pulsations would flow into the telephone receiver. As this is too high for audibility no sound would be heard in the telephones. Suppose the tone wheel is adjusted so that the circuit will be interrupted 49,000 times per second. In Fig. 94 is shown the resulting action. It can be seen that, due to the slower rate of the interruptions as compared with the oscillations, each succeeding oscillation will be interrupted at a different point. The result of this is a current of low frequency flowing through the phones as illustrated by the curve. Thus, for every fifty oscillations induced in the receiver aerial by continuous waves (6,000 meters) there will be one pulsation in the telephone receiver.

By variation of the speed of the tone wheel the tone of the signal may be regulated. It is connected in the circuit in the same manner as the tikker, with the exception that no condenser is placed across the telephones. In the *tikker method* of reception the circuit is interrupted at an *audio frequency* and the telephone condenser is charged and discharged at the same frequency. In the *tone wheel method* the circuit is interrupted at a *radio frequency* (above 10,000) only slightly different from the frequency of the incoming oscillations. The tone wheel is not used extensively, having the disadvantage of not being adapted to the reception of short wave-lengths.

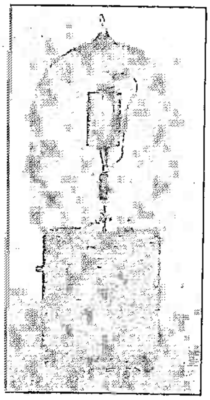

Fig. 95. The three electrode vacuum tube.

Courtesy of
The DeForest Radio Telegraph & Telephone Co.

The Regenerative Vacuum Valve: We will now consider the most important receiving device in use today. The vacuum valve bids fair to replace all other types of detector due to its marvelous sensitiveness and dependability. In the preceding instruction paper the action of the Fleming valve and the three electrode valve is explained. In order that the student may understand the rather involved action of the three electrode valve as used for the reception of undamped waves we will discuss the elementary theory more in detail.

In the first place, to understand the action occurring in a vacuum tube, a knowledge of the *electron theory* is essential.

All matter is considered as being composed of molecules. For instance, the smallest particle of water is called a molecule; but if we allow a current of electricity to flow through water we can separate it into two gases, viz., hydrogen and oxygen. The chemical formula for water is H20. By this we mean that two atoms of hydrogen and one of oxygen combine to form a molecule of water, the molecule being defined as the smallest subdivision of a substance obtainable, without dissociating the substance into its elements.

THE RECEIVING SET FOR UNDAMPED WAVES.

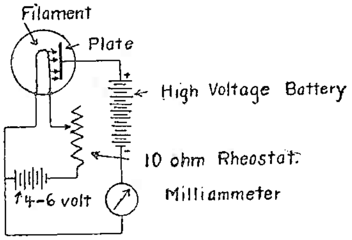

Fig. 96 Diagram of bulb showing flow of Electrons

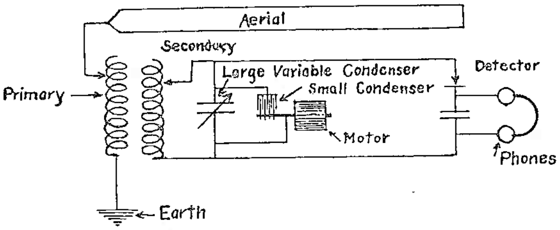

Fig 97. Receiving Circuit in which a Rotating Plate Condenser is employed.

The electron theory states that each normal atom of a substance consists of equal amounts of positive and negative elecericity. These equal amounts neutralize each other and therefore the atom has no detectable charge. The atom is assumed to have a nucleus of positive electricity which can not be removed, and that the negative electricity surrounds this positive charge. The negative charge exists in the form of electrons whose mass or weight is said to be 1-1800 of that of a hydrogen atom. The electrons or negative particles may be separated from the atom, and an atom which has a deficiency of electrons is said to be positively charged; but on the other hand, if an atom has an excess of electrons, it is considered as being negatively charged. The atom was considered for many years as being the smallest subdivision of matter; but, according to the above theory, the electron is a still smaller subdivision.

To summarize the above:

1. An atom consists of a positive nucleus about which are clustered negative electricity in the form of electrons.

2. An electron is considered as being the smallest particle of matter carrying the smallest known charge of electricity.

3. An atom possesses a positive charge when minus its normal number of electrons.

4. An atom possess a negative charge when it has more than its normal number of electrons.

5. Negative electricity can be removed from an atom but positive electricity can not.

In accordance with this theory, a current of electricity is a stream of electrons guided by a metallic conductor.

Before the electron theory was developed, the assumption was made that the flow of current in the external circuit was from the positive pole of the source to the negative pole, but this will conflict with the above definition of a current. A dry cell, for example, when connected in circuit is said to have an external current flow from the carbon to the zinc pole; but according to the theory the flow is from the zinc to the positive pole in the external circuit.

(The student should remember that the current is still considered as flowing from the positive to the negative pole in the external circuit, the flow of electrons being in the opposite direction.)

Any incandescent lamp has a current flowing through its filament. This current consists of a flow of electrons, part of which are employed in heating the filament to an incandescent state. A part of the remaining electrons is set into vibration and is thrown off, filling the immediate space about the filament. As the filament grows hotter, more electrons are thrown off until the point is reached when, due to the law that "Like charges repel and unlike attract," the electrons about the filament repel those coming out and the emission of electrons is brought to an end.

In the two electrode vaccuum valve circuit, shown in Fig. 96, if the positive pole of a high voltage battery is connected to the plate and the negative pole to one side of the filament, the plate will be charged positively. According to the electron theory, this means that there is a deficiency of negative electricity. If the filament is burning the electrons thrown off by the filament will be attracted by the plate and we will have a flow of electrons from the filament to the plate. That is, we will have a current of electricity flowing from the filament to the plate, if we follow the electron theory. But in accordance with the old theory, electricity flows in a direction opposite to the flow of electrons. The student should take careful note of this confusing point.

In Fig. 95 a photograph of a vacuum tube is shown. As illustrated in Fig. 96, as long as the filament is burning, electrons will be thrown off from the fiilament; and if the plate is charged positively there will be a constant flow of electricity in the plate circuit. A 4 to 6 volt storage battery is employed to light the filament, the strength of the current being regulated by a ten ohm rheostat in series with the circuit.

A twenty to one hundred volt flashlight or storage battery has its positive pole connected to the plate. In Fig. 89, instruction paper No. 9, a receiving circuit is illustrated, in which a three element valve is connected. As explained in the above-mentioned paper, there is a constant flow of electricity through the telephone receiver while the filament is burning. When no signals are being received, this current is a steady direct current, and does not produce any vibration of the telephone diaphragm. The grid, consisting of a coil of wire or perforated metal plate, is placed *between* the filament and plate. The grid in series with a condenser is connected to one side of the secondary variable condenser. A passing wave train will induce a train of oscillations of decreasing amplitude in the receiving circuit. These oscillations are of high frequency and place an alternate positive and negative charge on the grid.

The space surrounding the filament is filled with electrons (negative electricity), and if the grid is charged negatively there will be a repelling of the electrons emitted by the filament, due to the law that "like charges repel, unlike attract." This repelling of the electrons thrown off by the filament lessens the number which reach the plate and consequently a reduction of the plate current is the result. The next alternation of the incoming oscillations places a positive charge on the grid and the result is an increase in the plate current. It can be seen then that an incoming group of oscillations will cause the plate current to oscillate at the same frequency. By this we mean that the plate current will rise and fall at the same frequency, not that it will reverse its direction, as do the incoming oscillations. This repeating action will be considered more in detail later. We are more interested at the present moment in the rectifying action of the vacuum tube. If the grid is charged negatively it will repel the electrons from the filament and no current will flow from the grid to the filament. If, however, it is charged positively a current will flow from the grid to the filament (identical to an electron flow from filament to the grid); therefore, half of the alternations of each train will pass through from grid to filament, but the other half will be stored up in the grid condenser. This charge will pile up during the passage of a train of oscillations, thereby increasing the negative charge on the grid. This action tends to decrease the flow of electrons from *filament* to *plate* and consequently reduce momentarily (during the passage of a train of oscillations) the flow of current through the phones. Between the passing of two trains of oscillations there is a short interval of time, and during this interval the negative grid charge leaks off. The next train gives rise to another reduction of current, the number of reductions of current per second being dependent upon the wave train frequency. If the spark frequency of the transmitter is 1,000, 1,000 wave trains will be radiated and as a result there will be 1,000 reductions of current in the telephones of the distant receiving set. A reduction of current results in a vibration of the diaphragm of the telephone receiver; and with a frequency of 1,000, the note will be high and clear, which is very desirable in radio reception, especially in localities subject to atmospherics. The above is a description and explanation of the three electrode valve as used in damped wave reception. The student will observe that the vacuum valve acts as a relay, the rectifying action being a means to that end.

As this instruction paper deals with *undamped receiving,* we will now consider the action of the valve when employed for that purpose. In music we may have two piano wires of slightly different vibration frequencies. If the two wires are caused to vibrate, they will each set up a sound wave, but due to interaction between the two, a third wave whose frequency is the difference between the two fundamental waves, will be heard. This third sound wave is called a "*beat*" note. In organ music the production of "beats" is especially noticeable. The student will observe that the "beat" note is of *low frequency*, being the *difference* between the *frequencies* of the *two fundamental waves*.

Advantage was taken of this phenomena by Reginald Fessenden a number of years ago. He provided a source of high frequency oscillations at the receiving station and caused this current to be superposed on the incoming undamped oscillations set up by the waves from a distant station.

The frequency of the local current is adjusted to a slightly different frequency from that of the incoming signals, and the interaction of these two currents produces a "beat" current of audio-frequency. For example, suppose that the incoming current is induced by waves having lengths of 4,000 meters. The frequency of the current set up in the receiving circuits will be 75,000 oscilla-

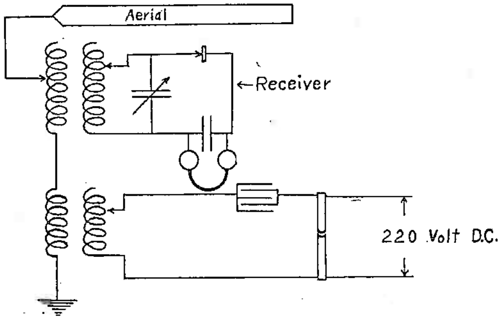

Fig. 98. Diagram of Heterodyne Receiver.

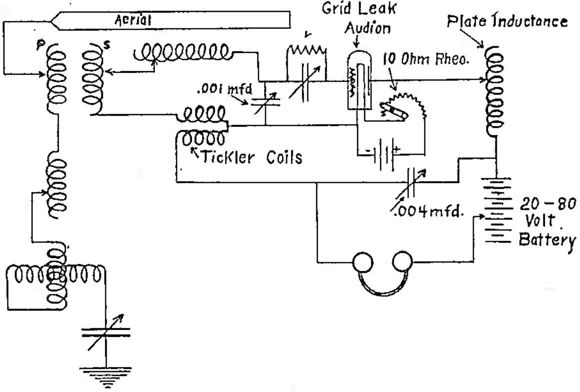

Fig. 99. Diagram of Regenerative Vacuum Valve.

tions per second. This is far too high to give indication in the telephone receiver or the human ear. However, if the local source of current supplies a frequency of 74,000 oscillations to the receiver circuits, the two will react, producing a beat current of 1,000 cycles which after rectification will give a high clear note in the telephone receiver. This arrangement was called by Fessenden a *"heterodyne."* In Fig. 98 is shown a diagram of the connections for heterodyne receiving. As illustrated the local source of current is inductively connected to the aerial circuit of the receiver. The resulting "beat" current is rectified by a detector, as shown in the figure.

The question might be raised as to the necessity for rectification if the "beat" current is of audio-frequency. This can be explained by reference to Fig. 92a, b, c and d. This "beat" current is made up of groups of oscillations as shown in Fig. 92c, which must be rectified before they will produce a sound. The amplitude of the local current is large and therefore the resulting audio frequency current will have a very large amplitude as compared to the incoming oscillations. This amplifying action is one of the great advantages of this system of receiving.

Either an arc generator, high frequency generator or a buzzer may be used as the local source of current, but it is preferable to employ a generator producing purely undamped oscillations.

A vacuum valve if properly connected will generate undamped oscillations, and is placed in inductive relation to the aerial circuit.
in the same manner as the generator illustrated in Fig. 98.

The "regenerative" vacuum valve detector is a modern development of the "heterodyne" or "beat" principle. Captain E. H. Armstrong was the first to experiment with this type of receiver.

In the discussion of the three electrode vacuum valve as a receiver of damped oscillations we learned:

1. That as long as the filament is burning there is a flow of direct current in the plate circuit and that this current being steady gives no indication in the telephone receiver.

2. That the oscillating currents set up by passing waves place alternate positive and negative charges on the grid, with the result that the plate current rises and falls at the same frequency.

This oscillating grid potential may be of very low value but will cause a relatively strong oscillating plate current. If by any means we can increase the oscillating grid potential there will be a further increase in the plate current.

If this oscillating plate current, being of the same frequency as the incoming current, could be impressed on the latter at the proper time, the potentials on the grid would be amplified and consequently a stronger plate current would flow.

In Fig. 99 is given a diagram of a circuit arranged so that part of the energy of the plate circuit may be transferred back into the secondary circuit for amplification of the grid potentials. The plate current can only increase to a certain value for a given tube and hence the degree of amplification is limited.

At the same time that this amplification is occurring local oscillations are being generated in the vacuum valve circuits. To understand the functioning of the vacuum valve as a generator, the following action must be taken into consideration.

While the filament is burning a steady plate current of about four thousandth ampere is flowing through one of the coils of the coupling transformer (see Fig. 99). As long as this current is steady, no current will be induced into the secondary circuit by

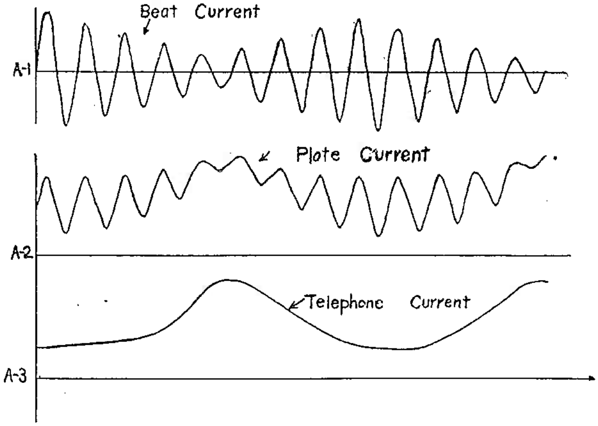

Fig. 100. Curves showing Action of Regenerative Vacuum Valve.

the action of the coupling transformer. If, however, the voltage of the plate circuit is changed for any reason, as by the opening of a switch in the plate circuit, an e. m. f. (potential) will be set up in the secondary circuit. Suppose this action places a positive potential on the grid, the result is that the plate current is increased. An increased plate current will cause a further transfer of energy to the secondary and a larger grid potential. This increase of plate current finally ceases, and the voltage of the grid falls to zero. The plate current then drops, placing a negative potential on the grid by inductive action, with the result that there is a further decrease of plate current. This decrease will eventually cease and the grid charge will again fall to zero, resulting in a rise in the value of the plate current. If this action is carefully studied, it can be clearly seen that there is an oscillating rise and fall of the current in the plate circuit, independent of the incoming oscillations.

The frequency of this generated current will depend on the values of the inductance and capacity in the grid circuit.

The interaction of this local current with the incoming oscillations gives rise to a "beat" current as described in the discussion of the "heterodyne."

In Fig. 100c, the "beat" current is illustrated. It is seen to consist of groups of increasing and decreasing amplitude. As the amplitude of a group increases a negative charge is placed on the grid, thus decreasing the plate current through the phones. A decrease in the amplitude will allow this negative charge to disappear and the plate current through the telephone increases. This increase or decrease of current through the phones occurs at an audio frequency. Such an action as is explained is above called "regeneration" or "reaction."

As illustrated in Fig. 100a, b, c, the two currents interact with each other and the addition and subtraction of amplitudes produces the "beat" current. That is, when two positive amplitudes occur at the same instant, the two will add together to form a large amplitude of the beat current. The next two amplitudes, howver, due to the difference in freqnecy may not occur simultaneously; therefore the resulting amplitude of "beat" current will be less. This action continues, producing oscillations having a periodic variation of amplitude.

THE RECEIVING SET FOR UNDAMPED WAVES.

The processes of *amplification, regeneration* and *detection* are all accomplished by the use of one vacuum tube.

In Fig. 99 is shown a circuit in which these three processes are accomplished. In order that the student may have a clearer understanding of the action taking place in such a circuit we will consider the various instruments and their function.

The following insrtuments are employed:

1. The aerial.
2. The aerial tuning inductance.
3. The varieometer.
4. The receiving transformer.
5. The short wave condenser.
6. The ground connection.
7. The secondary loading coil.
9. The tickler coils (coupling transformer).
10. The grid condenser.
11. The grid leak resistance.
12. The vacuum tube.
13. The "A" storage battery of 4 to 6 volts.
14. The fiilament rheostat.
15. The "B" flashlight or storage battery of 20 to 100 volts.
16. The telephone receivers.
17. Condenser in shunt to phones and battery.
18. The plate inductance.

This receiving set will respond to both *damped* and *undamped waves.* There are many different ways of connecting instruments for reception of undamped waves, but this may be considered a standard method. The dimensions of the coils and condensers are dependent on the wavelength of the signals to be received. The inductances may be either of the single or multiple layered types, while the condensers if variable are usually the semicircular rotary plate type, and if of fixed capacity they are made of tinfoil with mica or paper dielectric. The rotary variable condenser is described and illustrated in the preceding instruction paper.

THE RECEIVING SET FOR UNDAMPED WAVES.

Oscillations are induced in the *aerial* by passing waves if the aerial circuit is properly tuned.

The aerial tuning inductance allows adjustment of the aerial circuit to wavelengths greater than the natural wavelength of the aerial circuit. It may consist of an insulating tube four to seven inches in diameter and of the desired length wound with a single layer of No. 20 insulated wire. The number of turns is varied by means of a tap switch.

The variometer is described and illustrated in Instruction Paper No. 9. This device allows a minute variation of the inductance. For instance, we may vary the inductance in steps by means of the switch on the aerial tuning inductance, but to obtain a value between steps we can use the variometer. This enables the set to be tuned to exact resonance with the desired wavelengths. This is specially desirable when receiving undamped waves which, having no decrement, are very sharply tuned.

The receiving transformer transfers the energy of the incoming oscillations from the aerial circuit to the secondary circuit. The variable coupling between the primary and secondary winding enables the set to be tuned sharply to one wavelength, thus preventing the reception of undesired waves.

The short wave variable condenser is connected in series with the aerial and ground and is of the type shown in Fig. 84. It enables the wavelength of the aerial circuit to be adjusted to a less value than the natural wavelength of the aerial circuit.

The function of the *ground* has been fully explained in previous papers.

The secondary variable condenser of the same type as shown in Fig. 84 is connected in shunt to the secondary of the receiving transformer and one of the coils of the coupling transformer. Its action has been fully explained in preceding papers.

The secondary loading coil enables the secondary circuit to be tuned to long wavelengths. It is connected in series with the secondary winding of the receiving transformer.

The coupling transformer shown in Fig. 99, sometimes referred to as tickler coils, enables the two processes of amplification and regeneration to take place. It may consist of two single layered coils, connected in series and arranged so that the coupling may be varied. The middle point of the two coils being attached to one side of the filament. In some sets these two coils are of the multi-layered type, the coupling being varied by changing their relative positions.

The function of the tickler coils is, first to transfer part of the energy of the oscillating plate current set up by the incoming oscillations back into the grid circuit, thus producing amplification; and second, to enable the tube to generate oscillations of high frequency.

The function of *grid condenser* in this circuit is to produce an audio frequency variation of the plate current through the phones by storing up the negative charge of the rectified beat currents.

The grid leak resistance placed about the grid condenser allows the negative charges stored up in the grid condenser by the rectifying action of the bulb to leak off after the passage of a train of oscillations. If allowed to remain this negative charge may neutralize the effect of the positive charges placed on the grid. The resistance may be very high, ranging from several hundred thousand to five million ohms, depending upon the apparatus in the circuit.

A simple grid leak may be made by drawing a line in India ink between two points on a piece of paper, and then mounting the piece of paper in such manner that binding posts through a piece of hard rubber will make connection with the ends of the India ink line. The line of India ink has a very high resistance and will not allow the condenser to discharge as fast as it is charged, but is low enough to allow a sufficient leakage to prevent paralyzing of the bulb.

The vacuum tube has been described and explained quite fully. It consists of an evacuated glass bulb having a tungsten filament, a coil or perforated plate called a grid and a cylinder or plate of metal called the plate. The grid is placed between the filament and the plate. It is made in a number of different styles. A modern type of bulb is shown in Fig. 95.

The "A" storage battery or filament battery has a potential of 4 to 6 volts. It is used for lighting the filament.

The filament rheostat is employed in regulating the brilliancy of the filament. If the filament brilliancy is increased, more electrons will be thrown off. The rheostat is, therefore, a means of regulating the plate current.

The "B" battery of 20 to 200 volts is connected in the plate circuit. It may be of either the storage or flashlight type. This battery supplies the current which flows through the phone circuit. The increase or reduction of the current at an audio frequency gives signals in the telephones. The positive side of the battery is attached to the plate. The potential is varied by means of either a switch or rheostat.

The telephone receivers are connected in the plate circuit in series with the "B" battery. The resistance of the telephones, if of the magnetic type, is usually 1,500 to 3,000 ohms to each case. Telephone receivers used for wireless reception are of the double watch case style, having a band which fits over the head.

In Fig. 99 is shown an *inductance* connected in the plate circuit. This coil allows the plate circuit to be tuned to approximate resonance with the grid circuit.

The condenser shunted about the phones and high voltage battery acts as a by-pass for the high frequency oscillations in the plate current. That is, due to the impedance (resisttance plus reactance) of the magnet coils in the telephone receivers, considerable resistance is offered to these currents; but by placing a condenser in shunt, a low resistance path is provided. (Alternating or oscillating currents may pass through a condenser but direct current cannot.)

The Cascade Amplifier: In the discussion of the regenerative vacuum valve we mentioned the fact that in the circuit of Fig. 99 amplification occurred. The amplification or strengthening of the currents flowing in a receiving circuit may be also brought about by what is termed the *cascade amplifier.*

The cascade amplifier is an arrangement of a number of vacuum valve circuits by which the plate current of the first flows into the grid circuit of the second, and the plate current of the second into the grid circuit of the third until all the valves are connected. As many as eight vacuum tubes have been so connected.

In Fig. 101 is shown a diagram of the connection of an amplifier. In place of the phones in the plate circuit of the first tube a condenser is connected. The terminals of the primary of a transformer are connected to the two terminals of the condenser, while the secondary terminals are attached to a second variable condenser across the grid and filament of the second valve. All the valves are connected in this manner. The transeformer connecting the tubes may be either of the air core or the iron core type. If an air core transformer is employed, radio frequency (above 10,000 per second) oscillations will be transferred to the second valve, while the iron core type will transfer an audio frequency current to the second value. In the place of the transformer a resistance or reactance may be connected and will serve the same purpose. A two-step amplifier, such as is illustrated in Fig. 102, if properly designed, will amplify signals to 10,000 times that from the detector itself.

Constructional Details: In the various diagrams or hookups there are coils such as loading inductances, the primary and secondary coils of the receiving transformer, the plate inductance, the two coils of the coupling transformer, and coils of the amplifying transformer. For many years inductances employed in the radio receiving circuits were of the single layered type, the insulated wire being wound on cylindrical tubes of cardboard, hard rubber or other insulating material. In some cases the coils were of large size and of inconvenient length. In recent years many new developments in the design of inductance coils have been made. Multi-layered coils of small dimensions, having the same value of inductance as the former large coils, are now found in receiving apparatus. The disadvantages of the simple multi-layered coil is that it has a large value of capacity. This is, two adjacent layers will form a condenser. This capacity effect is undesirable in inductance coils and its elimination is very essential. In efforts to reduce the "inherent capacity," as it is called, various types of windings have been devised.

It is impossible to construct coils with a zero capacity, but it is possible to eliminate a considerable percentage of the capacity.

The effect of capacity in a coil is identical to the effect produced on a coil by placing a condenser in shunt to it. The presence of this capacity complicates the design of a receiver, it has undesirable effects on the operation of the set, and tends to increase the self-inductance of the coil itself at different frequencies. Various methods of winding the wire in the multi-layered coil have been employed for the purpose of partially eliminating this capacity.

Fig. 102. The two step amplifier.

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In Fig. 103 is illustrated a method called "bank winding." The first turn of wire is considered as being marked (1), the second (2) and so on, as shown in the figure. In this method the first and last turns are separated a considerable distance, while in the old method of winding, in which one layer of wire is wound on the other, there is a considerable voltage between turns of different layers. This can be readily understood if we consider that the voltage induced in a coil is dependent upon the number of turns. Another method of winding coils is to separate the different layers by strips of insulating material. This increases the distance between layers and thus reduces the capacity of the coil.

A method recently developed by a private manufacturing company employs a peculiar type of winding, in which the turns of one layer are wound at an angle to the turns of another layer.

Irrespective of what type of coil employed, the unused turns of the coil affect the operation of the receiving set. A device called a "dead end" switch is sometimes employed which disconnects from the circuit all turns not actually needed. This prevents the inductance and capacity of the unused turns from interfering with the action of the circuit.

No iron cores are employed in radio frequency circuits. If iron is present, there will be much loss of energy, due to eddy currents in the iron.

The reactance effect of a coil having an iron core is also much greater than when no iron is employed. The audio frequency transformer, sometimes employed to transfer energy from one vacuum valve circuit to another in the cascade amplifier, has an iron core.

Radio frequency currents differ from direct currents and low frequency currents in that they have a tendency to travel on the outer surface of a conductor. The reason for this is that when a

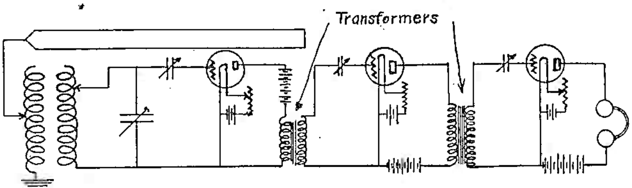

Fig. 101 Diagram of Cascade Amplifier

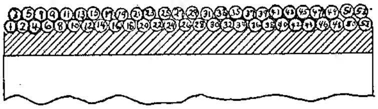

Fig 103 Diagram of Bankwinding.

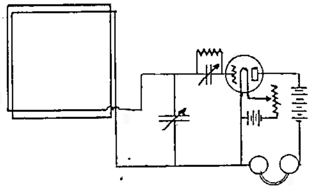

Fig 104. CLosed CoiL Aerial and Receiver.

current flow is set up in a conductor, it takes a longer time for the current to reach its steady value at the center of the wire than it does at the outer edges. It can be seen that if the current reverses rapidly as radio frequency currents do, sufficient time will not be given for the current to reach its maximum value at the center of the wire before it reverses. This non-uniform distribution of current is termed the *"skin effect,"* and due to the electricity being confined to the outer layers the resistance effect in a wire is greater than if employed for carrying direct current. There would be a large waste of metal if wires were made large enough to supply a sufficient surface area to carry a high frequency current without loss, and for that reason tubular conductors, stranded wire, and brass or copper strips are usually employed to carry high frequency currents.

In receiver circuits, a conductor made up of a number of strands of small insulated wire is very commonly used, and is called *Litzendraht* wire. As many as 48 strands of No. 38 wire are combined to form a single conductor in one standard form of high frequency cable.

The Loop Aerial Receiver: In the instruction paper on aerials the loop or closed coil aerial was described. This aerial is especially adapted to long undamped wave reception and for direction finders. This aerial, as installed for the reception of undamped wave signals, usually consists of a rectangular coil of wire. This closed coil or loop is connected as in Fig. 104 with a condenser across its terminals. This condenser is of the rotary variable type, and in the majority of sets does not exceed .001 microfarad capacity.

The detector and telephones are connected to the terminals of the variable condenser. All the tuning of this type of circuit is made by adjustment of the variable condenser.

For a wavelength of 2,500 meters about 960 feet of wire may be wound on a frame 6 to 10 feet square. By connecting cascade amplifiers or regenerative hookups in conjunction with a loop aerial transatlantic signals have been copied in the United States.

This method of receiving has the advantage of simplicity and compactness, but requires more sensitive detecting apparatus than does the ordinary receiving circuit.

QUESTIONS

Theory Lesson No. 10

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

206. Define undamped waves.

207. What is the difference between the two varieties?

208. What are the reasons for the employment of undamped waves in preference to damped waves?

209. Explain the difference between "wave frequency" and "spark frequency."

210. Why is it necessary to use a different type of detector for reception of undamped waves than for damped waves?

211. Name the different methods by which sustained waves are made audible in the telephone receivers.

212. Explain the action of the "tikker."

213. Is the Goldschmidt tone wheel adapted to reception of short wavelengths?

214. Explain the electron theory.

215. If filament is burning, what is the nature of the current flowing in the plate circuit?

216. What is meant by the "heterodyne" or "beat" system of reception?

217. Draw a diagram of the "regenerative vacuum valve."

218. Name the instruments employed in the above circuit.

THE RECEIVING SET FOR UNDAMPED WAVES.

219. Explain the action of the "tickler coils."

220. Give a diagram of a cascade amplifier.

221. Explain the advantage of "bank winding."

222. Why is it not possible to use iron cores in inductance coils employed in radio circuits?

223. What is Litzendraht wire?

224. Draw a diagram of a loop aerial receiving circuit.

225. What are the advantages of this system of receiving?

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

1345 PA. Ave., N. W. WASHINGTON D. C.

Answers to Instruction Book No. 10

206. Undamped waves are those with a constant amplitude and are continuous in their formation.

207. Damped waves are made in groups or trains by the discharge of a condenser and each succeeding wave become small in amplitude and soon die out entirely, while the undamped remain constant in their strength and also continuous.

208. The undamped waves have no decrement which confines them to one wave length; they are constant and continuous in strength, which allows lower potentials. The efficiency is greater, better for long waves and long distance; tone can be controlled by the opertor in receiving, and they can be used for Wireless Telephony.

209 The wave frequency is the number of waves leaving the aerial per second, and depends on the inductance and capacity in the circuit. The value for ships is between 500,000 and 1,000,000. Spark frequency is the number of discharges of the transmitting condenser traversing the spark gap per second, and equals twice the frequency in cycles or 1,000 per second.

210. The detector for the undamped must provide some means for breaking up the continuous waves into groups at regular intervals.

211. By a tikker, slipping contact detector, rotating plate condenser, Goldschmidt tone wheel, heterodyne receiver and regenerative vacuum valve.

212. A tikker is a device for interrupting the current induced in the receiving set and is usually placed in the secondary circuit at the rate of 600 to 1,000 times per second.

213. The Goldschmidt tone wheel is not adaptable to the short wave lengths.

214. The electron theory assumes that the atoms of a substance contain equal amount of positive and negative electrons which have the effect of neutralizing each other and are not detected by instruments. The positive charge is surrounded by the negative electrons and cannot escape. these negative electrons may be separated from the atom leaving an excess of positive and is said to be positively charged, while an atom which the negative electrons unite with have an excess of negative electrons and is negatively charged.

215. When the filament of an audion detector is burning there is a small steady flow of current from the plate to the filament and thru the B battery and phone circuit.

216. If a local source of oscillating current, with a small diference in the number of oscillations, is allowed to act on the oscillations coming in from an outside message, it will result in a much smaller frequency which is equal to the difference between the two frequencies. This method causes an audio frequency from the combining of two radio frequencies, and is called the heterodyne system, invented by Fessenden.

(OVER)

217. See figure 99.

218. The appartaus in the regenerative receiver consists of the aerial, loading inductance, primary of receiving transformer, variometer, short wave condenser, grid condenser, grid leak resistance, tuning condenser, vacuum tube, A battery (4 to 6 volts), filament rheostat, B battery (20 to 100 volts), telephone receivers condenser in shunt with the phone and the plate inductance.

219. The tickler coil feeds a part of the energy of the oscillating plate current back into the grid circuit, thus producing amplification: and besides, it allows the tube to generate oscillations of high frequency.

220. See Figure 101.

221. The bank winding provides a means of placing two or three layers of wire one on top of the other in such a manner as to possess large inductance with small capacity.

222. The iron core would give the property of excess inductance and large iron losses which would destroy the oscillations.

223. Litzendraht wire is cable made of many small wires insulated from one another by a coating but twisted together. This provides a very large surface for the large amount of copper used and has a very low resistance to high frequency currents.

224. See Figure 104.

225. A loop aerial receiver does not require an aerial or ground, it is compact, can be made portable and can be used for direction finders and long undamped waves.

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West Salem, Ohio.

Student No 13794 Lesson No 10 99%

206 Undamped waves may be defined as those
✓ of constant amplitude and continuous
formation.

207 The difference between the two waves are
more waves are radiated per. second with
the undamped than with the damped.
also since the undamped waves are
✓ continuous the wavelength stays one fixed
✓ length. allowing many stations to send
a slightly different wave lengths without
interference from each other. while damped
waves cover a broad wave and interfere with
the receiving of other stations.

also undamped waves have a constant
✓ amplitude while damped waves decrease in
amplitude.

208 The waves are of constant amplitude there is no
✓ decrement therefore they are confined to one
wavelength.

✓ The tone of the signals may be adjusted by the
operator.

✓ The efficiency is greater.

✓ Less power may be used since the waves are continuous the amplitude need not be so great.

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Westfall N.Y.

Student No. 13774 Lesson No. 10

Radio telephony is made possible.

209 The Number of discharges of a condenser per second is called spark frequency.

The rate at which the waves are produced is called wave frequency.

210 Since the waves are continuous the damped wave de~~t~~tector can not be used but if some means is used to chop up the incoming waves into an audio frequency succession of trains of waves the rectifying detector may be used.

211 1 The chopper in either the sending or receiving sets.

2 The tikker

3 The Goldschmidt tone wheel

4 The Heterodyne receiver

5 The rotating plate condenser

6 The slipping contact detector

7 The regenerative Vacuum valve.

212 The tikker is used in the receiving circuit. It consists of a brush which bears on the edge of a disk alternatingly making and breaking contact with the disk. a second brush bears continually on the side of the disk, as the motor revolves the circuit is

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Student No 13794 Lesson No 10

made and broken at a rate which depends upon the speed and the number of segments on the disk. The brush at one time makes contact with the metal disk and if signals are coming in the secondary condenser discharges through ✓ the disk into the telephone condenser but the next time the brush rests on insulation and the circuit is broken when this occours the condenser discharges through the phones.

213 ✓ No.

214 The Electron theory states that an atom when normal consists of equal amounts of positive and negative electricity, the atom has no detectable charge due to the fact that the two charges neutralize each other. The atom is supposed to have a nucleus of ✓ positive electricity and the negative surrounds this. the positive can not be removed, The negative or electrons can be seperated from the positive charge ✓ an atom possesses a positive charge when it is minus its normal number of electrons and is being negative charged when it has more than its normal number of electrons.

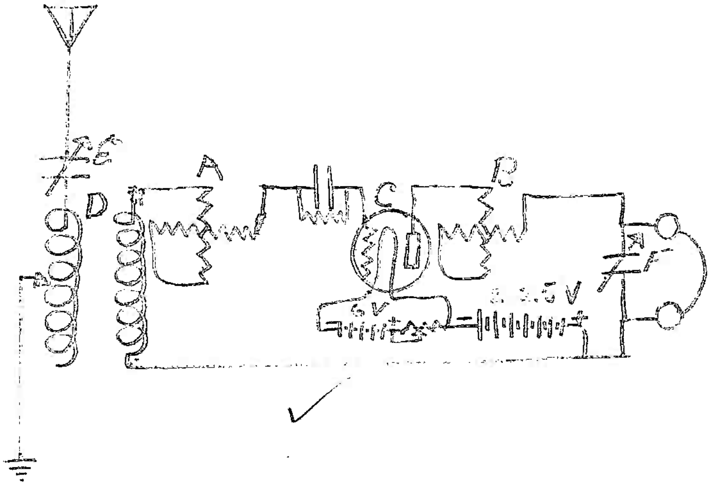
[illegible]
[illegible]

Student No 13777 Lesson No 10

215 When the filiment is burning the nature of the charge on the plate is positive and as the filiment is giving off electrons or negative charged electrons, these are attracted to the plate as unlike charges attract each other ✓

216 We mean by the Heterodyne or beat system of reception that. The frequency of a Local current is adjusted to a slightly different frequency than that of the incoming signals and the interaction of these two frequencies produce a beat which is of audio frequency which is then rectified by a detector so the sound is audible in the receiver. ✓

217



A and B Variometers
C Vacuum tube
D Vario coupler
E and F Variable condensers

✓

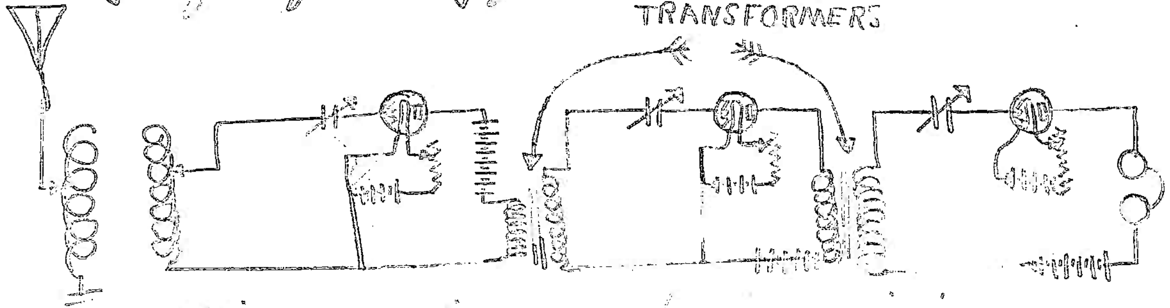
218 Aerial, 2 Variable condensers, Vario coupler, 2 Variometers, grid condenser, grid leak, Vacuum tube, 6 Volt A battery, 22.5 Volt B battery and telephones and potentiometer.

George J. Gudenjahn
West Salem O.

Student No. 13794 Lesson no. 10

219 The action of the tickler coils is to transfer part of the energy set up by the incoming oscilations back into the grid circuit to produce amplification and also to produce oscillations of high frequency from the tube. ✓

220



✓

Diagram of [illegible]

221 The advantages of bank winding is one turn of wire is seperated from the next one by a small space which greatly reduces capacity while in the old methot where one turn touches the next one the capacity is increased.

Review
VOW

222 Due to the loss of energy when an iron core transform is used in radio frequency circuits they can not be used the loss is due to eddy currents set up in the iron ✓

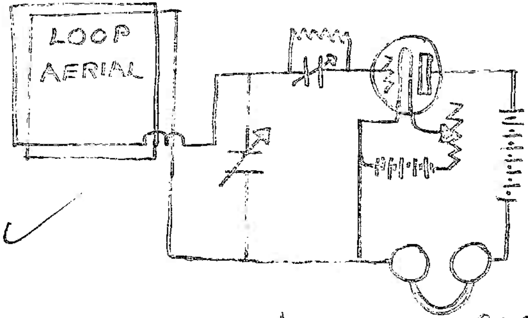
223 Litzendraht wire is a wire made up of many smaller wires it is used in winding wireless coils. also to make heavy connections. ✓

224

George J. Sardajian
[illegible]

Student No. 13794

Lesson No. 16



✓

Q25 The advantages of this method of receiving are its simplicity and compactness. also it may be used as a direction finder.

✓

LESSON TEXT No. 11

OF A

Complete Course in Radio Telegraphy

The Storage Battery

REVISED EDITION

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Washington, D. C.

RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 11

METHOD OF CALLING OTHER STATIONS

The call shall comprise the signal ▬ • ▬ • ▬ the call letters of the station called transmitted three times, the word "from" (de), followed by the call letters of the sending station transmitted three times.

The called station shall answer by making the signal ▬ • ▬ • ▬ followed by the call letters of the corresponding station transmitted three times, the word "from" (de), its own call letters, and the signal ▬ • ▬ meaning "go ahead."

For instance:

If NAA desired to call NAR, it would transmit in the following manner:

▬ • ▬ • ▬ ▬ • ▬ • ▬ ▬ • ▬ • ▬ NAR NAR NAR de NAA NAA NAA

NAR would answer thus:

▬ • ▬ • ▬ ▬ • ▬ • ▬ ▬ • ▬ • ▬ NAA NAA NAA de NAR NAR NAR ▬ • ▬

Make the following call on the practice set:

WSC de WBS NAB de NAK NAH de WSL

THEORY LESSON NO. 11

THE STORAGE BATTERY.

Requirements of International Regulations and U. S. Radio Laws.— A radio transmitter aboard ship is supplied with current from the ship's generator. This generator, located in the engine room, in addition to supplying current for the radio set, is also a source of power for the electric lights, motors, searchlights, and various other devices aboard the vessel. The engine room is located far below decks, and may, in case of a wreck, be flooded with water, thus putting generator out of commission. In this emergency, if no other source of current is available, the ship would be left without means for sending distress signals. Some auxiliary or emergency source of power is desirable, and to insure that the steamship companies equip their vessels with the necessary apparatus, the United States statutes (Act of August 13, 1912,) provide: "That from and after October first, nineteen hundred and twelve, it shall be unlawful for any steamer of the United States or of any foreign country navigating the ocean or the Great Lakes and licensed to carry or carrying fifty or more persons, including passengers or crew, or both, to leave or attempt to leave any port of the United States unless such steamer shall be equipped with an efficient apparatus for radio communication in good working order, capable of transmitting and receiving messages over a distance of at least one hundred miles, day or night. All auxiliary power supply, independent of the vessel's main electric power plant, must be provided, which will enable the sending set, for at least four hours, to send messages over a distance of at least one hundred miles, day or night, and efficient communication between the operator and the bridge shall be maintained at all times."

The International Radio Telegraphic Convention regulations require that "Ships provided with radio installations * * * are bound to have radio installations for distress calls, all the elements of which shall be kept under conditions of the greatest possible safety, to be determined by the government issuing the license. Such emergency installations shall have their own source of energy, be capable of quickly being set into operation, of functioning for at least six hours, and have a minimum range of 80 nautical miles for ships of constant service and 50 miles for those of limited duration of service."

Early Types of Auxiliary Apparatus.—Since the passage of the law of August 13, 1912, several different types of auxiliary sets have been in use. One of the first types of emergency set consisted of a 10-inch induction coil, a spark gap and a 30-volt storage battery. An induction coil of this type is supposed to give a 10-inch spark between the sharpened electrodes of a spark gap. As employed for emergency purposes, the secondary terminals of the induction coil and the leads from the aerial and ground are connected to either side of the spark gap, thus making what is termed a "plain aerial connection." So connected, the spark gap is in series with the aerial and ground, and an oscillatory circuit is formed, the inductance being supplied by the aerial and lead-in wires, while the aerial and earth provide the capacity. When the key in series with the storage battery is depressed, current flows through the interrupter and primary of the induction coil. The change in the strength of the current, due to the making and breaking of the circuit by the interrupter, causes a very high voltage to be induced in the induction coil secondary. The condenser, formed by the aerial and ground, being charged by the high voltage secondary current discharges across the gap, setting up a train of oscillations in the aerial circuit. The disadvantages of the plain aerial connection are that a highly damped interfering wave is radiated and that the range is limited to about 100 miles. For this reason, the plain aerial connection is seldom used. To overcome these disadvantages the Marconi Company arranged the circuit so as to make a tuned coil set. In the latter method, the induction coil is connected in the circuit in place of the step-up transformer, switches being supplied to transfer the oscillatory circuits from the transformer to the induction coil and vice versa.

Modern Auxiliary Apparatus.—The tuned coil set is still found on some vessels, but the policy now is to equip ships with more dependable apparatus. The above-described circuit is only capable of covering short distances, and it is considered advisable to have emergency apparatus whose range approximates that of the main set. The modern equipment may be one of the three following types:

1. A one-half kilowatt panel set operated by a storage battery capable of supplying current for a period of at least three hours.

2. A storage battery of sufficient capacity to operate the main set for four hours.

3. An auxiliary current supply consisting of a direct-current generator driven by a gasoline or oil engine. This set is usually placed on the upper deck in order that it can be used even if the engine room is flooded. It supplies current for the deck lights as well as for the main radio transmitter.

Many passenger ships have a one-half kilowatt panel transmitter as an auxiliary to the main set. It is available not only for emergency purposes, but also for short-distance communication when the main set is unnecessary. The range of this set is surprisingly high, distances of 1,500 miles at night time being not uncommon. A description of this set will be given in the instruction paper on "Standard Marine Sets."

The majority of ships are now being equipped with a large storage battery for operation of the main transmitting set, no additional equipment other than the storage battery and switchboard being supplied. The circuit employed in connecting this battery to the charging source and the radio set is shown in Fig. 110. The battery is employed not only as a source of current for the radio transmitter, but in many cases to supply current for the lighting of decks in case of an emergency.

The Storage Battery.—From the above the student will observe that the storage battery is quite important as a source of current for the radio set. In the following pages will be given a fairly complete discussion of the two principal types of storage batteries in use.

The storage cell is one form of the electro-chemical cell. We learned early in the course that there were two types of cell, the primary and secondary. The primary may consist of a jar of acidulated water, in which are immersed two dissimilar plates. As long as the two plates are not connected externally, very little chemical action will occur, but upon connecting the plates with a wire, a current immediately begins to flow, due to a strong chemical action at one of the plates.

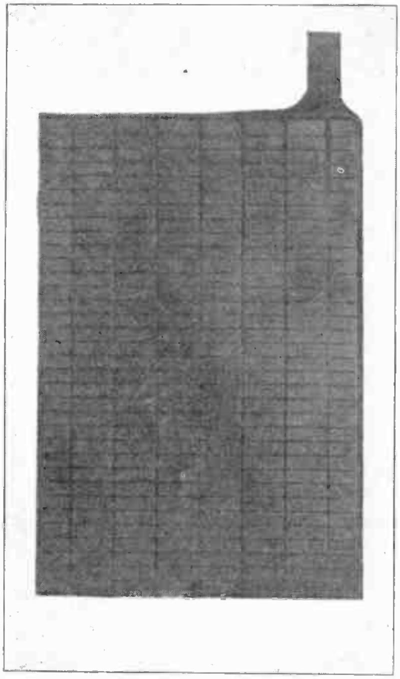

Fig. 105. The Negative Plate of the "Exide" Cell.

Courtesy of
The Electric Storage Battery Co.

The simple cell may consist of zinc and copper plates and a solution of sulphuric acid and water. The zinc plate is consumed, combining with part of the sulphuric acid to form zinc sulphate. The negative plate and the solution of all primary cells must be renewed from time to time. The primary type of cell takes many forms, and there are many combinations of dissimilar metals which when immersed in the proper solution will deliver a current.

The storage cell belongs to a class called secondary cells. Instead of renewals of solutions and negative plate, this cell after discharging merely requires that a current flow through it from an outside source for a few hours, in order that it may again be capable of delivering a current.

The term "storage" applied to this type of electro-chemical cell is not strictly correct, as there is no storage of electricity as in the Leyden jar. A current flowing through a storage cell from an outside source merely changes the chemical composition of the plates in such a manner that it will deliver a current for a time. Although there is no storage of electricity, the effect is the same as if there were. By passing a current through a storage cell (charging) we store up energy which, when we discharge the cell, is delivered to us again

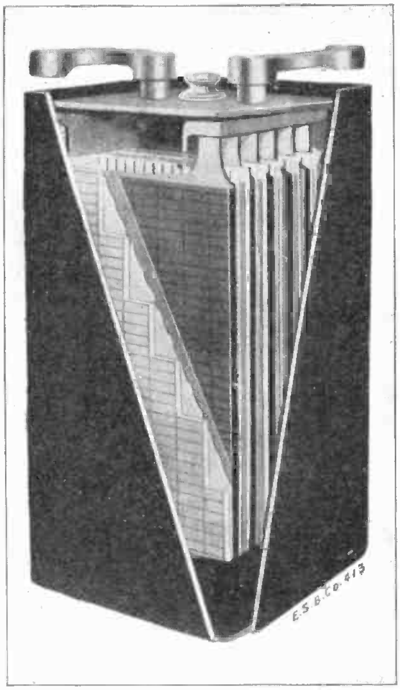

Fig. 106. Cutaway View of An Assembled "Exide" Lead Cell.

Courtesy of
The Electric Storage Battery Co.

Therefore, we may define a storage cell as an electro-chemical cell in which the energy of an electric current may be converted into chemical energy, which in its turn can be used to produce an electric current.

The storage cell, also known as an accumulator or secondary cell, can be employed as a portable source of current, as used in electric automobiles or trucks, and as a reservoir, from which we may obtain electrical energy at a time when other means are not available, as used in the submarine.

We may divide storage cells into two principal types, as follows:

1. The lead cell.
2. The Edison cell.

The lead cell has plates of lead and lead oxide and an electrolyte of sulphuric acid and water. It is very widely used as an auxiliary source of power for radio and also finds wide uses in the industries.

The Edison cell has plates of iron oxide and nickel, with an electrolyte of caustic potash. The cell is superior in many ways to the lead cell, but for certain purposes the latter is preferred. The Edison cell is of rugged construction and is very suitable as a source of power for driving submarines, due to the fact that no harmful fumes are given off.

The Lead Cell.—The lead storage cell is probably more widely distributed than the Edison cell. The Electric Storage Battery Company manufactures several types. The "Exide" and "chloride" types are employed in radio installations. The same materials are used in both, the difference being in their construction. The containing vessel may be glass or hard rubber, usually the latter when made for portable use, as in the radio station.

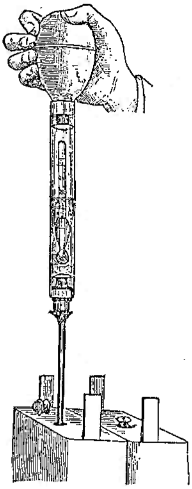

Fig. 107. Hydrometer and Syringe.

A number of lead plates (see Fig. 105) containing holes or grooves are coated with a paste made of red lead, litharge and sulphuric acid. Alternate plates are connected to different terminals, those connected to the negative terminal being one more in number than those connected to the positive terminal. The plates are placed in a containing vessel and a 20% solution of sulphuric acid added. A current of electricity is then caused to flow through the cell for a number of hours, the result being that hydrogen gas collects on the plate from which the current leaves the cell. This hydrogen gas combines with the oxygen of the plate, leaving the paste in the form of spongy lead. At the same time, the plate at which the current enters the cell is absorbing oxygen, converting the paste into lead peroxide. Finally, one plate will be coated with spongy lead, forming the negative plate of the battery, while the other plate is coated with lead peroxide and is termed the positive plate. The cell is now charged and will deliver a current for a certain length of time. This current will flow from the cell in a direction opposite to that of the charging current, the potential being 2.1 volts when the cell is fully charged.

A cell of the above construction is known as the "Exide" and is employed very extensively for radio purposes.

Another type, very similar to the "Exide," has the trade name of "Ironclad Exide." Instead of a perforated plate coated with peroxide of lead, the positive plate consists of a frame supporting a number of conducting rods, each of these rods being surrounded by peroxide of lead, and the latter by a hard-rubber tube. This rubber tube has a large number of horizontal slits which allow entrance of the electrolyte. The negative plate of spongy lead is identical with that of the "Exide" cell. With both type of cells, sheets of hard rubber or wood are used to separate the plates. The "chloride" cell has a positive plate made by filling the openings of a perforated cast-lead plate with soft corrugated lead ribbons. The cast grid serves not only as a rugged support, but also as a good conductor (the corrugated lead not being a good conductor). The **negative plate** is constructed in a similar manner to the negative plate of the "Exide."

Each cell consists of a number of plates separated by thin sheets of hard rubber or wood, there being an alternate positive and negative plate. An assembled lead cell is shown in Fig. 106.

The Action Occurring in the Lead Cell.—Before we consider the action of the cell it might be well to summarize the above. We have learned that—

1. The storage cell (also known as the secondary cell or accumulator) is a type of electro-chemical cell, that differs from the primary cell in that for renewal it merely needs to have current flow through it from an outside source.

2. By conversion of electrical energy into chemical energy, the storage cell forms a portable and convenient source of electrical energy which can be employed when any other source would be out of the question or where it is inconvenient to have generating plant running continuously.

3. The two types of cells in general use are the "Edison" and the "lead."

4. The lead cell contains plates of lead, the positive plate being coated with lead peroxide and the negative with "spongy lead." These plates are immersed in a solution of sulphuric acid and water.

5. Three types of lead cells are in general use—the "Exide," the "Ironclad Exide" and the "Chloride," the difference between the three being merely that of construction.

6. The "Exide" cell is made by coating perforated plates with a paste of litharge, red lead and sulphuric acid. The charge converts the plates connected to one terminal into lead peroxide (positive) and the remainder of the plates into soft spongy lead (negative).

The "chloride" has a positive plate, made by filling the openings in a cast-lead grid with corrugated lead ribbon, and a negative plate of similar construction to that in the "Exide."

THE STORAGE BATTERY

7. A **storage battery** is a number of storage cells connected together in series, parallel or series parallel.

The electrolyte or solution of the lead cell is made of four parts pure water and one part pure sulphuric acid.

By **"charging"** a cell is meant the process of chemically changing the plates so that the cell will deliver a current, this being brought about by causing a current to flow through the cell for a time.

By **"discharge"** of a cell is meant the delivery of electrical energy by the cell to an external circuit.

When a cell is placed on discharge the current is produced by the combination of the sulphuric acid of the solution with the active material of the plates. The product of this combination is lead sulphate and water. The lead sulphate fills the pores of the active material, and the water is left in the solution, causing it to become thinner. The volume of sulphate formed by this combination is greater than the volume of sulphuric acid and lead which entered into the combination. The result of this is that as the discharge goes on, the sulphate which fills the pores in the plates prevents the action of the solution on the active material. Therefore the voltage will gradually drop as more and more sulphate is formed. The maximum voltage of a lead cell is ordinarily about 2.1, while the lower limit is 1.75. The voltage should never be allowed to drop below 1.75, because after this point is reached the voltage falls off very rapidly, and possible damage to the plates may result.

In charging direct current of greater voltage than the maximum potential of the storage battery is caused to flow through the cells in an opposite direction to that which the current takes when the cell is discharging.

The process of charging breaks up the lead sulphate formed when the cell is discharging. That part of the sulphuric acid which entered into combination with the lead is driven back into the solution, where it again forms sulphuric acid, while the lead remains as part of the active material.

The sole object of charging, then, is to drive the sulphate from the plates back into the solution, thus leaving spongy lead on the negative plate and lead peroxide on the positive. Observe that, while discharging, the strength of the electrolyte is decreasing, but in charging the electrolyte gradually gains strength or density.

Specific Gravity.—Several methods are in use for the determination of the state of charge of a storage cell. One of the most important indications is that of specific gravity.

Specific gravity may be defined as the ratio of the weight of a given volume of the solution or electrolyte in question, to the weight of an equal volume of pure water. That is, it is a measure of the density. For instance, if a cubic inch of water weighed 1 ounce, and a cubic inch of a 20%

solution of sulphuric acid weighed 1.5 ounces, the specific gravity of the latter soluiton would be 1.5.

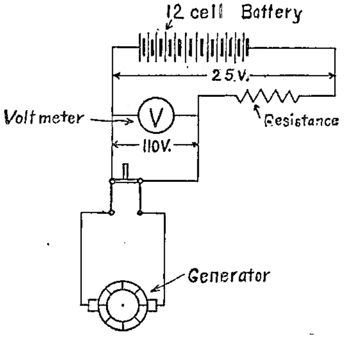

Fig. 108. Simple Charging Circuit.

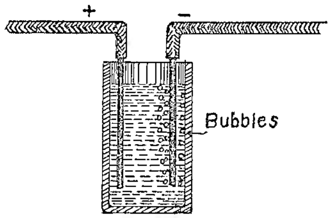

Fig. 109. A Simple Polarity Indicator.

As a cell is discharging, the solution becomes thinner, due to the production of water and the loss of sulphate, and consequently the density, or **specific gravity,** grows less, while on charging, it increases because of the driving of the sulphate back into the solution.

By taking a reading of a cell the state of charge is made known, indicating whether the cell is fully charged or not. The specific gravity of a fully charged "Exide" or "Ironclad" cell usually ranges between 1.205 to 1.215 when fully charged, and on discharge should not be allowed to drop below 1.180. (The figures are usually referred to as twelve five, twelve fifteen and eleven eighty.)

The device employed in determining the specific gravity of the electrolyte is called a "hydrometer" (see Fig. 107), which consists of a small tube of glass, both ends of which are closed, having a quantity of shot in one end and a scale at its upper end. If this device is immersed in pure water, the tube will sink to a point on the scale marked 1, but if sulphuric acid or other soluble substance is added to the pure water, the hydrometer will not sink so far. The electrolyte of a fully charged "Exide" cell will cause the hydrometer to sink to a point on the scale marked 1.205 to 1.215.

Overdischarging, undercharging and excessive overcharging are all injurious to the plates of a cell. A proper use of the hydrometer will prevent such abuse of storage cells. The type of cells supplied for radio purposes are so made that it is impossible to place a hydrometer in the solution; and to take a reading, it is necessary to make use of a glass syringe inside of which there is a hydrometer. The syringe is placed in the opening of the cell, the rubber bulb compressed, and then allowed to expand, sucking up a sufficient quantity of the solution to float the hydrometer. After taking the reading, the solution is returned to the cell. In. order to get accurate readings it is wise to rinse syringe in distilled water after each test. This device is shown in Fig. 107.

Capacity of Storage Cells.—By capacity of storage cells, we mean the quantity of electricity, in ampere hours, they are capable of delivering on discharge. (Sometimes this is measured in watt hours.) The ampere hour is the quantity of electricity flowing past a given point in the circuit in one hour when the strength of the current is one ampere. One ampere hour is equal to 3,600 coulombs (there being 3,600 seconds in one hour), a coulomb being that quantity of electricity passing a given point in one second when the current is one ampere.

The capacity of a battery of cells depends upon the manner in which they are connected, whether series, parallel or series parallel. When connected in series, the capacity of the battery is the same as that of a single cell in the series, but when in parallel the capacity is equal to the product of the capacity of one cell and the number of cells in the battery. Ordinarily the cells are connected in series when used as an auxiliary source of power for the radio set, the capacity ranging between 60 and 224 ampere hours. The larger size is employed when current must be supplied for the deck lights as well as the radio set.

A 60-ampere-hour battery will deliver one ampere for sixty hours, or thirty amperes for two hours. These figures are not accurate, as the quantity of electricity obtainable on discharge depends to some extent on the rate of current flow.

The "Exide" cell is rated on a four-hour basis, and hence we might expect to get a current of fifteen amperes for a period of four hours from a 60-ampere-hour cell.

The "Chloride" cell is usually rated on an eight-hour basis, and from a 60-ampere-hour battery we would get 7.5 amperes for eight hours. In most cases, the normal rate of charge is the same as the normal rate of discharge. We will consider this subject more in detail in the following article.

The Charging Process.—In Fig. 108 a fundamental diagram of a charging circuit is given. The cells are connected to the charging source in such manner that the current must flow into the cells in the opposite direction to that of the current flowing from the cells when they are discharging. Therefore, the positive terminal of the source must be connected to the positive side of the battery and the negative terminal to the negative side of the battery.

The voltage of the charging source must exceed that of the battery to be charged. It is also necessary to place a resistance in series with the circuit when charging to prevent too great a flow of current through the battery.

The necessity for this resistance will be apparent when we consider that the internal resistance of a storage cell is exceedingly low, being in some types of cells merely a fraction of an ohm. As shown by Ohm's law, such a low resistance would allow an excessive flow of current.

The method of connecting such a resistance is shown in Fig. 108. It may consist of a coil of wire or of a number of incandescent lamps connected in parallel. The amount of resistance necessary will depend on the **normal charging rate.**

The normal charging rate is that strength of current which will charge a cell completely in as short a time as possible without damage to the plates. In many cells this is identical with the normal discharge rate.

The normal discharge rate is the maximum strength that may flow during discharge without damage to the plates.

The normal rate is usually fixed by the manufacturer.

The resistance to be employed in the charging circuit of an "Exide" battery can be found by Ohm's law.

For instance, a battery whose maximum potential is 60 volts is to be charged by a source of current whose potential is 110 volts.

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

Where—E = voltage of charging generator.
e = voltage of battery.
I = normal charging rate.
R = resistance.

If the normal charging rate is 5 amperes—

$$R = \frac{110\text{-}60}{5}$$

$$R = \frac{50}{5} = 10 \text{ ohms.}$$

10 ohms would be the proper resistance for the circuit.

In charging, a higher rate than the normal charging rate may be used at the beginning of the charge, but care should be taken that this rate be reduced after gassing begins. In discharging, a higher rate than the normal may be employed for short intervals of time.

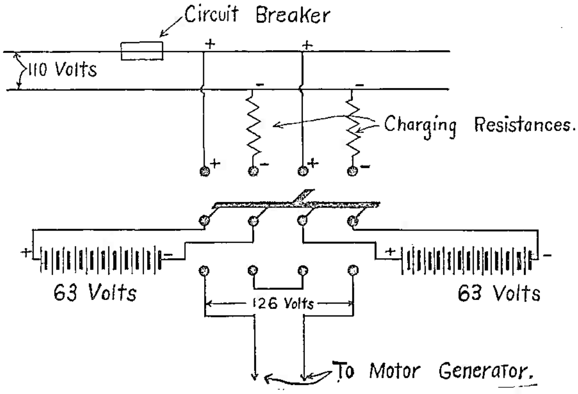

Fig. 110. Charging and Discharging of a Large Battery.

By "gassing" is meant the bubbling of the electrolyte, caused by the rising of the gas set free toward the end of the charge. This gassing is caused by the electric current breaking up the water of the solution into its components, hydrogen and oxygen. At the beginning of the charge, the current does the easiest thing first—that is, the driving of the sulphate back into the solution. After this has been partly completed, the surplus current begins to decompose the water. The liberated hydrogen gas forms an explosive mixture with the air, and for this reason no flames should be brought near the battery while charging.

In order to determine the polarity of the charging source, so that the battery will be charged in the right direction, we may employ either a volt-meter, a polarity indicator or a glass of salt water.

The polarity indicator is a small glass tube filled with a solution and having two terminals. When connected to a source of current, the end of the tube which is connected to the positive side of the line will turn blue. If the terminals of the source are immersed in a glass of salt water the negative will give off more bubbles than the positive. (See Fig. 109.)

In charging a 60-cell storage battery, the cells may be connected in series for discharging and in series parallel for charging. This is necessary due to the fact that the potential of the battery is 126 volts, while the charging source only supplies 110 volts. Hence it is necessary to reduce the voltage of the battery by connecting two series banks in parallel, thus getting a battery potential of 63 volts when connected to the line. The voltage of a series parallel connection of cells is equal to that of one bank alone.

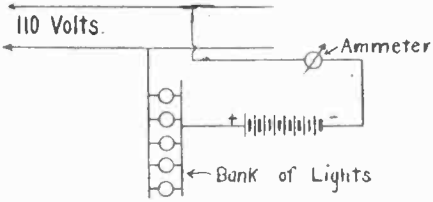

Fig. 111. Charging With a Lamp Bank Resistance.

The connections for so charging a large battery is shown in Fig. 110. A resistance is connected in series with each bank to prevent the current from exceeding the normal charging rate. The above circuit is the one employed in many ship installations.

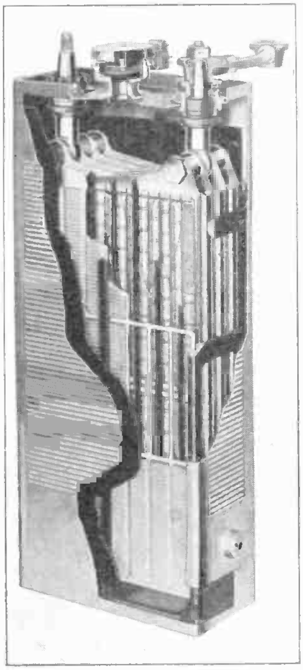

Fig. 112. Cutaway View of An Assembled Edison Cell.

Courtesy of the Edison Storage Battery Co.

The question may arise as to the functioning of a parallel bank of incandescent lamps, as used to limit the flow of current through a battery. When lamps are in series, the resistance of the circuit will be equal to the sum of the resistances of the lamps. For instance, two 16-candlepower lamps connected in series, each having 220 ohms resistance, would give a total resultant resistance of 440 ohms. Inserting in Ohm's law, the current flow will be found to be ¼ ampere. When lamps are connected in parallel, each lamp supplies a separate path for the current from one side of the current to the other. Two lamps would give two paths with less resultant resistance. As explained under the subject of divided circuits, each lamp will take one-half ampere, and therefore the total flow of current in the circuit will be one ampere. This can be verified by reference to the formula for resistances in parallel.

The number of lamps in parallel, necessary to charge a battery, will be equal to the quotient obtained by dividing the charging rate by the amount of current each lamp will take. That is, if the charging rate is 10 amperes, the number of 16-candlepower lamps in parallel will be 10 divided by .5 or 20 lamps. (See Fig. 111.) (A 16-candlepower lamp will carry .5 ampere.)

In the charging of a cell, if the sulphate is not entirely driven out of the plates, there is a tendency for it to become hardened. That is, if the charge is incomplete, the sulphate remaining in the plates will be more difficult to remove by subsequent chargings. This reduces the active material, and consequently the capacity of the cell. "Sulphated" is the term applied to the condition of plates having too much lead sulphate. Another cause of "sulphating" is allowing a battery to remain in a discharged or partially discharged condition. Too much emphasis cannot be laid on the necessity for a complete charge of the lead cell. The lack of a complete charge is sometimes referred to as "starvation."

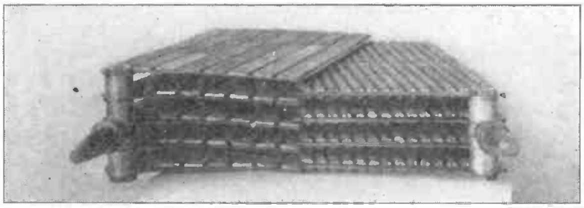

Fig. 113. View of the Positive and Negative Plates of An Edison Cell.

Courtesy of the Edison Storage Battery Co.

Starvation is one of the most common causes of injury to batteries. Overcharging, if persisted in, tends to cause the active material to fall out of the plates.

Another trouble sometimes encountered in the operation of storage batteries is known as "buckling." Buckling may be defined as the warping or bending of the plates caused by an unequal expansion of the two surfaces of the plates. This unequal expansion of a plate is due to an uneven distribution of sulphate in the pores of the active material. Overcharge, over discharge or too high a rate of charge are the common causes of buckling. Sulphating from any cause whatever may cause this trouble.

Shortcircuiting of the cells may be caused by the active material falling to the bottom of the jar and forming a connection between the lower ends of the plates. This shortcircuiting of the plates is also a cause of sulphating and buckling.

The state of charge of a cell may be determined by the following:

1. The voltage when cells are discharging at their normal rate.

2. The specific gravity.

3. The amperehour meter.

4. When no indicating instruments are available, allowing the cells to gas from two to four hours may be considered as an indication that the cells are fully charged. (This is true only when the cells are known to be in good condition and when the normal charging rate is employed.)

5. The color of the plates. (This method cannot be used with the type of cells supplied for auxiliary sets.)

Care of the Lead Cell:

1. The lead cell should be kept clean and dry, allowing no dust or debris to collect on the tops. Acid spray of moisture in combination with dust or other particles will cause a leakage from the positive to the negative terminal.

2. The electrotype should be kept one-half inch above the tops of the plates.

3. The specific gravity of the electrolyte should be 1.205 to 1.215 for the fully charged "Exide" cell, and should never drop below 1.180.

4. A battery not in constant use should be "floated." (That is, a small current should be allowed to flow through the battery at all times except when charging and discharging.) This floating charge tends to keep the battery fully charged at all times. Due to local action in the cell and to leakage, the cells gradually lose their charge if allowed to stand idle for a time.

5. Keep terminals and connections tight and free from corrosion.

6. In order to make up for any losses, batteries in radio service should be charged twice each month.

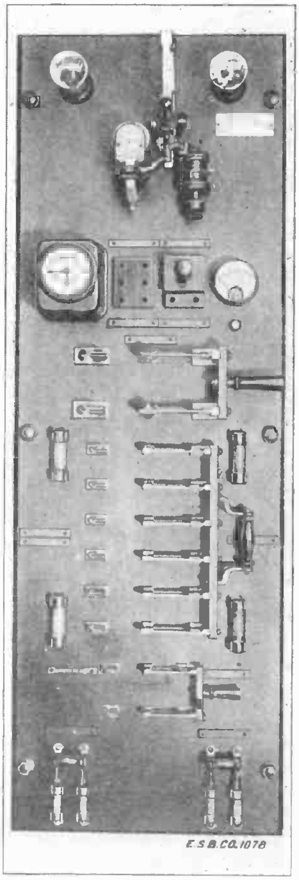

Fig. 114. Battery Charging Panel.
Courtesy of the Electric Storage Battery Co.

7. Be sure that the polarity of the charging current is correct.

8. See that the cells do not beocme shortcircuited by the sediment in the bottom of the container jar.

9. If the specific gravity of a cell is low, charge cell until there is no further rise in the gravity and then add electrolyte of the proper density until the normal reading is obtained.

10. Keep all flames from the vicinity of the battery while charging.

11. Never allow voltage per cell to drop below 1.8.

12. Do not overdischarge, undercharge or overcharge. (Overcharge is not as dangerous to the plates as overdischarge or undercharge.)

13. Do not allow cells to remain in a discharged or partially discharged condition.

Handling and Storing Water.—When handling or transporting water for battery use, it is very important not to use metallic vessels, owing to the possibility of contamination. Pure distilled water has a great affinity for all the base metals except lead and tin. Glass or earthenware containers are suitable, but care must be taken that they be kept clean. For storing water, gladd carboys with corks are suitable. If a large amount is to be kept on hand, it may be stored in a lead lined tank with lead or tin-lined connections.

Pilot Cell.—Select one cell in a battery as a pilot cell, and take and record a hydrometer reading at least once a day as a guide to the state of the battery as regards charge or discharge. If battery is charged in two parallel sets, select a pilot cell in each.

Battery Log.—Keep a record in a log book of the duration and dates of charges and discharges, when water is added, record hydrometer readings, as above, and any other useful remarks. To facilitate keeping records, mark batteries with numbers, where there are several. This does not mean cells or trays of one battery, because these can be counted from the positive end, following the electrical circuit.

When a battery is to stand idle for any considerable period, it should not be left without attention. When a battery is likely to be out of service for four months or longer and connections have not been arranged for "trickle charge."

Remove filling plugs and add pure water until the level reaches the bottom of the filling tube. Replace filling plugs, turning them as far as they will go to insure their being firmly seated. Never charge a battery with the filling plugs out, as the automatic vents are then closed and flooding will result.

Put on charge at the proper current rate as given in table and continue the charge until the specific gravity of the electrolyte in all cells, as shown by the hydrometer syringe, has held at a maximum (ceased to rise) for a period of five hours and all the cells are gassing freely. When fully charged, place the battery where it will be dry, cool and free from dust. To avoid freezing in cold weather especial care must be taken that water is added just before and not after charging.

Once every four months during the out of service period, remove filling plugs and add water, replace plugs and give battery what is known as a "freshing charge;" that is, charge until all cells have been gassing freely and evenly for one hour. Then the battery may be allowed to stand for another four months. Disconnect terminals to prevent loss of charge.

If it is not practicable to have the battery charged at periodic intervals as above described, it can be allowed to stand (provided it has first been fully charged) for a period not exceeding six months, but better results will be obtained if the freshening charge every four months is given. Always add water and charge the battery before putting back in service.

If the periodic charges have not been given during the out of service period, charge for at least 24 hours at normal rate before putting battery into service again.

To prepare electrolyte from sulphuric acid of 1.835 specific gravity, mix with water for desired specific gravity, taking the following precautions: Use a glass, china, earthenware or lead vessel. Never metallic other than lead. Carefully pour the acid into the water, never water into acid. Stir thoroughly with wooden paddle and allow to cool before reading the gravity.

Sulphuric acid and water do not mix readily, the water tending to remain on top in a layer. When mixing, the true strength of the mixture cannot be read until they are thoroughly mixed. After mixing they remain mixed. To put a battery in dry storage that is to be out of commission for longer than a year. Provide a place free from dust, give the battery a full charge, have on hand enough pure water to fill all the cells. After charge empty the battery solution by tilting and turning over the battery and immediately replace the solution with the water.

Allow the battery to stand filled with water for approximately five hours then drain and thoroughly dry. Put a tax on each battery giving date put in storage.

To put a battery in wet storage that is to be out of commission for less than a year. The most satisfactory results can be obtained by charging continuously at a very low rate, which is so low that gassing is avoided and yet gives enough charge to maintain the batteries in good condition. This charge is termed a "trickle charge." It has the added advantage of keeping the batteries in condition for putting into use at any time on short notice.

The Edison Cell.—This cell differs from the lead cell both in construction and material. The plates of the "Edison" are made of iron oxide and nickel and are immersed in an electrolyte of caustic potash. This cell when fully charged has a voltage of 1.2 and has a minimum voltage of .9. No specific gravity reading is necessary with this type of cell, except once or twice a year, when a renewal of the electrolyte may be desirable. The caustic potash enters the plates at one part of the cell, but is returned to the solution at the same rate in another part of the cell, thus causing no change in the specific gravity. A nickel-plated steel can is employed as a container, instead of glass or hard rubber, which construction makes this cell more rugged than the lead type. It has many advantages over the

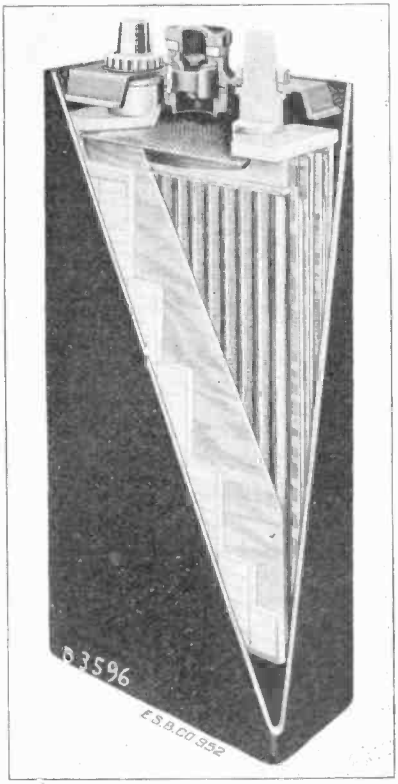

Fig. 115. Cutaway View of "Ironclad" "Exide" Cell.
Courtesy of the Electric Storage Battery Co.

lead cell, but for certain purposes the lead type is to be preferred. A photo of the assembled cell is shown in Fig. 112, and a photo of the plates in Fig. 113.

Construction of the Edison.—The positive plate of the Edison cell consists of a nickel steel grid or frame which supports thirty perforated steel tubes filled with alternate layers of pure flake nickel and nickel hydrate, while the negative plate consists of a nickel steel grid which supports twenty-four steel pockets filled with iron oxide and a small quantity of metallic mercury. The addition of pure flake nickel in the positive plates increases the conductivity of the active material, and likewise the metallic mercury increases the conductivity of the negative plate. A view of these plates is given in Fig. 113. Each cell has a number of positive and negative plates arranged in alternate order, the positive being connected to one terminal and the negative to the other. The electrolyte is a 21% solution of potassium hydrate (caustic potash) and a small amount of lithium hydrate. Caustic potash is a preservative of nickel steel, and therefore there is no deterioration of the cell due to standing in a discharged or partially discharged condition. The water used in this cell should be free of acids and sulphur.

Chemical Reaction of the Edison Cell.—When charged for the first time, the nickel hydrate of the positive plate becomes nickel oxide and the iron oxide becomes metallic iron. On discharge the nickel oxide of the positive changes to a different form of nickel oxide, while the metallic iron changes again to iron oxide. The caustic potash enters into the chemical reaction, but is turned back into the solution in another part of the cell. Hydrogen gas is liberated by the breaking up of the water in the cell by the current, and as this gas mixed with air forms an explosive mixture, all flames should be kept away from the cells during or immediately after charge.

Care of the Edison Battery.—The Edison cell does not require as much attention as the lead type. Overcharge and overdischarge have no effect on the Edison cell, and it may be left in a discharged or partially discharged condition without damage to the plates.

1. Keep the electrolyte one-half inch above the tops of the plates.

2. Keep all flames from the vicinity of cells during and immediately after discharge.

3. Keep cells clean and dry.

4. Do not lay a tool or other piece of metal on the cell.

5. In charging, determine the polarity of the charging source before connecting to cells.

6. See that proper rate of current flow is present.

7. Keep battery room partly open while charging to allow escape of the hydrogen and oxygen gases.

8. Pure distilled water should be used, although it is not imperative. The water should at least be free of acids or sulphur.

Comparison of the Two Types of Cells.—The lead cell has a maximum voltage of 2.1 and a minimum of 1.7. The Edison cell has a maximum voltage of 1.2 and a minimum of .9.

The lead cell should be charged and discharged at or near the normal rate. The Edison cell may be overcharged or overdischarged or even shortcircuited without injury to the plates.

Pure water must be used in the lead cell, while any water free from acids or sulphur may be employed in the Edison cell.

The lead cell cannot be overcharged to any great extent nor over-discharged without serious injury to the plates. The Edison cell is not so liable to injury from the above causes.

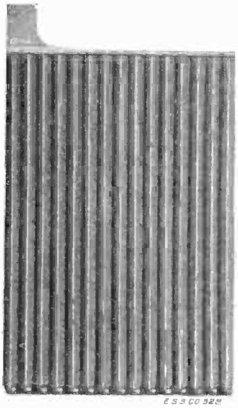

Fig. 116. The "Exide" Positive Plate.

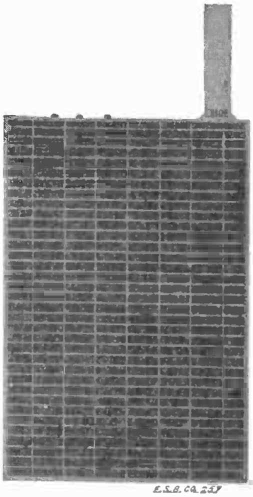

Fig. 117. The "Ironclad" "Exide" Positive Plate.

Courtesy of the Electric Storage Battery Co.

The lead cell, if allowed to remain idle, will lose its charge, and if left in a partially discharged or discharged condition for any length of time, deterioration of plates will probably occur. The Edison cell will retain its charge for a long time and is not damaged by being left in a discharged condition.

The Ampere Hour Meter.—The ampere hour meter is a device employed to measure the quantity of electricity flowing in a circuit. It is connected in the charge and discharge circuits of a storage battery and measures the quantity of electricity placed in or taken from a battery. It measures the product of the current in amperes and the time in hours. In one form, it operates similarly to a motor, consisting of a copper disc arranged so as to float in a pan of mercury. A spindle extends through the center of the disc and rests in jeweled bearings. A permanent magnet is placed on either side of the disc, producing a magnetic field at right angles to the disc. The current to be measured is caused to flow from one side of the mercury pan through the mercury to the disc, through the disc and out through the mercury to the other side of the pan. The current flowing through the disc has a magnetic field about it which interacts with the one produced by the permanent magnet, causing the disc to revolve in the same manner as the armature of a motor. According to the left-hand motor rule, the disc will rotate. The speed of this motor will be proportional to the current strength, and as each revolution corresponds to a certain quantity of electricity, by proper connection of the spindle to an indicating dial, we may measure the quantity flowing through the meter. The pointer on this dial or scale moves over the scale from a zero to a maximum value as the battery discharges and in the opposite direction when battery is charging.

We cannot expect to get as much energy from the battery as we place in it, due to the unavoidable losses in the battery; therefore the ampere hour meter is arranged so that, in charging, more current must flow into the battery for a given scale reading than will flow from the battery on discharge for the same scale reading. As a lead cell has an efficiency from 80 to 90%, to charge a 60 ampere hour battery we must place about 70 ampere hours into it.

Underload and Overload Circuit Breakers.—This device is employed in the charging circuit, is function being to open the circuit when current drops below a certain value. If set for 10 amperes, as soon as the current falls below 10 amperes, it will open the circuit. It is sometimes combined with a device called the overload circuit breaker, which is arranged to open the circuit when the current rises above a certain value. If set for 10 amperes, as soon as the current exceeds 10 amperes, it will open the circuit.

It is essential that the voltage of the charging source be greater than that of the battery being charged. In case the charging voltage drops below that of the storage battery, there would be a flow of current from the battery back through the charging generator. This action would probably depolarize the generator field. (Neutralizing or reversing the polarity.) To prevent this, an underload circuit breaker is employed. An underload circuit breaker consists of a solenoid, a bar attached to a plunger and two contacts. When plunger and bar are pushed up, the circuit is closed and the magnetized solenoid holds bar against the two contacts. If the current falls below the correct value, the solenoid becomes weak, and consequently the bar drops, opening the circuit.

The Modern Circuit for the Auxiliary Source of Power.—In Fig. 110 is shown the type of circuit employed in connecting the storage battery to the charging source and to the radio set. An ampere hour meter, underload and overload circuit breaker voltmeter, ammeter and 4 or 6 pole double-throw switch are included in the circuit. By throwing large switch one way the battery is connected in parallel to the charging course, and by throwing it the other way the battery is conneceted in series for operation of the motor generator. (All of the above instruments are not shown in the figure.)

SPECIAL INSTRUCTIONS ON STORAGE BATTERIES

Students Notes for Aiding in the Final Examination for a Commercial License.

The examining officer requires that the student shall place at the top of the sheet, bearing the complete diagram of the transmitting and receiving apparatus, the kilowatt capacity or rating, with the name of the type or maker of the same; that is to say, ½, 1 or 2 KW transmitter of the Marconi type; or if it happened to be made up of standard apparatus from a number of different companies, it may be called a composite transmitter.

After the student has specified the KW rating of the transmitter, it is necessary that the emergency storage battery which is contained on this sheet shall be marked clearly, specifying the number, type and capacity in ampere hours of the cells used. These are two types of cells, the lead cell and the Edison storage cell. In the case where the lead cell is used, the number should be 60, and where the Edison storage cell is used 100 cells are employed. As regards the capacity, the following maximum values should be specified:

For ½ KW— 60 ampere hours
1 KW— 80 ampere hours
2 KW—140 ampere hours

These values may be increased slightly if it is desired to operate emergency lights aboard the ship from this battery, but it is recommended that the student do not take this matter into account in his examination. Example: At the top of the sheet the student writes 2KW. Navy type transmitter. The battery specification should read as follows: 60—lead cells with the capacity of 140 Ampere Hours.

The storage battery which is an auxiliary source of power in cases of emergency is covered by Section 1, the Act of June 24, 1910, and amended July 23, 1912, by the Department of Commerce and forbids the usage of storage battery for purposes which would be detrimental to the up-keep of the apparatus. The battery must be fully charged and ready for immediate use.

Any defects in the battery or any other part of the radio equipment should be reported to the master of the vessel immediately. Such neglect of duty on the part of operators may be considered sufficient cause for the suspension or revocation of their license.

Operators should not use a storage battery for the purpose of operating audion bulbs. An entirely separate battery should be provided for this purpose, and operators so using an audion for their own private use are subject to a fine and the revoking of their license in case this knowledge comes to the attention of the Radio Inspector.

DEFINITIONS AND DESCRIPTIONS OF ITEMS AND PARTS USED IN LEAD ACID STORAGE BATTERIES

Acid. As used in this book refers to sulphuric acid (H^2SO^4), the active component of the electrolyte.

Alternating Current. Electric current which does not flow in one direction only, like direct current, but rapidly reverses its direction or "alternates" in polarity so that it will not charge a battery.

Ampere. The unit of measure of the rate of flow of electric current.

Ampere Hour. The unit of measure of the quantity of electric current. Thus, 2 amperes flowing for ½ hour equals 1 ampere hour.

Battery. Any number of complete cells assembled in one or more trays.

Cell. The battery unit, consisting of an element complete with electrolyte, in its jar with cover.

Cell Connector. The metal link which connects the positive post of one cell to the negative post of the adjoining cell.

Charge. Passing direct current through a battery in the direction opposite to that of discharge, in order to put back the energy used on discharge.

Charge Rate. The proper rate of current to use in charging a battery from an outside source. It is expressed in amperes and varies for different sized cells.

Corrosion. The attack of metal parts by acid from the electrolyte; it is the result of lack of cleanliness.

Cover. The rubber cover which closes each individual cell; it is flanged for sealing compound to insure an effective seal.

Discharge. The flow of electric current from a battery through a circuit. The opposite of "charge."

Electrolyte. The fluid in a battery cell, consisting of specially pure sulphuric acid diluted with pure water.

Element. One positive group and one negative group with separators, assembled together.

Filling Plug. The plug which fits in and closes the orifice of the filling tube in the cell cover.

Flooding. Overflowing through the filling tube. With the **"Exide"** automatic filling tube, this can usually occur only when a battery is charged with the filling plugs out.

Freshening Charge. A charge given to a battery which has been standing idle, to insure that it is in a fully charged condition.

Gassing. The bubbling of the electrolyte caused by the rising of gas set free toward the end of charge.

Gravity. A contraction of the term "specific gravity," which means the density compared to water as a standard.

Group. A set of plates, either positive or negative, joined to a strap. Groups do not include separators.

Hold-down Clips. Brackets for the attachment of bolts for holding the battery securely in position.

Hydrometer. An instrument for measuring the specific gravity of the electrolyte.

Hydrometer Syringe. A glass barrel enclosing a hydrometer and provided with a rubber bulb for drawing up electrolyte.

Jar. The hard rubber container holding the element and electrolyte.

Maximum Gravity. The highest specific gravity which the electrolyte will reach by continued charging, indicating that no acid remains in the plates.

Plates. Metallic grids supporting active material. They are alternately positive (brown) and negative (gray).

Polarity. Electrical condition. The positive terminal of a cell or battery, or the positive wire of a circuit, is said to have positive polarity; the negative, negative polarity.

Rectifier. Apparatus for converting alternating current into direct current.

Resistance. Material (usually lamps or wire) of low conductivity inserted in a circuit to retard the flow of current. By varying the resistance. the amount of current can be regulated.

Rubber Sheet Separators. Thin perforated hard rubber sheets used in combination with the wood separators in **"Exide"** navy types of batteries. They are placed between the grooved side of the wood separators and the positive plates.

Sealing Compound. The acid proof compound used to seal the cover to the jar.

Separators. Sheets of wood, either ribbed or flat, specially treated, inserted between the positive and negative plates to keep them out of contact.

Short Circuit. A metallic connection between the positive and negative plates within a cell. The plates may be in actual contact or material may lodge and bridge across. If the separators are in good condition, a short circuit is unlikely to occur.

Specific Gravity. The density of the electrolyte compared to water as a standard. It indicates the strength and is measured by the hydrometer.

Splash Cover. A thin, perforated, hard rubber sheet, used in "Ironclad-Exide" cells. It can be seen through the filling tube. It protects the wood separators from injury.

Starvation. The result of giving insufficient charge in relation to the amount of discharge, resulting in poor service and injury to the battery.

Sulphated. The condition of plates having an abnormal amount of lead sulphate caused by "starvation" or by allowing battery to remain discharged.

Tray. The containing case or box which holds the cells.

Tray Terminals. Devices attached to the positive post of one end cell of a tray and the negative post of the other end cell, by means of which the try is connected to another try or to the service circuits.

Tray Unit. A tray containing a number of cells completely assembled.

Trickle Charge. This means that the battery is at all times receiving just enough current to counteract local action and keep it in the prime of condition with entire capacity always available.

Voltage. Electrical potential or pressure, of which the volt is the uni.t

QUESTIONS

Theory Lesson No. 11.

Answer the following questions and submit your lesson for grading.

226. What was the disadvantage of the first type of auxiliary transmitter?

227. What forms may the present-day auxiliary equipment take?

228. What is the difference between the primary cell and the storage cell?

229. Explain the construction of the "Exide" cell.

230. What is meant by the "electrolyte" of the cell?

231. Explain what is mean by "charging" and "discharging."

232. If a pint of pure water weighed one pound, and a pint of salt water weighed one and four-fifths pounds, what is the specific gravity of the salt water?

233. How does a hydrometer enable the condition of a storage cell to be determined?

234. Explain fully the meaning of capacity and what factors determine the capacity of a cell.

235. Define normal charging rate and normal discharge rate.

236. Draw a diagram of the circuit employed in charging a large battery.

237. What is meant by "sulphating?"

238. How many lamps would you connect in parallel when charging a 60-cell battery at a 10-ampere rate?

239. Why is it advisable to keep flames from the vicinity of a battery on charge?

240. Describe the construction of an Edison cell.

241. Is a hydrometer of value when charging an Edison cell?

242. Compare the Edison and lead cells, explaining in full the differences in their construction and operation.

243. What is the function of an ampere hour meter?

244. What is the specific gravity of an "Exide" cell?

245. What kind of water would you add to make up for evaporation?

246. What is meant by buckling?

Correspondence Course

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1345 PA. AVE., N. W. WASHINGTON, D. C.

Answers to Instruction Book No. 11

226. The induction coil connected across a gap in the plain aerial hook-up produced a highly damped wave which was suitable only for short distance.
227. Present emergency sets are: a ½K.W. transmitter with storage battery or the main transmitter with a storage battery, gasoline or oil driven engine directly connected to a D. C. Generator.
228. A primary cell must have new chemical parts put in when the cell is discharged, while the storage battery can be recharged by passing a current thru in the opposite direction from that of discharge.
229. The exide cell is a lead storage cell made by the Electric Storage Battery Co. The positive and negative plates are made of lead plates containing grooves or holes into which a paste of red lead is pressed. Alternate plates are connected together; one set, having one less plate, forms the positive and the other set the nagative. These are put in a hard rubber container with a 20% solution of sulphuric acid. A current is passed thru the solution (into the positive plates) and the positive plates become lead peroxide (a redish-brown color), and the negative plates become spongy lead (a steel-gray color).
230. The electrolyte is the solution into which the plates are put.
231. Charging is the process of forcing current from a source of power thru the cells in the opposite direction from which the battery is supplying current, which restores each cell to its original or charged condition. Discharging is the drawing of current out of the cells for supplying power to some piece of apparatus.
232. Specific gravity of salt water equals 1.8 divided by 1 or 1.8.
233. The hydrometer indicates the specific gravity or strength of the electrolyte and is an indication of the amount of charge in the cell.
234. The capacity of a cell expresses its ability for delivering current and is expressed in ampere hours, being the product of the number of amperes the cell will deliver times the hours. Most cells are rated on a 5 or 8-hour basis.
235. Normal charging or discharging rate is the current value in amperes which the cell is rated at and is found by dividing its capacity in ampere hours by its hours' rating; that is to say, 5 or 8.
236. See Figure 110.
237. Sulphating is the forming of a thin, hard scale on the surface of the plates and is caused by allowing the cell to stand in the discharged condition or discharging it beyond the proper amount.
238. This would depend entirely upon the charging voltage, the size and voltage of the lamp. Assume a 60-watt lamp with 120-V pressure for it to consume ½ ampere will flow thru one, and to allow 10 amperes it will require 10 divided by ½ or 20 lamp.
239. Hydrogen gas, which is explosive, when mixed with the proper amount of air, is given off from a charging lead cell.
240. The positive plates of an Edison cell are made from round tubes (of perforated nickeled steel), filled with nickeled oxide, and these are supported on a nickeled steel frame. The negative plates are made by many thin flat cases (perforated nickeled steel about 5 inches long, 1 inch wide and ⅛ inch thick), filled with iron oxide and put in a nickeled steel case with a 21% solution of caustic potash for the electrolyte.
241. The hydrometer gives no indication of the condition of the charge in an Edison cell and is never used for this purpose.

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-over-

242. The lead cell has acid for the solution or electrolyte, while the Edison cell has an alkaline solution. Charged voltage of a lead cell is 2.1 and the dis charge voltage is 1,7, while the Edison cell has 1.2 volts when charged and .9 when discharged. Lead cells should be charged or discharged at about the normal current or less, while the Edison cell may be charged or discharged at or much above the normal rate. Pure distilled water should be added to the lead cell, while any water free from acid or sulphur may be put in the Edison cell. Edison cells may stand in discharged conditions, while lead cells are injured by this action. Edison cells do not give off explosive gases.

243. An ampere hour meter measures the quantity of electrical energy (in ampere hours) contained within the battery and indicates the condition of the charge.

244. The specific gravity of the exide cell when charged is 1.215 and when discharged is 1.18.

245. Distilled and pure water.

246. Buckling is the warping or bending of the plates due to heat caused from excessive current. This will ruin a cell.

100%

George J Gunderjohn
West Salem O.

Student No. 13794

Lesson No. 11

226 The waves were highly damped and the distance that it would cover was only about 100 miles.

227 a panel set of one half kilowatt operated by storage batteries which are able to supply current for at least three hours.

a set which is supplied by a direct current generator driven by an oil or gasoline engine, the generator and engine are placed on the upper deck so it can be used even if the engine room is flooded.

a storage battery of a large enough capacity to operate the main set for about four hours.

228 a primary cell must have a renewall of parts and a new solution to again put it into use.

a storage cell must have an auxillary current which must be a direct current flow through it for a few hours, in order that it may again be able to give a current.

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229 An Exide cell consists of a number of lead plates which contain holes or grooves which are filled with a paste made of red lead, litharge and sulphuric acid
The plates are then placed in a containing vessel so that alternate plates are connected to different terminals and that those which are connected to the positive terminal are one less than those connected to the negative terminal. a 20% solution of sulphuric acid is then poured into the vessel. current from an outside source is then allowed to flow through the cell for a few hours until the cell is charged.

230 The electrolyte of a cell is the solution into which the negative and positive plates are immersed in a exide storage cell it is a 20% sulphuric acid solution.

231 When a cell is charging a current of electricity is allowed to flow through the cell for a number of hours, this causes hydrogen gas to collect on the plat

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from which the current leaves the cell, The hydrogen gas combines with the oxygen of the plate making the paste into the form of a spongy lead. at the same time the plates at which the current enters is absorbing oxygen which converts the paste into lead peroxide, at last the plates on the negative side will be covered with spongy lead and the plates on the positive side covered with lead peroxide The cell is now charged and will discharge a current for a time, the current flowing in a direction opposite to that of the charging current, a cell in discharging returns to its origional state after which it must again be charged.

232 The specific gravity would be $\overset{1.8}{1.45}$ for the salt water.

233 When a cell is charging the sulphate is driven from the plates back into the solution this causes the specific gravity to increase when the cell is discharging the sulphate forms on the plates and the solution becomes thinner also more water is produced

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on this account a hydrometer may be used to determine the condition of a storage cell.

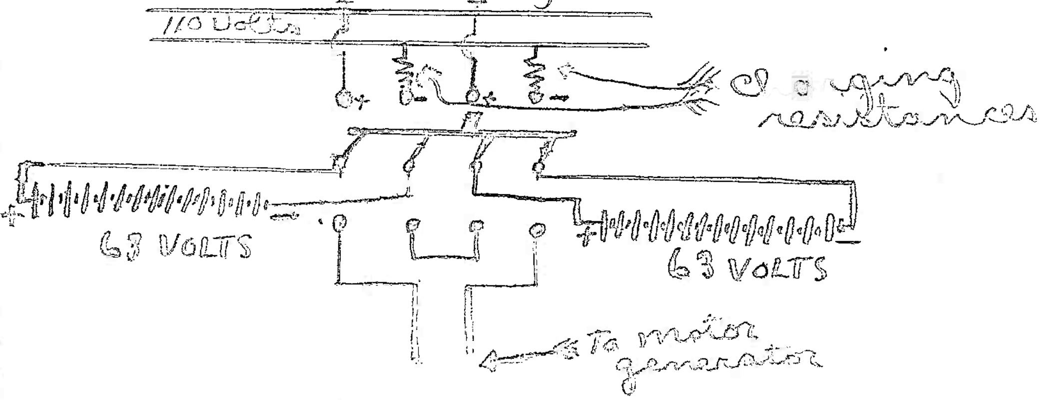
234 The capacity of a storage cell is determined by the quantity of electricity in ampere hours it is able to deliver on discharge.

The capacity of a cell may be determined by the manner in which they are connected whether in parallel, series or series parallel, when in series the capacity remains the same as a single cell when in parallel the voltage remains the same but the capacity is the sum of all the single cells.

235 The normal charging rate is the rate at which the cell may be charged in the least time possible without damage to the cell.

The normal discharge rate is the rate at which the cell may be discharged at a maximum rate without damage to the cell.

236



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Student No. 13794 Lesson No. 11

237 When the sulphate is not all driven out of the plates in charging there is a tendancy for it to become hardened and will be harder to remove afterwards by charging this reduces the capacity of a cell by reducing the active material from this the word sulphated comes from as applied to the plates having too much lead sulphate.

238 a 16 candle power lamp uses .5 of an ampere and if the charging rate is to be 10 amperes 20 lamps in parallel are needed

$10 \div .5 = 20$ lamps needed.

239 When the battery is charging Hydrogen gas is formed and given off by the cells this in combineing with oxygen becomes explosive therefore no flames should get near the battery when charging or right afterwards

240 An Edison cell consists of a nickel steel frame which supports thirty steel tubes which are perferated, these tubes are filled with alternate layers of Nickel hydrate and pure flake nickel, the other or negative plate has twenty four steel cups filled with monoxide and a small quantity of mercury these cups or pockets

are supported by a nickel steel frame, each cell has a number of + and - plates arranged in alternate order all the + plates connected to the + terminal and all the - plates to the - terminal.

The solution used in this cell is a 21% solution of Potassium hydrate and a small amount of Lithium hydrate.

241 No.

242 The lead cell The Edison cell

Voltage {2.1 and a minimum of 1.7} {1.2 to .9}

The lead cell must be charged and discharged at the normal rate or the cell will be damaged

The lead cell will lose its charge when standing idle and if left in that condition will sulphate and the cell may be permenantly injured, distilled water must be used.

The solution of a lead cell is a 20% sulphuric acid solution.

The lead cell has lead for the positive and negative plates.

The Edison cell may be charged and discharged at a high rate or even short circuited without injury to the cell.

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any water free from sulphur or acids may be used in the Edison cell.

An Edison cell retains its charge for a long time and may be left in a discharged condition without injury.

An Edison cell uses a 21% solution of Potassium Hydrate and a small quantity of lithium hydrate for its electrolyte.

An edison cell uses nickel steel supports and steel tubes for its plates.

243 The function of an Ampere hour meter is to measure the quantity of electricity flowing in a circuit.

244 The specific gravity of an exide cell is 1.205 for a fully charged battery and about 1.180 for a dead battery.

245 I would add only pure rain water which would fall into a glass container or jar when it was standing out in the open away from buildings or any place where metals will come in contact with it or if I could not get water this way I would distill the water into a glass or earthen jar so it would stay chemical pure.

246 Buckling is the [illegible] bending or warping of the

OVER plates caused by the unequal expansion of the

LESSON TEXT No. 12

OF A

Complete Course in Radio Telegraphy

Radio Measurements

REVISED EDITION

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RADIO TELEGRAPHY

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THEORY AND CODE LESSON NO. 12

RADIO MEASUREMENTS

MIXED CODE FOR SPEED TESTS

Nr; 1)

ACGHT JKASY FPOEU PKEIT CJZYS XBAFY AQXZT
DKWOT ALFKQ XHSYE ZPLAY BNGUW LSKRI BLWOT
CNALQ POAXZ YAZGQ AKQIR FLSOE CLZKX XCXCX
DBVUB TOAPD VWJGK KXLPA AKQIT CLSKT XPAOT
FKEIT PLZXQ SYATE
CALSK SKAJT DKAJT
ZJAHT XKAJP PZXQV
XLKAU CJAHT CLAKD

Nr; 2)

12938 49827 30814 21103 28736 29401 29104 29831 21483 28739
20387 68473 21003 11287 48993 28749 12837 29114 29840 29837
08374 83244 48372 21039 38571 29831 20385 29841 29534 29100
29480 01398 28475 56883 38273 39580 29857 31594 29851 39684

No; 3)

aj247 kh749 bm284 dz930 ax837 sj94o wj104 cn832 38574 kf740
pa837 24rys fj948 38hjz xy597 bv345 dj837 zx694 fk583 px290
zj385 gk694 vn372 gh593 fk574 kx992 dh499 sj283 xm873 1f937
1k382 dj382 sk795 dk699 do933 sk300 eu563 ti683 gj233 fu588

Nr; 4)

387gk 593sk 201ax qp483 594kz 030zx qp169 dk369 573zl 36qrk
sk395 480cb 472gh 493ks 396la 680sk 385kd 599qm ghr94 672gk
587sh 472ks 47311 gh573 gh573 69gj4 684if 68gj4 68f4x 57417
58fh4 68s15 9600d gj4ex 58gj3 g94kd r94ya gjrks 4848g 68eks

Nr; 5)

sjfhr gjtui vndha xpqlz djahz bnxva nkfry ghdge hksuw bnsha
vmdny xlskq vnets cnsha fkeut dkeis dksjt vlsow fjayq xleop
d“tm” gj“vm 41“sk cm,a. sj,n” ,ske” .;sh’ cnsh” .s,io cns’;
cn,.? dh?ah xns.: cns’, cl:.? cnsj” dhwi’ ens,: sh”n’ cnend;

Let us know how long it takes you to transmit this on the key.

SECRET WIRELESS TELEGRAPH CODE

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
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	A
C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Z	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

Each station has a short word code call which is only known to the operators. Assuming that one station call is w-i-r-e and the other r-o-p-e and w-i-r-e station is sending a secret message to r-o-p-e it is outlined thus:

W i l l s e n d b a t t l e s h i p t o d a y
ROPEROPEROPEROPEROPEROP
NWAPJSCHSOIXCSHLZDISUON

The letters that are really sent are on the bottom line and are obtained from the place where W and R meet at N, where I and O meet at W, etc.

These letters can be sent in any code without interception providing the station code word is known only to the operators. The receiving station writes down the letters received—N W A P J S C H S O I X C S H L Z D I S U O N—and writes above these its own code—R-O-P-E—over and over again and then with the chart finds that R through to N gives W. O through to W gives I, P through to A gives L, and E through to P gives L, which is the translation of the first word of the message.

The government assigned station calls are first used in calling the desired station and its code word is kept a secret.

FOREWORD

The subject of radio measurements is of considerable importance to the student. We wish to make it plain, however, that a thorough knowledge and understanding of all the subjects covered in this paper are not essential to the acquiring of a commercial license. We make this statement for the benefit of those students who, from lack of schooling, may find it difficult to understand some of the mathematical formulas. The student should understand that, while not absolutely essential, a thorough knowledge of the material presented in this instruction paper will be very helpful and will serve as an introduction to more advanced study of this fascinating art. In the early part of this paper we will review certain principles and laws of elementary electricity and magnetism, as well as of audio and radio frequency currents. Certain subjects not fully explained in preceding instruction papers will be considered in detail.

Electrical Units—Many students have trouble in understanding the relation between the different electrical units. We will consider here only those practical units which the student will require in the operation of radio instruments.

The four most important units are the **volt, ampere, ohm** and **coulomb,** being the units for pressure, current strength, resistance and quantity.

The **volt** is the unit of pressure (potential) and may be defined as that pressure or potential which will cause one ampere of current to flow through a resistance of one ohm.

The **ampere** is the unit of current strength (rate of flow), and is sometimes defined as the strength of current flowing in a circuit when the pressure is one volt and the resistance one ohm.

The **ampere** is also defined as that current which, when passed through a silver plating bath will deposit .001118 gram of silver per second.

The **ohm** is the unit of resistance and is the resistance of a circuit in which one volt will cause one ampere of current to flow. It may also be defined as the resistance of a column of mercury 106.3 centimeters in height, of constant cross section and weighing 14.4521 grams at the temperature of melting ice (32° Fahr.).

In considering the above definitions, one should bear in mind that the voltage of a circuit represents the pressure that causes a current to flow in the circuit. This pressure may be compared to that employed in a city water supply system. No water will flow in the mammoth network of pipes until a pressure is supplied, to overcome the resistance offered by the piping and to overcome gravity. Similarly, in an electrical system, a pressure must be supplied to overcome the resistance offered by the circuit to an electrical current.

The **"rate of flow"** or **current strength** in a circuit is measured in amperes and indicates not "how much" but "how big" the current flow is. Many students have difficulty in obtaining a clear conception of current strength. Roughly speakng, it might be considered as the cross sectional area of the current.

The **coulomb** is the unit of quantity, and is that quantity of electricity flowing past a given point in a circuit when one ampere flows for one second. In other words, if the product of the current in amperes and the time in seconds equals one, the quantity of electricity represented will be one coulomb. **Note** that the products of **amperes** and time gives the quantity. Another unit for quantity is the **ampere hour**, which is equal to 3,600 coulombs. (One hour equals 3,600 seconds.)

The relation between the first three units—the volt, ampere and ohm—is given by Ohm's law, which states that the current strength is equal to the potential in volts divided by the resistance in ohms.

By Ohm's law, we may define a **volt** as that pressure present in a circuit when the product of the amperes and ohms in a circuit is equal to one.

$$E = I \times R$$

Volts equal amperes times ohms.

Likewise, there will be **one ampere** in the circuit when the quotient obtained by dividing the volts by the ohms equals one.

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

And, **one ohm** resistance when the quotient obtained by dividing the volts by the amperes equals one.

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

A dynamo is a source of electrical current, and the electromotive force which causes this current to flow will depend on the rate at which the lines of force between the field magnets are cut. Therefore, the voltage will depend on the strength of the field magnets and the revolutions per minute.

The voltage of an electromechanical cell depends on its elements and method of construction.

The current strength in amperes in a circuit depends on the voltage and resistance, as shown by Ohm's law. We may speak of the potential of a transmission line, but not of the amperage. That is, we may describe a circuit as being a 100-volt, 1,100-volt, 2,200-volt line, but we cannot speak of the amperage, because the latter depends on the variable resistance and voltage of the circuit.

The resistance of a circuit is dependent not on the voltage and amperage, but upon the material, cross-section and length of the conductor forming the circuit.

Power is defined as the rate of doing work. The practical unit of power is the **watt** and is that work done in a circuit in which the product of volts and amperes equals one. The power of a circuit is equal to the product of volts and amperes. A horsepower equals 746 watts, and a kilowatt equals 1,000 watts.

Capacity has been defined as that property of a circuit by which it stores up energy in electrostatic form. A condenser is a device possessing this property of capacity and consists of two conducting surfaces separated by an insulator (dielectric). Two parallel wires, if insulated from each other, possess capacity. The closer the two conductors are the greater the capacity.

The **farad** is the unit of capacity, being the capacity of a condenser which will be charged to a potential of one volt by a quantity of electricity equal to one coulomb.

A formula may be given showing the relation between these quantities.

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

where C = capacity of farads
Q = quantity in coulombs
E = voltage.

The property of capacity is very important in radio telegraphy and a thorough understanding of it is essential.

A formula for the capacity of a condenser is:

$$C = \frac{Ka}{36 \times 3.1416 \times 1000{,}000 \times T}$$

where C = capacity in microfarads.
K = dielectric constant.
a = area of dielectric in cms.
T = thickness of dielectric in cms.

The capacity in farads or microfarads of a circuit or condenser depends on the dimensions of the conducting surfaces, the material and thickness of the dielectric, and the nature of the surrounding medium.

Two clouds may be considered as conductors separated by a dielectric of air, and if charged by atmospheric electricity, this dielectric may be punctured by a discharge called lightning. Any two conducting surfaces, if insulated from each other, possess the property of capacity.

The **farad** is too large a unit for ordinary purposes, and we have come to use the millionth part of the farad (the microfarad) for practical calculations.

Inductance is that property of a circuit by which energy is stored up in electromagnetic form. It is as important as capacity in the study of radio, and these two properties may be termed the **fundamental elements** upon which radio telegraphy is based.

The **henry** is the unit of inductance of self-induction. A circuit is said to have an inductance of one henry, if the current changing at the rate of one ampere per second, induces a counter e. m. f. of one volt. Note that **capacity** is the property of a circuit by which energy is stored up in a stationary form, while inductance is the property by which energy is stored up in a moving or current form. That is, when a current flows in a wire, lines of force are about the wire. These lines of force represent energy in electromagnetic form. In the definition above, a circuit is said to have an inductance of one henry if one volt counter e. m. f. is set up by the current changing from 1 to 2 amperes per second, from 3 to 2, or from 5 to 6 per second continually.

It should be thoroughly understood that the inductance in henrys is a measure of the ability of a circuit to store up energy in electromagnetic form. The henry is a large unit, and for that reason we use the one billionth part of a henry, called the centimeter, the thousandth part called the millihenry and the millionth part called the microhenry.

To summarize:

1 henry = 1,000,000,000 centimeters.
1 henry = 1,000,000 microhenrys.
1 henry = 1,000 millihenrys.

The centimeter as used in this connection must not be confused with its use as a unit of length.

The inductance in henrys of a circuit or coil depends on the dimensions, shape, the size of the wire, the nature of the surrounding medium and its position relative to other circuits.

Audio and Radio Frequency Currents—In radio circuits we deal with alternating currents of high frequency. The necessity for employing high frequency current arises from the fact that electromagnetic waves of length suitable for radio telegraphy are of high frequency. (One oscillation produces a wave, and a train of oscillations produces a train of waves.) With the exception of the 60 to 600 cycle current in the key and charging circuit of a damped wave transmitter, the frequencies range from 15,000 oscillations for the 20,000-meter wave to 3,000,000 for the 100-meter wave.

The student is asked to remember that a cycle and an oscillation are identical in meaning, the term "cycle" beng applied to low frequency currents and the term "oscillation" to currents reversing their direction of flow many thousands of times per second.

A current whose frequency is above 10,000 oscillations per second is termed a **"radio frequency"** current, while a current having less than 10,000 oscillations per second is termed an **"audio frequency"** current.

The efficient production of radio frequency currents is one of the problems confronting the radio engineer. Several methods are in use, the most common being that of "condenser discharge." Prof. Joseph Henry, in 1838, discovered that the discharge of a condenser is oscillatory. That is, that the discharge consists of an alternating current of high frequency. Prof. Hertz found that the frequency and consequently the length of wave radiated by each oscillation is dependent on the amount of inductance and capacity in the circuit.

Damped and Undamped Oscillations—Oscillations produced by the discharge of a condenser occur in groups, or trains, the oscillations of each train having a decreasing amplitude.

Undamped oscillations are those of constant amplitude and continuous formation. The methods employed in their production will be taken up in the following paper.

A point appreciated by few students is that the **frequency** of a current in an oscillatory circuit is not necessarily the **actual** number of oscillations occurring per second. In the case of a 500-cycle synchronous set there will be 1,000 charges placed in the condenser per second, and will result in there being 1,000 trains of oscillations in the closed circuit. The actual number of oscillations per second will be equal to the product of the number of trains and the number of oscillations per train.

The oscillation frequency may be defined as the rate at which the oscillations occur in the circuit. This rate depends upon the values of the capacity and inductance of the circuit. In the example given above, suppose the oscillation frequency to be 500,000 and the number of oscillations per train to be 24. There being 1,000 trains per second and 24 oscillations per train, the actual number of oscillations produced will be 24,000. Hence, there is an interval of time between trains. The oscillations occur at the rate of 500,000 per second, but the actual number is only 24,000.

Manifestly, the actual number will depend on the **oscillation train frequency** and upon the rapidity with which each train is damped out.

We call the decrease in amplitude "damping" or "decrement." To denote any particular amount of damping we use the term "logarithmic decrement." Logarithmic decrement is explained in Instruction Paper No. 6. We will discuss its measurement in the latter part of this paper.

Resonance—The term "resonance" is not clearly understood by many students. By resonance between two electrical circuits, we mean that they have the same frequency of oscillation. The frequency of an oscillation circuit depends on the values of the inductance and capacity in the circuit.

For a given value of the inductance and capacity in the circuit, there will be a corresponding frequency of the oscillations. If either the condenser or coil of wire is made larger, there will be fewer oscillations per second, because the larger the condenser, and the larger the coil or circuit, the longer will it take for the oscillations to flow from one side of the condenser to the other. If it takes longer for an oscillation to complete itself, there necessarily must be a less number per second; or, in other words, the frequency is less. If we have two circuits in inductive relation to each other, and the frequency is the same in each, the two are said to be in "resonance." To have resonance it is necessary that the product of the inductance and capacity in one must equal the product of the inductance and capacity of the other. Note that it is unnecessary that the value of the capacity or inductance of one circuit equal the value of the capacity and inductance of the other, but that the products must be equal.

Should oscillations occur in one of these resonant circuits, there will be a maximum transfer of energy by induction (magnetic lines of force) to the other circuit. The resonant condition is present between the closed and open oscillatory circuits of the transmitter and between the aerial and secondary circuits of the receiver.

Measuring Instruments Employed in the Transmitting Set—In the key circuit of the damped wave transmitter we have the following measuring instruments—the voltmeter, the ammeter, the wattmeter and the frequency meter.

The **voltmeter** measures the difference of potential across the leads from the generator armature.

The **ammeter** measures the strength in amperes of the current flowing in the key circuit.

The **wattmeter** indicates the power in watts of the current flowing in the key circuit.

The **frequency meter** indicates the number of cycles per second of the alternating current supplied by the generator armature.

The above instruments are usually arranged on a bakelite panel board and are employed solely for the measurement of the low voltage, low frequency currents flowing in the key circuit.

The **hot wire ammeter** is connected in series with the instruments of the aerial circuit, and indicates the value of the current flowing in the aerial circuit. A description of its construction has been given in a previous instruction paper. The function of this instrument is:

1. To indicate the number of amperes of the current flowing in the aerial circuit.

2. To enable the placing of the closed and aerial circuits in resonance.

The value of the first is that the operator is informed by the ammeter reading whether or not the transmitter is functioning properly. (The greater the flow of current in the aerial circuit the greater the range.) The second function, that of placing the two circuits in resonance, is possible, due to the fact that there is a maximum transfer of energy when

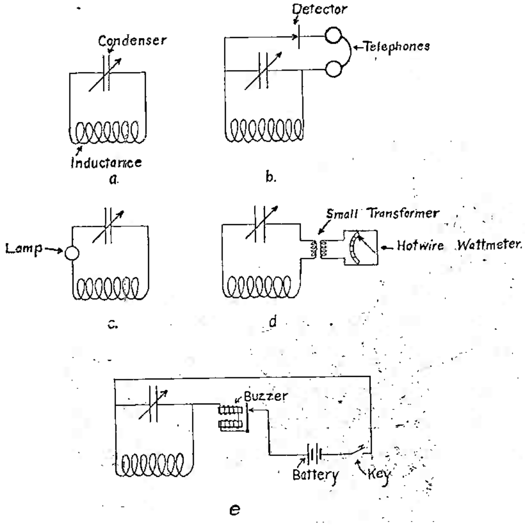


Fig. 120, a, b, c, d, e. Wavemeter Circuits.

a condition of resonance is present between the two circuits. That is, if the key of the transmitter is depressed the condenser discharges and continues to discharge as long as charges are placed in the condenser. The flow of oscillation trains in the closed circuit due to these discharges sets up lines of force about the secondary in the aerial circuit, thereby transferring energy. The reading of the hot wire ammeter is a maximum when the two circuits are adjusted to the same wave length.

The Wavemeter—The wavemeter is a very important instrument used in the adjustment and tuning of radio sets. It consists essentially of a variable condenser and a fixed inductance coil. (The inductance coil may be variable and the capacity fixed, if desired.) An arrangement of this kind is an oscillatory circuit and possesses a variable frequency. By adjustment of the variable condenser, different frequencies may be obtained. A fundamental circuit diagram of a wavemeter is given in Fig.

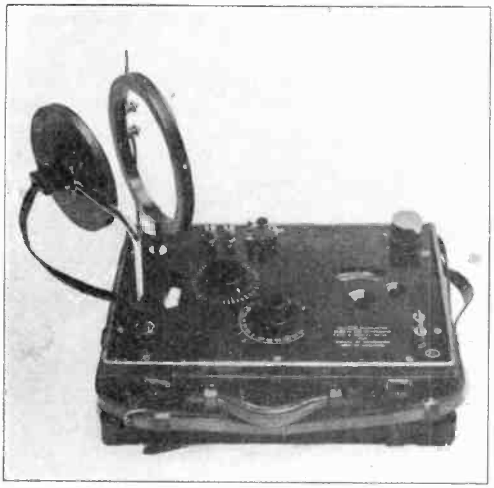


Fig. 118. Kolster Decremeter and Wavemeter (Exterior View). (Courtesy of the Bureau of Standards.)

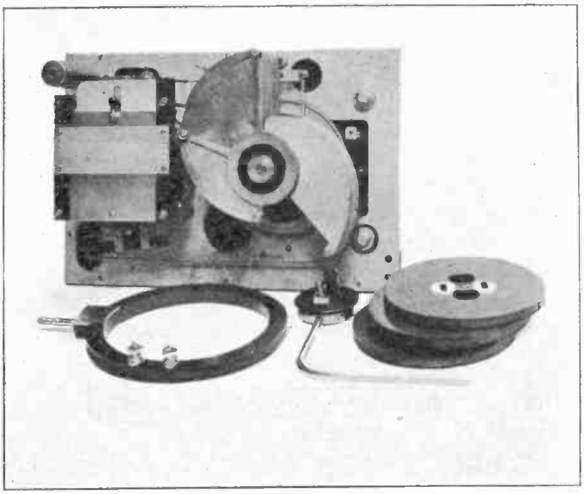


Fig. 119. Kolster Decremeter and Wavemeter (Interior View).
(Courtesy of the Bureau of Standards.)

120a. The condenser is of the common semi-circular plate type, such as is shown in Fig. 84, while the inductance may be a single or multiple layered coil of insulated wire. This wire is preferably of the stranded type (Litzendraht) and is wound on a flat spool of hard rubber or other good insulator. In Figs. 118 and 119 are shown the front and back view of a modern type of wavemeter. As stated previously, at any given adjustment of the capacity or inductance of an oscillatory circuit we have a corresponding frequency. Hence, if the wavemeter condenser is calibrated, we may read from the scale the wave length to which the wavemeter is adjusted. If we place this wavemeter near a circuit in which oscillations occur and adjust or vary the capacity of the condenser, we may place the wavemeter in resonance with the oscillating circuit in question. In order to know when we have a state of resonance we must have an indicator of some kind attached to the wavemeter circuit. There are various devices which may be employed to indicate resonance. As shown in Fig. 120b, a **crystal detector in series with a telephone receiver** may be shunted above the wavemeter condenser. When the wavemeter is in resonance with the oscillating circuit, there will be a maximum transfer of energy to the wavemeter in the form of oscillations.

The wavemeter, in conjunction with the detector and telephones, is a receiving set. The oscillations induced in it will be rectified by the detector and a maximum current will be indicated by the loudest sound in the phones. If the condenser capacity is decreased the frequency of the wavemeter will be increased, throwing it out of resonance with the other circuit and reducing the signals in the telephone receiver.

Another indicator that may be employed is illustrated in Fig. 120c. A **small lamp** is placed in series with the condenser and inductance of the wavemeter. When the wavemeter is in resonance with a nearby oscillating circuit, the lamp will glow brightly and, as with the above circuit, the wave length will be indicated by the pointer on the condenser scale.

A third arrangement (see Fig. 120d) used for certain measurements, consists of a wavemeter and a **hot wire milliameter** (instrument measuring in thousandth of an ampere) or a **hot wire milliameter** (measuring from .01 to .1 watt). Either of these instruments is connected by means of a small transformer to the wavemeter circuit.

Several other devices, which may be used for the same purpose as the above-described instruments, will not be discussed in this course of lessons.

The student should understand that the wavemeter is not attached in the circuit of the radio set, but is placed at various distances from, and in inducance relation to, the circuits to be measured. The distance depends on the sensitiveness of the indicating device and on the strength of the current in the circuit to be measured.

Sometimes it is desirable to radiate weak electromagnetic waves of a given length. We may accomplish this by attaching a buzzer, battery and key to the wavemeter, as illustrated in Fig. 120c. If the buzzer is set into operation, oscillations will be set up in the wavemeter circuit and weak waves will be radiated for a short distance. The length of these waves will depend on the adjustment of the wavemeter capacity and on the size of the inductance coil. The use to which the above arrangement may be put will be discussed later.

A wavemeter with a calibrated condenser is usually supplied with a number of fixed inductance coils, so that a wide range of wave lengths may be measured. The coils are usually connected in shunt to the condenser by means of a flexible conductor. There must be a wave-length scale for each inductance coil. Instead of placing all the scales on the condenser, the wave lengths may be plotted in the form of curves on cross-section paper.

With a given coil in shunt to the condenser there will be a given range of wave lengths to which the wavemeter can be adjusted by means of the variation of capacity.

For instance, one coil may give a range from 150 to 600 meters and the next from 500 to 1,000 meters, etc.

Uses of the Wavemeter—Connected as a receiver, the wavemeter may be employed:

1. To tune a transmitting set to a given wave length.
2. To measure the logarithmic decrement of the trains of oscillations, when used in conjunction with a hot wire wattmeter or milliammeter.
3. To plot a resonance curve.
4. To measure the percentage of coupling between the open and closed circuits of the transmitter.

As a transmitter the wavemeter may be employed:

5. To measure the wave length of a distant station.
6. To calibrate a receiving set so that it may be preadjusted to any given wave length.

Tuning a Transmitter to a Given Wave Length—Ship transmitters are usually tuned to three wave lengths: 300, 450 and 600 meters. Probably 90 per cent of merchant ship radio communication is handled on 600-meter wave length, but ships must be tuned to the other two wave lengths also. The 450-meter length is employed whenever it is desired to communicate without disturbing other stations in the vicinity.

To tune a set to a given wave length, such as 600 meters, a number of measurements must be taken. The **closed oscillation circuit,** consisting of condenser, primary of the oscillation transformer and the spark gap, must be tuned to 600 meters. In this circuit the inductance is the only variable element. The variation is made possible by means of clips attached to the leads from the condenser and spark gap. As shown in Fig. 121, the wavemeter, with detector and phone attached, is placed in inductive relation to the closed circuit. To tune to 600 meters, the pointer of the wavemeter condenser is adjusted to 600 meters and the detector adjusted to a sensitive condition. With the aerial and ground disconnected from the secondary of the oscillation transformer, the key of the transmitter is depressed, causing a discharge to occur across the gap and oscillations to flow in the closed circuit. The clip attachment on the inductance of the transmitter closed circuit is changed from turn to turn until the loudest sound is heard in the phones of the wavemeter. If the pointer of the wavemeter condenser is now varied to wave lengths to either side of the 600-meter and the signals from the transmitter remain loud, it is an indication that the wavemeter is in too close proximity to the transmitting set. Remove to a greater distance until the signals are heard loudest only at the 600-meter position. **The closed circuit is now adjusted to 600 meters.**

The aerial circuit must now be tuned to resonance with the closed circuit, but before this can be done, the natural wave length of the aerial circuit should be determined; otherwise we may find that our aerial is too large for adjustment to a 600-meter wave length.

The natural wave length of the aerial circuit is that length of wave it will radiate with no added inductance or capacity.

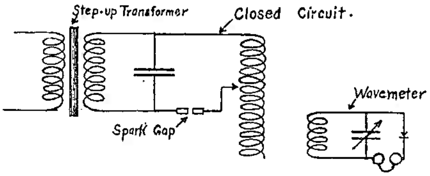


Fig. 121. Arrangement for Measuring Wavelength of the Closed Oscillatory Circuit.

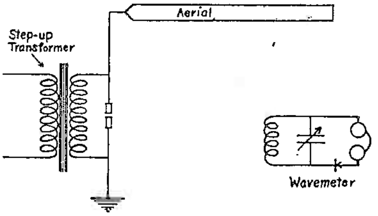


Fig. 122. Method of Obtaining the Natural Wavelength of the Aerial Circuit.

To measure the natural wave length it is necessary that we cause oscillations to flow in the aerial circuit. If we place a spark gap in series with the aerial and ground leads and then connect the secondary terminals of an induction coil or step-up transformer to either side of the gap we will have a **"plain aerial transmitter."** If current is supplied to the primary of the step-up transformer, the aerial and ground will be charged. The discharge of this condenser across the gap consists of a series of oscillations.

If the wavemeter is placed in inductive relation to the earth lead, and the condenser pointer varied until the loudest sound is heard in the phones, we may read the natural wave length from the wavemeter scale. Such a circuit is shown in Fig. 122. Suppose we find the natural wave length to be 400 meters. To adjust the aerial circuit to 600 meters it will be necessary to add concentrated inductance in the form of a coil of wire. This coil of wire may be wound in the form of a helix, with one layer of bare wire having a space of an inch or more between turns. This coil should be wound on a cylindrical frame of hard rubber or other good insulator. In modern sets the **spiral** type of coil is employed extensively, copper, ribbon being wound in the shape of a spiral on an insulating frame. This inductance employed for loading (sometimes termed an "aerial tuning inductance") is varied by means of a clip in connection to the different turns.

In Fig. 123 is shown the closed circuit (tuned to 600 meters) in inductive relation to the aerial or open circuit. In the aerial circuit we find the loading coil (aerial tuning inductance) in series with the aerial and the secondary of the oscillation transformer. The two circuits may be put in resonance by the following procedure:

Trains of oscillations are set up in the closed circuit by pressing the transmitting key and, as the primary of the closed and the secondary of the oscillation circuits are in inductive relation, energy will be transferred to the aerial circuit. A hot wire ammeter is in series with the aerial circuit and registers the strength of the induced current. Note the reading given by this instrument and then vary the clip connection on the aerial tuning inductance, adding more and more turns. As the natural wave length was 400 meters, if we add turns of inductance, the wave length of the open circuit will approach that of the closed circuit. When the reading of the ammeter is a maximum, the two circuits are in resonance. That is, if we increase or decrease the number of turns we now have on the aerial tuning inductance, a drop in the ammeter reading will occur.

Now that the closed and open circuits are in resonance, the only remaining measurement to be made is that of the **"radiated wave."**

Apparently, we should have a radiated wave equal to that of the closed and open circuits, but such may not be the case. Due to the mutual induction between the primary and secondary, there will be a transfer of energy from the aerial circuit back into the closed, if the two coils are in too close inductive relation. The result of this action is that there may be a radiation of two waves of different lengths by the aerial. One of these waves will be greater and one less than the wave length to which the set is tuned. The oscillations set up in the closed circuits by the discharge of the condenser set up lines of magnetic force about the secondary and induce oscillations in it. These oscillations in turn set up lines of force about the primary and current is thus transferred back, the amount being dependent on the closeness of coupling. The inductive action of the secondary on the primary alternately assists and opposes the oscillating current in the closed circuit.

This mutual induction between the two circuits is alternately (many thousands of times per second) added to and subtracted from the self-induction (inductance) of the aerial circuit.

The wave length of any circuit depends on the value of the inductance and capacity, and if the inductance is increased and decreased many thousands of times per second, the wave length will be increased and decreased at the same rate. The addition or subtraction of the mutual induction causes two or more waves to be radiated by the aerial.

The Government regulations define a pure wave as that radiated by a transmitter when the energy in any of the lesser waves (less in energy) does not exceed 10 per cent of that in the greater wave.

If the coupling of the oscillation transformer is decreased (the coils separated) we may cause the radiation of practically one wave length, but it will cut down the transfer of power to the aerial circuit. We compromise by radiating more than one wave length, but limiting the energy in the lesser waves.

As shown in Fig. 123, we place the wavemeter and wattmeter attachment at a considerable distance from the transmitter, so that it may be affected by the radiated wave only. The key of the transmitter is pressed and the pointer of the wavemeter moved over the scale, noting at the same time the reading of the wattmeter. There will be two or more points on the scale of the wavemeter at which the wattmeter gives a high reading. Note the wave lengths and the reading of the wattmeter. We desire to get a radiated wave of 600 meters, and if the wave lengths radiated are above and below this length, the coils of the oscillation transformer must be separated until the wavemeter shows a maximum of 600, and also that the wattmeter at any other wave length is less than 10 per cent of that at 600 meters.

The regulation requiring a pure wave is necessary in order that interference to stations operating on other wave lengths may be reduced.

To summarize the above:

To tune a station it is necessary—

1. To measure the wave length of the closed oscillatory circuit.
2. To measure the natural wave length of the aerial circuit.
3. To tune the open and closed circuits to resonance.
4. To measure the radiated wave and determine whether it complies with the Government regulations for a "pure" wave.

The apparatus necessary for the above measurements are:

1. Wavemeter.
2. An attachment consisting of a detector and phones.
3. An attachment consisting of a wattmeter and small transformer.

The Measurement of Logarithmic Decrement—The U. S. Regulations state that: "At all stations the logarithmic decrement per complete oscillation in the wave trains emitted by the transmitting aerial shall not exceed two-tenths (.2), except when sending distress signals and messages relating thereto."

Logarithmic decrement may be defined as the natural logarithm of the radio of the amplitude of one oscillation to the amplitude of the next oscillation in the same direction. (See page 14—Instruction Paper No. 6.)

The logarithmic decrement is a convenient method of expressing the rate of decay of the oscillations of a train. If the logarithmic decrement is .2, as required by law, there will be about 24 oscillations per train, and the waves radiated by such oscillations will not cause excessive interference.

The student should bear in mind that the decrease in amplitude is due to a loss of energy from the oscillatory circuit, such as resistance, radiation and transfer by induction. The oscillations we are interested in are those in the aerial circuit because they set up the waves in the ether. If there are less than 24 waves per train, interference will be caused by the broad wave radiated. (By broad wave is meant the wave motion set up when the energy is scattered over a wide range of wave lengths.)

To radiate more than 24 waves per train it is necessary to reduce the losses in the transmitter circuits. Of course, the loss due to radiation is useful and is the result we are after, but the losses due to resistance and retransfer must be reduced to as low a value as possible. In the design and construction of a set the ohmic resistance may be reduced to a low value and the loss due to reaction of the secondary on the primary is in part dependent on the spark gap and also on the closeness of coupling.

To measure the logarithmic decrement of a train of oscillations, we make use of the same apparatus as for the measurement of the radiated waves. (See Fig. 123.)

A wavemeter with wattmeter attachment is placed at a certain distance from the transmitter, depending on the power of the transmitter and other circumstances. The key of the transmitter is depressed, causing oscillations to flow in the aerial circuit and, consequently, waves to be radiated. The pointer of the wavemeter is moved over the scale until the pointer of the wavemeter indicates a maximum reading. Note the capacity in microfarads of the condenser scale and the reading of the wattmeter at this resonance position. Now move the pointer of the wavemeter to a point of less capacity where the reading of the wattmeter falls to one-half of the reading at the resonance point. The value of the capacity at resonance may be called "Cr" and that where wattmeter falls to one-half of its value at Cr as "Cl." Insert these two capacity readings of the wavemeter condenser in the following formula:

$$D^T + D^W = \frac{Cr—Cl}{Cr} \times 3.1416$$

where Dt = logarithmic decrement of the transmitter.

Dw = logarithmic decrement of the wavemeter.

Cr = capacity of wavemeter condenser at resonance. (Highest reading of the wattmeter.)

Cl = capacity of the wavemeter condenser below resonance when the reading of the wattmeter falls to one-half of its value at resonance.

The decrement of the wavemeter (dw) is usually marked on the wavemeter.

By subtracting it from the answer obtained by solving the above equation, we obtain the logarithmic decrement of the transmitter.

The derivation of the above equation will not be given in this course of lessons. Other formulae similar to the above, giving slightly greater accuracy, are in use, but the above formula will illustrate a simple method of obtaining the decrement.

A formula for determining the number of oscillations per train when the logarithmic decrement is known is given below.

$$\text{The number of oscillations per train} = \frac{4.605 + Dt}{Dt}$$

where Dt = Log. decrement of the transmitter.

Some modern sets have as low a decrement as .05. By insertion of 0.5 in the formula above, it can be seen that there are 93 oscillations in each train flowing in the aerial circuit of such a set.

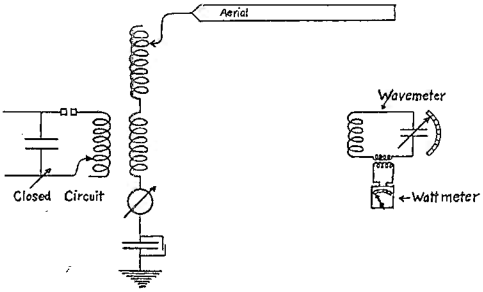


Fig. 123. Arrangement of Circuits for Measuring the Wavelength of Radiated Wave.

The Resonance Curve.—A resonance curve may be defined as a graphic method of showing the relation between the energy radiated and a given range of wave lengths. Two resonance curves are shown in Figs. 124 and 125. The lower edge of the sheet of cross-section paper is laid off in wave lengths, while the left-hand edge is laid off in hundredths of a watt (usually from .01 to .1 watt). The resonance curve indicates at what wave lengths the energy of the transmitter is radiated, whether the energy is radiated sharply on one wave length or over a wide range of wave lengths.

The same apparatus is employed as for measurement of the logarithmic decrement. The wavemeter with wattmeter attachment is placed at a certain distance from the set (such a distance that the closed circuit will not affect the wavemeter) and the pointer of the wavemeter moved over the scale while the key of the transmitter is depressed. At the lower range of

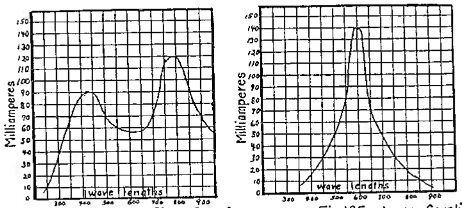


Fig. 124. Close Coupling Fig. 125. Loose Coupling.

Fig. 124 and Fig. 125. The Resonance Curve.

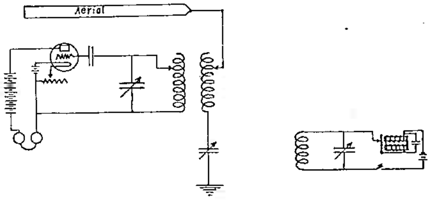


Fig. 126. Calibration of a Receiving Set.

wave lengths on the wavemeter scale no wattmeter reading will be obtained, but as the resonance position is approached by the pointer, the reading of the wattmeter will increase. As the pointer of the wavemeter is moved over the entire scale, the readings of the wattmeter for each wave length is noted and the values plotted on the sheet of cross-section paper. A line is drawn through the points plotted and is called a resonance curve. As shown in Fig 124, the greater proprotion of the energy radiated is on two wave lengths. The student is asked to observe that considerable energy is radiated on wave lengths to either side of the two principal wave lengths.

If the coupling of the transmitter is loosened the resonance curve will be quite different. In the latter case, only one hump will be found and the energy of the transmitter will be confined closely to one wave length, as shown in Fig. 125.

Determination of the Percentage of Coupling.—The percentage of coupling of a transmitting set is a measure of the coupling between the primary and secondary coils of the oscillation transformer. When we tune the two circuits of a transmitter to a given wave length, unless we employ loose coupling between the primary and secondary, there will be two waves radiated, one above and the other below the basic wave length. In Fig. 124, we have a resonance curve showing that the two principal waves are 425 and 800 meters, the basic wave length being 600 meters.

To find the percentage of coupling we may employ the following formula:

$$K = \frac{(WL)1 - (WL)2}{WL} \times 100$$

where K = percentage of coupling
(WL)1 = longer wave
(WL)2 = shorter wave
WL = basic wave length

Inserting the values found in Fig. 124 in the above formula:

$$K = \frac{800-425}{} \times 100 = \frac{37500}{} = 62.5\%$$

It is desirable to employ that percentage of coupling that will cause the radiation of most of the energy on practically one wave length. If we use very loose coupling we will radiate a single wave, but due to the distance between the coils, there will be a loss of energy, and the efficiency will be low. Hence we strike a mean between a very sharp wave on the one hand and a broad wave on the other.

Calibration of a Receiving Set.—The variable inductances and condensers of most receiving sets are not marked in wave lengths. The receiving operator cannot preadjust such a receiver to any given wave length unless he knows from experience the proper values of inductance and capacity. The variable elements of an inductively coupled receiver are:

1. The primary variable inductance.
2. The primary variable condenser.
3. The secondary variable inductance.
4. The secondary variable condenser.

If these variable elements are calibrated in wave lengths—that is, marked so that for adjustment of the receiver to any given wave length it is only necessary to turn the pointers to a certain definite position on the scales—the process of tuning will be simplified. Modern navy sets are now calibrated in this manner.

To calibrate a receiver, a wavemeter, with a buzzer, battery and key attached, is placed in inductive relation to the aerial circuit of the receiver. In Fig. 126 is shown the arrangement used. When the key of the buzzer is depressed, the condenser of the wavemeter is charged and oscillations will occur in the circuit. Weak waves will be radiated, their length being dependent upon the value of the inductance and the wavemeter capacity. Setting the wavemeter pointer at some low wave length, we adjust our receiver until the signals from the wavemeter are loudest. At this point the receiver and wavemeter are in resonance and the four variables are marked with this value of wave length. The wavemeter is set at another value and the receiver again adjusted. This procedure is carried out over the entire range of the receiver. A fixed value of coupling may be employed for the entire range of wave lengths, but the student should remember that a change in the coupling will make necessary a readjustment of the values of inductance and capacity.

The calibration of a receiver must necessarily vary with its design and construction, but the principle is the same in all cases. The calibration of the aerial circuit will only be true for the given aerial, but the calibration of the secondary circuit is true, no matter what aerial may be used.

Measurement of the Wave Length of a Distant Station—In case the receiving set is not calibrated and the wave length at which a distant station is transmitting is to be determined, the following procedure may be followed: The receiving station is adjusted to resonance with the distant station and a wavemeter with a buzzer attachment is placed in inductive relation to the aerial circuit. With buzzer in operation, the wavemeter pointer is varied until the buzzer signals are received loudest at the same adjustment of the receiver as for the distant station. The wavemeter, the receiver and the distant station are now in resonance with each other, and we can read the wave length of the distant station from the scale of the wavemeter.

ABBREVIATIONS OF UNITS

Unit.	Abbreviation.
amperes	amp.
ampere-hours	amp-hr.
centimeters	cm.
centimeter-gram-second	cgs.
cubic centimeters	cm^3
cubic inches	cu. in.
feet	ft.
foot-pounds	ft-lb.
grams	g.
henries	h.
inches	in.
kilograms	kg.
kilometers	km.
kilowatts	kw.
kilowatt-hours	kw-hr.
kilovolt-amperes	kva.
meters	m.
microfarads	mfd.
micromicrofarads	micro-mfd.
millihenries	mh.
millimeters	mm.
pounds	lb.
seconds	sec.
square centimeters	cm^2
square inches	sq. in.
volts	v.
watts	w.

THE RELATION OF NATURAL WAVE-LENGTH, FREQUENCY, AND INDUCTANCE-CAPACITY PRODUCT IN CONDENSER CIRCUITS.

Meters	n	L x C	Meters	n	L x C	Meters	n	L x C	Meters	n	L x C
100	3,000,000	0.00282	500	600,000	0.0704	700	429,000	0.1379	900	333,000	0.228
110	2,727,000	0.00341	505	594,000	0.0718	705	426,000	0.1399	905	331,000	0.231
120	2,500,000	0.00405	510	588,000	0.0732	710	428,000	0.1419	910	330,000	0.233
130	2,308,000	0.00476	515	583,000	0.0747	715	420,000	0.1439	915	328,000	0.236
140	2,143,000	0.00552	520	577,000	0.0761	720	417,000	0.1459	920	326,000	0.238
150	2,000,000	0.00633	525	572,000	0.0776	725	414,000	0.1479	925	324,000	0.241
160	1,875,000	0.00721	530	566,000	0.0791	730	411,000	0.1500	930	323,000	0.243
170	1,764,000	0.00813	535	561,000	0.0806	735	408,000	0.1521	935	321,000	0.246
180	1,667,000	0.00912	540	556,000	0.0821	740	405,000	0.1541	940	319,000	0.249
190	1,579,000	0.01015	545	551,000	0.0836	745	403,000	0.1562	945	317,000	0.251
200	1,500,000	0.01126	550	546,000	0.0852	750	400,000	0.1583	950	316,000	0.254
210	1,429,000	0.01241	555	541,000	0.0867	755	397,000	0.1604	955	314,000	0.257
220	1,364,000	0.01362	560	536,000	0.0883	760	395,000	0.1626	960	313,000	0.259
230	1,304,000	0.01489	565	531,000	0.0899	765	392,000	0.1647	965	311,000	0.262
240	1,250,000	0.01621	570	527,000	0.0915	770	390,000	0.1669	970	309,000	0.265
250	1,200,000	0.01759	575	522,000	0.0931	775	387,000	0.1690	975	308,000	0.268
260	1,154,000	0.01903	580	517,000	0.0947	780	385,000	0.1712	980	306,000	0.270
270	1,111,000	0.0205	585	513,000	0.0963	785	382,000	0.1734	985	305,000	0.273
280	1,071,000	0.0221	590	509,000	0.0980	790	380,000	0.1756	990	303,000	0.276
290	1,034,000	0.0237	595	504,000	0.0996	795	377,000	0.1779	995	302,000	0.279
300	1,000,000	0.0253	600	500,000	0.1013	800	375,000	0.1801	1000	300,000	0.282
310	968,000	0.0270	605	496,000	0.1030	805	373,000	0.1824	1010	297,100	0.287
320	938,000	0.0288	610	492,000	0.1047	810	370,000	0.1847	1020	294,200	0.293
330	909,000	0.0306	615	488,000	0.1065	815	368,000	0.1870	1030	291,300	0.299
340	883,000	0.0325	620	484,000	0.1082	820	366,000	0.1893	1040	288,500	0.304
350	857,000	0.0345	625	480,000	0.1100	825	364,000	0.1916	1050	285,700	0.310
360	834,000	0.0365	630	476,000	0.1117	830	361,000	0.1939	1060	283,000	0.316
370	811,000	0.0385	635	472,000	0.1135	835	359,000	0.1962	1070	280,400	0.322
380	790,000	0.0406	640	469,000	0.1153	840	357,000	0.1986	1080	277,800	0.328
390	769,000	0.0428	645	465,000	0.1171	845	355,000	0.201	1090	275,200	0.334
400	750,000	0.0450	650	462,000	0.1189	850	353,000	0.203	1100	272,700	0.341
410	732,000	0.0473	655	458,000	0.1208	855	351,000	0.206	1110	270,300	0.347
420	715,000	0.0496	660	455,000	0.1226	860	349,000	0.208	1120	267,900	0.353
430	698,000	0.0520	665	451,000	0.1245	865	347,000	0.211	1130	265,000	0.359
440	682,000	0.0545	670	448,000	0.1264	870	345,000	0.213	1140	263,200	0.366
450	667,000	0.0570	675	440,000	0.1283	875	343,000	0.216	1150	260,900	0.372
460	652,000	0.0596	680	441,000	0.1302	880	341,000	0.218	1160	258,600	9.379
470	639,000	0.0622	685	438,000	0.1321	885	339,000	0.220	1170	256,400	0.385
480	625,000	0.0649	690	435,000	0.1340	890	337,000	0.223	1180	254,200	0.392
490	612,000	0.0676	695	432,000	0.1360	895	335,000	0.225	1190	252,100	0.399

QUESTIONS

Theory Lesson No. 12.

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

Leave one and a half inch margin (for correction purposes), and write only on one side of the paper.

246. What is the difference between the ampere and the coulomb?

247. Explain the difference between the spark frequency of the closed oscillation circuit and the oscillation frequency.

248. What is meant by resonance?

249. Name the measuring instruments employed in the key circuit.

250. Name the different devices employed in conjunction with the wavemeter.

251. For what purposes may the wavemeter be employed?

252. Why is it necessary to measure the natural wave length of the aerial circuit when tuning the transmitter to a given wave length?

253. Define a pure wave.

254. Why does the law require that the logarithmic decrement shall not exceed .2?

255. Define a resonance curve.

256. Describe the instruments necessary for the plotting of a resonance curve.

257. How would you determine the percentage of coupling?

258. How would you calibrate a receiving set?

259. Describe the measurement of the wave length of a distant transmitting station.

260. What is the purpose of the hot wire ammeter in the aerial circuit?

261. When would you employ a buzzer attachment on a wavemeter?

262. What three wave lengths are employed by ship radio sets?

263. Of what value is a resonance curve?

264. How would you determine the purity of a radiated wave?

265. Give a diagram of a wavemeter with a detector and telephone attached.

Correspondence Course

NATIONAL RADIO INSTITUTE
1345 Penna. Ave., N.W. Washington, D. C.

Answers to Instruction Book No. 12

246. An ampere is the rate of flow of electric current, while the coulomb is a quanity which depends on the current and the time in seconds which the current is flowing.
247. The spark frequency is the number of sets of sparks crossing the gap per second, and is equal to the number of discharges of the condenser per second, while the oscillation frequency is the number of oscillations or cycles of the current takes place per second in the closed oscillatory circuit.
248. Resonance refers to two circuits in which the oscillation frequency is the same or the wave lengths emitted by each are the same. This condition is true when the product of the capacity times inductance is the same for both circuits.
249. The instruments in the key circuit are the voltmeter, ammeter, wattmeter and frequency meter.
250. A fixed inductance, a variable condenser, detector and phones or a small glow lamp. Sometimes a key and an induction.
251. For tuning a transmitter, for calibrating a receiver, use as a decrementer in conjunction with a wattmeter, or to use as a receiver.
252. So one may know the shortest wave length the Aerial will transmit in order that the operator will not produce waves too short for resonance with the transmitting aerials.
253. A pure wave is where two or more waves are emitted, the energy in any one of the lesser waves does not exceed 10% of that in the greatest wave.
254. To prevent a broad interfering wave which would endure for a short time only and then would die out very suddenly. It would be difficult to tune.
255. A resonance curve is a line showing the relation of energy being radiated and the value of wave lenghts for a given range.
256. A wavemeter with a low reading wattmeter is loosely coupled to the transmitter for obtaining the readings for a resonance curve.
257. Where two circuits, open and closed oscillatory,have been tuned or adjusted to the same wave length (called the Basic wave length) and these two circuits are coupled together, a wave with two wave lengths emitted or radiated, the coupling in per cent is determined by dividing the difference between the two waves emitted by the value of the basic wave length and multiplying this result by 100.
258. A receiving set may be calibrated by the use of a wave meter with a buzzer, battery and key or switch attached and in the following manner: Set the pointer of your wavemeter condenser to a value for a short wave length (say, 200 meters), then place the wavemeter coil in inductive relation with the receiving aerial circuit and close the key. While these feeble waves of 200 meters are being radiated by the wavemeter adjust the pointers of the primary inductance and capacity, secondary inductance and capacity until you hear the loudest signals in the phones. Now the receiver is in tune with the 200 meter wave. The four tuning devices mentioned about should each bear a mark under the pointer setting and the number 200 be added. Next, set the wavemeter condenser to emit another wave length (say, 250 meters); repeat the operation and do the marking; continue in this manner until you have covered the range of the receiver.

-over-

259. This could be done by tuning in the distant station wave with a calibrated receiver or by means of a wavemeter with phone, where the wavemeter coil is inductively coupled to the aerial circuit, or one could tune the distant station to resonance with any receiver and determine the receiver's setting by means of using a wavemeter as a transmitter and tuning the transmitter to give loudest signals in the receiver already set.

260. The hot-wire ammeter may be used to measure the amount of current being radiated by the aerial or it may serve to determine resonance of the open and closed oscillatory circuits.

261. A buzzer would be added to a wavemeter when it was to be employed as a transmitter of known wave lengths.

262. 300, 450 and 600 meters are wave lengths used by ships.

263. The resonance curve shows whether the energy of a wave is being radiated on one or more wave lengths, and indicates the sharpness of the radiated wave.

264. The purity of a wave would be determined by the amouut of energy radiated in the weaker waves as compared in per cent with the energy in the greatest wave.

265. See wavemeter in Figure 121.

Copyrighed 1921 by J. E. Smith, Washington, D. C.

100%. George J. Gudejoh
West Salem O

Student No. 13777 Lesson No. 12

246 The difference between ampere and Coulomb is that, ampere is a term used to denote the current strength of electricity or the cross sectional area of the current while Coulo is the unit of quantity and denotes that quantity of electricity flowing past a certain point in a circuit when one ampere flows for one second.

247 The differenke between the spark frequency of the closed oscillation circuit and the oscillation frequency is the frequency of a current in an oscillatory circuit does not need to be the actual number oscillations taking place per second, for the number of oscillations actually taking place per second is equal to the product of the number of oscillations per train and the number of trains. while Oscillation frequency is the rate at which the oscillations occour in the circuit

248 Resonance is defined as, when resonance is obtained between two electrical circuits both circuits have the same frequency of oscillations.

George J. Gudenich
Route 1 Salem, Ohio

Student No. 18794 Lesson No. 12

249 Voltmeter, Ammeter, frequency meter and wattmeter.

250 A variable condenser, a fixed inductance, crystal detector in series with telephones, a small lamp in series with the inductance and condenser. A Buzzer, battery, key, and a small transformer and a hot wire wattmeter.

251 To tune transmitting sets to a certain wave lengths
To measure the wavelength of a distant station
To plot a Resonance curve.
To calibrate a receiving set so that it may be preadjusted to any given wave length
To measure the Logarithmic decrement of the Train of oscillations.
To measure the percentage of coupling between the open and closed circuits of the transmitter.

252 The natural wavelength of an aerial must be found first before tuning the transmitter to a certain wave length because otherwise the aerial may be found to be too long to tune it to that certain wavelength

George J. Guderjahn
West Salem

Student No. 13794 Lesson No. 12

253 A pure wave is defined as that radiated by a transmitter when the energy in any of the lesser waves does not exceed 10% of that in the greater wave

254 The reason that the law requires that the logarithmic decrement shall not exceed .2 is. if the decrement exceeded this amount the wave would be so broad that it would interfere with other stations and communication would be impossible by wireless except the wave lengths of the stations were greatly different.

255 A resonance curve may be defined as a graphic method of showing the relation between the energy radiated and a given range of wave lengths.

256 The instruments necessary to plot a resonance curve are a wave meter with a watt meter attachment this is placed at a distance from the set where the closed circuit will not effect the wave meter, and while the key is depressed the pointer of the wave meter is moved slowly over the scale, as the resonance position is

approached by the pointer, the pointer on the wattmeter will increase, as the pointer of the wave meter is moved over the scale the readings of the wattmeter for each wave length is noted, and the values are then plotted on a sheet of cross sectional paper, a line is then drawn through the plotted points and this is called a resonance curve.

257 The percentage of coupling is determined by the following formula

K = % of coupling
$(WL)^1$ = longer wave
$(WL)^2$ = shorter wave
(WL) = basic wave length

$$\left\{ K = \frac{(WL)1 - (WL)2}{WL} \times 100 \right\}$$

when the two circuits of the transmitter are tuned to one wave length, two waves will be radiated one above and one below the basic wave length by determining these wave lengths by the aid of the wave meter and substituting these known wave lengths in the above formula. the percentage of coupling may be found.

George J. [illegible] jr
West [illegible] Ohio

Student No. 19494 Lesson No. 12

258 To calibrate a receiving set I would place a wavemeter with a buzzer, battery and key in inductive relation to the aerial circuit of the receiver. now when the key is depressed waves of lengths equal to that of the inductance and the wave meters capacity will be radiated. the wave meter is set for a certain wave length and when the signals come in the loudest in the receivers all the instruments in the receiving circuit that need adjusting are fixed at that certain place for that certain wave length. when this is done the wave length of the wavemeter is again set to another wave length and that marked on the instruments this is continued until all the wave lengths are marked on the receiving instruments.

259 To find the wave length of a distant station the receiving instruments are adjusted to resonance with the sending station, now a wavemeter with buzzer and battery is placed in inductive relation to the aerial circuit. with the buzzer

George J. [illegible]
West Salem, [illegible]

Student No. 13997 Lesson no. 12

Joing the wavemeter pointer is varied [illegible] the buzzer signals are received the loudest at the same adjustment of the receiver as for the distant station when this occours all the instruments are in resonance with each other and the wave length can be read directly from the wavemeter.

260 The purpose of the hot wire ammeter is to indicate the number of amperes of current flowing in the aerial circuit and also to enable the closed and aerial circuits to be placed in resonance.

261 To measure the wavelength of a distant station also to calibrate a receiving set so that it may be preadjusted to any given wave length.

262 300, 450 and 600 meters

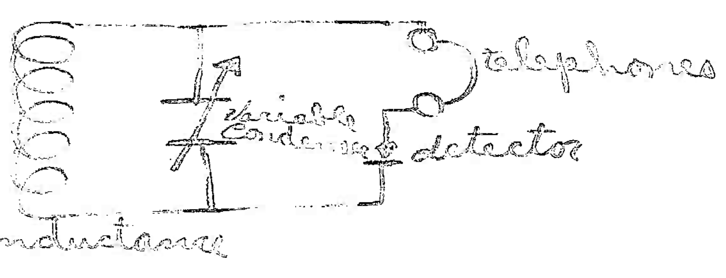
263 The value of a resonance curve is that it indicates at what wave lengths the energy of the transmitter is radiated sharply and at what place the instruments radiate over a wide range of wavelengths the resonance curve is also used to find the logarithmic decrement of the transmitter.

George J. [illegible]
West [illegible]

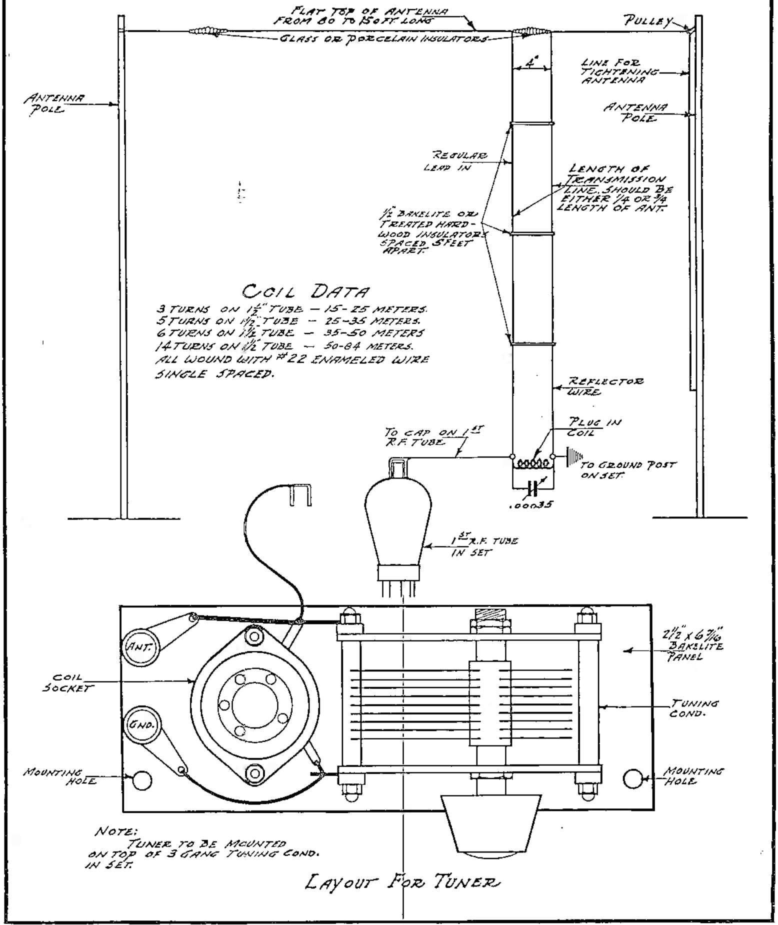
Student No. 13994 Lesson No. 12

264 I would determine the purity of my wave by placing the wavemeter and wattmeter at some distance from the transmitting set so that the radiated wave effects it only. The key is now pressed and the pointer of the wave meter moved down the scale and note the reading of the wattmeter. There are always two or more places on the wave meter where the wattmeter gives a high reading, the reading of the wattmeter and wave lengths are noted and taken down. to get a wave length of a certain length and if the wave lengths ~~are~~ radiated are above and below this length the oscillation transformer must be moved until the wave meter shows the greatest on the certain wave length wanted, and also that the wattmeter at any other wave length is less than 10% of that at the certain wave length that I wanted.

265



S.W. TRANSMISSION TYPE ANTENNA



COIL DATA

3 TURNS ON 1 1/2" TUBE — 15-25 METERS.
5 TURNS ON 1 1/2" TUBE — 25-35 METERS.
6 TURNS ON 1 1/2" TUBE — 35-50 METERS
14 TURNS ON 1 1/2" TUBE — 50-84 METERS.
ALL WOUND WITH #22 ENAMELED WIRE SINGLE SPACED.

NOTE:
TUNER TO BE MOUNTED ON TOP OF 3 GANG TUNING COND. IN SET.

LAYOUT FOR TUNER

E. H. SCOTT RADIO LABORATORIES, INC.
(FORMERLY SCOTT TRANSFORMER CO.)
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CHICAGO, ILL. U. S. A.

SCOTT SHORT WAVE TECHNICAL BULLETIN #3

SPECIAL ANTENNAE FOR SHORT WAVE RECEPTION

During the last few months we have been doing considerable experimenting here at the laboratory with all kinds of antennae and particularly with those for use on short wave reception, and have made some very interesting discoveries.

I would suggest that if you desire to secure maximum results on short waves that you have two antennae, one of about 60 feet including the lead-in, for reception on the broadcast band, and another one as long as possible or up to 150 feet, for use on the short waves.

The direction the antenna runs in, also makes quite a lot of difference in the efficiency you get on your reception of distant stations. Here in America on the broadcast band the best results are generally secured with an antenna running East and West, for most of the better stations are found East or West.

For short wave reception, however, it will be found that an antenna running in a North-Easterly direction will give the best all around results, at least from a location such as Chicago. We are largely interested in FOREIGN reception on the short waves and that means stations located in Europe or in the East or Australia. You should secure a map and from your particular location find out what direction Europe points to. You will find that from the United States it generally points in a North-Easterly direction.

We started experimenting with a fairly long antenna and tuned it with a .00035 condenser and a plug-in coil that would resonate the antenna on the particular wave length we wished to tune on. It requires a set of about four coils to cover the band from 15 up to 50 meters. You will find there is very little worth listening to above 50 meters on the short wave band.

While the results from a regular straight "L" shaped antenna, tuned with a coil and condenser is a very decided improvement over one not tuned, we started experimenting with various lengths of antennae with a tuned transmission line running from the antenna in place of the usual lead-in. This system we found made a tremendous difference to the volume of a weak station.

It is a well known fact that the ordinary type of lead-in not only changes the natural period or wave length of the antenna but reradiates some of the energy as well, and a tuned transmission line running from the receiver to the antenna will greatly reduce this loss of signal strength due to reradiation.

The circuit and lay-out of the transmission type of antenna is shown in the sketch and is not hard to make. It can be just as long as you like, provided you have the length of the transmission line coming in correct proportion to the flat top.

Following are the lengths of antenna you can use measured along the flat top only, with proper length of transmission line coming from it.

For antenna 80 ft. long, transmission line should be 20 or 60 ft.
" " 100 " " " " " " 25 " 70 ".
" " 120 " " " " " " 30 " 90 ".
" " 130 " " " " " " 32 " 96 ".
" " 140 " " " " " " 35 "105 ".
" " 150 " " " " " " 37 "111 ".

The transmission line should be either one-quarter or three-quarters the length of the flat antenna, never half or equal length.

The sketch clearly shows the details of the antenna. First picture the regular "L" type antenna with its lead-in. The transmission line antenna is exactly the same as this, but with the addition of another wire running parallel to the lead-in and spaced with insulators 4" apart from it. At the top of the transmission line you have an insulator. Notice there is no connection between this other wire and the antenna or its lead-in until the two are connected thru the tuning condenser and coil.

The transmission line is tuned by a variable condenser and coil as shown in the diagram. You can build this tuner yourself if you have a .00035 variable condenser, a tube socket and some tube bases. If you do not wish to build it, we can supply the whole outfit made up, antenna, transmission line and tuner all ready to erect at a net price of $7.50 complete. The diagram shows how it should be connected to the set.

We build the tuner on a small piece of bakelite with the condenser and coil socket mounted. It can be screwed on top of the cover over the three gang condenser. You solder a grid cap to the wire coming out of the side of the coil that does not run to ground and this cap is connected to the top of the grid cap on the 1st R.F. tube in place of the red wire that now runs from the choke coil on the side of the condenser. If you like you can remove this coil and red wire altogether.

It is better to run the two leads from the transmission line into the set with rubber covered wire so that they will not short. To use the outfit you simply plug-in a coil that covers the wave length of the station you wish to tune for. You can generally get a signal of some sort and the variable condenser should be rotated until you find a spot where the signal increases in volume considerably. If you find that you cannot increase the signal strength, no matter whether the plates or the condensers are all the way in or out, then you do not have the right size of coils plugged in. Try another one with more or less turns on it until you find one that has a distinct tuning effect on the signal.

I believe that with these instructions no one will have any difficulty in erecting one of these antenna, but should there be anything you do not understand, I should be glad to have you write me. I should also be very glad to receive reports from all Scott All Wave owners who erect the antenna, giving me an idea of the results they are getting from it.

E. H. SCOTT RADIO LABORATORIES, INC.

E H Scott

President.

READ THESE INSTRUCTIONS CAREFULLY - THEY CONTAIN IMPORTANT AND SIMPLE INSTRUCTIONS SHOWING HOW TO TUNE FOREIGN STATIONS ALL OVER THE WORLD ON THE SHORT WAVES WITH THE SCOTT ALLWAVE SUPERHETRODYNE

I have received many letters asking for more detailed information on the reception of short wave stations. Many owners of Scott All Wave Receivers have never tuned on the short waves before, and for that reason do not realize that tuning on them is very different to tuning on the broadcast band.

BEST RESULTS ON SHORT WAVES DURING DAYLIGHT

I occasionally receive letters from owners who, on trying out their receiver for the first time, report poor results on the short waves. On investigating I have found that they did most of their tuning at night. Apparently a very large number of owners do not know that reception on the very short waves, that is, from 15 to 30 meters is best during broad daylight and that you can often listen to stations four and five thousand miles away at noon, even in the middle of summer, with as much volume as you can get from a local station that is transmitting on the broadcast band.

To illustrate and prove the point that reception on short wave lengths varies at different times during the day and night, take just one American station, say W3XAL at Boundbrook, New Jersey. You will find that it is listed under seven different wave lengths - 187.3, 49.15, 31.35, 25.6, 19.82, 16.87 and 13.35 meters. Now why should one broadcasting station on the short waves be licensed to operate on seven different lengths, when they only allow a station on the broadcast band to operate on one wave length?

WHY TUNING ON THE SHORT WAVES BELOW 30 METERS SHOULD BE DONE DURING DAYLIGHT

As soon as the sun begins to peep over the horizon stations on wave lengths below 30 meters start coming in, getting stronger as the sun gets higher in the sky and soon you may be listening to a station 5000 miles away. However, after you have had a little experience tuning on the short waves you will notice that stations above 30 meters which come in with good volume during the hours of darkness begin to fade very rapidly as daylight appears.

A pretty good rule to follow is to tune for stations between 15 and 30 meters between sunrise and sunset. Tune for stations between 30 and 40 meters between late afternoon and early evening. During the evening there is very little use of trying to tune any foreign short wave stations below 30 meters, except those on code.

HOW TO TUNE IN EUROPEAN STATIONS

The best foreign short wave stations lie between 20 and 50 meters, with possibly the pick of them between 25 and 30 meters. Three of the best European stations are 12RO, Rome, Italy on 25.4 meters; G5SW at Chelmsford, England at 25.53 meters and FYA Pontoise, France at 25.6 meters. All of these stations can be heard quite regularly in U.S.A. between three and six o'clock in the afternoon during Spring and Summer. G5SW, However, is always off the air on Saurday and Sunday afternoons but occasionally you can hear 12R0 at Rome and FYA at Pontoise both Saturday and Sunday afternoons.

HERE'S THE WAY TO GET ROME-ITALY

To locate station 12RO first find W8XK at Pittsburgh, Pennsylvania at 25.25 meters. After you have located this station, then move your dials up just one or two degrees and you should find 12RO at Rome. You will easily recognize it by the class of music it transmits, generally Grand Opera or Symphony Concerts, and by the fact that all announcements are made by a lady speaking in Italian. They announce quite frequently and you will be able to catch the words "Roma Napoli".

HOW TO GET ENGLAND

After you have listened to the Italian station for a while, move your dials up about one degree and you should find G5SW at Chelmsford, England. In the early part of the afternoon you will find them broadcasting playlets or educational talks but around five o'clock they generally put on a dance orchestra from one of the leading London Hotels and at six o'clock they sign off with Big Ben in the House of Parliament chiming the hour of Midnight. One of the things difficult to understand at first is why you can listen to Big Ben strike Midnight when it is only 6:00 P.M. in Chicago. Many listeners will now see why they failed to hear this station when they tuned for it in the evening. Almost all stations broadcast at times to conform with the time in their own part of the world.

HOW TO GET FRANCE

Now just about one degree on the dial above G5SW you should be able to find FYA at Pontoise, France. This station broadcasts talks in French principally, but they generally sign off with the "Marseillese", and very often they have some music also. Recently Maurice Chevalier's brother was heard singing from this station.

European stations, with perhaps the exception of PCJ in Holland which broadcasts European programs for American and Australian listeners and others, close down generally at 6:00 P.M. while South American stations are just beginning to come in at 6:00 P.M. and are heard from then on until Midnight.

Stations in Siam, Japan, Australia and the Eastern part of the world are just beginning to come in in America when we are getting up for our breakfast, so that if you wish to hear stations in this part of the world you must listen for them in the early hours of the morning.

HOW TO GET THE SOUTH AMERICAN STATIONS

As evening comes on in U.S.A. you can begin to tune for the South American stations. Start about 7:30 P.M. and first locate station W2XE on 49.02 meters. When you have found it drop just one or two points and search for HRB at Tegucigalpa, Honduras, or HKC at Bogota, Colombia. These two stations come in vory well and are quite interesting to liston to.

On Thursday evening tune for El Prado at Riobamba, Ecuador which puts on a program that is very good from 9:00 to 11:00 P.M. on 39.8 meters.

HOW TO GET THE POLICE CALLS

During the evening you can also liston to Police Calls all over the country. These will be found around about 70 on the 84-184 meter coils. You will also find it interesting to listen in during the evening on the amateurs talking on phones. These will be found on the dial between 80 and 100 on the 38-84 meter coils.

HOW TO TUNE IN AUSTRALIA

During the early hours of the morning you can tune in two of the most interesting stations of all. These are VK2ME at Sydney, Australia and VK3ME at Melbourne, Australia. VK2ME is on the air every Sunday morning between 5:30 and 7:30 A.M. and VK3ME is on the air every Wednesday and Saturday morning between 4:30 and 5:30 A.M. Central Standard Time.

To locate VK2ME at Sydney, start Saturday evening by plugging in your 27-38 meter coils, being sure to connect the red wires to the caps of the 1st R.F. and 1st detector tubes and your antenna to the S.W. binding post located at the side of the large condenser cover. Now tune around 35 on the dials and you should very quickly locate W3XAF at Schenectady, New York. When you find it, switch off your set and leave your dials set and get up in the morning at a time that corresponds to between 5:30 and 7:30 A.M. Central Standard Time and you will find by moving your dials down just about a degree, Sydney, Australia will come rolling in with the volume of a local.

After you have listened to VK2ME then try for VK3ME at Melbourne any Wednesday or Saturday morning. Get up at a time which corresponds to between 4:30 and 5:30 A.M. Central Standard Time, then move your dials just about a degree above W2XAF and you should locate VK3ME.

I started checking the transmission from those stations last June, and since that date have made a complete log of every regular program they have transmitted and have also made from two to twelve aluminum recordings of each program. Half of these I have sent to VK3ME and VK2ME and the other half of the records I have kept here in the laboratory for our record of the transmission. This will give you an idea of the volume with which these stations come in.

WHY YOU SHOULD FIRST LOG U.S. SHORT WAVE STATIONS

The first thing a beginner at short wave tuning should do is log as many U.S. and Canadian short wave stations as possible and mark down their dial settings. These stations will then act as guides in locating foreign stations.

In trying to locate short wave stations, rotate the dials very slowly, and by slowly I mean just that. Do not twirl the dials rapidly and expect stations to come rolling in, for you will be disappointed if you do. Do not turn the volume control on too far, for it is just as bad as not having it turned on far enough.

Remember that short wave stations have a habit of fading in and out more than broadcast stations. Do not think there is something wrong with your set if a station comes in with tremendous volume one minute then slowly fades out until it is very weak, then begins to come back again. This is a natural phenomenon of short wave reception. However, an unsteady or surging line current may cause excessive fading.

WHY EUROPEAN STATIONS ARE BETTER DURING

SPRING AND SUMMER

Also remember that for us here in America, European stations come in best during the Spring and Summer months. You will probably notice that it is hard at this time of the year to pick up the European stations and perhaps you will be puzzled over such a state of affairs. Some have written me about it, thinking that this failure to receive Europe was due to some defect in their receiver, but here is a very easy way for you to prove to yourself that this is not so. You will admit that if you can tune in a station 10,000 miles away, it is not the fault of the receiver if it does not pick up stations which are only about 4000 miles distant. To prove the ability of your Scott All Wave on distance, tune in VK2ME at Sydney, any Sunday morning between 5:30 and 7:30 A.M. Central Standard Time. Now Sydney is about 10,000 miles from Chicago and if you can tune in a station at that distance, it proves the receiver's ability to tune in stations a shorter distance away.

I have never heard a satisfactory explanation as to why the European stations are so poor at this time of the year, but we do know that it is a fact. But reception from Europe is marvelous the latter part of the Winter, all thru the Spring and during the Summer. On a number of occasions last Spring, I had 12RO in Rome so clearly that it was actually possible to hear the members of the orchestra tuning their instruments before the Symphony Concert began, and also the hum of the conversation in the first few rows of the audience.

SOUTH AMERICAN STATIONS BEST DURING WINTER MONTHS

The South American stations are heard best during the Winter months. I have been listening in to Australian stations for nearly six months now and they are still coming in good, so it is possible that we will get good reception from Australia all the year around.

FOREIGN STATIONS OFTEN HARD TO IDENTIFY

Identifying short wave broadcast stations is often difficult due to the fact that many different languages may be heard. Reception is world wide and it is quite natural to expect stations to broadcast and announce in their native languages. To identify every station heard, a listener must first become quite familiar with short wave tuning.

The first requirement is an accurate list of short wave stations, free from false and discontinued stations. The list published by the International Short Wave Club, P. O. Box 713, Klondyke, Ohio, is excellent. Then by simple comparison of the wave length and the scheduled stations in the list and the time of reception a great many stations may be tuned in.

HOW TO IDENTIFY FOREIGN STATIONS

The handicap of different languages presents a problem that makes it difficult to tell what station you are listening to. Five languages are in most common use, namely, English, German, French, Spanish and Dutch. The opening announcement of German stations is generally "Actung, Actung" meaning "Attention". Other easily learned words are "Kurswellendsender" (short wave station) and "Rundfunksender" (broadcaster). The French stations almost always announce "Hilo, Hilo, Ici - -" which means "Hello, Hello, this is - -". Other words are "Radiotelephonique" (radio telephone stations), and "Emmission" (broadcast). Spanish stations are accustomed to opening an announcement as "LaEstacion" (the station) and common words, easily understood, are "Transmisores" (transmitter), "Telefonia" (Telephone"), "Senor and Senorita" (Mr. and Miss). Dutch stations are often heard saying "Dames and Herrn" (ladies and gentlemen).

HERE ARE IDENTIFYING CALLS OF SOME OF THE BEST FOREIGN STATIONS

Telephone stations are often identified by the cities or stations which they call. For example, Holland stations will call "Hello Bandoeng," when working one of the Javenese stations. FTN in France calls LSG Buenos Aires " H ilo, Hilo, Buenos Aires ici Paree." Other identifications are, HRB - Cuckoo call three times before announcing. F31CD - Striking of gong and calls, "Hello, this is Saigon." PCJ - Ticking of clock between selections. Also uses English. Rabat - 60 beats on a mentronome per minute. LSG - calls "Hilo, Paree, ici Monte Grande." KA1XR - Announces "Hello, Kootwijk hier ist Bandoenig." Zeesen - Announces "Here ist der Kurzwellensender von Koenigswurtsterhausen." KIO announces "Coco-Head calling." 12RO - Lady announcer says "Raddio Roma Napoli." El Prado - Announces "Estacion El Prado, Riobamba, Ecuador." HSIPJ - Six notes on a piano or musical instrument. American short wave stations may be identified by the call letters of the broadcast stations they relay.

GOOD TUBES ARE NECESSARY

Remember that to get maximum efficiency on the short waves you must have really good tubes. Just one poor tube will ruin the operation of the whole set. It is a good idea to keep a couple of spare 227's, 224's and 245's on hand so that you can try these spare tubes in your set as substitutes to see if a weak tube is causing trouble or loss of sensitivity. Instructions for doing this will be found in the regular Service Manual.

If you are using poor tubes you will not get maximum efficiency. We have recently made a series of tests on tubes and know that many of the widely advertised tubes, will not stand up and will not give good results in the Scott All Wave. Therefore, if you are using tubes that were not supplied with the receiver do not become discouraged if the results are not all you expected. The tubes we supply are specially tested and guaranteed for six months.

TROUBLE SHOOTING TIPS

1- When using the receiver on the short waves, make sure that the plug-in coils are making good contact and that the coils with the center pins throw the small switches underneath the sub-panel to the right and that the points on these switches are making good contact. I would advise you to clean off the contact points of the switches with a piece of very fine sandpaper and also clean thr prongs of the coils now and again.

2- It may be that the small balancing condensers for the short wave tuning condensers have become shorted in some way. These balancing condensers are located one next to the drum dial in the small condenser can, and one all the way to the right in the large condenser can. Loosen these just about one turn and see if it makes any difference in reception.

3- Perhaps the short wave binding post mounted on the large condenser can has become shorted to the case. In order to check this unsolder the lug which grounds one side of the choke coil to the case. After you have it unsoldered and pushed away so it is not making connection to the choke coil, check with a continuity meter from binding post to ground. You should not get a reading. If you do, the binding post is grounding. In order to correct, loosen the binding post and change its position slightly until it disappears. When the reading disappears retighten the binding post and re-solder the lug to the choke coil.

4- Maybe your aerial is defective in some way, or you are using one that is too long. An aerial of about 50 to 60 feet in length including the lead-in for the broadcast band is about right for the average locality; although in some localities this may be long, or it may be that you could use a longer one. It would pay you to experiment somewhat with the length of the aerial.

5- When using the short waves, if your location is free from electrical disturbances you will be able to use a longer aerial, one of about 100 feet in length will give you good results. But if you have a noisey location the longer aerial you use the more noise you will pick up. Also try running your aerial in a different direction. This sometimes helps to a very great extent. The new transmission line antennae should be used if you want maximum results.

SOME GOOD TIPS FOR SHORT WAVE TUNERS

Don't expect short wave stations to tune broadly. Most distant short wave stations tune very sharp.

Don't expect to hear stations all over the world the first day you tune the set. It requires some experience in tuning to get the best results.

Don't get discouraged if reception is poor one day. It might be fine the next.

Don'ttwirl the dials rapidly and expect to tune in short wave stations. Turn the dials slowly and keep the dial readings fairly close together.

Don't tune for stations when they are not on the air. The Scott Short Wave log will give you a good idea of the stations that are on the air at a certain time.

Don't tune above 30 meters for distant stations in daylight.

Don't tune below 25 meters for distant stations after dark.

Don't expect many distant foreign stations above 50 meters.

Don't think that the best reception is always at night. Short waves offer you the opportunity of tuning in stations around the world twenty-four hours every day in the week.

You will notice that many short wave stations can be heard two places on the dial. This is due to the interlocking circuit of the Scott All Wave, so log only the readings at which the station comes in best.

When tuning on the short waves you should keep the dial readings fairly close together. You will find that it is possible sometimes to tune in a station with a considerable difference in the reading between the two dials. For example you may get a station in at 35 on your oscillator dial and only 30 on the R.F. dial, and apparently these are the correct readings.

However, just move the R.F. or right hand dial to read the same as the oscillator dial, then very slightly retune the oscillator dial when you will find the station will come right in. In this way you will be able to tune in stations with the same readings on both dials.

You will also find that the dial reading will change slightly until the tubes are thoroughly warmed up. For example you may be listening to a foreign station then it may start to fade but if the set has just been turned on carefully retune it and you will find you can bring the signal back again. When the tubes have become thoroughly heated up, say after you have operated the set for 10 or 15 minutes, then the station will stay exactly where it is tuned.

On the 84-184 meter band you will notice that stations operating above 200 meters can be heard, oftentimes, two or more together. At first it would appear to be the fault of the set, but what you hear is merely the 1st and 2nd harmonics of the broadcast station. Most stations on the broadcast band now have harmonic suppressors to eliminate the 3rd, 4th and 5th harmonics which you would otherwise hear on all S.W. coils. However, these suppressors do not cut out the 1st and 2nd harmonics and they fall in the 84-184 meter band. By a glance at the S.W. log you will see that there are only three things you can pick up on the 84-184 meter band, namely, (1) Amateurs (2) Airports (3) Police Calls. In other words, this is all voice not music. If you hear any music on this band, just pass it by because you will know it is the 1st and 2nd harmonics from a station operating above 200 meters.

The bulletins that are sent you every month or six weeks contain information that is of practical value to all Scott All Wave owners and should be read carefully.

If you are really interested in short wave reception, I would most strongly advise that you join the International Short Wave Club of Klondyke, Ohio. It will cost you just $1.00 per year and for that you will receive a monthly magazine giving interesting information about short wave stations all over the world and the best time to tune them in. Send your $1.00 to Mr. J. A. Green President of the Club, Box 713, at Klondyke, Ohio. If you wish you may tell him that I recommended your joining the Club.

Remember I am ready at all times to assist you, and shall be glad to hear from you if there is anything you do not understand.

Cordially yours,

E. H. SCOTT RADIO LABORATORIES, INC.

E H Scott
President

When writing me about short wave reception, please let me know whether you have tried for each of the stations mentioned.

98%

George J. Gudenjohn
11 - St Salem, O

Student No. [illegible] Lesson no. 14

286 300 meters and 600 meters.

287 PRB means that the ship wishes to communicate by the International Signal Code

288 The United States and International requirements for auxillary sets is An auxillary power supply independent of the ship main power plant must be provided whitch will enable the sending set to send messages over a distance of 100 miles day or night for a period of at least four hours.

289 For divulging or publishing any message which the operator picks up the penalty is on conviction a fine of not more than $250.00 fine or not more than 3 months imprisonment or both.

For sending false signals a fine may be given on conviction of not more than $2500.00 or imprisonment for not more than 5 months or both.

For interfering with other stations a fine may be given on conviction of not more than $500.00 or 1 year imprisonment or both.

By violating any of the Radio laws as set down by the government the owner of the station may be fined not more than $100,00

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21 East Salem Ct.

Student No. 13744 Lesson No. 14

290 The exchange of superfluous signals and words is prohibited to all licensed stations.

291	QRA	what station is that
	QRB	" " " is your distance
	QRC	" " " is your true bearing
	QRD	where are you bound for
	QRF	" " " " " " from
	QRG	what line do you belong to
	QRH	what is your wave length
	QRJ	How many words have you to send
	QRK	How do you receive me
	QRL	are you receiving badly.
	QRM	are you being interfered with
	QRX	shall I stand by
	QRY	when will be my turn
	QSA	are my signals strong
	QSM	what is your true course
	QSN	are you in communication with land
	QST	General call to all stations
	QSU	will call when finished
	QSW	increase your spark frequency
	QSY	Shall I send on a wave length of ____ meters.

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West Salem, P

Student No. 13774 Lesson No 14

292 300 and 600 meters or above 1600 x - 2

293 No ship station within 15 miles of a navy or military station shall use a transformer input exceeding 1 K.W. nor with 5 miles of such a station a transformer input exceeding ½ K.W.

294 I would give the preliminary call -·-·- Then the call letters of the station called, would be transmitted three times then the word "from" (de) and following my own call transmitted three times. as

—·—·— XYZ. XYZ. XYZ. (de) ABC. ABC ABC.

295 Radio stations either coastal or shipboard which are engaged in the transmission of long Radiograms shall suspend work at the end of each period of 15 minutes and listen in on 600 meters wave length during a period of 3 minutes before again resuming their transmitting

296 The U.S. law in regard to secrecy of messages is The contents of messages must not be told only to the person or persons to whom the message is sent or to their authorized agents. or to another station employed

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West Salem, O.

to relay such messages to its destination unless legally required to do so by the court or other competent authority.

Any person found guilty of this may be punished by a fine of not more than $250.00 or imprisonment for a period of not more than 3 months, or both.

297: Worn bearings, the commutator becoming worn, brushes out of neutral, collector rings, The winding either shorted or open, the starter box burning out, [illegible] the radio room is likely to be flooded with moisture.

298: When generator refuses to generate it may be due to one of these causes.

The field rheostat might have burnt out and to locate the burnt out section a battery and telephone is used, the terminals of the testing circuit are shunted across successive contacts until an "open" is indicated by no sound in the head telephones.

To test the generator for open circuit a electric light is connected in series with one lead from a 110 volt source of current and the two remaining terminals are connected to the coil terminals, if the light doesn't light an open circuit is present. This test may

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be either applied to the armiture windings or to the field windings of the generator.

If breakes occour in the generator circuits all terminals and wires must be gone over carefully to find the trouble.

299 The trouble may be due to the pulling of the starting box lever over too quickly and thus not allowing the motor to have sufficient time to develope a counter E.M.F. and when a short circuit occours in the motor armature or in the shunt field windings the same results will happen.

300 A salt water rheostat is made of a metallic bucket, a stick is placed across the top, the bucket is filled with salt water, one terminal of the 110 Volt source is connected to the bucket and the other to the motor, the remaining wire from the motor is connected to a ½ inch rod whic fits in a hole in the board, as the rod is pushed down in the bucket the resistance to the current gradually decreases until the rod touches the bottom, the motor is now going full speed and the salt water rheostat may be short circuited by a piece of wire.

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Since a 16 candlepower light takes ½ ampere, (if a carbon lamp is used} on 110 volts and when two such lamps are in parallel 1 ampere will flow in the circuit, therefore 60 lamps in parallel will carry 30 amperes, thus by turning on more and more lights the current in the motor will increase, until the motor is running at full speed, the lamps are then short circuited by a piece of wire. thus a bank of lamps may be used to start a motor.

301 If an open occours in the transformer primary the voltmeter will indicate the voltage and the ammeter will cease to be deflected since it is in series with the primary

When the ammeter shows an abnormal increase in deflection a short is indicated in the primary

If the voltmeter should burn out the generator windings should be tested by a test light for shorts or other trouble.

302 By flash test is meant the testing of the transformer secondary, the spark gap is adjusted, and if when the key is pressed a good spark is obtained the secondary is all right

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but if no spark jumps the gap an open or short is indicated in the secondary windings.

303 When all the condenser units are punctured to continue communication a direct aerial connection must be used. brief

304 In order that the set will send on the normal wave length when one unit is punctured inductance must be added at the primary of the oscillation transformer until the hot wire ammeter shows a maximum deflection or the same as it indicated before the unit was punctured.

305 If no signals are heard when the aerial and ground are connected to the receiver the buzzer is put in operation and the point on the crystal are adjusted to maximum loudness, if then none are received all connections, all wires, all switches lead in and the aerial should be carefully inspected signals should then be heard unless nobody within the range of your set is sending.

306 The motor generator bearings should be gone over frequently and kept well oiled The radio set should be kept clean and dry

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West Salem, O.

Student No. 13794 Lesson No. 14

No dust should be allowed to settle on the set. The set should be gone over frequently to tighten all loose connections and nuts.

The aerial and ground should be inspected regularly. The aerial should be kept fairly tight at all times

Test aerial frequently for leakage.

Keep storage cells well charged and solution ½ inch above plates at all times

Keep brass or copper parts polished at all times

Key contacts should be kept smooth and even at all times.

Care should be exercised in taking any of the machinery apart for fixing that it be properly assembled again or serious trouble may be caused.

Commutator, collector rings and brushes should be kept clean and free from grease.

307 Sulphation of a cell is caused by letting it stand in a discharged condition, undercharging and overdischarging.

308 The electric current in passing through the cell starts to decompose the water, that is the water is turned into hydrogen and

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West Salem, Ohio

Student No. 13794 Lesson No. 14

oxygen, it is this decomposing of the water that causes the cells to bubble.

307 The charging current is reduced and the charging terminals placed on the cell in which the voltage has dropped. the current is turned on and the cell allowed to charge for a time.

308 A solution of pure sulphuric acid and pure water is mixed in this proportion 1 part acid to 4. parts water. this solution is added to the cell with the low Specific Gravity reading, some of the old solution being drawn out to make room for the new, when the cell is charged the specific gravity will be about the same as that of the other cells.

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

1345 PENNSYLVANIA AVE. N. W. WASHINGTON, D. C.

ANSWERS TO INSTRUCTION BOOK No. 14

286. The two international wave lengths for ships are 300 and 600 meters.
287. P. R. B. means, "Do you wish to communicate by the International Flag signals?"
288. The international law requires that the Emergency set shall transmit over a distance of 80 miles for 6 consecutive hours, while the United States laws require a distance of 100 miles for 4 consecutive hours.
289. A fine of $25 and revoking license for divulging the contents of a message. For interference with communication a fine of $500 and one year of imprisonment. For false signals, $1,000 and 2 years' imprisonment. For send fraudulent distress signals, a fine of $2,500 and five years' imprisonment.
290. The exchange of superfluous signals and words is prohibited.
291. See page 46 of the U. S. Radio Laws or the sheet with abbreviations.
292. Commercial wave lengths must be 600 meters or less or they must exceed 1,600 meters.
293. The operator shall not use more power than is needed to send the message the desired distance.
294. The operator should first listen on various wave lengths to assure himself that he will not interfere with other communications; then he sends the attention signal C. T., then the call letters, three times, of the station being called, followed by the letters "d e" and his call letters three times.
295. When the message contains more than 40 words, the sending station should interrupt the transmission by the signal U. D. after every 20 words and should not resume the transmission until the receiving station acknowledges the receipt of the last word with the signal K (to go ahead).
296. An operator shall not tell the contents of a message to any person except to the party to whom it is directed or the proper officer.
297. The most common sources of trouble with a motor generator set are: hot bearings, dirty commutator or collector rings, poor brush contact, grounded field or armature, open or short circuited coil in armature or field winding, dirty or loose contact in the connections, resistance units burnt out in starter, burnt contacts on starter and burn-out coils or an open circuit in the field rheostats of motor and generator.
298. If the generator was running at the proper speed, inspect the field to see that the proper current is flowing in it, then test the strength of each pole piece with small screwdriver, then test the armature by holding the test lamp terminals on the commutator bars and then move the terminals to the brushes and finally to the point where there was no pressure.
299. Armature or shaft bound by frozen bearing or other obstacle, too rapid cutting out of starting resistance, open circuit in motor shunt field, short circuit on line between starter and motor armature or a short circuited or grounded coil on the armature.
300. Fasten a wooden board across the top of a metal bucket which is nearly full of salt water. Connect one wire to the metal bucket and the other wire to a movable metal rod which slides up and down thru a tightly fitting hole in the board top.
301. The reading of the ammeter will indicate trouble in this circuit. A large reading will mean a short circuit in the line or in the primary of the step-up transformer, while no reading will show an open or broken circuit. A voltmeter or test lamp will serve to test for the defective part in the open circuit. The badly burned contact points on the key are often the trouble. These should be filed smooth.
302. The flash test on the secondary of the step-up transformer is made by putting a short spark gap across the secondary and pressing the key. If a spark occurs it indicates the secondary to be O. K.
303. If all the transmitting condensers are punctured transmission may be carried on by use of a plain aerial, *i. e.*, connect a spark gap in the aerial circuit with the high tension source of power connected across it.
304. Inductance may be added by increasing the turns of wire in the primary of the oscillation transformer which will make up for the decreased capacity due to taking out the punctured condenser.
305. First, put buzzer in operation and test the crystal, and if you hear the test in phones the receiver is in good condition. If no test is heard, inspect all connections from the receiver to the change-over and make sure they are clean and tight. Examine the aerial and ground leads and connections. Test your phones for a break in the cords, test for a short circuit in your tuning condenser and also test for a broken wire in primary and secondary of your receiving transformer.
306. The essential duties for the proper upkeep of a radio set are: Keep the set clean and dry, keep the bearings clean and well oiled, clean the collector rings and commutator, keep the lead-in and antenna wires taut, test aerial for leakage, keep storage cell plates covered with electrolyte, correct specific gravity of electrolyte, keep the battery charged, and have all contact points, key breaks and switch contact blades smooth and polished.
307. Sulphation of a cell is due to overdischarge of the cell, allowing it to stand in the discharged condition and permitting the cell to stand long periods of time without being used. Too dense an electrolyte will cause sulphation also.
308. Too great a charging current will cause a lead cell to gas violently on starting the charge.
309. Treat the cells separately to a slow overcharge, making sure the electrolyte and plates are in proper condition.
310. The specific gravity of a lead cell electrolyte should be brought from a low reading to normal value by removing some of the weak solution and adding a strong solution (sp. gr. about 1.4) until the hydrometer shows about 1.250. This correction of the sp. gr. should always take place when the cell is charged.

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100%

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Student No 13794 Lesson No. 15

1 600 meters, and 300 meters for commercial stations, for navy stations between 600 and 1.600 meters.

2 Pure wave length is defined as all the energy being radiated in two or more wave lengths, more or less sharply defined as indicated by a wavemeter, the energy in one of the lesser waves shall not exceed 10% of that in the greatest.

3 at all stations the logarithmic decrement per complete oscillation in the wave trains sent by the transmitter shall not exceed .2 except in sending distress signals.

4 In sending distress signals the transmitter of a station on shipboard may be tuned in such a manner as to create a great interference with the greatest radiation.

5. An operator on hearing a distress signal should first determine if his ship is the nearest one, so as not to cause interference with another vessel which might be

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Student No. 13774 Lesson no. 15.

closer than he is. if none are closer he should make every effort to find out the full particulars from the vessel in distress receipt of which should be immediatly acknowledged, full information should then be placed in the ship masters hands and from that time on the radio officer should work under the masters direction.

6 When within five miles of a navy station the transformer input shall not exceed ½ kilowatt.

When within 15 miles of a navy station the transformer input shall not exceed 1 K.W. except for sending out distress signals.

7 All stations are bound to transmit radio correspondance with the least energy necessary to insure safe communication.

8 To communicate with a shore or inland station, I would transmit the Radiogram to the nearest station possible and from there it would be relayed to the station desired

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Student No 13794 Lesson No. 15

9 No. what you receive should only be told to those to whom the message is intended or to their authorised agents. or to another station employed to forward such message to its destination.

10 Commercial Radio stations either ship or shore are bound to carry on Radio Communications with one another regardless of the system of wireless telegraphy used.

11 The requirements of an operator to obtain a first class License are

He must pass a satisfactory examinatio in the adjustment, operation, and care of commercial Radio apparatus, including the fixing of the apparatus in case of breakdow also the change from one wave length to anoth. He must be able to transmit and receive in the continental Morse code at a speed of 20 words per minute (5 letters per word) He must have complete knowledge of the care of the auxillary power system, He must be completely informed on all Radio laws and International regulations.

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He must also know the requirements of the act of Aug. 13, 1912.

The requirements to obtain a 2nd license are the same as for the 1st class except the applicant need not be able to transmit and receive at a 20 word rate, but can receive a 2nd class license on being able to copy as low as 12 words per minute.

12 On calling another station you should send the signal —·—·— then send the stations call three times then send the word from (de) followed by your own call transmitted three times

—·—·— abc, abc, abc, (de) xyz, xyz, xyz.

13 QRM are you being interfered with.
answer
QRP Shall I decrease power {decrease power}
QRS shall I send slower {send slower}
QRT shall I stop sending {stop sending}
QST general call to all stations

The requirements for an emergency set are. It must be independent of the ships main electric power plant and must be able the operator to send messages for at least four hours and must be able to send messages o

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a distance of 100 miles either day or night.

15 Application for a license must be made to the U.S. Radio Inspector in the district in which you are located.

16 I am located in district No. 8 Detroit, Mich.

17 yes he must get an amateurs license and when this is given, a call is given to the station by which the station may be called, since the commercial operator works for a company and in many cases different stations, he is not given a call letter but the station which he operates has a call letter by which he is called while operating that certain station, also a commercial operator can work under a range of wave lengths from 300 to 600 meters while an amateur is required by law to work on 200 meters or less.

18 An official list of all ship and land radio stations with their call letters may be obtained from the, Superintendent of Documents, Government Printing Office, Washington, D.C., at a small cost.

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The official list is required by every land or ship station open to General Public service as part of their equipment.

89 They must be on duty at all times on a first class vessel and are required to make entries in the Radio log every 15 minutes to prove that a continuous watch is maintained a second class station must have at least 7 hours continuous watch and a watch of 10 minutes at the beginning of every other hour. Third Class stations have no fixed periods of service.

90 Keep Radio set clean and dry.
Go over set frequently to adjust parts and tighten connections.
Look out for broken parts and connections
Watch bearings of motor generator and keep well oiled. inspect aerial and lead in frequently inspect aerial frequently for leakage.
Keep solution in storage cells ½ inch above top of plates and keep them well charged at all times
Keep brass and copper parts well polished and keep Key contacts smooth and even.
Keep salt water off of set and prevent corrosion.

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CODE LESSON No. 15

SEND ON PRACTICE SET:

h l m q
s v n k
s l n o
p r w e
s q p c

e h a t s
m q r u v
w y c d i
z g o b l
d r n t k
l v e r n

1 a 3 7 p
q m 6 b ½
7 p m f z
l 6 4 5 m
p 8 9 h 4
u w 8 ¼

p 8 6 l m 4
q m 4 8 9 s
f z 3 2 g v
m 8 6 h w 4
q b c p a x
4 c j 7 9 ⅛

THEORY LESSON No. 15

Radio Laws and Regulations of the United States

TEST QUESTIONS ON UNITED STATES RADIO LAWS.

1. What is the normal wave-length for ships?
2. Define a pure wave and state the law about its use.
3. How sharp a wave must be used?
4. What kind of a wave is sent in cases of distress? Answer fully.
5. If acting as ship operator what would you do on hearing a distress signal? Answer fully.
6. State the law regarding the power used when within 5 or 15 miles of a Naval Station.
7. What is the law regarding the use of unnecessary power?
8. How would you communicate with a shore or inland station?
9. Should you tell what you hear in a wireless message?
10. What is the law regarding inter-communication?
11. What are the requirements for an operator in order to obtain a First or Second Class Certificate?
12. Explain the method of calling another station.
13. Give the meaning of the following abbreviations: QRM, QRP, QRS, QRT, QST.
14. State the requirements for an emergency set.
15. To whom does one apply for an application for a license?
16. In what radio district are you located?
17. Must a First Grade Operator get any other license before operating a set constructed by himself? Answer fully.
18. Where may one get an official list of all ship and land radio stations with their call letters and what stations must have lists?
19. How many hours during the 24 must operators be on service on a transatlantic vessel?
20. Mention a few things which a ship or land operator should do to his set to keep it in first class condition.

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1 a fuse is used to protect small circuits where the amperage is not large.
A circuit breaker is used where the current carried in the circuit is large, where a large fuse would be a source of danger due to the molten metal flying.

2 A pole changer in a battery circuit is used so that the current charging the battery always flows in the correct direction through the cells.

3 Twice the Number of lead cells necessary or 120 100 @ 1.2 volts x - 2

4 The current would reverse and run the generator as a motor. circuit breaker would trip and open the circuit x - 5

5 The parts of a motor starter are.
The switch which turns the current into the solenoid, the solenoid pulls up a plunger which is connected on to the starter box handle, the handle cuts out the resistances as it is drawn over the studs by the solenoid, the resistance is used to carry the heavy current while starting the motor, when the handle is drawn clear over a release magnet holds the lever in the running position, a plunger working in an oil cup is attached to the handle to keep it from being drawn to quickly over the resistance studs thus doing away with the danger of burning out th

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motor armature.

6 It is a compound wound motor and its advantages are its constant speed under all conditions thus allowing the generator to deliver a constant current frequency.

7 The frequency of the A.C. is raised by increasing the resistance of the motor field rheostat.

8 The power of the A.C. generator is decreased by adding decreasing resistance in the generator field rheostat.

9 The voltmeter measures the difference of voltage across the leads from the generator armature

Ammeter measures the current strength in amperes flowing in the key circuit.

The Hot wire Ammeter indicates the value of the current flowing in the aerial circuit. it also enables the placing of the closed and aerial circuits in resonance.

The wattmeter is used to indicate the power in watts flowing in the key circuit.

The frequency meter indicates the number of cycles per second of the alternating current from the generator armature.

10 A reactance regulator is a variable choke coil used to regulate the current flowing in the primary

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of the step up transformer, also to place the key circuit in resonance with the secondary circuit.

11 The protective resistance rod is a carbon rod of high resistance its terminals are connected to the leads of the power main, its middle point is connected to the earth, it is used to prevent the puncture of the windings of a motor generator by a current of high voltage caused by induction from the sending set while in operation.

The lightening switch consists of a single pole double throw switch which permits grounding the aerial during a lightening storm, that the instruments may not be damaged.

12 The parts of a step up transformer are.
One laminated iron core
One primary winding and one secondary winding.

13 They are placed in series so that the capacity will remain the same as one of them alone but the high voltage is distributed between them so that there is less danger of a break down.

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14 When so many gaps are used and resonance is made between the open and closed circuits, the voltage must then be regulated from the A C generator by the A.C. field rheostat if a note cannot be produce then that is clear. more plates are added and the A.C voltage increased until a clear note is obtained. care must be taken to have the two circuits in resonance before adding plates to get a clear note.

15 The circuits broken are.
The primary circuit to the step up transformer
The aerial is disconnected from the sending set
The ground is disconnected from the sending set
The circuits made are
The aerial. and ground are connected to the receiver

16 The 110 Volt line switch is thrown in.
The motor generator is brought to full speed by pressing the button of the Automatic starter
The motor generator is then adjusted by means of the motor rheostat and generator rheostat to give the correct reading on the volt meter and ammeter; the change over switch is then thrown to the left connecting the aerial and ground to the sending set also connecting

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the primary to the power supply ready for sending.

17 Two uses for the buzzer testor is to connect to the receiving circuit that the detector may be preadjusted to its maximum sensitiveness

It is used in connection with a condenser and an inductance to preadjust a receiving set to a certain wave length.

When the buzzer is in operation radio frequency waves of certain wave lengths are radiated depending on the number of turns on the inductance and the capacity thus by varying the coupling of the receiving transformer the maximum loudness in the receivers is heard, the receiving set is then adjusted to that certain wave length.

18 I would adjust my potentiometer by means of the sliding contact and the receivers the slider is mooved until the critical voltage is found which added to the voltage of the incoming oscillations will cause a large increase in the voltage flowing in the phones, thus causing maximum loudness in the phones to be heard.

19 The crystal is adjusted to its maximum sensitiveness, the coupling of the receiving

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transformer is tightly coupled and at the same time the slider on the primary is varied until signals are heard the coupling is now varied to give maximum loudness in the phones and freedom from interference, the condenser is now varied to give maximum loudness in the phones.

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LESSON No. 1

ANSWERS.

RADIO TELEPHONY.

1. Ship to ship and ship to shore, across the ocean or a continent, in an isolated region as the Arctic section, between moving trains, also between a moving train or wagon and a fixed point, between mine levels, forestry stations, submarine and aeroplanes.

2. For long distance land service and transoceanic service.

3. (1) Radition of speech energy, (2) Distortion of the speech, (3) Amplification of speech in Transmitter and Receiver, (4) Secrecy of transmission and (5) Reduction of disturbances.

4. A large inductance will smooth out the overtones and make the speech drummy.

5. Too much capacity in the circuit makes the speech squeaky.

6. See Fig. 3, page 5. G is a D. C. generator of 400 to 600 volts and supplies the energy. R is a resistance to regulate the current, L is a choke coil to prevent heavy oscillating thru G, K is the Arc, C condenser, L inductance and R resist to form a shunt circuit.

7. Poulsen placed the Arc in a hydro-carbon vapor chamber (by alchol or gasoline), used carbon negative side and a copper with water cooling device, revolved the carbon electrode by a motor so as to burn even, and put on opposite side of arc two strong electro-magnets.

8. See Fig. 4, page 5.

9. The approximate maximum distance is 170 to 200 miles.

10. See Fig. 5, page 6.

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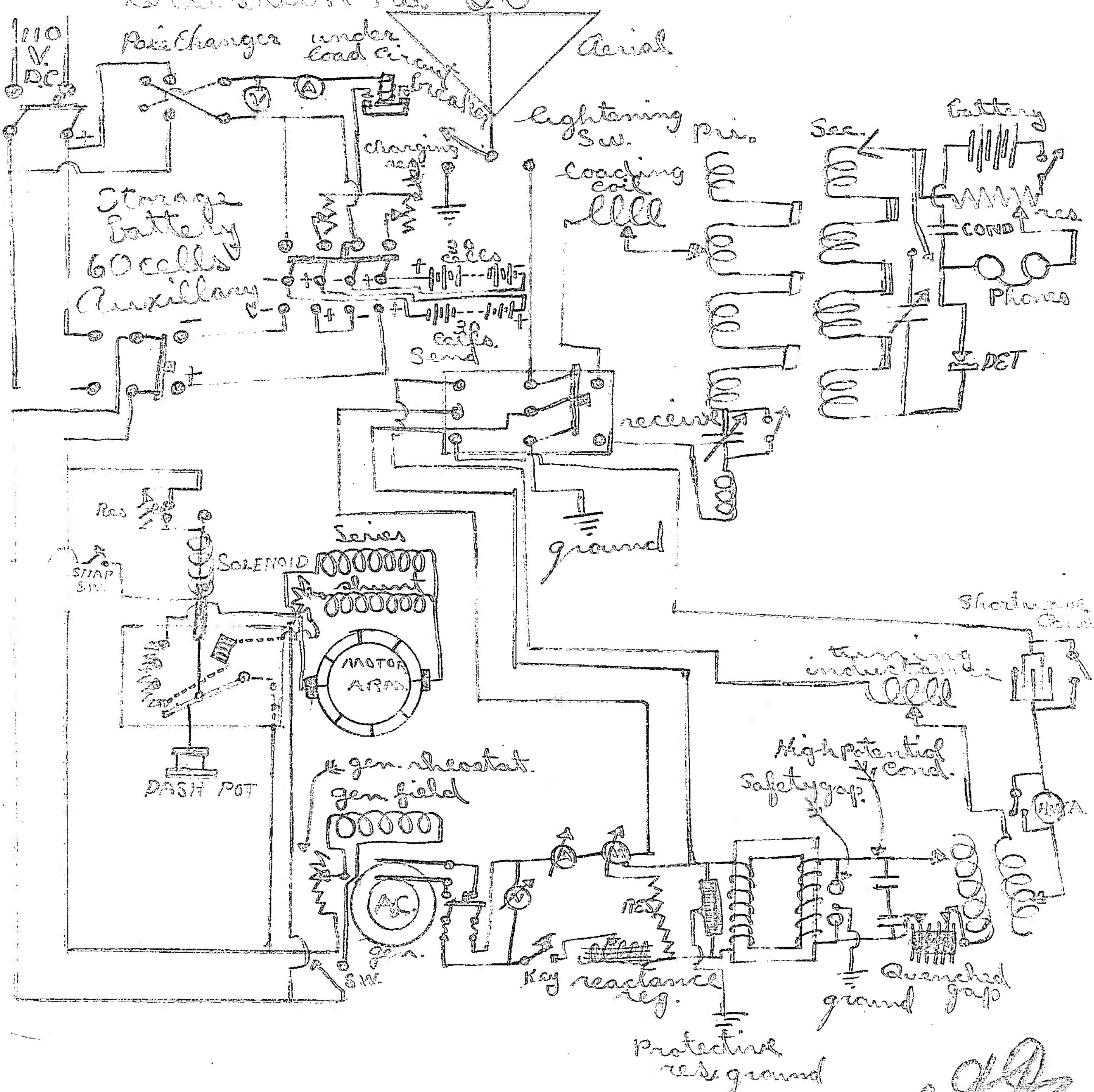
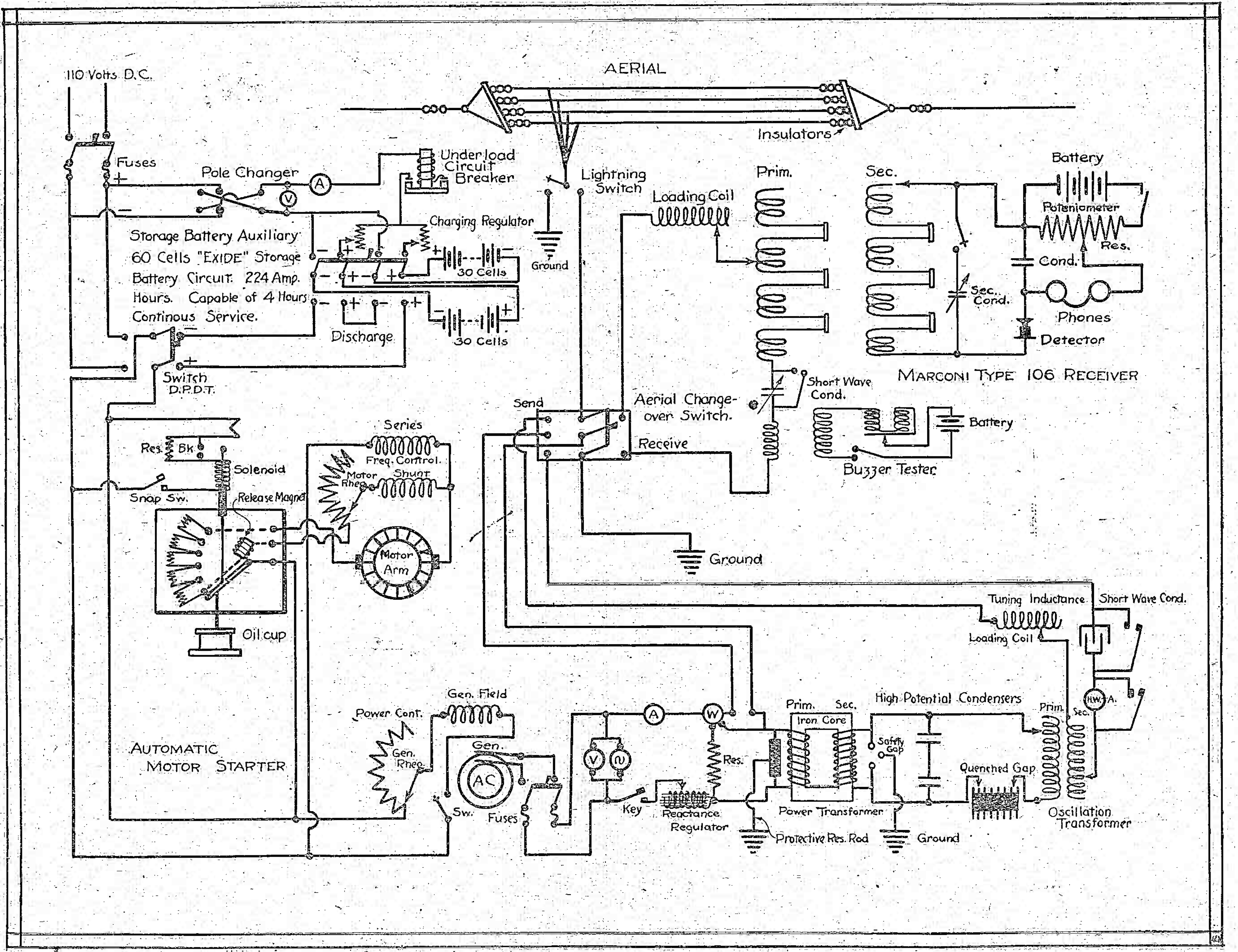
Question No. 20



Complete Wiring Diagram of Transmitter and Receiver showing 2 K. W. 500 cycle Transmitting Set.



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Correspondence Course

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FINAL SHEET No. 18

Questions on Diagram of 2 K. W. 500 cycle Transmitting Set

SUBMIT ANSWERS TO THE FOLLOWING QUESTIONS.

1. Tell the difference between a fuse and a circuit breaker for protection.
2. What is the purpose of a pole changer in a battery circuit?
3. If an Edison battery were used, how many cells would it include?
4. If the ship generator should stop while the battery was charging what would happen?
5. Name the parts of the motor starter and explain the duty of each.
6. Name the type of motor and state its advantage.
7. How would you raise the frequency of the A. C.?
8. What piece of apparatus would you operate to decrease the power output of the A. C. Generator?
9. Explain the purpose of each of the 5 instrument meters.
10. What is a reactance regulator and why used?
11. Explain two kinds of Protective devices for high Electrical surges and lightning.
12. Name the parts of a step-up transformer.
13. Why are the two transmitting condensers connected in series.
14. Explain how to adjust the Quenched gap with the proper number of plates.
15. Name the circuits broken and made when the Aerial change-over switch is thrown to the right.
16. Give the operations in order for starting the Transmitting set.
17. Explain two uses for the testing buzzer.
18. How would you adjust your Potentiometer?
19. Explain the method of tuning in a station.
20. Draw the complete diagram from memory.

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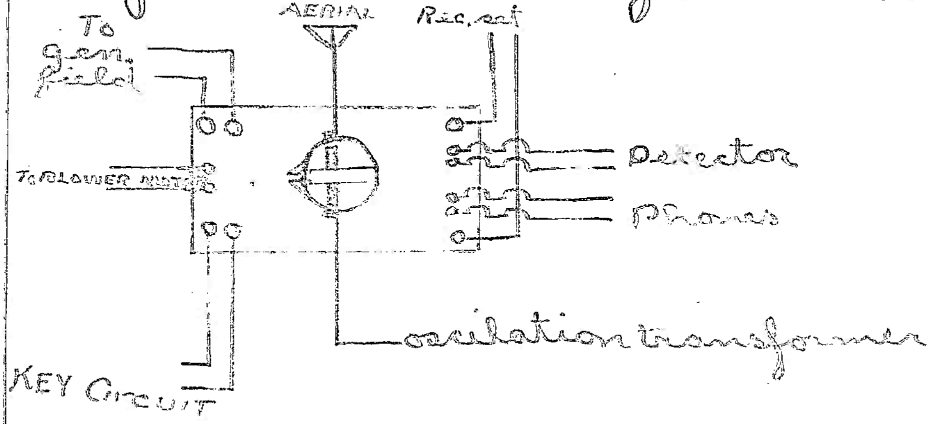
Lesson No. 16

1 It is called an antenna switch because it changes the aerial to either a sending or receiving position.
Its object is to disconnect the receiving apparatus while sending in order that the receiving set might not be damaged while sending.

2 

3 When the key is pressed the alternating current from the line circuit is raised from 110 volts to 10.000 or higher; but the frequency remains unchanged in the charging circuit the high voltage charges the condensers. the condenser immediately discharges across the gap and through the primary of the oscillation transformer, in discharging across the gap the frequency is raised in the circuit to Radio frequency

4 When a few condensers are removed from the closed circuit the resonance is changed between the two circuits and therefore

the normal wavelength will be reduced. To again bring the set to resonance more turns are added to the oscillation transformer primary this increases the wavelength of the set until the normal wavelength is again obtained, this is indicated by the hot wire ammeter giving a maximum reading when resonance is reached.

5 The distance between the spark gap electrodes being too great.

6 A spark gap is inserted in series with the aerial the aerial circuit is then energized by a high voltage transformer, if the insulators leak. the energy, instead of jumping the gap will pass across the insulators down the rigging to the ground, partly or entirely short circuiting the transformer.

7 Carbonization of the insulators.
Breakage due to swaying of the ships.
Carbonization may be remedied by scraping the insulator good and covering it with an insulating compound. if however the insulator is badly burned it must be replaced either by a new one or a piece of

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Marlin rope soaked in oil may be used for a temporary repair. this also must be done when the insulator is broken.

8 If there is an open in the primary of the step up transformer the ammeter in the key circuit will not be deflected when the key is pressed the voltmeter shows the pressure in the key circuit

If there is an open in the secondary of the step up transformer no sparks will occur between the electrodes of the spark gap when the key is pressed

7 When the key is pressed oscillations are taking place between the gap when the key is let up the gap does not return at once to its state of high resistance and waves are emitted which are highly damped. now by cooling the gap by a forced air blast when the key is let up the sparks are blown out instantly thus allowing a pure wave to be radiated as the gap returns to its state of high resistance instantly.

10 The Vertical aerial, this aerial is claimed to be the best radiator of Electromagnetic waves

The inverted L type aerial, this aerial possesses directional effects, and radiates the greater part of the energy in the direction opposite the

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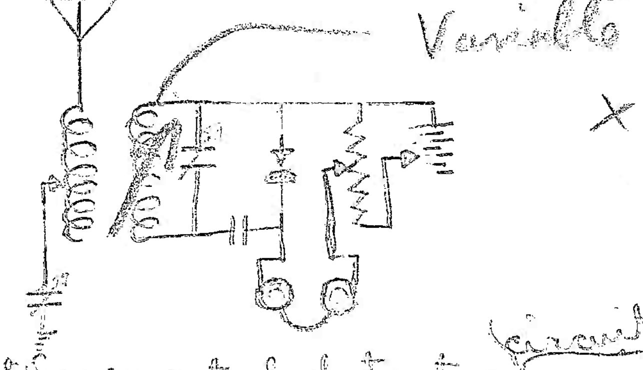
free and
The T type aerial, this radiates equally from both ends.

11 The antenna current is measured by a hot wire ammeter placed in series with the aerial lead in and the set. the needle is deflected over a graduated scale which shows the current radiated.

If none were provided I would connect a small glow lamp in series with the open oscillatory circuit of the transmitter, and is connected by a loop of wire having a sliding contac, now when the adjustments are made in the primary and secondary circuits of the oscilation transformer as to give the greatest glow to the light, resonance is then obtained between the two circuits.

12 A close coupling is used for listening in, as by that method a broad range of wave lengths may be carried

13



X - 1

The crystal detector (circuit) using Carborundum

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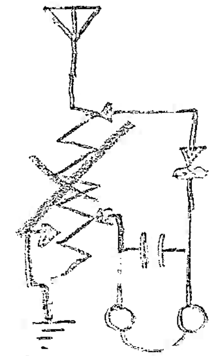
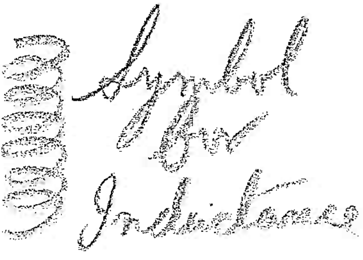
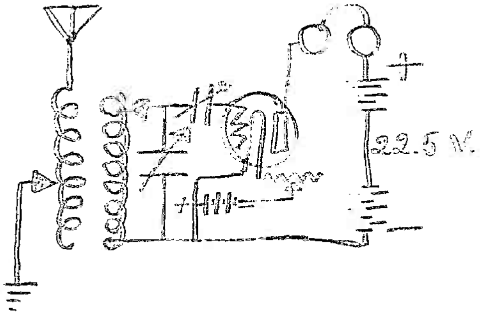


circuit using galena detector.



x — 2

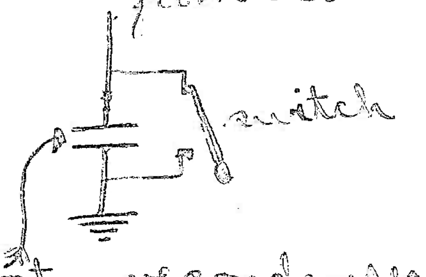


Circuit using a vacuum tube as a detector.

14 I vary the coupling to change from a broad to a sharp wave, to cut out interference from other stations sending on nearly the same wave length, also it helps to cut out atmospheric disturbances

15 Carborundum, Radiocite, Perikon, galena silicon

16 By using a short wave condenser in the ground lead from transmitting set



When the switch is closed the condenser is shorted allowing the set to radiate on 450 meters, when the switch is opened the condenser is placed in series cutting down the capacity and only allows the set to radiate on 300 meters

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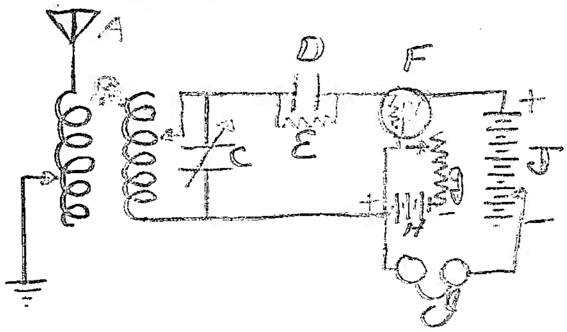
17



A = aerial
B = receiving transformer
C = secondary variable cond.
D = grid cond.
E = grid leak
F = vacuum tube
G = filiment rheostat
H = A Battery
I = phones
J = B battery

The aerial absorbs energy from the passing waves.

The receiving transformer transfers the energy of the incoming oscillations from the aerial circuit to the [illegible] circuit.

The secondary variable condenser supplies the capacity necessary to allow adjustment to various wave lengths. It allows also a very sharp adjustment on the wave length.

The grid condenser is to produce an audio frequency variation of the plate current through the phones by storing up the negative charge of the rectified currents.

The grid leak allows the negative charges stored up in the grid condenser by the rectifying action of the tube to leak off after the passage of a train of oscillations.

The vacuum valve detector is used to change the incoming radio frequency waves into audio frequency waves.

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The filiment rheostat is used to regulate the amount of current used by the filiment.

The A Battery is used to light the filiment

The phones are used to transform the rectyfied waves from the detector into sound.

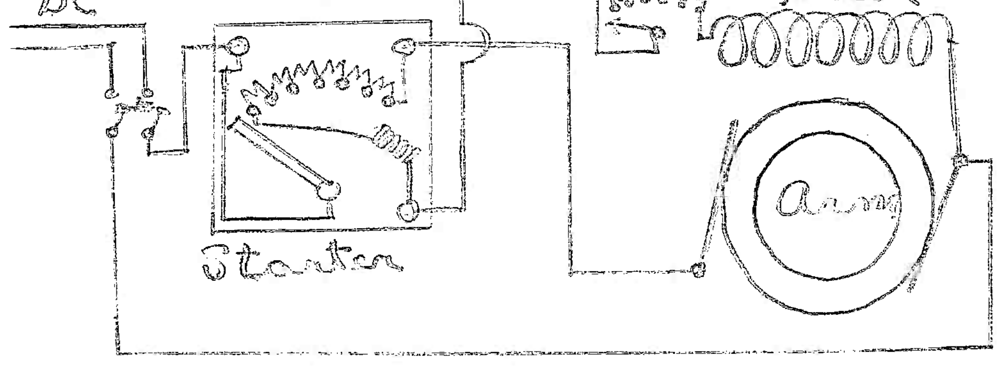
The B battery is used to supply the current that flows through the phone circuit.

15 By a Hydrometer

The instrument consists of a glass tube with a bulb on one end and a rubber tube fastened on the other, inside the glass tube is placed a hydrometer glass, to use this the bulb is pressed and the tube is pushed into the cell, the bulb is let go and the electrolyte is drawn into the glass the hydrometer will now float in the glass and the reading is taken at the surface of the liquid.

19 Distilled water only. It is added when the liqui in the cell gets lower than ½ inch above the plate

20



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21 When starting a motor slow the fuses or circuit breaker are liable to open on account of the high current, also the resistances are likely to burn out in the starter box.

When starting to fast, the armature and field coils burn out because of to much current to sent through them before the motor can speed up to develope a counter E.M.F. to withstand this current.

22 I would clean a commutator of a motor by fixing a piece of fine emery cloth on a half round block which would fit the commutator a handle should be fastened on the block, now when the motor is running it is an easy matter to clean a very dirty commutator. Care should be taken not to press the block to hard on the comutator.

23 This trouble may often be found to be caused by pulling the handle of the starter over too quickly.

This is also caused by a short in the motor armature or in the shunt field windings

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24 In a shunt wound motor the field windings are shunted accross the brushes of the armature. a rheostat is connected in series to regulate the field current.
In a series wound motor the field coils are placed in series with the armature.
In a compound motor windings, there is a combination of the two top methods, there are two fields one is connected in series with the armature and the other connected in shunt to it.

25 The signal to end a radiogram is ·—·—·

26 The cable count is the method used to determine charges as at present used by the cable companies. In the cable count all words including the address and signatures are counted and charged for.

27 They are more sensative, not that the resistance causes this, but it is caused by the magnetic flux generated by the incoming feeble currents.

28 Anyone found guilty of sending fraudulent signals may be punished by a fine of $2.500 or 5 months imprisonment, or both.

29 I would use a close coupling so as to cause a maximum of interference with the greatest of radiation. (OVER)

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LESSON No. 16

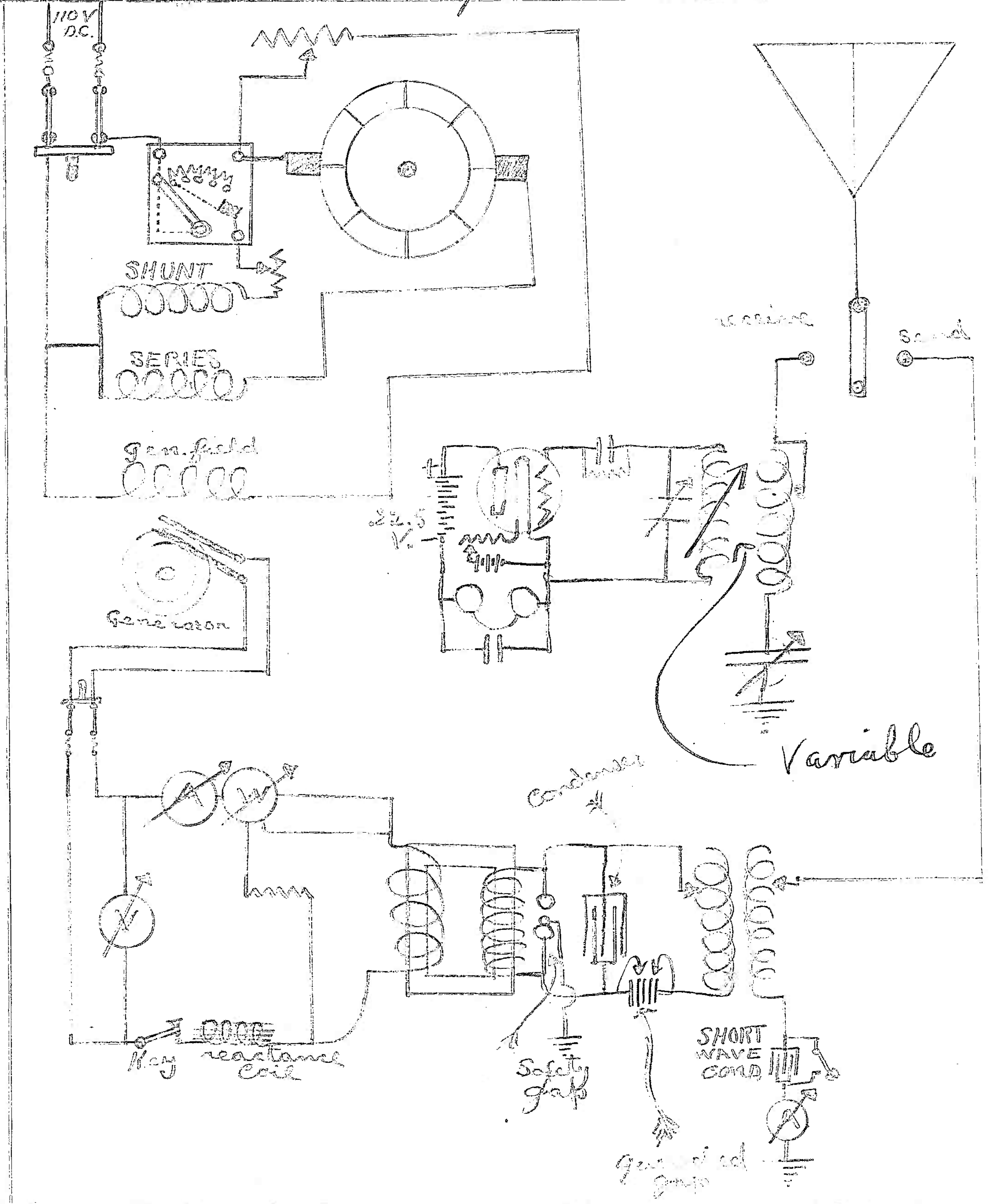
FINAL TEST QUESTIONS

1. Why is a change-over or transfer switch called antenna switch? What is its object?
2. Draw diagram of connections for the above switch.
3. Describe what takes place in the closed oscillatory circuit when key is pressed.
4. What is the effect if a few condensers are removed from closed circuit and the set retuned to resonance by the aerial tuning inductance?
5. What is the most common cause for breakdown of transmitting condensers?
6. How would you test the insulation of an antenna?
7. What causes the breakdown of the antenna insulators? How would you remedy this trouble?
8. How would you test an open in primary or secondary of the step-up transformer?
9. What advantage is there in the cooling gap by an air blast or other means?
10. Name three types of aerials and explain the difference in effect.
11. What method is used to measure the antenna current? What would you use in its place in case none were provided?
12. What coupling is used for listening in? Why?
13. Name three types of detectors and give diagrams of connections.
14. Why do you vary the coupling?
15. Name a few crystal detectors.
16. How do you change from 450 to 300 meter? Show by a sketch the changes.
17. Draw the diagram of an Audion receiving set. Explain the parts and their functions.
18. How is specific gravity measured? Describe the instrument and method.
19. What kind of water is used and when added?
20. Make a sketch of a motor starter with a shunt motor.
21. What is the effect of starting a motor slow? Fast?
22. How would you clean the commutator of the motor?
23. Suppose breaker blew and fuses opened on starting, where would you look for the trouble, and why?
24. State difference between series, shunt and compound motors.
25. What signals end a radiogram?
26. Explain cable count.
27. Why use high resistance telephone?
28. Give the penalty for sending fraudulent signals.
29. What coupling would you use in sending distress signals? Why?
30. What effect does suddenly using closed coupling have on the resonance of the two circuits?

100%

George [illegible]
[illegible]

Student No. 13794 Lesson 17b



Variable

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2 A quenched gap consists of a number of copper disks with cooling flanges carefully ground and mounted in a rack, these plates are separated by insulating disks about 1-100 of an inch thick when the plates are in the frame they are pressed closely together by a bolt at the end of the frame.

The advantages are.

The oscillations in the condenser circuit are rapidly damped out, allowing a clear sharp wave to be radiated.

It is noiseless in operation.

It permits the use of transformers having low voltage secondaries.

3 The secondary of the oscillation transformer is telescoped into the primary, throwing the two circuits out of resonance, thus allowing a broad wave to be radiated.

4 The disadvantages are

It radiates a highly damped interfering wave which interferes with receiving stations which are listening in on that wave length or near it

It also may cause a break down of the aerial insulation due to the strain from the low frequency high voltage current which is superimposed upon the high frequency

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oscillations flowing in that circuit.

5 The fundimental wave length of an aerial is the wave length of an aerial due to it's capacity and inductance, without the addition of an aerial tuning inductance or a short wave condenser in series.

6 Slight carbonization of the insulators may be remedied by scraping the insulators and then covering them with an insulating compound.

As a temporary repair for a broken insulator a piece of marlin rope soaked in oil may be used.

Leakage at the insulators may be stopped by decreasing the coupling at the transmitting set this also cuts down the range of the set.

7 Alternating current is used in wireless work because by it's use high voltages are obtained without the use of a uncertain interrupter which is necessary on an induction coil. also the amount of energy that any interrupter will handle is limited to about one K.W. while an alternating current transformer will handle energy up to 500 K.W.

8 If the fuse on the D.C. line has blown, it should be replaced.

If the generator field windings are found op

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by a test, the field rheostat may have blown out this may be tested by a battery and telephones and the burnt out section shunted by a piece of wire.

If the primary is tested and found open it should be removed and repaired.

If the secondary of the transformer is shorted or burnt out the coils should be removed and the burnt out one removed, the rest are put back in place and then are connected in series, the power should then be reduced to the transformer.

Punctured condensers are replaced by spares. if these are not available the remaining ones are then connected in parallel and the transformer input reduced.

? When used to tune a transmitting set to a given wave length the wavemeter consists of an inductance, telephones, detector and a variable condenser.

To find the wavelength of a distant station a buzzer, battery, key, variable condenser and inductance are necessary.

To calibrate a receiving set so that it may be preadjusted to any given wave length requires the same instruments as for finding the wave length of a distant station.

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West Salem Ohio

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To measure the percentage of coupling between the open and closed circuits of a transmitter requires inductance, variable condenser, small transformer, and wattmeter.

To plot a resonance curve a wavemeter with wattmeter attachment is used

10 In many present day sets the power is reduced in steps by a moving secondary which may be placed at right angles to the primary windings or any place between the maximum and minimum positions desired thus the current in the antenna circuit may be decreased in steps from a maximum value to a zero value.

11 Condensers are sometimes immersed in oil to raise their capacity, the dielectric value of oil is greater than air.

12 To varying the coupling of a receiving transformer has the effect of damping the whole set when tight coupling is used thus many stations are heard, to loose couple the transformer makes it possible to tune sharply and thus tune out the stations not wanted.

13 a battery and buzzer is used in a receiving circuit is used to find the most sensitive spot on the crystal

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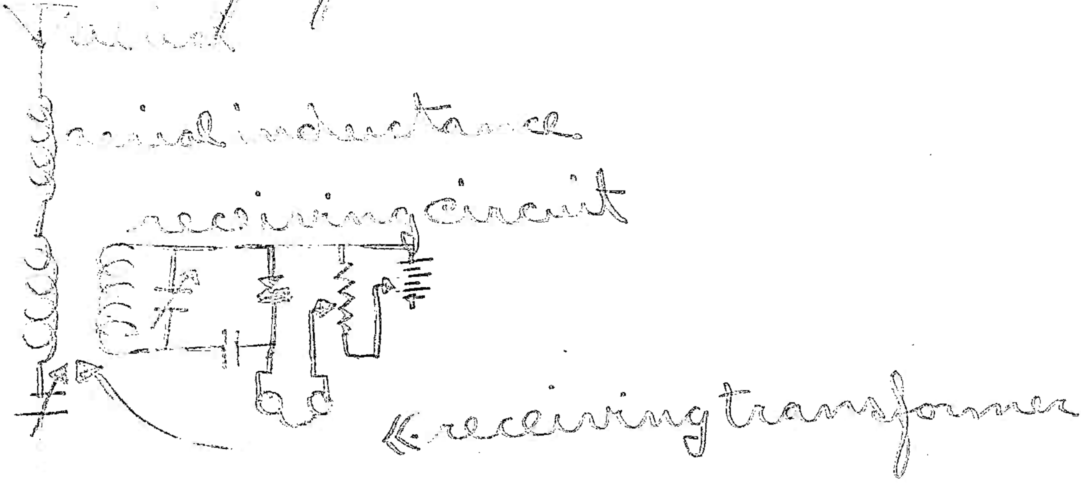
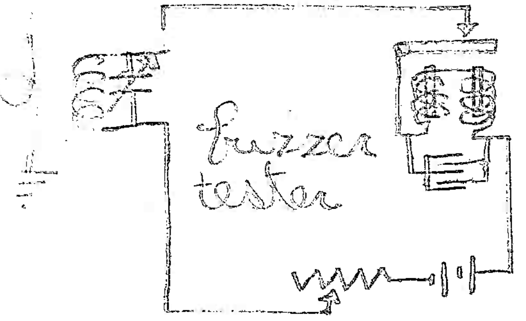
in the absence of incoming signals.

14 By using a buzzer in connection with the wave meter and the whole placed in inductive relation to the receiving set, thus the wave meter is set to emit certain wave-lengths which are wanted, the positions for each wave length is then plainly marked on the receiving set or tabulated for future use.





15 I would start the buzzer going and by working the cat whisker over the crystal the most sensitive spot may be found this is told by the maximum loudness of the buzzing in the [illegible]

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Student No. 13794 Lesson no 176

16 the effects of broad tuning are the set covers a broad range of wave lengths and consiquently many stations are able to be heard and much interference is incountered.
The effects of sharp tuning are no interference is incountered and the station wanted may be tuned in to its maximum loudness.

17 The capacity of a storage battery means the quantity of electricity, in ampere hours, they are capable to deliver on discharge.

18 The storage cell should be kept clean and dry.
The acid should be kept ½ inch above tops of plates.
The battery should be kept charged at all times
The terminals and connection should be kept tight and free from corrosion.
Do not overcharge, overdischarge or undercharge.
Do not allow cells to remain long in a discharged condition.
See that the plates do not become shorted by sediment dropping to the bottom of the cell.

19 The frequency of an alternator means the number of cycles produced by the alternator per second.

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Student No. 13794 Lesson No. 17b

20 The object of the circuit breaker is to automatically open the circuit in event of abnormal conditions, in the circuit. The circuit breaker is placed in the circuit which it is to controle, by means of a handle the breaker is closed when the current varies a magnet which is operated by the current will be energised sufficiently to trip the contact arm and thus open the circuit.

21 By decreasing the resistance in the generator field rheostat allowing more current to pass to the windings

22 The remedy for a burned out starting rheostat is a salt water rheostat which is made by using a metal pail full of salt water an iron rod supported by a stick across the top of the pail, one terminal of the 110 volt current is connected to the pail the other to the motor while the remaining cord from the motor is connected to the iron rod, as the rod is pushed down in the pail the resistance to the current decreases until the rod touches the bottom, the motor is thus braught gradually to full speed when the bucket is then shorted by a piece of wire.

23 The advantage of a Compound wound motor is a constant speed is maintained under all conditions, thus assuring a steady flow of current from the generator.

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Student No. 13794 Lesson No 17B.

24 If the station does not answer the call after it has been transmitted three times at intervals of two minutes, the call shall not be resumed until after an interval of 15 minutes the station issuing the call having first assured himself no other correspondance is in progress.

25 Cable count.

All words including the address and the signature are counted and charged for in the cable count. all messages are divided into three main classes, Plain language, Code language and Cipher language.

26 The exchange of superfluous signals and words is prohibited to all licensed stations.

27 This combination of letters infers that the ship wishes to communicate by means of the International Signal Code.

25 The call of inquiry CQ is sent out by the ship wishing to send to the nearest shore station. this call is an invitation for any stations in the vacinity of the sender to eply to his call.

The operator may also secure from the captain the latitude and longitude of the vessel and then by reference to the navigators maps, locate the position of prominent land stations nearist him

Correspondence Course

NATIONAL RADIO INSTITUTE

1345 PA. AVE., N. W. WASHINGTON, D. C.

LESSON No. 17b

FINAL TEST OUESTIONS

Transmitting apparatus:

1. Draw a complete diagram for the transmitter and receiver.
2. Describe a quenched gap and explain its advantages, and state why they are advantages.
3. How do you adjust a transmitter to emit a broad wave?
4. What are the disadvantages of a plain aerial transmitter and state why they are disadvantages.
5. What is the fundamental wave-length of an aerial?
6. Name some preventative and remedies for a leaking antenna.
7. Why is alternating current used in wireless work.
8. If your spark stopped suddenly while transmitting, give the order in which you would look for the trouble and the method of repair in each case.
9. For what other purpose may a wavemeter be used, and what appliances are required in each case?
10. Describe how the power may be reduced in steps.
11. Why are condensers sometimes immersed in oil?

Receiving apparatus:

12. What is the effect of varying the coupling?
13. Of what use is a battery and buzzer in a receiving circuit?
14. How would you mark a receiver for different wave-lengths? Give a sketch.
15. How would you adjust the receiver to maximum sensitiveness?
16. What are the effects of broad and of sharp tuning?

Storage batteries:

17. What is meant by the capacity of a storage battery?
18. What attention should be given to a storage battery?

Motor generators:

19. What is meant by the frequency of an alternator?
20. What is the object and operation of a circuit breaker?
21. How do you increase the voltage of an A. C. generator?
22. What is a remedy for a burned-out starting rheostat?
23. What is the advantage of a compound wound motor?

Radio Laws:

24. What is the regulation for the repetition of a call?
25. What system of count is used? Explain it.
26. What is the international regulation regardiig superfluous signals?
27. Wheat is meant by the signal PRB?
28. How do you find the nearest *shore* station, what signal is used, and why should you want to find out which station is nearest?

WALKER MULTI-UNIT INTRODUCTION -READ CAREFULLY

READ CAREFULLY-
There is considerable int
reception of signals by
made on the radio de
several years past
to do if he did
appeal. The
may be re
It

erest aroused in short wave reception. We hear of Foreign
thusiastic short wave fans almost daily. Demands are
for parts and accessories which bring back memories of
average radio fan knows not what it is all about or what
particular radio fan the Walker Multi-Unit will certainly
is small and his opportunity to know "what it is all about"
num expense.

by the fan that successful short wave reception is dependent
tions. It is known to be tricky; none will deny. Don't call
eighbors to enjoy with you the broadcast programs of Australia,
first attempt you make to tune a short wave receiver or adapter.
similarity between S.W. tuning and the operation of your broad-
gle control.

ing really difficult about the tuning of a short wave receiver
ce is required. The sharpness of the stations is such as to
to be on the alert when he hears the weakest whistle or carrier
he may pass up the station during the tuning. Once you are
re the stations may be heard on the dial, no skill will be re-
setting for your particular unit may differ from that of your
the length of antenna, etc., may not be alike. The tube used must be
oscillator. B batteries will be more efficient than Eliminators as the flow of current must be constant. When a B Eliminator is used allowance must be made.

The requirements of successful short wave reception are such as to total a large investment and one should hesitate before making a heavy investment until he has become familiar with the conditions of the new and alluring short wave possibilities. The Walker Multi-Unit will be found to be an inexpensive guide.

The most interesting hours to hear S.W. broadcast are between late afternoon and early evening. At this time some of the stations discontinue S. W. transmission at about 7 to 8 o'clock E.S.T. Determine, if possible, the transmission hours of the stations you are interested in. Because you are located within a short distance of a S.W. station, reception will not be certain as there is what we call "skip distance" which will permit the tuning of a more distant station and yet you may fail to tune the station near-by. Much experimenting is being conducted in short wave transmission and it will not be long before these new frequencies will be much more popular. The many uses of the Walker Multi-Unit are such as to permit the fan to derive the greatest benefit from his investment now. Its use as an extra stage of tuned radio frequency is most popular and a test will be sufficient for you to determine your interest. The increased selectivity, volume and range is sure to impress the fan.

WALKER MULTI-UNIT INSTRUCTIONS.

Read instructions carefully to insure maximum efficiency. Where the wiring of a receiver is faulty or the parts are damaged, no material gain in sensitiveness will result. Nor, will this unit cause receivers which are inoperative to function. The purpose of the unit is to improve reception and to be applied to other uses as mentioned in our literature. Each unit has been carefully tested at the factory in actual operation. The .0001 fixed condenser should be mounted to #1 post of unit and the free end connected to the antenna only when the antenna is too long to permit oscillation while tuning the short waves. The Short Wave Plug-in Coil is designed to cover a wave band which includes all of the popular stations. Due to the capacity of the unit tuning condenser, a single coil will suffice. As all four wires of the plug are not always in use, care should be exercised so that no shorting of the exposed ends will occur.

SCREEN GRID R. F. AMPLIFIER
(No. 222 type tube - D. C. Receiver)

No. 1

Remove grid leak and
black to #2, yel
al "B" of uni
of unit),
Attach
R.

ixed condenser from unit. Connect red wire of plug to #7, #5, green to #4. Connect a wire from "B" plus 45 to termin- his is not convenient, connect a short wire between #6 and "B" t wire with clip to "G". Insert No. 222 tube in socket "T". ap of tube. Plug in large coil to socket "C". Remove 1st er and insert in top of plug. Insert plug in socket from emoved. Disconnect antenna from receiver and fasten to #1. e remains connected to receiver unless your antenna coil is of ed type, that is, the primary winding is separate of the secon- s no direct wire connection with each other. With antenna coil the ground wire is connected to #2 along with the black wire. ected and a connection is made between the antenna post of re- . Another wire is connected from the ground post of receiver r to #6 of unit, whichever is best. Set "FIL" at 3. Do not point as damage to tube may result. Set "VOL" at about 4. and tune a station in the usual way, rotating the dial of unit heard. Readjust the dial of the receiver and unit for clarity. " control for volume. The use of the unit with the receiver ter volume and sensitiveness. The selectivity when using the tube is not as great as when the ordinary 201-A tube is used but vement in clarity compensates for this. The "VOL" control is of the ut- importance. Its use will be appreciated with practice and experience. Var- ous adjustments of this control may be necessary in tuning, as a certain setting may prevent a station from being heard due to the degree of selectivity which is possible.

No. 2

SCREEN GRID R. F. AMPLIFIER
(No. 222 Type Tube - A. C. Receiver)

The use of a separate filament supply for the screen grid D. C. tube is advisable to minimize A. C. hum and interference. A simple and inexpensive filament supply may consist of 3 1-1/2 volt dry cells, wired in series, that is, the plus of one cell is connected to the minus of another. Connect the minus of #2, plus to #7. Connect green wire to #4, Yellow to #5. Remove grid leak and condenser. Connect from B plus 45 to "B" on unit (when this is not convenient, connect a short wire from #6 to "B" on unit. Fasten short wire with clip to "G". Insert No. 222 tube in socket "T". Attach clip to cap of tube. Plug in large coil to socket "C". Remove 1st R. F. tube from receiver and insert in top of plug. Insert plug in socket from which tube had been removed. Disconnect antenna and fasten to #1. OPERATION: same as in No. 1.

No. 3

EXTRA STAGE TUNED R. F., PRE-AMPLIFIED, BOOSTER
UX 199, 201-A, 112-A Type Tube, D. C. RECEIVER.

Grid leak and condenser remain in position across "B" and "G". Connect red wire of plug to #7, black to #2, yellow to #5. Insert extra tube in socket "T". Plug in large coil to socket "C". Remove antenna from receiver and connect to #1. Connect a wire from #4 to antenna post of receiver. Remove 1st R. F. tube from receiver and insert in socket of plug. Insert plug, along with tube, in 1st R. F. socket of receiver. When used with a 199 type tube receiver the FIL control is set at position 3 of scale. With the regular or standard 6 volt tube receiver, the FIL control is adjusted to "Full on" position-about 7-1/2 on scale. Should your receiver incorporate an inductively coupled antenna coil (this should be determined before making any connection changes) remove the ground wire from receiver and fasten to #2 along with the black wire of plug. Now, connect a wire from B 90 plus to the ground post of the receiver.

OPERATION: Refer to the list of stations you have tuned with your receiver and adjust the dial or dials and prepare for operation as tho the unit was not in use. After you have adjusted your receiver and turned on the set, rotate the dial of the unit until the station is heard. An adjustment of the VOL control may be necessary. A readjustment of the receiver dial, unit dial and VOL control will prepare the station for logging. The Vol control is all-important in its use and a little practice will enable the operator to master the setting for maximum range. This additional control with the unit permits the additional selectivity and range which is lacking in the average receiver. To disconnect the unit from service merely remove the antenna wire from #1 and fasten to the regular post of your receiver. Turn off the unit by adjusting the VOL control to zero position. (This applies with D. C. receiver only. When an A. C. set is used it is necessary to remove the tube from the unit or the plug from the set.) As an experiment, remove grid leak and condesner from unit panel and connect the long metal link furnished across the terminals "B" and "G". This procedure may be necessary with some types of receivers.

No. 4 EXTRA STAGE TUNED R. F., PRE-AMPLIFIER, BOOSTER.
A. C. RECEIVER.

Grid leak and condenser remain in position across "B" and "G". Connect red wire of plug to #7, black to #8, yellow to #5. Insert extra 226 type tube in socket "T" of unit. Plug in large coil to socket "C". Remove antenna from receiver and fasten to #1. Connect a wire from ground post of receiver to #2. Connect a wire from #4 to Antenna post of receiver. Remove 1st R. F. tube from receiver and plug in to socket of plug. Insert plug, along with tube, in 1st R. F. socket of receiver. FIL control is set at Zero position.
OPERATION: Same as when unit is used with D. C. Receiver.

No. 5 SHORT WAVE ADAPTER OR CONVERTER.
D. C. RECEIVER -- 199, 201-A, 200-A Type Tube

Grid leak and condenser remain connected across "B" and "G" on unit. Connect red wire of plug to #7, black to #2, yellow to #6. The green wire is not used in this instance and care should be taken that the exposed end does not make contact with any other wire. Remove detector tube from receiver and insert in socket "T" of unit. Insert plug in detector socket of receiver. Remove antenna from set and connect to #1. Fasten ground wire to #2 along with black wire. Should you use a B eliminator with variable detector control, increase the voltage to about 67 1/2 to 80 volts. When B batteries are used the increase in detector voltage can easily be made. With the 199 Type Tube receiver the control FIL is adjusted to position 3 on scale. With the regular or standard 6 volt tube receiver the FIL control is adjusted to "full on" position - about 7 1/2 on the scale. Try Ant. on #1 or #3.

OPERATION: The object in increasing the detector voltage is to permit easier tube oscillation. Due to the extreme sharpness in tuning and for fear that the weaker signals may be passed, a pair of ear phones are almost necessary. These are attached to the set in place of the speaker. When the volume of a station is sufficiently great the speaker may be used. The change-over may require a slight adjustment of the unit dials. To determine whether the unit has been correctly connected and is ready for S. W. operation, insert the large coil in socket "C". Turn on your receiver and rotate the dial of the unit until a signal is heard. When this is accomplished replace the large coil of unit with the small coil. Adjust the VOL control of unit to zero position. A hissing noise should be heard in the phones. This will indicate that the tube is oscillating. By readjusting the VOL control this oscillation will cease. Remember to keep the unit in an oscillating condition while you are tuning a station. While some tubes are better oscillators than others, select a tube which oscillates freely. The fingers of one hand are placed on the VOL control which is pointed to zero position, the fingers of the other hand are used to rotate the dial of unit very slowly. When a whistle or carrier wave of a station is heard, increase the VOL for clarity. The proper adjustment of the tuning dial, VOL and FIL will prevent hand capacity. The dials of the receiver are not used and in some cases the tubes may be removed from the R. F. sockets should an increase in volume result. As an experiment, connect #3 and #4 together by means of the short metal link furnished. When this is done the VOL is not used but the regeneration is controled by means of FIL. This is only applicable with a D. C. receiver. When an A. C. set is used the FIL control remains set at zero position. Remember that patience is required. Once you hear a station make note of the dial setting so that it can again be tuned quickly when desired.

No. 6 SHORT WAVE ADAPTER OR CONVERTER.

A. C. Receiver

There are two methods of using this unit with an A. C. receiver. One method is the use of the Walker No. 227 A. C. Adapter Plug, which is quite a convenience and will permit the use of the 5 prong A. C. detector tube. Instructions for the use of this plug are enclosed in each plug carton.

The other method, while not so convenient, is more efficient. This is the use of a separate filament supply and a D. C. tube such as the 200-A or 112-A. A 6 volt storage battery or 4 1-1/2 volt dry A batteries are necessary. Connect the "A" plus to #7 and the "A" minus to #2. Fasten a wire from the ground post of the receiver (the ground wire remains connected to the set) to "A" minus. Connect the small brass contact furnished to a wire and insert the contact in the "plate" terminal of the detector tube socket of the receiver, after the tube has been removed. Fasten the end of the wire to #5. Remove the antenna from the receiver and fasten to #1. The FIL control is adjusted to "full on" position - about 7-1/2 on the scale. Insert the D. C. tube in socket "T" of unit. Operate the unit the same as for the D. C. Receiver, Short Wave Adapter. Try Ant. on #1 or #3.

No. 7 SINGLE TUBE RECEIVER - SHORT or REGULAR WAVE.

(199, 201-A, 200-A type tube)

Grid leak and condenser remain in position. Connect antenna to #1, ground wire to #2. A plus to #7, A minus to #2. Connect B minus to #7, along with A plus. Connect one terminal of phones to B plus 45 and the other terminal of phones to either #5 or #6. Insert tube in socket "T", coil in socket "C". When tuning short waves the small coil is used and a connection is made across #3 and #4 with short metal link. OPERATION: Set "FIL" at position 3 when the 199 tube and 4-1/2 volt "A" is used. With the 6 volt tube and battery, entire range of "FIL" may be used. Set "VOL" at about 2. Rotate dial until a signal is heard. Readjust "VOL", "FIL" and dial for volume and clarity.

No. 8 SINGLE DIAL OPERATION WITH D. C. SUPER HETERODYNE

The use of the unit with a D. C. super heterodyne receiver will permit single dial operation, utilizing the intermediate, detector and audio circuits. Fasten the red wire of plug to #7, black to #2, yellow to #5. The oscillator tube is not used and may be removed from the receiver. Remove the first detector tube and insert in socket of unit marked "T". Insert plug in 1st detector socket. Plug in the large coil to socket "C". The grid leak and condenser remain mounted on panel. Set "FIL" at full on position. Set "VOL" at about 3. The volume control or potentiometer of the receiver should be set at full increase position. Tuning is now done with the dial of the unit. To tune short waves merely exchange coils and connect across #3 and #4 with the short metal link. Read instructions on tuning in No. 1 and No. 5.

No. 9

SINGLE DIAL OPERATION - D. C. RECEIVER

(199 or 201-A Type Tube in R. F. Stages)

Grid leak and condenser remain connected across "B" and "G". Connect antenna to #1. Fasten red wire of plug to #7, black to #2, yellow to #5. Plug large coil in socket "C". Remove 1st R. F. tube from receiver and insert in socket of unit marked "T". Insert plug in socket of set from which tube had been removed. OPERATION: With some receivers it is necessary to connect a wire between ground and #2 of unit, along with the black wire. With the 199 type tube, do not adjust "FIL" beyond 3. With the 201-A type tube, entire use of "FIL" may be made. Adjust volume control of receiver to full increase and set the tuning dial or dials to a reading of about 50. Turn on "FIL". Adjust the "VOL" so that a hissing noise is heard in the speaker. Tuning is now done with the dial of the unit. The use of the "VOL" is important and the operator will become familiar with its effect thru practice. The unit will now function as a "Driver". Local stations will be heard t more than one setting of the dial. Maximum selectivity should result.

No. 9A

SINGLE DIAL OPERATION-A. C. RECEIVER.

(226 type tube in R. F. Stages)

Connect as in No. 9, except that the black wire is connected to #8 instead of #2. The wire between ground of receiver and #2 of unit is now necessary. "FIL" is set at zero position and is not to be used. OPERATION: same as in No. 9.

No. 10

EXTREME FLEXIBILITY POSSIBLE

The advanced radio fan and service man will quickly grasp the opportunities for experiment that this unit will afford. To define each relative use in detail would require a heavy volume on "Radio Theory and Practice". The experienced fan should familiarize himself with the circuit and connections as shown in our folders enclosed in each carton. This, he will find, should prove sufficient to carry on with any experiment which may suggest itself.

No. 11

LOOP - R. F. AMPLIFIER

When a .00035 loop is used no tuning coil is required for the unit. One end of loop is connected to #3 and the other end to "B". The use of the long metal link across "B" and "G" is continued. Should the loop have a center tap, it is to be connected to #2. An antenna coil is necessary in your receiver to use the unit ahead of same. All sets designed for use of antenna and ground have this coil incorporated in the circuit.

No. 12

"AUDIO" OSCILLATOR.

For portability and convenience, a UX 199 tube, 4-1/2 volt C battery for filament supply and a small 45 volt B battery are required. Connect C plus to #2, B plus 45 to #6, C minus to #7 and B minus to #3. Connect #3 and #4 together with short meta link. Set "FIL" at 3. This control is also used as a switch to shut off the unit. When a 201-A type tube is used the connections remain the same but a 6 volt filamen supply is necessary. In this event, full use of "FIL" may be made. OPERATION: A test will determine whether your design of receiver will require the use of grid leak and condenser. When they are not used it is necessary to connect across "B" and "G" with the long metal link. Set "FIL" in position depending upon voltage of tube used. Adjust the tuning dial of unit to about 50 on scale. Turn on your receiver and rotate the dials until the signal transmitted by the oscillator is heard. A squeal or whistle heard in the loud speaker will indicate whether the oscillator is functioning properly. The "pitch" of the signal may be varied by changing the value of the grid leak in use. A simple calibration of the unit may be

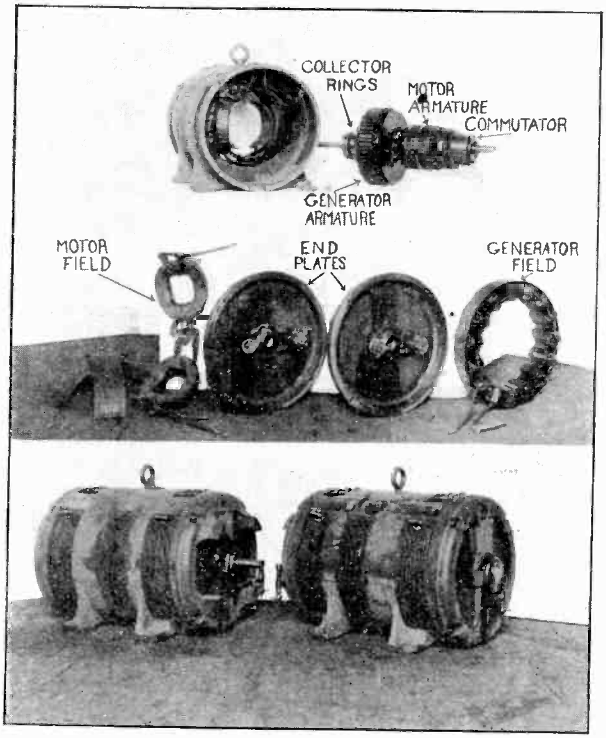

Fig. 41. Exploded and Assembled views of a Two-Kilowatt Five Hundred cycle Motor Generator having Revolving Armature

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

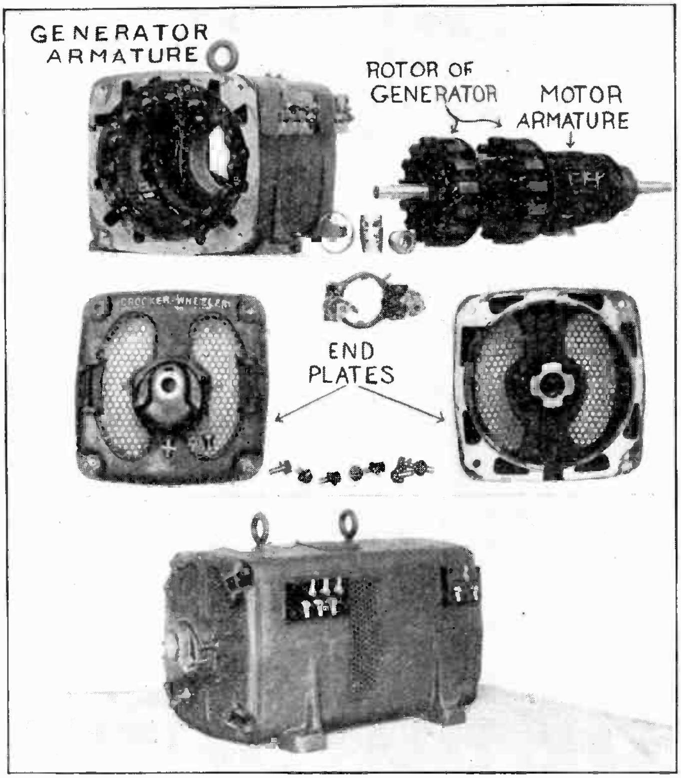

Fig. 42. Exploded and Assembled views of a Two-Kilowatt Five Hundred cycle Motor Generator of the Inductor Type

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

THE MOTOR GENERATOR

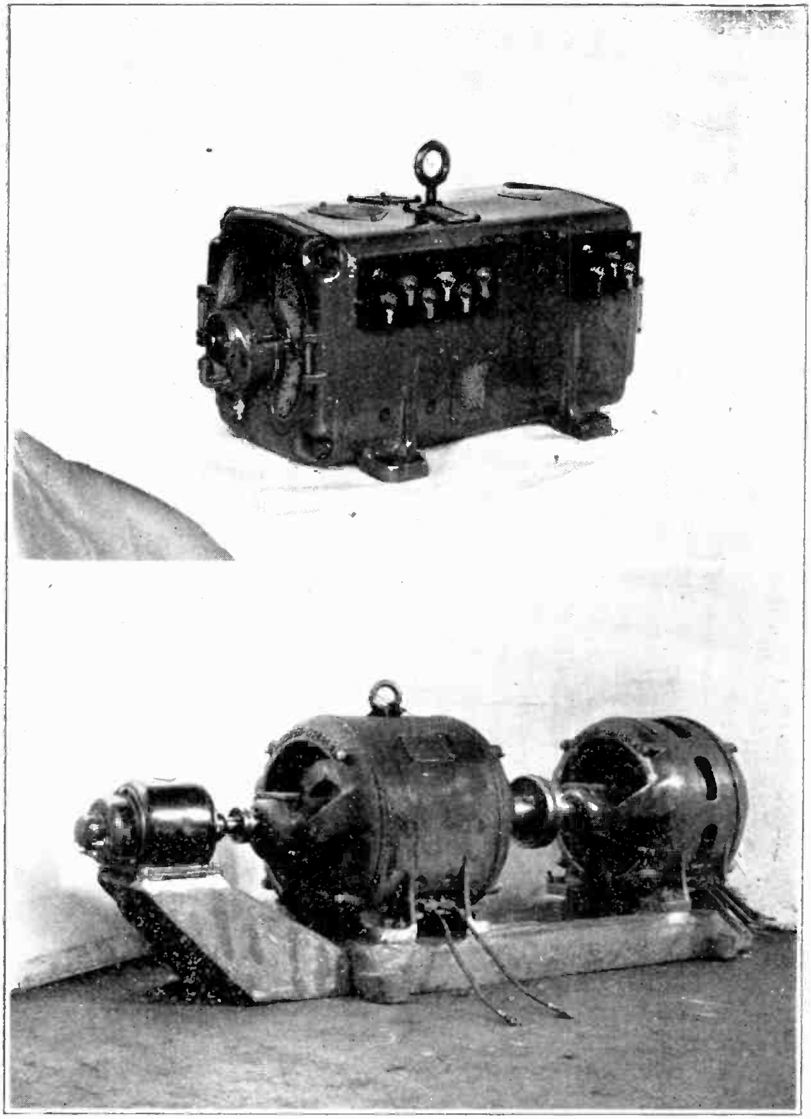

Fig. 47a. Top—Outside view of 500 cycle inductor type Alternator
Bottom—5 K. W. 500 cycles Motor-Generator set with an Exciter mounted on a pedestal at the left-hand end

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

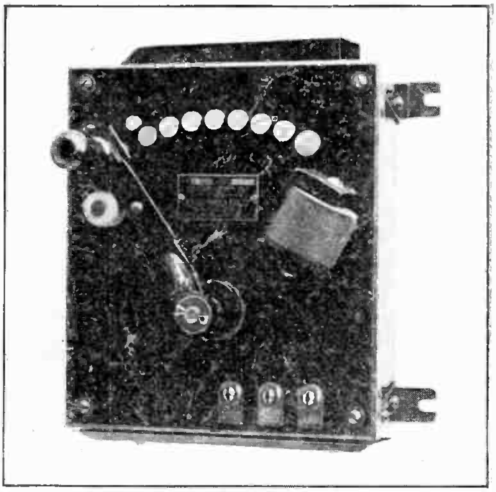

Fig. 48. Cutler-Hammer Hand Motor Starter

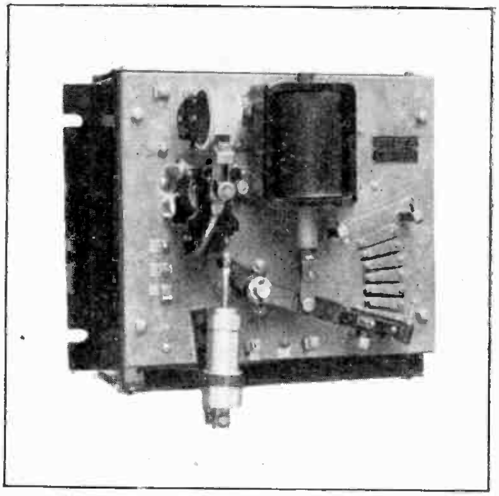

Fig. 49. Cutler-Hammer Automatic Motor Starter

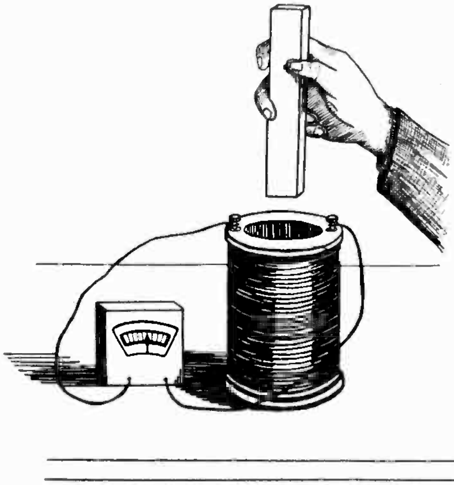

Fig. 21—Electromagnetic Induction.

about a block of wood and connected the terminals to a galvanometer. Another coil was wrapped about the first and connected to a battery. He found, that upon closing the circuit of the coil in series with the battery, that the needle of the galvanometer was momentarily deflected, and upon opening the circuit that the needle was again deflected, but in the opposite direction.

36. This experiment opened up a new field of investigation in electrical science, and the principle deduced from it is of very great importance, due to it being the basic principle of the production of electricity by mechanical motion. One method of demonstrating this principle is illustrated in Fig. 21. If a bar magnet is thrust into a coil of wire, whose terminals are connected to a galvanometer, there will be a slight deflection of the galvanometer needle, and upon removing the magnet an opposite deflection of the needle.

These deflections are due to a flow of current set up in the coil by the action of the lines of force about the bar magnet. If the number of lines of force cutting the turns of the coil are increasing, due to an approaching north pole of a bar magnet, the coil will have a pole of similar polarity induced on the end nearest the approaching pole, but if the magnet is being withdrawn from the coil, the number of lines of force thru the coil will be decreasing, producing a south pole on the end nearest the receding pole. That is, the current induced in the coil by the movement of the magnet, is in such a direction that it will produce an opposing field to an approaching magnet and a field in the same direction as that of a receding magnet.

37. In place of the bar magnet; we may use a coil of wire connected to a battery, as in Faraday's experiment. This experiment is illustrated in Fig. 22. The coil connected to the battery is called the **primary,** while that connected to the galvanometer is called the **secondary.**

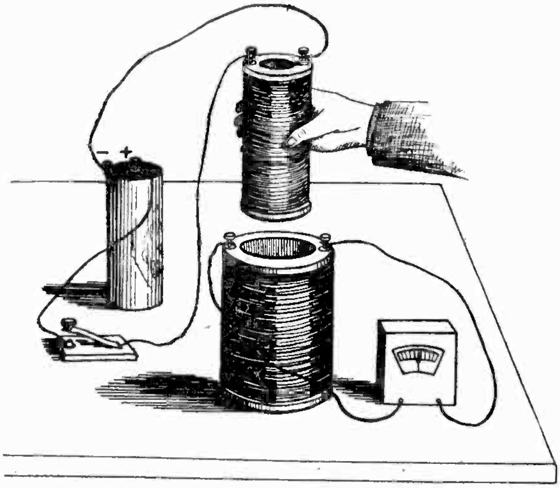

Fig. 22—Electromagnetic Induction.

If the primary is placed within the secondary and allowed to remain stationary, no current will be induced, but if the primary circuit is opened a momentary deflection of the galvanometer will occur. This is due to the current falling from a maximum to a zero value, and consequently a decrease in the number of lines of force about the primary to a zero value.

A similar deflection occurs when the switch is closed, but is not nearly as strong as the deflection resulting from breaking the circuit.

In the experiment described above, the magnetic field has been moving.

38. In a third method, as shown in Fig. 24, the lines of force are stationary and the secondary coil moves. The current is induced by causing the secondary to move through the field in such a manner, that the number of lines of force threading through it are varied. If the coil or conductor passes across the field with a rotary motion, as in Fig. 24, the number of lines of force enclosed by the coil varies, producing a current in it.

39. Laws of Electromagnetic Induction:

1. **A current may be induced in a coil by varying the number of lines of force threading through it.**

This is brought about in two ways: By causing a magnetic field to approach or recede from a stationary coil or by causing a coil to be rotated through the field, so as to vary the number of lines of force threading through it.

2. **The voltage induced in the secondary coil will depend upon the number of lines of force cut per second, and upon the number of turns of wire in the coil.**

3. **If the number of lines of force cutting through the coil is increasing in number, the field produced will oppose that of the bar magnet or primary coil.**

LESSON TEXT No. 7

OF A

Complete Course in Radio Telegraphy

The Transmitting Set

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The Receiving Set for Undamped Waves

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through the armature and thus prevents the burning out of the armature windings.

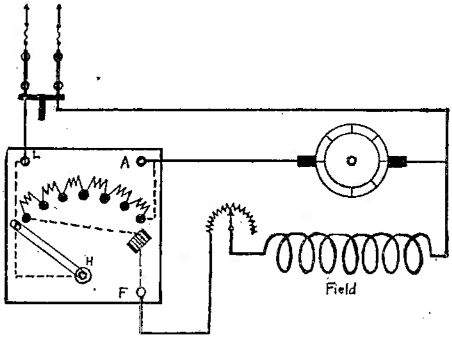


Fig. 47. Cutler Hammer Hand Starter and Connections

Therefore, in starting a motor, some provision must be made to prevent the current from damaging the armature while the motor is developing a counter e. m. f.

If the current should be applied directly to the brushes damage might be done to the commutator and might possibly burn out the armature.

A variable resistance called the motor starter is connected in series with the armature and is so arranged that all the resistance is in series while starting, and which may be gradually reduced until the motor is running at full speed.

At first, the armature current is flowing through all the resistance of the starter and is of a very low value, but small as it is, the armature will turn over slowly and generate a counter e. m. f. of low value. When more of the variable resistance is cut out, the motor revolves faster, generating more counter e. m. f. to oppose the direct current. Thus, the motor starter is a resistance box, all of whose resistance is put in series with the motor armature, when starting, but is gradually reduced over a period of about 15 seconds until the driving current is connected directly to the armature.

THE MOTOR GENERATOR

There are various types of motor starters on the market.

The two principal divisions are:

(1) The Hand Starter.

(2) The Automatic Starter.

The Cutler Hammer hand starter is shown in Fig. 48. It consists of several coils of resistance wire, a handle, contact studs and a small electromagnet. The terminals of the resistance coils are soldered to the studs on the back of the panel. As the handle passes over the contacts on the face of the panel, connection is made to the coils. When the handle is on the first contact, all the resistance wire is in series with the armature and the current flow is a minimum, but as the handle moves over each successive contact, the corresponding resistance coil is removed from the circuit. The small magnet holds the handle in the running position. In case the current in the line fails for any reason, this magnet being in series with the field winding, will lose its power and allow the handle to go back to the off position. This release of the handle, when the current ceases to flow, protects the armature from possible damage in case the current should be again turned on. Usually 15 seconds is sufficient time to start most motors and should not be greater than this because of the danger of burning out the resistance wire.

The General Electric Starter is similar to the Cutler Hammer, the principal difference being the connection to the release magnet, which in the General Electric Starter is connected directly across the line.

The resistance wire in any starter is an alloy of several different metals. German silver wire and other alloys are used in the different makes of starters.

In case the handle of the starting box flies back and the motor stops, the trouble is probably an open circuit in the field, a short circuit in the release magnet or is due to the current being cut off.

If the release magnet should develop a short circuit, the handle may be fastened temporarily in the running position by means of a cord.

In case a resistance coil in the starting box should burn out, the bad coil may be shunted by means of a piece of wire attached to the two contact studs affected. If two adjacent coils are burned out, it may be necessary to renew the resistance by means of lamps connected in series parallel, but due to the fact that motor generators usually start on no load the resistance coils may be shunted and still cause no great damage to the motor.

THE MOTOR GENERATOR

THE AUTOMATIC STARTER:—In recent years automatic starters have been employed extensively in ship wireless sets. By means of an automatic starter the operator merely needs to press a button to start or stop his motor generator, which in some cases is installed in another room, to prevent the noise from its operation to interfere with receiving. The automatic starter usually consists of some form of solenoid operated device.

In Fig. 49 is shown one type of automatic starter used on 2 K. W. sets. A solenoid is arranged so as to cause an arm to move upward and short-circuit the resistance coils. This motion is gradual and serves the same purpose as pulling the handle of the ordinary starter over by hand. To prevent the solenoid from pulling the arm up too quickly, a dash pot is used. A rod attached to the starter arm is fastened to the piston of a small cylinder. As the starter arm moves up, the piston moves also and tends to produce a vacuum in the cylinder, but due to a small leak in one end of the cylinder the arm is allowed to move slowly upward. The cylinder is called a dashpot and in some cases is filled with oil instead of air.

THE FIELD RHEOSTAT:—The function of the field rheostat in the motor field circuit is to vary the speed of the motor and consequently that of the generator. The immediate effect of the field rheostat is the variation of the current flow in the field windings and as a result of this an increase or decrease of the number of lines of force set up about the field poles.

The motor armature in revolving as a motor also acts as a generator and the voltage thus produced causes a current to flow in opposite direction to the current that drives the motor. The voltage of any generator is proportional to the rate of cutting of the lines of force in the field. Hence the counter e. m. f. produced in the motor armature depends upon the change in number of the lines of force brought about by variation of the field rheostat.

The amount of current flowing into the motor armature depends upon the magnitude of this opposing e. m. f., and as the speed of the armature is dependent upon the amount of the driving current that flows into the armature, a weakening of the field by means of the field rheostat will cause the motor to speed up and a strengthening of the field will cause the motor to slow down. To state the matter more briefly: An increase in the value of the resistance in the motor field will increase the speed of the motor, while a decrease in resistance of the rheostat will decrease the speed of the motor.

THE MOTOR GENERATOR

A decrease of resistance in the generator field winding will increase the current through the generator field and thus increase the number of lines of force.

The revolving armature will cut through this increase in number of the lines of force and generate a higher voltage. A decrease of current flow in the field has an opposite effect on the voltage.

As the power of a generator depends upon the product of its volts and amperes, the power may be varied by means of the generator—field rheostat.

The power may also be controlled by variation of the speed of the armature, but if a constant frequency is desired it will be necessary to maintain a constant speed of the revolving armature.

As one cycle is produced by the armature passing two adjacent field poles, the number of cycles per second depends on the number of revolutions per second and on the number of field poles. The number of revolutions of the generator is governed by the motor field rheostat.

The frequency of a machine having a revolving armature may be calculated by means of the formula:

$$F = \frac{N \times S}{2}$$

Where:

F equals frequency in cycles per second.
N equals number of field poles.
S equals revolutions per second.

The Marconi 240 cycle type of motor generator is designed to have an armature speed of 2400 revolutions per minute or 40 revolutions per second.

The number of field poles may be calculated by substituting the above data in the formula given above.

$$F = \frac{N \times S}{2}$$

$$240 = \frac{N \times 40}{2} \quad \text{or } N \times 40 = 2 \times 240$$

$$40\ n = 480$$

$$n = 12 \text{ field poles.}$$

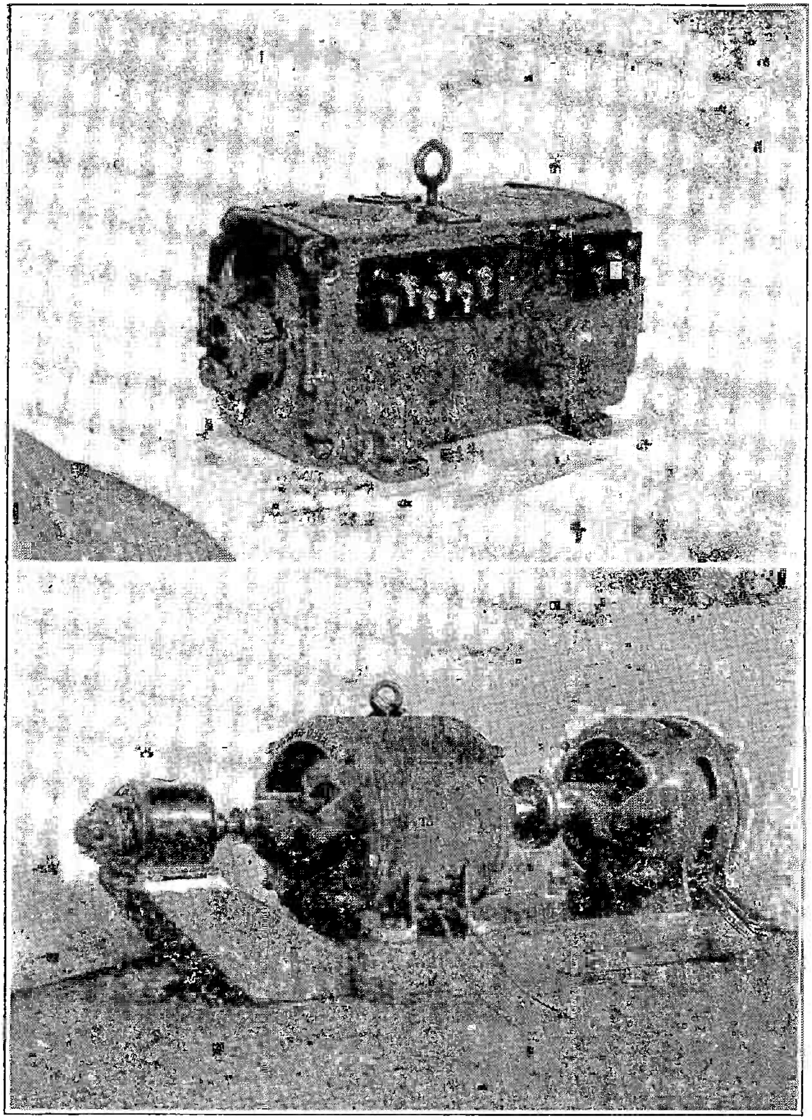


Fig. 47a. Top—Outside view of 500 cycle inductor type Alternator
Bottom—5 K. W. 500 cycles Motor-Generator set with an Exciter mounted on a pedestal at the left-hand end

Courtesy of Crocker-Wheeler Company, Ampere, New Jersey

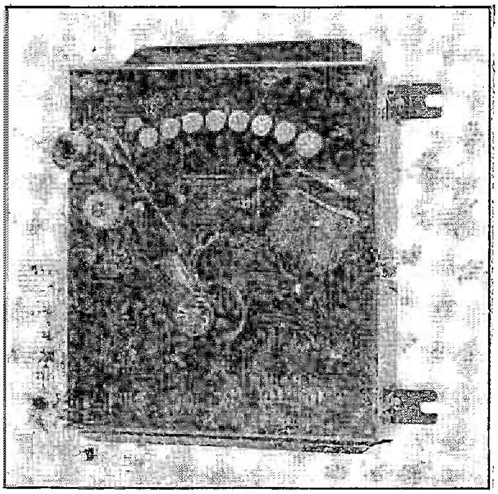


Fig. 48. Cutler-Hammer Hand Motor Starter

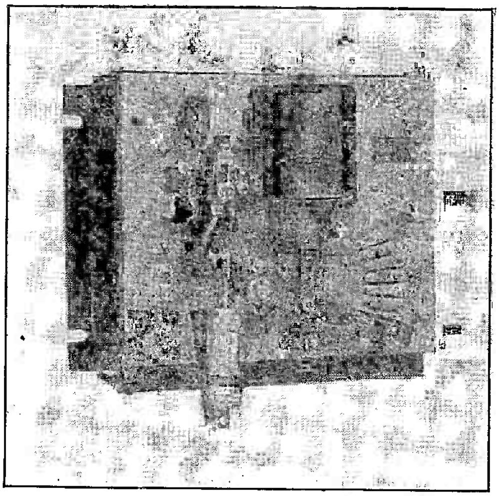


Fig. 49. Cutler-Hammer Automatic Motor Starter

THE MOTOR GENERATOR

The student should take note of the fact that there are two principal quantities to be varied in the operation of a motor generator. The **frequency** of the generator is varied by means of the **motor field rheostat** and the **voltage** of the generator by means of the **generator field rheostat.**

The field rheostat is merely a variable resistance wire wrapped on a rectangular piece of slate and a slider arranged so as to make contact with the different turns. When connected in series with the field windings one terminal of the field coil makes connection with the slider and one end of the coil makes connection with the source of direct current. As the slider moves over the coil more or less number of turns are included in the circut, varying the strength of the current flow in proportion.

PROTECTIVE DEVICES:—Whenever a wireless set is in operation, high frequency, high voltage currents flow in certain circuits. On acount of the high voltage circuits being parallel at certain points to the motor generator circuits, dangerous voltages may be induced in the latter. The insulation of the motor generator windings is not designed to carry currents of high voltage and frequency and thus there is constant danger of breakdown unless protective measures are taken.

The stray currents induced in the motor generator windings in seeking the shortest possible path to the ground, may jump from the field windings to the frame, or from the armature to the shaft and in thus puncturing the insulation, a path is made for the low voltage currents which operate the motor generator. A protective measure used to neutralize this induction from the high frequency circuits is to install all wiring in metal conduit. This conduit is grounded and will conduct to earth all stray currents induced in it.

An important device for the protection of the set consists of two one-half microfarad condensers connected in series and is called a protective condenser. The middle connection of the two condensers is connected to earth and the two remaining terminals are connected either (1) across the armature of the motor, (2) across the armature of the generator, (3) across the field and frame of motor, (4) or across the field and frame of generator. This device, shown in Fig. 50, will allow high frequency, high voltage currents to flow through it to the earth, but will not allow the low voltage, low frequency currents to pass. Fuses may be connected in series with the condensers to protect the motor generator in case of a short circuit of a condenser. In case of such short circuit the low voltage current of the motor generator will in passing through the protective condenser, blow the fuse and prevent breakdown of the set.

Another device shown in Fig. 51 that serves the same purpose as the protective condenser is the protective resistance rod. It consists of a graphite rod of about 6000 ohms resistance, having its middle point connected to the ground, and the two end terminals connected to the same points as given above for the protective condenser. The graphite rod will conduct the high voltage, high frequency currents to the ground, but due to its high resistance it will not conduct the low voltage currents flowing in the motor generator.

Upkeep of Motor Generator:—The parts of a motor generator most likely to give trouble are the bearings, commutator and the collector rings. Lack of oil or improperly fitted bearings will cause heating and unless the trouble is corrected will cause the shaft to ''freeze'' in the bearings. The commutator and collector rings are also a frequent source of trouble due to sparking. The common cause of sparking at the commutator are:

1. Brushes bearing unevenly on the commutator.
2. Grooved commutator.
3. Raised insulating wedges.
4. Brushes not being in neutral field.
5. Open circuit in armature.
6. Dirty brushes or commutator.
7. A partially short circuited field coil.

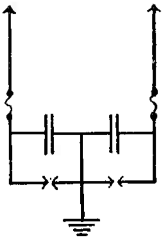


Fig. 50. Protective Condensers.

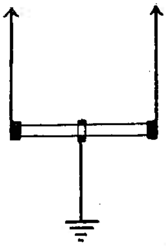


Fig. 51. Protective Resistance Rod.

THE MOTOR GENERATOR

The collector rings may also give trouble from sparking, caused by dirt or grease.

The attention required by a motor generator is fully covered by the following list of rules:

1. Keep the motor generator dry and free from dust and grease.

2. Keep all connections tight.

3. See that thrust bearings on the end of the bearings prevents end play of the armature.

4. See that protective condensers or protective resistance rods are properly connected and that they do not come loose from vibration.

5. Keep bearings well oiled and see that rings carry oil properly. The bearings should be inspected every day.

6. Keep a close watch on the valves of the petcocks to see that they do not jar loose and allow the oil to leak out.

7. Keep contacts of automatic starter clean and properly adjusted.

8. See that brushes fit evenly. To make them fit, place a piece of sandpaper between commutator and brush with the rough side up and then pull backward and forward until brush fits the curved surface of the commutator.

9. Keep commutator clean and polished. Clean with fine sandpaper, never with emory cloth. Polish with a coarse piece of canvas.

10. Do not over-speed motor. After operating set for a time, the sound will indicate the proper speed.

11. In case of burn-out of coils in field rheostat or starter, shunt by means of a piece of copper wire.

12. If necessary to remove armature, remove generator end plate, and then in removing armature, be careful of commutator connections.

THE MOTOR GENERATOR

QUESTIONS

INSTRUCTION PAPER No. 5

These questions should be answered in ink on the standard letter size sheet of paper (eight and a half by eleven inches).

The student's name and initials, address and his class number must appear at the top of each sheet.

The questions should not be written out, but the number written down and the answer written immediately after it.

The student must not copy his answers word for word from the paper, but above all things be fair with himself.

101. What is a motor generator?

102. Why is a motor generator required aboard ship?

103. What kind of field excitation is necessary for the generator?

104. What is an inductor alternator?

105. What three principal types of motor generators are in use?

106. Give circuit diagram of the differentially compounded motor and simple alternator type.

107. What is the function of the differential field winding?

108. What is a dynamotor?

109. What is a rotary converter?

110. Explain briefly the action of the motor starter.

111. Give a diagram of the Cutler Hammer Starter.

112. What are the advantages of the automatic starter over the hand starter?

113. What is the function of the motor field rheostat?

114. What is the function of the generator field rheostat?

115. How many poles would be necessary for a generator delivering 120 cycles at 2400 revolutions per minute?

116. In what two ways can the voltage of a generator be controlled?

117. Why is it necessary to use protective devices on the motor generator?

118. Describe the protective condenser.

119. Name five causes of a sparking commutator.

120. How often should the bearings of a motor generator be inspected?

CORRESPONDENCE COURSE

NATIONAL RADIO INSTITUTE

1345 PA. Ave., N. W. WASHINGTON, D. C.

Answers to Instruction Book No. 5

101. A motor-generator is two electrical machines, belted or directly connected together for the purpose of changing current into another current with different characteristics.
102. To change 110 D. C. ship power into 500 cycle A. C. current for wireless energy.
103. Direct current field excitation.
104. An inductor alternator is constructed with both field and armature coils on the outer stationary frame, while the motor contains the project steel poles.
105. 1st. Shunt motor with simple alternator.
     2nd. Shunt motor with compound wound alternator.
     3rd. Differential wound motor and simple alternator.
106. See Figure 45.
107. To reduce the resultant field strength as the load increases, which will increase the speed to counteract the decrease in speed due to this load, finally resulting in a constant speed motor.
108. A dynamotor is a machine with one field, one armature having two windings. One winding receives electrical energy to drive the armature and current with new characteristcs are taken from the other winding.
109. A rotary converter is an electrical machine with one field, one armature with one winding. A. C. or D. C. is supplied to it for operation, and the opposite kind of current, with a fixed ratio of voltage, is drawn from this winding.
110. The handle of the starter is moved onto the first round brass contact, now several coils of resistance wires are in series with the armature; as the handle is moved over the contact points the resistance is removed from the circuit and full voltage is placed on the revolving motor amature. The handle is held in this position by the small field magnet coil which is in series with the motor shunt field. If the power goes off the lines, this field magnet loses its current and releases the handle and a spring pulls this back to the starting position.
111. See Figure 47.
112. The automatic starter works by the simple pushing of a switch button and it causes a smooth, even acceleration of the motor to its full speed.
113. The motor field rheostat regulates the speed of both motor and generator, which in turn determines the generator frequency in cycles which should be maintained constantly at approximately 500 cycles.
114. The generator field rheostat regulates the A. C. voltage of the generator.
115. F=P x R.P.M.-:-120 or 120=P x 2400-:-120 or P=120-:-20=6 poles.
116. The generator voltage can be controlled by the generator field current or by the speed of the generator armature.
117. To protect the motor and generator windings from heavy electrical pressures and surges which might be induced in the wire leading to these machines.
118. The Protective condenser device consists of two condensers joined in series and connected across the motor or generator armature. A ground connection leads from the mid point between these two condensers.
119. Causes for a sparking commutator are brushes out of position, dirty commutator,a raise bar or mica strip, a burnt-out or open armature coil, improper fitting of the brushes.
120. Inspect the bearing whenever the set is operated.

Student No.
13794

George J. Gunderjahn
West Salem Ohio

Lesson No. 5.

No.

101 a motor generator is a machine used to change direct current to alternating, alternating to direct and direct current at one voltage to direct current of another voltage.

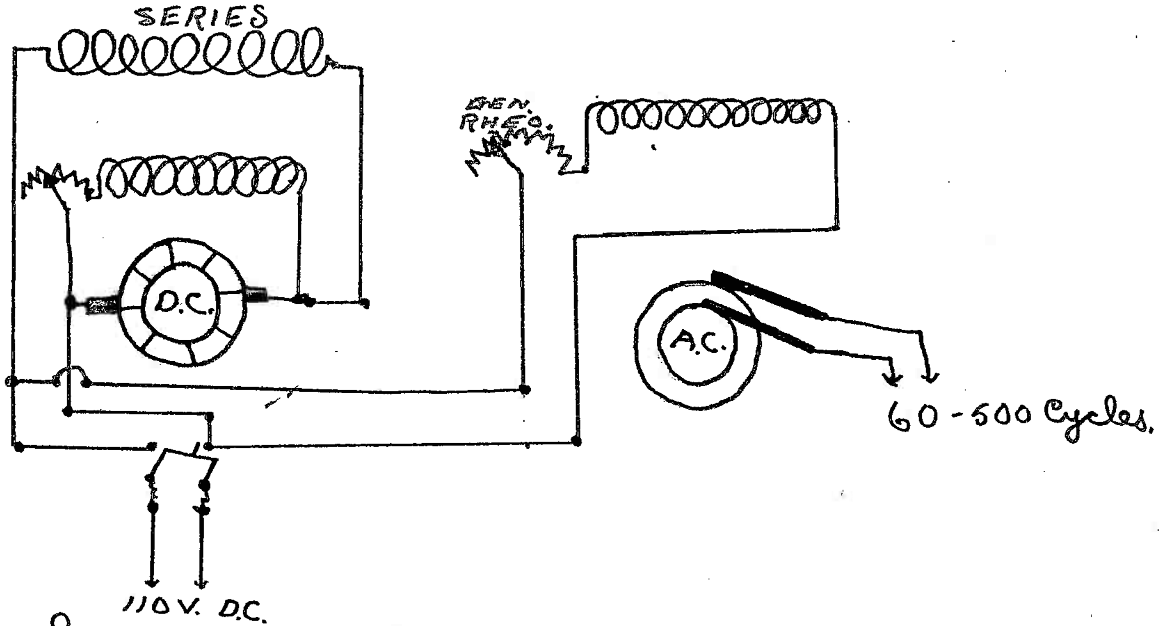
102 Because in most all ships the electrical plants furnish direct current and so some means must be used to change it to alternating current before it will run the wireless transmitter set. For this conversion a motor generator is used.

103 a direct current is necessary for the field excitation of a generator.

104 an inductor alternator is a generator having no revolving coils. The armature coils are arranged around the inner surface of the frame in two circular rows, between these two circular rows the field coil having the same diameter as the armature coils is placed. The revolving core is laminated to prevent eddy currents. The core has teeth radiating outward from the center, when this revolves it alternatingly cuts the lines of force of the field coil and induces a current of electricity in the armature coils. The frequency of this machine depends upon the no. of armature coils. The teeth on the revolving core are equal in No. to the No. of armature coils.

105 1. Shunt wound motor and simple alternator
2. Differentially compounded motor and simple alternator.
3. Shunt wound motor and accumulately compounded alternator

106



107 The function of the differential field windings is to maintain a constant speed and therefore a constant frequency of the generator current.

108 The Dynamotor is a machine for changing a direct current to an alternating current or a direct current at one voltage to a direct current to another voltage. it consists of one armature with two windings on it, one winding is connected to a commutator the other to collector rings. Direct current is supplied to one winding on the armature driving it as a motor, The other winding being wound on the same core cuts the lines of force set up by the field magnets has an alternating current set up in it. this current is carried to the external circuit by the collector rings.

109 The rotary converter has only one armature winding on the core one end of which is connected to a commutator. the other to collector rings. a direct current entering at the commutator causes the armature to revolve as a motor. and on account of the armature passing through the field has an alternating current inducted

in it. this current is then carried to the external circuit by means of the collector rings.

110 The action of the motor starter is to prevent the burning out of the armature windings. this is done by starting the motor slowly with all the resistance in series with the motor. this resistance is successifully cut out as the motor gains speed The faster the motor goes the greater the opposing E. M. F. generated in the windings will be. this counter E.M.F. opposes the direct current preventing the motor burning out. thus a starter is a resistance box, all of whose resistance is in series when starting, but is gradually reduced until the current is directly connected to the armature.

111

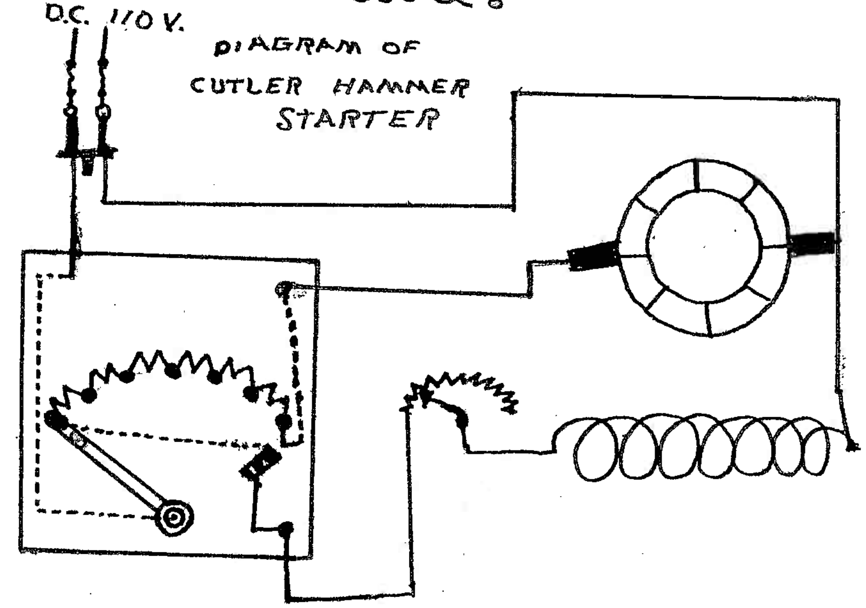


DIAGRAM OF CUTLER HAMMER STARTER

112 The advantages of the automatic starter over the hand starter are

The conveniance in operating the starter by a single push of a button.

This starter also allows the exact time necessary for the cutting out of the resistance in series with the motor.

Student No
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George J. Guderjahn
West Salem Ohio

113 The function of the motor field reostat is to vary the speed of the motor and therefore the speed of the generator. this causes a variation of the current flow in the field windings, this results in an increase or decrease in the No. of lines of force set up about the field poles.

114 The function of the generator field reostat is to vary the voltage of the generator.

115 $F = \frac{n \times S}{2}$ F = frequency in cycles per. second.
n = No of poles
S = revolutions per second.
2400 revolutions per. minute = 40 revolutions per second
120 cycles per. second
{to find the No. of field poles.}

$$120 = \frac{n \times 40}{2} \quad \text{or} \quad n \times 40 = 2 \times 120$$

$$40n = 240$$

$n = 6$ field poles necessary

116 The voltage of a generater may be controlled by means of the generator field reostat.
It may also be controlled by varying the speed of the armature of the generator by means of the motor reostat.

117 Protective devices are necessary on motor generators, on account of the high frequency high voltage currents which flow in certain circuits whenever the wireless set is in operation.
This heavy current is sometimes induced in the motor generator circuit and unless a proper ground has been made before hand will destroy the windings of the motor generator or the insulation, which then allows the low frequency

currents of the motor generator to jump to the frame putting the machine out of order.

118 The protective condenser consists of two one half microfarad condensers connected in series. The middle connection is then grounded to the earth. The two connections left are then either connected across the armature of the motor, across the field and frame of the generator across the field and frame of the motor or across the armature of the generator. this device allows the induced high frequency, high voltage current to pass to the ground, but will not allow the low frequency, low voltage currents to pass.

119 Five causes of sparking at the commutator are.

1. grooved commutator
2. brushes bearing unevenly on commutator
3. Brushes out of neutral position
4. Dirty commutator or brushes.
5. Open circuit in armature.

120 The bearings of a motorgenerator should be inspected every day.

LESSON TEXT NO. 2

OF A

Complete Course in Radio Telegraphy

Electrical Units
The Electric Current

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THEORY AND CODE LESSON NO. 2

In studying this course, you will find yourself progressing step by step from the simplest principles and problems in electricity to the most intricate ones. Naturally your ability to solve the lessons following will depend largely on the concentration and effort devoted to these.

If you have difficulty, don't get discouraged. It is a common saying that the value of anything is in direct proportion to the difficulty encountered in attaining it. Therefore, if you have trouble in mastering any part of this lesson, or any lesson for that part, you are merely improving yourself and testing your determination to go thru to the finish.

* * *

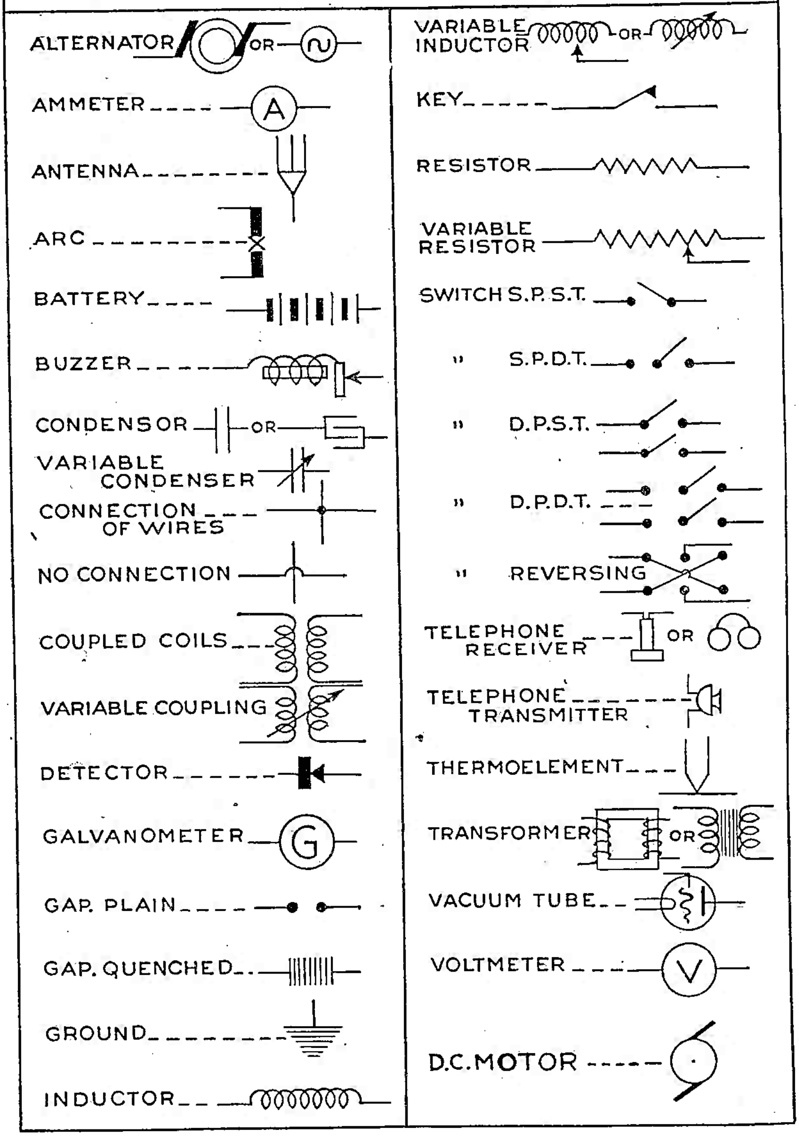
Turn again to the code alphabet in the first assignment of material and practice those symbols until you can repeat from memory the exact symbol which represents any letter of the alphabet regardless of the order in which they come to your mind.

Now practice sending this article on the key and buzzer being careful not to sacrifice speed for accuracy and always making sure that the interval between words is properly proportioned to the length of the dots and dashes you are sending.

> "We live in an age of split seconds. Wireless messages may now be transmitted and received practically between any two points on the surface of the earth in a fraction of a second. This is the amazing progress since the first workable wireless apparatus was invented twenty-five years ago by Marconi. Six years later he sent the first wireless signal across the Atlantic from Cornwall to Newfoundland. On that historic occasion he could transmit nothing except repetitions of the letter S, but in another two years he sent complete messages."

You are now ready to turn to your second theory lesson and learn about electric circuits and how they are formed. Study carefully the matter following:

KEY TO SYMBOLS OF APPARATUS



THEORY LESSON NO. 2

DIAGRAMS OF CONNECTIONS

For convenience in illustrating graphically the connections of an electrical circuit, certain symbols are used to denote the particular predominant property which that part of the circuit possesses. When several of these symbols are used to illustrate certain connections, it is known as a "Diagram of Connections." At the beginning of this lesson text we give a number of these symbols and certain variations of them which are most commonly met with in Radio Telegraphy.

The student should first read the names of the apparatus and satisfy himself that he knows what it is and the purpose for which it is used. He should then write all the names, numbering them numerically, on a sheet of paper. Now take No. 1, which is the alternator or A. C. Generator represented by the symbol, 2 concentric circles with a heavy black line bearing on each circle. This symbol should be drawn several times on paper until it is thoroughly impressed on the student's mind as the symbol for an alternator.

Proceed in this manner with the remaining symbols until they are all committed to memory. Now, in order to test your accuracy in making these symbols, select a certain order of numbers as 1—3—5—7—9, etc., put the name after these numbers as 1—Alternator, 3—Antenna, etc., then draw the symbol for each without referring to the book. Practice the drawing of these symbols until they can be made quickly, neatly and with accuracy.

This is absolutely essential for future progress in executing the diagrams which show the methods of connecting the instruments and apparatus for a complete radio transmitter and receiver. These symbols are also constantly appearing on the pages of the lesson texts.

ELECTRICAL UNITS

The radio operator and also the radio engineer must have a complete and thorough knowledge of the electrical units which are used in the calculation of radio measurements in determination of power, pressure, current and other quantities used in the transmission and receiving of radio messages. All of the fundamental units will be presented in this book and in as simple manner as possible, so that the student may have a clear understanding of quantity and unit used to represent it in the electrical operations which are performed in radio communication.

One may receive a clear understanding of the common electrical terms by referring to terms which apply to material substances such as the flow of water through pipes. We are all familiar with water pressure which is present in our homes and which is being exerted on the faucets in our sinks. We speak of the water pressure in terms of so many pounds per square inch. That is to say forty-five pounds water pressure means to the engineer forty-five pounds force exerted on each square inch area against which it presses. We have an electric pressure which corresponds to our water pressure and it is being exerted on the ends of the wires which lead to our switches for lighting lamps in our homes. This pressure is measured in volts and not in pounds. The common pressures used in our homes are 110 and 220 volts. All our lamps and household appliances are built to operate on 110 volts. It is necessary that a fixed value of pressure should be adopted as a standard throughout the United States so that people living in one city and having electric utensils such as flat irons, fans, vacuum cleaners, etc., should be able to use the same appliances in any other place into which they might move. These electric pressures are produced by an electric generator, sometimes called a dynamo, located in the main power house. Just the same as water pressure is caused by pumps at the pumping stations. We are all familiar with what happens when the faucet is opened. A stream of water runs out and the amount depends upon the pressure and also the degree to which we open the faucet. Just so is it in the case of the electric pressure. If the switch is turned on so that the pressure may exert its force upon the electric lamps a current of electricity will flow through the lamp and cause it to light or if it is an electric motor the current will flow through the motor and cause it to run.

Now in order that we may measure the flow of water we adopt the term so many gallons per minute as a method of computation. In the case of the electric current we speak of the amperes of electricity which means the volume of flow of the electrical energy. The number of amperes of electricity which will flow through a lamp or other piece of apparatus depends upon two quantities. First, the amount of pressure which is forcing the electricity and second, the resistance with which it meets in passing through this piece of apparatus. In the case of a flow of water we do not think in any definite terms of the resistance with which it meets and we have no definite unit to express this opposition but it is always present and is very noticeable if we place a great many bends and other obstructions in the pipe line through which our water is flowing. In the flow of electricity one must consider very carefully this property of resistance which is present in all electrical conductors and is measured by a unit called ohm.

OHMS LAW

The three units just mentioned, volt, ampere, and ohm derive their names from men who devoted their lives to the study of electricity during the early discoveries in this branch of science. Volta was an Italian who invented the first means of furnishing electric pressure in the form of his voltaic cell, which was the first known source of electrical energy by chemical means. Ampere was a Frenchman who studied the flow of electricity through metals and liquids. Ohm was a German who discovered the law which bears his name and is familiar to every electrical engineer. The law is I equals $\frac{E}{R}$. "I" is the electric current in amperes. "E" is the electric pressure in volts and "R" is the resistance in ohms. This equation should be memorized by the student and he should become familiar with its uses in the many ways in which it is applied to problems that arise from time to time. For example: If one wishes to know the electric current which would flow through the coil of wire of 2 ohm resistance when connected to a 6 volt storage battery he may supply these known values; that is to say six volts for the value "E" and two ohms for the value "R" in this equation and solve for "I" which would be three amperes. In another instance we may have the values of pressure given as 110 volts and the flow of current as 5 amperes to solve for the resistance which would be found again from substitution. That is to say "E" equals 110, "I" equals 5, solving for "R" we obtain the value of 22 ohms. The unit of electrical power is the watt and is obtained by multiplying the amperes by the volts; that is to say "W" equals E x I. This is similar to the measurement of mechanical work where a certain force is exerted through a distance thus accomplishing a given amount of work. If one lifts 100 pound weight up a distance of three feet we say he has done 300 foot pounds of work. In the same way if the pressure of 110 volts forces a current of 2 amperes through a fan motor we say that 220 watts of electrical power has been supplied to the fan. In the measurement of a large amount of electrical power for factories and cities are expressed in terms of kilowatts, one kilowatt being equal to one thousand watts. We have the same example in our home life; that is to say, we buy our sugar and flour by the pound, but in buying coal we order a ton which is equivalent to 2000 pounds. We speak of the capacity of our electrical appliances in terms of watts. For example we have 25 watt, 40 watt, and 60 watt lamps, these values being determined from the amount of electric pressure and current which is supplied to them.

THE ELECTRIC CURRENT

Difference of potential, electromotive force, pressure and voltage are all terms having practically the same meaning.

Potential is a term used to denote that which causes a current to move along a conductor.

An electric potential or pressure is necessary before we can have a flow of current in a circuit. The unit of potential is the volt, and may be defined as that electromotive force, which will cause a current of one ampere to flow through a resistance of one ohm. That is, if an electric cell of one volt electromotive force is used to light the filament of an incandescent lamp having a resistance of one ohm, the current through the lamp will be one ampere. The difference of potential between two points A and B on a wire conducting current is shown in figure 6.

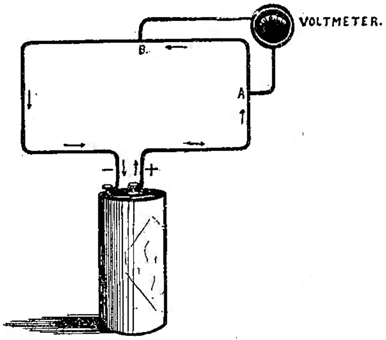


Fig. 6—Difference of Potential

To illustrate electrical potential, we will take the following example: If water will flow from tank A to tank B through a connecting pipe C, we infer that the hydrostatic pressure at A must be greater than that at B, and we attribute the flow directly to this difference in pressure.

Now, if water is not continually supplied to tank A, we know that the pressure at A and B must soon become the same.

Now, take two bodies A and B and connect them by a conducting wire C, it will be found that a charge of positive electricity that passes from A to B or of negative from B to A are of different potential, as we are accustomed to say that the electrical potential is higher at A than at B, and we assign this difference of potential as the cause of the flow. Thus, just as water tends to flow from points of higher hydrostatic pressure to points of lower hydrostatic pressure, so electricity is conceived of as tending to flow from points of higher electrical pressure or potential. Now, if no electricity is supplied to the bodies A and B their potentials very quickly become the same. In other words all points on a system of connected conductors in which the electricity is in a stationary, or static, condition are necessarily at the same potential; for if this were not true, then the electricity which we imagine all conductors to contain would move through the conductor until the potentials of all points were equalized.

Potential depends on:

a. The size and shape of the body.
b. The amount of charge in the body.
c. The presence of nearby charged bodies.

In speaking of the potential of a body we mean the difference of potential which exists between the body and the earth, for the electrical condition of the earth is always taken as zero to which the electrical conditions of all other bodies are referred. Thus a body which was positively charged is regarded as one which has a higher potential than that of the earth, while a body which is charged negatively is looked upon as one which has a potential lower than that of the earth.

MEASUREMENT OF POTENTIAL

Potential is measured by the amount of work necessary to move unit positive charge from the earth to the body.

A simple method of comparing the potential difference which exists between any two charged bodies and the earth, is to connect the charged body successively to the knob of any electroscope which has an outside case of metal connected electrically to earth. (Abbreviated p. d.) If the electroscope is calibrated in volts, its reading gives the p. d. between the body and the earth. Such calibrated electroscopes are called Electrostatic voltmeters. These instruments are the simplest and in many respects the most satisfactory forms of voltmeters to be had. Their use, both in laboratories and in electrical power plants is rapidly increasing. In quadrant form they can measure a p. d. as small as 1/1000 volt and in commercial forms as large as 200,000 volts.

It may be well to say at this time that a large p. d. can be measured without a voltmeter, this can be accomplished by measuring the length of the spark which will pass beteeen the two bodies whose p. d. is sought. The p. d. is about proportional to spark length, each centimeter of spark length representing a p. d. of about 30,000 volts if the electrodes are large compared to their distance apart.

LAWS OF POTENTIAL

a. The presence of opposite charged bodies lowers the potential of the first body.

b. The presence of similarly charged bodies raises the potential of the first body.

The electrical units of measurements are difficult to understand by a single illustration and so they will be presented again in another manner.

22. The electrical unit of current strength or rate of flow is the ampere. The number of amperes in a circuit is a measure of "how big" the current flow is. The student should not confuse this unit with the unit of quantity. Roughly speaking, the amperage of a circuit may be com-

pared to the cross sectional area of a flow of water. The ampere may be defined as that current produced by one volt pressure in a circuit whose resistance is one ohm.

23. The electrical unit of quantity is the coulomb. It may be defined as that quantity of electricity passing a given point in a circuit when the product of amperes and seconds equals one. For instance, if the current in a circuit is one-tenth of an ampere and it flows for ten seconds, the product of amperes and seconds will equal one. That is, a quantity of electricity equal to one coulomb will pass a given point in the circuit. Observe that it requires both amperes and time in seconds to produce coulombs.

24. Resistance may be defined as that property of a conductor by which it opposes the flow of electric current through it.

The unit of resistance is the ohm and may be defined as the resistance of a column of mercury 106.3 centimeters in height, of uniform cross section and weighing 14.4521 grams at a temperature of 32 degrees Fahr. It may be further defined as the resistance of a circuit in which the potential is one volt and the current one ampere.

Resistance depends upon the material, the size and the length of the conductor. For any given conductor the resistance varies inversely as the cross sectional area and directly as its length. In other words, the larger the conductor, the less the resistance; the longer the conductor, the greater the resistance.

Metals usually are of low resistance, liquids of considerable resistance, and pure water of high resistance.

The passage of a current of electricity through a conductor produces heat, the amount of which depends upon the resistance of the conductor and the current strength. In wiring houses for incandescent lighting the size of the wire used will depend upon these two factors. If wire of too small diameter is used, there is danger of the wire melting due to the heat and causing a fire.

ELECTRICAL CIRCUITS

An electrical circuit is a complete path for the flow of electricity as shown in figure 7, sometimes called a closed circuit, and is composed of various conducting substances which may form the parts of electrical apparatus such as an electric lamp, curling iron, vacuum cleaner, flat iron, heater, and many other electrical household appliances which are in daily use. The open circuit and short circuit which were defined in lesson text No. 1 are shown in figures 8 and 9. These electrical appliances and the various wires which are used in connecting them together, may form several different circuits, each of which has its own method of connection and to which there is applied a technical term

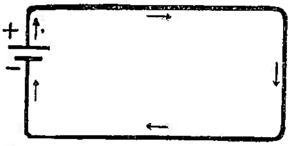


Fig. 7—A Circuit

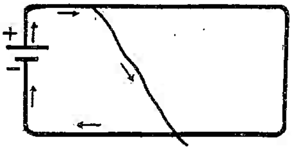


Fig. 8—A Short Circuit

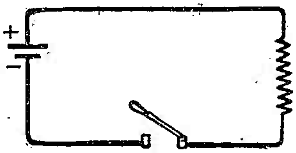


Fig. 9—An Open Circuit

describing the method of its connection. Take for example four coils of wire which may be connected in the following manner:

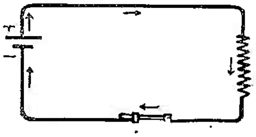


Fig. 10--A Closed Circuit

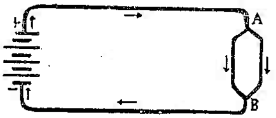


Fig. 11--Divided Circuit

The end of one coil is connected to one terminal of a dry cell, the other end of the coil is connected to one end of the second coil and the other end of the second coil is connected to one end of the third coil, and so on until the three coils are connected together with the end of the last coil joined to the other terminal of the four dry cells as shown in figure 14. These coils are said to be connected in series and the amount of current passing through each coil is the same in amount and direction.

Let us think for a moment of connecting three pieces of pipe in this same manner, that is to say, joining the end of one pipe to the next and so on until the three pieces of pipe form one straight continuous pipe for a flow of water which might be furnished by a tank to which one end of the series group of pipes were joined. Now if there were ten gallons of water flowing out of the tank into the first pipe each minute there would be a flow of ten gallons through the first, second and third pipes and this would be the amount of water which would run out at the end of the last pipe. The flow of current through the coils of wire is exactly like this flow of water and we arrive at the final rule of law for the flow of current in a circuit. That is to say, that the flow of current measured in amperes is the same in all parts of a series circuit.

Now in regard to the pressure or electric force for the entire circuit, we may find this value by adding together the pressures consumed or used up in each one of the coils which will give us the volts of electric power on the entire circuit, or, in other words, the law governing the pressure in a series circuit states that the voltage on the circuit is equal to the sum of the voltages on all its several parts.

Example—In Fig. 12 a divided circuit has two branches, each of 5 ohms resistance. The resultant resistance between A and B is one-half of 5, or 2.5 ohms. In case the divided circuit has unequal resistance this rule will not apply. To calculate the resultant resistance of two or more unequal resistances in parallel it would be necessary to use reciprocals, a branch of mathematics, with which many students are unfamiliar.

Let us now consider another method for connecting these coils. Join one end of all coils together and connect these joined ends to one binding post of four dry cells. Then connect the other ends of the coils together and connect these by a wire to the other binding post of the four dry cells as shown in figure 12. These coils are now said

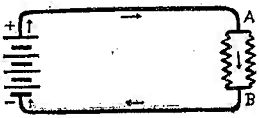


Fig. 12—Resistance in Parallel

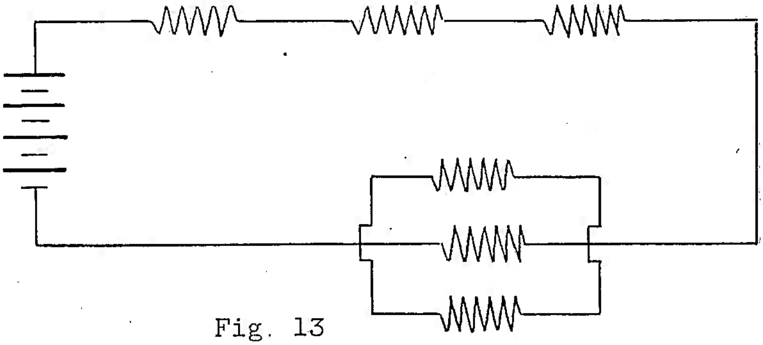


Fig. 13

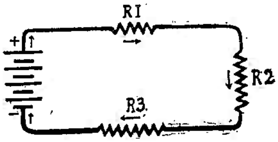


Fig. 14—Resistance in Series

to be connected in parallel. If the student will study for a moment the action that will take place in the flow of electricity, or, if we turn our thought to the case of the coils representing water pipes, one may readily see that the water will divide when it reaches the joining points of the pipes and a small part of the entire water will flow through each one of the pipes. The flow of electricity will be divided in the same manner and a small part of the total current will flow through each of the coils. The total current flowing in a parallel circuit is found by adding together the current flowing in each one of the several branches, while the pressure upon each of the several branches of a parallel circuit is equal in amount as measured in volts. One may make a circuit combining these two arrangements and call it a series-parallel circuit as shown in figure 13.

The three methods of connecting appliances and apparatus in electrical work have been carefully described and illustrated in the above paragraphs and each one of these arrangements has its own particular advantage where a certain result is to be accomplished.

As an illustration. Suppose that we desire to obtain six volts of electric pressure for lighting the lamps on an automobile by the use of dry cells. One dry cell furnishes a pressure of 1 5/10 volts. In order to obtain six volts of pressure it would be necessary to multiply this 1 5/10 by 4, in other words we could use 4 dry cells and connect them in series, thus having a total pressure of the sum of the pressure of the 4 cells added together making the total pressure furnished by this arrangement of six volts. If on the other hand we desired to light a number of electric lamps in a home where each lamp is to receive the same pressure, then it is desirable to connect these lamps, say four or more in parallel across the same two wires which are maintained at a constant pressure of 110 volts. Each lamp will take a certain amount of current say one-half ampere and thus the total amount of current taken by the circuit will be equal to the sum of the current taken by all the lamps. There are other cases where the combination of these two methods are required and the series-parallel connection is used.

27. Ohm's Law—The relation of volts, amperes and ohms in a circuit is expressed very clearly by a law discovered by Dr. S. G. Ohm.

In a given circuit, the strength of the current is equal to the electromotive force divided by the resistance. If we let I equal the current in amperes, E equal the voltage and R equal the resistance in ohms, we may express Ohm's law as follows:

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

In plain language—amperes equals volts divided by ohms. Another form of Ohm's law states that: The resistance of a circuit is equal to voltage divided by number of amperes: That is:

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

Still another form derived from the first states that: The e. m. f. of a circuit equals the product of current in amperes and the resistance in ohms. Symbolically:

$$E = I \times R$$

The following examples illustrate the application of Ohm's law:

Example One—A circuit has a resistance of 10 ohms and a voltage of 110. What is the current in amperes?

Solution—According to the first form of the law—amperes equals volts divided by ohms, therefore, substituting the values of volts and ohms from example one in the formula, we have:

Amperes=110 ÷ 10 or 11 amperes.—Ans.

Example Two—An electrochemical cell gives a voltage of 1 1/2 and is connected to a circuit in which the current is one-half ampere. What is the resistance?

Solution—Resistance equals volts divided by amperes, therefore, 1 1/2 ÷ 1/2 = 3 ohms.—Ans.

Example Three—The resistance of a circuit is 10 ohms, the current is 11 amperes. What is the pressure?

Volts equals ohms times amperes, therefore, 10 × 11 = 110 volts.—Ans.

It may be seen that if two of the quantities used in Ohm's law are known the third may be readily calculated.

In the form $I = E \div R$, we see that to increase current we must decrease resistance or increase voltage.

The volt may be defined as that e. m. f. which will cause a current of one ampere to flow through a resistance of one ohm. Comparing that definition with Ohm's law, $I = E \div R$; if the current is one ampere and the e. m. f. is one volt, the resistance must be one ohm.

Ohm's law forms the basis of many important electrical calculations and therefore the student should thoroughly ground himself in the practical application of this law.

In the form given above, the law is only applicable to direct current circuits.

28. A brief description of primary and secondary cells has already been given in the previous instruction paper. We will describe several of the more prominent primary cells, leaving the secondary cell until later in the course.

The wireless operator seldom has need for detailed knowledge of primary cells, the secondary cell being the most important, in wireless telegraphy.

The Leclanche cell is a primary cell, consisting of a glass jar, small earthenware jar, carbon rod, zinc rod and two solutions. One of the solutions is of salammoniac and is contained in the outer glass jar, while the other solution is a mixture of manganese peroxide and broken gas carbon. The porous earthenware jar contains the latter solution and the carbon plate. The outer jar contains the salammoniac solution and the zinc rod. The function of the porous earthenware jar, surrounding the carbon rod, is to prevent the formation of hydrogen gas on the carbon plate from stopping the current. The cell gives a voltage of 1.48 and will give good service for about 18 months. The cell must then have a renewal of solution and zinc rod.

The Leclanche cell is adapted to a circuit which is only used occasionally, such as an electric door bell circuit. The reason for this is that after the current flows from the cell for a time the carbon element becomes coated with a hydrogen gas, which insulates it, causing the current to drop in value. The porous earthenware jar tends to prevent this film, but is only a partial remedy.

The Edison cell has plates of zinc and black oxide of copper and a solution of caustic potash. The potential of the Edison cell is only .7 volt, but the current output is high.

This type of cell gives better results on closed circuits, that is, on circuits which are closed the greater part of the time.

Dry cells are very important at the present time, due to their use in flashlights and for gas engine ignition. The absence of a fluid gives them many advantages over the fluid type of cell. The dry cell is a form of the Leclanche cell, having zinc and carbon elements and an electrolyte of salammoniac.

The container is a zinc cylinder closed at one end, forming the negative element of the cell. The positive element, of carbon, is in the form of a rod in the center of the zinc shell, but insulated therefrom. Between the zinc and carbon a mixture of carbon, coke and manganese dioxide is placed. The solution of salammoniac forms a paste with the carbon, coke and the manganese dioxide. The term dry cell, applied to this type, is not exactly correct, as it must have a certain proportion of water. To prevent the evaporation of electrolyte the top of the cell is closed with pitch.

29. The term "battery" is used when referring to a number of electrochemical cells connected together. A single dry cell gives about 1.5 volts when new. If two dry cells are connected together by means of a wire, in such a way that the carbon element of one is connected to the zinc element of the other, the potential at the two remaining terminals will be 3 volts, but the amperage will only be that of a single cell.

If the two cells have their carbon elements connected together and their two zinc elements connected together, the potential will be that of one cell alone, but the amperage will equal the sum of the amperage of each cell. That is, if the amperage of one cell is 20, the amperage of two connected as above will be 40.

These two methods of connecting cells are quite important, both in primary and secondary cell circuits. The first method is called the series connection, by which the positive pole of one cell is connected to the negative pole of the next, continuing in this manner until all the cells of the battery are connected. This method is illustrated by Fig. 15. This type of connection gives a potential at the terminals equal to the sum of the potentials of the several cells, while the amperage will be that of one cell only.

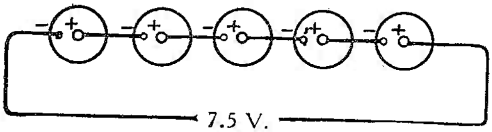


Fig. 15—Dry Cells in Series

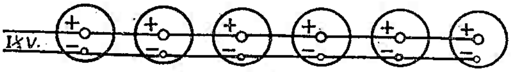


Fig. 16—Dry Cells in Parallel

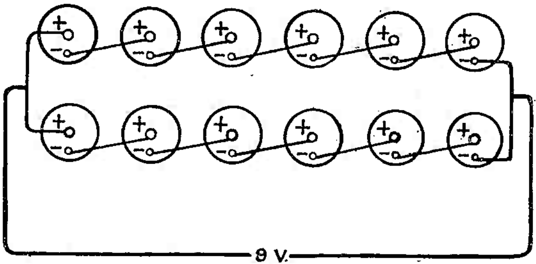


Fig. 17—Dry Cells in Series-parallel

The second method is called the parallel connection and is illustrated by Fig. 16. The voltage, of a battery so connected, is that of one cell alone, while the amperage will equal the sum of the amperage of each cell.

The current output or amperage depends upon the area of the plates in any given type of cell, and that is why the parallel connection gives the increased current. The positive plates being all connected together in the parallel connection, the effect is the same as if the battery were one large cell having a positive plate with a surface area equal to the sum of all the positive plates of the battery.

A third method of connecting cells, illustrated in Fig. 17, is a combination of the first two methods, and is called the series parallel connection. Two or more cells, connected in series, are connected in parallel with another set of an equal number of cells. The two sets in series are called banks, the number of cells in each being equal.

The voltage of a series multiple connection is equal to the voltage of one cell multiplied by the number of cells in one bank, and the amperage is equal to the amperage of one cell multiplied by the number of banks.

Any number of cells may be put in a bank and any number of banks may be placed in parallel.

30. Work may be defined as the overcoming of force or resistance through a distance. If a 10-lb. weight is carried up a ladder, work is done in overcoming the force of gravity. The unit of mechanical work is the foot pound, which is the work done in lifting a pound one foot against the force of gravity.

In electricity, if a current passes through a resistance, work is done and heat is produced.

Power may be defined as the rate of doing work. Thus, one horsepower is that power necessary to raise 33,000 pounds one foot in one minute, or 550 pounds one foot in one second.

The unit of electrical power is the watt which may be defined as the power consumed by a current of one ampere flowing under a potential of one volt. Therefore, to calculate the power consumed in a circuit it is necessary to take the product of the volts and amperes.

Watts = E × I; where I equals current in amperes and E equals voltage.

Example—A current of 10 amperes is flowing in a circuit whose resistance is 10 ohms. Find the power in watts.

Solution—Ohm's law states: I × R = volts.
10 × 10 = 100 volts.

Therefore, substituting in the formula for power: Watts = E × I.
100 × 10 = 1,000 watts.—Ans.

A horsepower is equal to 746 watts, about three-quarters of a kilowatt.

A kilowatt is 1,000 watts.

A watthour may be defined as the work done in a circuit when the product of watts and hours equals one. For instance, if the power is one-fifth watt and the time is five hours, the product of watts and hours will be one—that is, one watthour.

More briefly, it is one watt for one hour. A kilowatt hour is 1,000 watts for one hour. In selling electricity for power or lighting purposes the charge is per kilowatt hour. For instance, the 40 watt tungsten lamp consumes 40 watt hours of current every hour. The number of hours it will burn in consuming one kilowatt hour can be determined by dividing 40 into 1,000, which equals 25 hours.

The product of kilowatts and hours equal kilowatt hours.

In actual practice the number of watt hours or kilowatt hours is measured by an instrument called the watt hour meter.

MEGOHM

PROBLEMS IN POWER AND COST OF POWER

There are many instances in the measurement of resistance when the number of ohms are several millions. The Megohm (1,000,000 ohms) is the unit used to express these large values. For example, 8.25 megohms means 8,250,000 ohms.

The common method of selling electric power is by the unit kilowatt-hour. This value may be found by multiplying the volts times amperes divided by 1,000, then times the number of hours. For example, assume a certain D. C. electric motor requires 2 amperes at 110 volts to operate it and that it runs 8 hours, the kilowatt-hours (K. W. Hrs.) would be

$$2 \times \frac{110}{1000} \times 8 = \frac{220}{1000} \times 8 = \frac{1760}{1000} = 1.76 \text{ K. W. Hrs.}$$

If the price charged for electric power was ten cents per K. W. Hr., the cost of power for running the motor would be 1.76 × .10 = 17.6 cents.

An instrument called the watt-hourmeter is employed to record during the month the total quantity of power in kilowatt-hours which is used in that period. The instrument is constructed very much like a small electric motor with recording dials to indicate the number of revolutions of the armature (or rotating part). The more power that flows through the meter the faster it turns and the number of revolutions also depends on how long the power continues to flow.

The dial reading at the first of one month is subtracted from the dial reading at the first of the next month to obtain the power, in kilowatt-hours, which has passed through it for that period. These kilowatt-hours times the cost per kilowatt-hour is the charge made to the customer.

Answer the following questions on this lesson and also solve the code lesson immediately following and submit your answers to this Institute in the same manner as you did the first lesson. Lessons may be typewritten.

QUESTIONS

Theory Lesson No. 2.

27. What two things are necessary before a current will flow in a circuit?

28. What forms the conducting path of an electric current?

29. What four quantities are used in dealing with electricity?

30. What is a circuit?

31. Define closed circuit, open circuit, and short circuit?

32. Name some common conductors.

33. How are current carrying wires insulated?

34. Name five insulating materials.

35. What is meant by potential?

36. Name the different terms used to represent electromotive force.

37. What is the unit of quantity?

38. How does it differ from the unit of current strength?

39. What is an ohm?

40. What is a divided circuit?

41. A 10 volt battery is connected to a circuit having a 10 ohm, a 12 ohm, and a 15 ohm resistance in series. What is the total value of resistance in the circuit?

42. Explain Ohm's law.

43. Give three ways of expressing Ohm's law.

44. Describe a Leclanche cell.

45. Why is the dry cell of importance?

46. What three methods are used in connecting cells? Explain each.

47. A battery has three cells in series, each cell having an e. m. f. of 1.5 volts. What is the total voltage or e. m. f. of the battery?

48. What is a horsepower?

49. What is the unit of electrical power?

50. How do you calculate the power consumed in an electrical circuit?

51. What is a kilowatt?

CODE LESSON NO. 2

Translate from English into code and submit for correction:

Wire and Wireless Systems Linked.

Conversation between a city home with ordinary telephone equipment, and an airplane in the clouds above it, is forecast by a reported method for connecting wire and wireless systems. The originators do not believe that wireless telephony will ever supplant the present wire system entirely, but they hold that it has its use in communicating with ships, moving trains, islands, and inaccessible places in general.

Correspondence Course
NATIONAL RADIO INSTITUTE
1345 PA. AVE., N. W.   WASHINGTON, D. C.

Translation from English into Code

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ANSWERS TO LESSON TEXT No. 2

27. First, there must be a complete path or circuit; and second, an electric pressure applied to this circuit.
28. A copper wire or some metal conductor.
29. The volt, coulomb, ampere and ohm.
30. An electric circuit is a complete conducting path for an electric current.
31. A closed circuit has a source of current with a completed circuit connected to it.
    An open circuit is a path with a break or gap in it.
    A short circuit is one which by some unexpected means conducts current through a much shorter path than is normally done.
32. Gold, silver, platinum, copper, aluminum and most other metals.
33. By covering the wire with rubber or other insulating substances.
34. Rubber, mica, glass, porcelain and slate.
35. Potential is the difference in electric pressure between two points.
36. Difference of potential, electric pressure, voltage and electromotive force.
37. The coulomb is the unit of quantity of electricity.
38. The coulomb is the total amount, while the ampere is the rate of flow or size of stream flowing.
39. The ohm is the unit of electric resistance for an electric circuit or any part of it.
40. A divided circuit is where the current has two or more paths open to the flow of the current.
41. $10+12+15=37$ ohms resistance.
42. Ohms Law says the current *I* in any circuit equals the volts *E* divided by the resistance *R*.
43. (1) $I=\frac{E}{R}$ (2) $E=I\ R$ (3) $R=\frac{E}{I}$
44. Leclanche cell has a carbon plate in a small porous cup with manganese peroxide and broken gas carbon. This porous cup is placed in an outer glass jar containing Sal-ammoniac solution with a zinc rod.
45. The dry cell is very compact, has no liquid to spill and will stand rough treatment without injury.
46. Series, parallel and series-parallel.
    In the series connection the pressure of the cells add together, while the current output is the same as for one cell.
    In the parallel connection the current output equals the sum of the current for each in the parallel group, but the pressure is equal to that of one cell.
    In the series-parallel the pressure equals the sum of the pressure in each series group, and current output equals the amperes for one cell times the number of groups in parallel.
47. $3\times1.5=4.5$ volts. Ans.
48. One horsepower is the rate of doing work and in mechanical work it is doing 33,000 foot pounds of work per minute. In electrical units it is 746 watts.
49. The small unit of electrical power is the watt, while the kilowatt (K. W. = 1,000 watts) is the large unit.
50. Watts = volts × amperes.
51. 1 kilowatt equals 1,000 watts.

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Student No. 13794 Lesson No 2

Ques No.

27 The two things which are necessary before a current will flow in a circuit are first the circuit must be complete or unbroken from the source back to the source and second there must be a difference of potential between the + and - poles.

28 a complete or unbroken circuit from the + to the - pole forms the conducting path through which an electric current may flow.

29 The four quantities which are used in dealing with electricity are Volts, Amperes, Ohms, and Coulombs.

30 a circuit is a complete or unbroken path for the flow of electricity from the source through the circuit and back again to the source.

31 a closed circuit is one where the electricity has an unbroken path

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from the battery or Dynamo through the instruments and back to the source.

Open Circuit is defined as when the electricity has not a complete path over which it may flow, as when the switch on an electric light is turned off.

a short cirkuit is when the electricity finds a shorter way back to the source instead of through the instruments, this frequently happens in an accidental way as when one conductor falls accross the other.

32 Some common Conductors are Copper, iron, phosphor bronze, german silver, mercury, and carbon.

33 Current carrying wires are insulated in many ways, outside wires are insulated only by several layers of cotton braid saturated with water proofing of pitch. inside ires are covered first with rubber en braid is put over this, sometimes he braid is woven of asbestos.

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Ques no.

34 Five insulating materials are Glass, porcelain, rubber, asbestos, and mica.

35 Potential is used as a term to name that pressure which is necessary to cause a current of electricity to flow along a conductor.

36 Different terms used to represent electromotive force are, voltage pressure, Difference of potential and the abbreviations P.D. and E.M.F.

37 The unit of quantity is the Coulomb.

38 The difference between a coulomb and the unit of current strength which is the ampere is, that it requires amperes and time in seconds to produce coulombs while in amperes, time is not required as it is used to denote only how big the current is.

39 An Ohm is that resistance which allows a current of one ampere

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to pass through a conductor under the potential difference of one volt.

Another way is the resistance offered to an unvarying electric current by a column of mercury at 32° fahr. 14.4521 grams in mass, of uniform cross sectional area, 106.3 cm. in length.

40 A divided circuit is one where the conductor coming from the + pole branches off into two or more conductors which again unite into one conductor leading to the − pole.

41 The total value of resistance in the circuit would be 12 ohms + 15 ohms + 10 ohms = 37 ohms.

42 Ohms law may be explained as the relation of amperes, volts and ohms in a circuit, this is clearly shown by the law discovered by Dr Ohm which is "In a given circuit the amount of current is equal to the E.M.F. in volts divided by the resistance in Ohms.

43 Three ways of expressing Ohms law are

$$\text{amperes} = \frac{\text{Volts}}{\text{Ohms}} \qquad \text{Ohms} = \frac{\text{Volts}}{\text{amperes}}$$

$$\text{Volts} = \text{amperes} \times \text{ohms}$$

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Ques No 44 a Leclanche cell consists of a glass jar, Porous cup, carbon rod, zinc rod 2 solutions and broken carbon into the outer glass jar a solution of Salammoniac is put in, into the porous cup a solution of manganese peroxide and the broken carbun is put the porous cup and its contents are now placed into the solution contained in the glass jar, the zinc rod now placed in the solution contained in the glass jar while the carbon rod is placed in the porus cup the zinc rod is the — pole, the carbon one the + pole.. The use of the porous cup is to stop the formation of hydrogen gas on the carbon rod from stopping the electric current.

45 The dry cell is of importance in that it is portable, non polarizing, and with out a fluid which is easly spilled.

46 The three methods used in connecting cells are series, parallel and series parallel.

The series method is this the + pole of one cell is connected to the — pole of the next and so on as in the drawing:

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The parallel system of connecting cells is all the + poles are connected together and all the − poles.

The series parallel is a combination of the two former methods, two ore more cells are connected in series. they are then connected in parallel with an other set having an equal number of cells as the first, these cells in series are called banks.

47 The total voltage or E.M.F. of the battery of three cells in series, each having a voltage of 1.5 volts would be 4.5 volts.

48 A horse power is that power required to raise 33.000 lbs one foot in one minute or 550 lbs. one foot in 1 second.

49 The unit of electrical power is the Watt.

50 The power consumed in an electrical circuit is found by the unit Kilowatt hour in many cases this method is carried out by multaplying volts X amperes divided by 1000 then times the No. of hours the current was used this gives the no. of kilowatts used, this answer is now multaplyed by the price charged by the company per. K.W. hour

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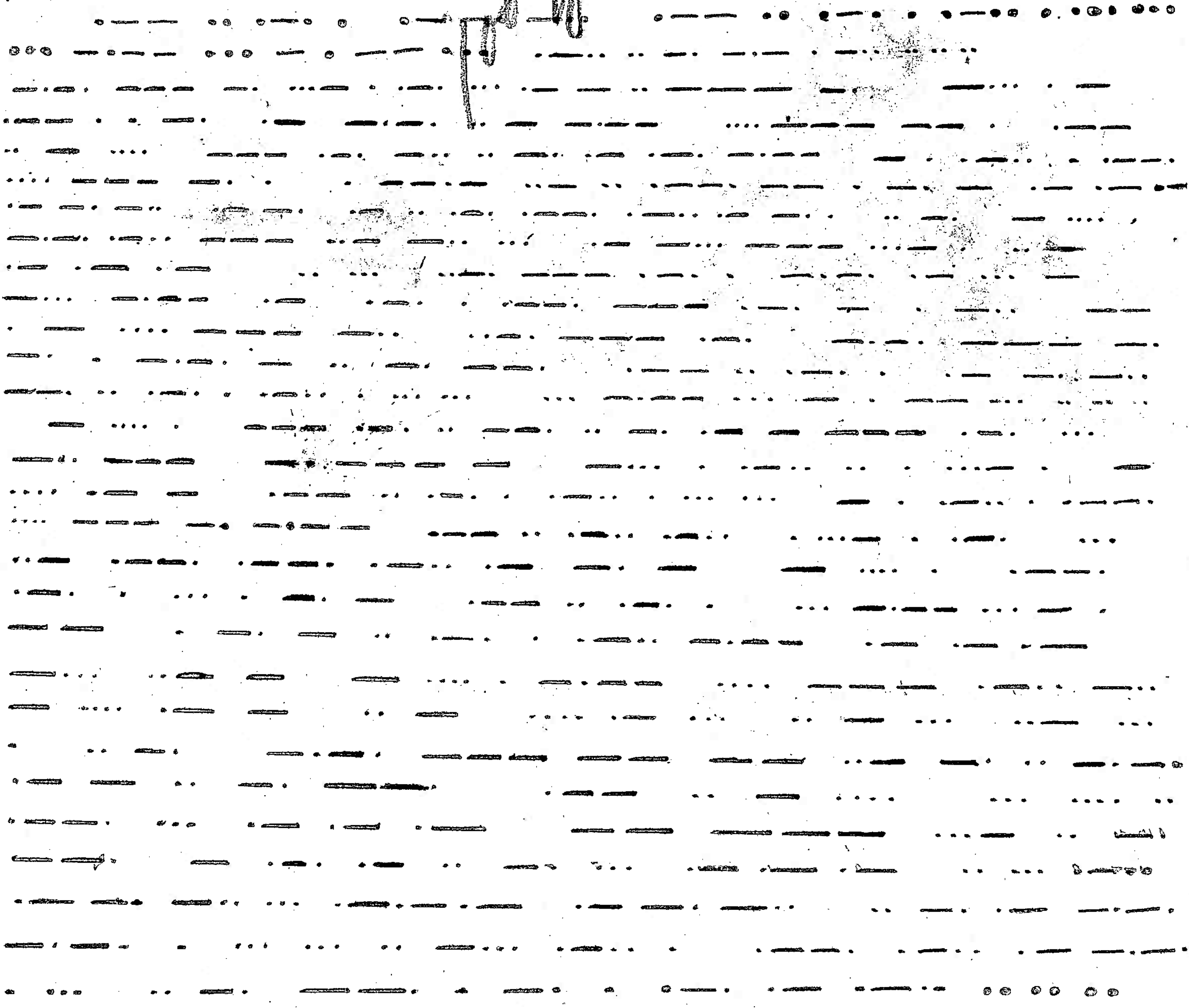
where the amount of current used in a month is to be recorded a watt hour meter is used this consists of a sort of a motor, driving dials on the instrument when more current is used the motor goes faster, when less is used the motor slows up accordingly. The Kilowatt hours are found on this machine by subtracting the last months reading from the present reading the ans. gives the No. of K.W. used that month, this ans. then is multiplied by the charge the electric light company makes per K.W.H.

51 A Kilowatt is one thousand Watts.

Code Lesson No. 2



LESSON TEXT No. 3

OF A

Complete Course in Radio Telegraphy

Electromagnetic Induction Part 1

REVISED EDITION

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THEORY AND CODE LESSON NO. 3

By this time you should know the alphabet well; be able to send the symbol for any letter you may be asked to send without the least hesitation. If you can not do this, turn to lesson one again and practice that alphabet.

You are now ready to take up learning the symbols for the various punctuation marks. Study the symbols as given below and practice them as diligently as you did the alphabet. Continue to practice until you can send the symbol for any punctuation without referring to the text.

Period (.)	•• •• •
Comma (,)	•▬•▬•▬
Semicolon (;)	▬•▬•▬•
Colon (:)	▬▬▬•••
Interrogation or Repeat(?)	••▬▬••
Exclamation Point (!)	▬▬••▬▬
Apostrophe (')	•▬▬▬▬•
Hyphen or Dash (-)	▬••••▬
Bar for Fraction ()	▬••▬•
Parenthesis ( ) Before and after words	▬•▬▬•▬
Quotation Marks (" ") Before and after each word or passage quoted	•▬••▬•
Underline (_____) Before and after words or part of phrase	••▬▬•▬

Now practice sending this article and include all the punctuation marks (periods, commas, etc.) When you have completed, repeat the operation.

> "J. Andrew White, Editor, Wireless Age, recently said this: It is my opinion that we have reached but the inception stage of a wireless era. I am convinced that the young man or woman who undertakes the study of the radio art at this time is embracing the one best opportunity to fill a proper niche in the gallery of epochal world events."

You should now study the theory as given below. Study it thoroughly and make sure that you are not skimming over the definitions and principles but try to fix them in your mind by co-relating them to some everyday events or surroundings which you observe.

THEORY LESSON NO. 3

ELECTROMAGNETIC INDUCTION

31. Under the heading of magnetism the lodestone and the artificial magnet were discussed. We learned that magnets are surrounded by lines of force, these lines of force extending from one part of the magnet, called the north pole to another part called the south pole. The process of magnetizing a piece of steel with a lodestone or with an artificial bar magnet is called **magnetic induction.** A current of electricity can be induced in a coil of wire by a moving magnetic field, and also by moving a coil of wire in a stationary magnetic field. The process of inducing currents of electricity by means of a moving magnetic field, or by moving

a coil in a magnetic field is called **electromagnetic induction.** If a compass is brought near a current carrying conductor the needle of the compass will be deflected to a position at right angles to the conductor, thus indicating that there is a magnetic field about a current flowing in a conductor. A graphic illustration of this field is given in Fig. 18. If a current carrying wire is placed in a vertical position through the center of a piece of white cardboard, covered with a thin layer of iron filings, it will be observed that the fillings arrange themselves in circles about the wire.

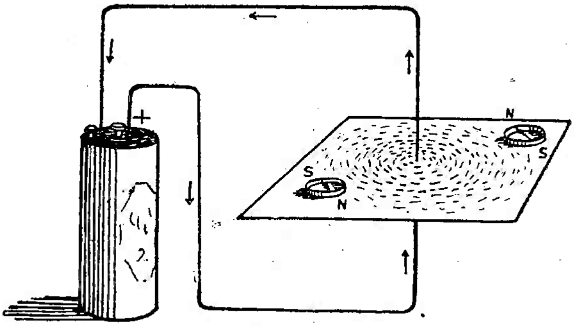

Fig. 18—Lines of Force about a Current-carrying Wire.

These circles are concentric, that is to say, they all have a common center which is the middle point within the conductor producing them, and get larger in size and number according to the increased value of current (measured in amperes) flowing in the wire.

The lines or circles have not only size (length in the circumference) but also have direction. That is to say, the line may be going around the wire to the left (counter clockwise) as shown by the compasses in figure 18, or they may go in the reverse direction, clockwise, in case the current were reversed in the wire by changing the ends where they are connected to the dry cell. In other words, the lines are reverse when the current is reversed and the intensity, or number of lines, change as the current changes in amount.

32. A convenient method of determinating the direction of the lines of force about a current carrying wire may be stated as follows: **If the wire is grasped with the right hand, as shown in Fig. 19, in such a manner that the thumb points in the direction of the current, the figures will then extend about the wire in the same direction as the lines of force.**

3. A **solenoid** is a coil of wire wound in the form of a cylinder. If such a coil has a current flowing through it it will have the same characteristics as a bar magnet. That is, as illustrated in Fig. 20, one end will be a north pole and the other end will be a south pole. **If the coil is grasped with the right hand, with the fingers pointing in the direction of current flow; the thumb will point toward the north pole.**

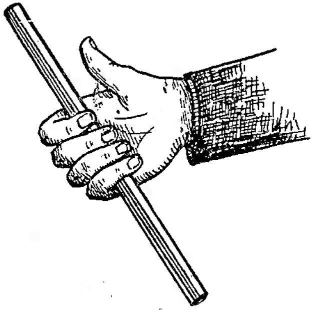

Fig. 19—Right Hand Rule for Direction of Current Flow.

There is another rule which is preferred by some authors and the writer thinks it is less confusing for all cases. It is known as the corkscrew rule and is thus explained. Imagine the point of a screw placed in the end of the wire and now turn this screw so it will move in the direction of the flow of the current. The direction of rotation of the screw will represent the direction of the circular lines of force set up by this current.

Next let us consider what happens when a piece of wire carrying current, as shown in Fig. 19a, is bent into a loop. Let us apply either law and we find the lines are all going away from the observer as we look at the lines on the inside of the loop. If one should insert a round piece of soft iron within the loop, the far end of this iron core would be the north pole of a magnet.

The lines of force about each wire combine to form closed loops extending through the interior and from one end to the other on the outside of the solenoid. The strength of the magnetic field about a solenoid depends upon the value of the current flowing through it, and also upon the number of turns of wire.

34. If an iron core is inserted within the solenoid its magnetizing power will be greatly increased. This increase in power is due to the

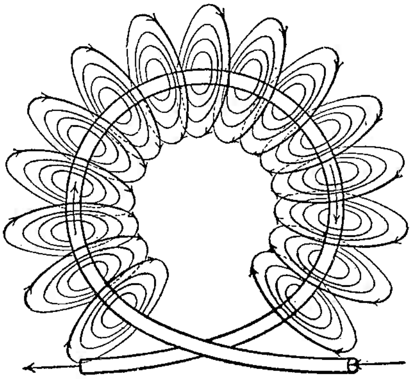

Fig. 19a—Field about a single loop carrying a current.

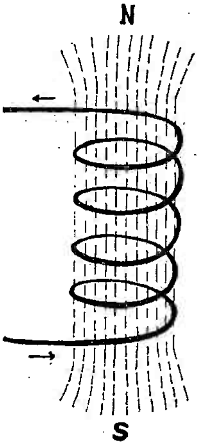

Fig. 20—Lines of Force about a Solenoid.

greater permeability of the iron core as compared with that of air. A solenoid with an iron core is called an **electromagnet,** and may have many turns arranged in one or more layers.

From the preceding paragraphs one may readily conclude the following rule: The strength of an electromagnet depends upon the product of the amperes and number of turns of wire in the coil, termed ampere-turns and also upon the quality of the material making up the magnetic core. For example, an electromagnet with 20 turns of wire carrying 5 amperes would have the same strength if 100 turns carrying one ampere were placed in the iron core. In each case the magnet would have 100 ampere-turns.

Let us turn our attention from the production of magnetic lines by electric currents and consider the effects upon a conductor when it moves upward in front of a north magnetic pole as shown in Fig. 20a. An electric pressure or force called E. M. F. (electric motive force) measured in volts, is induced in the wire. This is the principle of producing electric power in a generator and is called **electric magnetic induction.**

Whenever a conductor cuts magnetic lines or magnetic lines cut an electrical conductor there is induced in the conductor an electric pressure.

35. In 1831 Michael Faraday discovered **the principle of electro-magnetic induction.** In one of his experiments, he wrapped a coil of wire

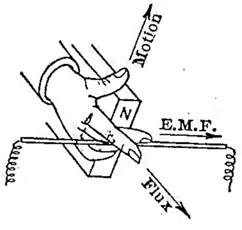

Fig. 20a—Right-hand rule for induced E. M. F.

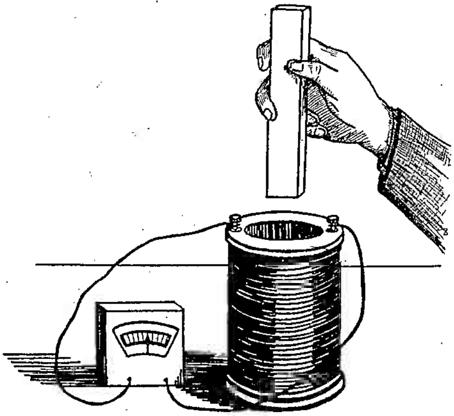

Fig. 21—Electromagnetic Induction.

about a block of wood and connected the terminals to a galvanometer. Another coil was wrapped about the first and connected to a battery. He found, that upon closing the circuit of the coil in series with the battery, that the needle of the galvanometer was momentarily deflected, and upon opening the circuit that the needle was again deflected, but in the opposite direction.

36. This experiment opened up a new field of investigation in electrical science, and the principle deduced from it is of very great importance, due to it being the basic principle of the production of electricity by mechanical motion. One method of demonstrating this principle is illustrated in Fig. 21. If a bar magnet is thrust into a coil of wire, whose terminals are connected to a galvanometer, there will be a slight deflection of the galvanometer needle, and upon removing the magnet an opposite deflection of the needle.

These deflections are due to a flow of current set up in the coil by the action of the lines of force about the bar magnet. If the number of lines of force cutting the turns of the coil are increasing, due to an approaching north pole of a bar magnet, the coil will have a pole of similar polarity induced on the end nearest the approaching pole, but if the magnet is being withdrawn from the coil, the number of lines of force thru the coil will be decreasing, producing a south pole on the end nearest the receding pole. That is, the current induced in the coil by the movement of the magnet, is in such a direction that it will produce an opposing field to an approaching magnet and a field in the same direction as that of a receding magnet.

37. In place of the bar magnet; we may use a coil of wire connected to a battery, as in Faraday's experiment. This experiment is illustrated in Fig. 22. The coil connected to the battery is called the **primary,** while that connected to the galvanometer is called the **secondary.**

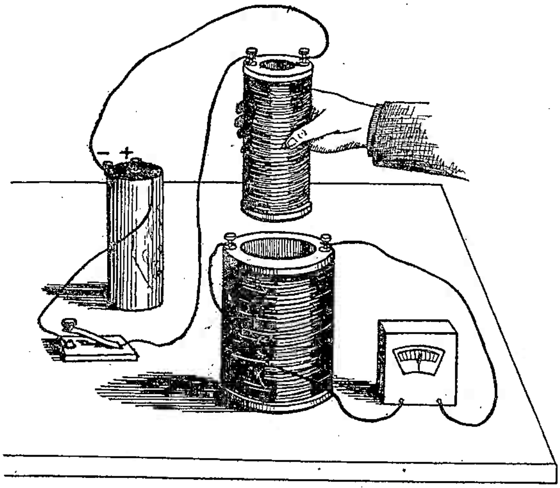

Fig. 22—Electromagnetic Induction.

If the primary is placed within the secondary and allowed to remain stationary, no current will be induced, but if the primary circuit is opened a momentary deflection of the galvanometer will occur. This is due to the current falling from a maximum to a zero value, and consequently a decrease in the number of lines of force about the primary to a zero value.

A similar deflection occurs when the switch is closed, but is not nearly as strong as the deflection resulting from breaking the circuit.

In the experiment described above, the magnetic field has been moving.

38. In a third method, as shown in Fig. 24, the lines of force are stationary and the secondary coil moves. The current is induced by causing the secondary to move through the field in such a manner, that the number of lines of force threading through it are varied. If the coil or conductor passes across the field with a rotary motion, as in Fig. 24, the number of lines of force enclosed by the coil varies, producing a current in it.

39. **Laws of Electromagnetic Induction:**

1. **A current may be induced in a coil by varying the number of lines of force threading through it.**

This is brought about in two ways: By causing a magnetic field to approach or recede from a stationary coil' or by causing a coil to be rotated through the field, so as to vary the number of lines of force threading through it.

2. **The voltage induced in the secondary coil will depend upon the number of lines of force cut per second, and upon the number of turns of wire in the coil.**

3. **If the number of lines of force cutting through the coil is increasing in number, the field produced will oppose that of the bar magnet or primary coil.**

4. If the number of lines of force cutting through the coil is decreasing in number, the field produced will have the same direction as that of the bar magnet or primary coil.

40. Self-induction may be defined as that property of a circuit, which tends to prevent any change in the strength of a current flowing through it.

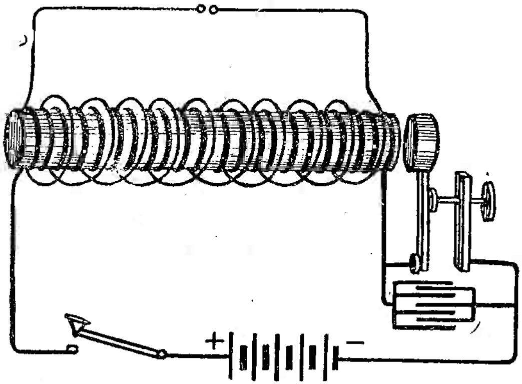

Fig. 23—Secondary Type of Induction Coil.

A solenoid, through which a current is flowing, has a magnetic field about each turn. The field about any one turn cuts through the adjacent turns, inducing a current which is opposite, or the same in direction as the original current, depending respectively upon whether the inducing current is increasing or decreasing in value.

If the circuit of a solenoid, connected in series with a key and battery, is opened suddenly, a spark will occur at the key contacts. This spark is due to what is termed the electromotive force of self-induction. At the instant the key is closed, the current is of course at a zero value, and, due to the opposing current, it does not reach its maximum value at once, but upon opening the key, the current decreases to zero, and the induced current being in the same direction increases the total value of current, thus causing a spark to occur at the key contacts.

The value of this extra current of self-induction depends upon the number of turns of wire in the solenoid, the permeability of the core and the strength of the inducing current.

This property of a coil of wire is made use of in gas engine ignition. The spark occurring when the circuit is broken is used to explode the gaseous mixture in the gas engine cylinder.

41. The principle of self-induction may be stated as follows: **The production of an extra current in a coil is dependent upon a change in the strength of the current flowing through the winding and consequently a change in the number of lines of force cutting the turns of the coil.** As long as the current is steady no extra current will be induced.

42. In the last article we discussed self-induction or the inductive action of a current carrying coil or circuit upon itself.

Under the heading of **mutual induction**, we will discuss the inductive action occurring between two circuits.

Mutual induction may be defined as the induction between two circuits, when the current in one of the circuits is changing in value.

43. If two circuits or coils are placed near together and have no metallic connection, a current flowing in one circuit sets up a magnetic field about the other circuit. The first circuit is called the primary, while the second circuit is called the secondary. If the current in the primary circuit changes in value, the number of lines of force threading or cutting through the secondary will vary proportionately. This change in the strength of field induces a current in the secondary. Fig. 22 illustrates the action of mutual induction between two circuits. The primary circuit consists of a dry cell, key and primary of a few turns of wire, while the secondary consists of a coil of many turns and a galvanometer. If the primary circuit is closed and the primary coil inserted into the secondary, a deflection of the galvanometer will result. If the primary coil is withdrawn an opposite current will result in the secondary with a consequent, opposite deflection of the galvanometer.

44. Another method of inducing currents in the secondary circuit, is to allow the primary to remain stationary within the secondary, making and breaking the primary circuit in order to change the number of lines of force threading through the secondary. We learned that a single coil would have a greater extra current induced in it when the circuit was opened. We have a similar effect on the secondary when the current in the primary is broken. Mutual induction will occur between the two straight wires, if they are parallel, but the greatest induction occurs between two coils.

45. The principle of self-induction is made use of in a device called **a primary induction coil.** It consists of an iron core, upon which is wound one or more layers of fairly large insulated wire. Due to the great permeability of the iron core, the magnetic field about the coil for a given current is much greater than that produced by the same coil having an air core. The purpose of a primary induction coil is to produce a fat, hot spark when the circuit is broken and is used in some types of gasoline engines to ignite the mixture of gas and air in the cylinder. In these engines the point of make and break is located in the cylinder.

46. The principle of mutual induction is used in another device called the **secondary induction coil.** This type of coil consists of an iron core of soft iron wire, a primary of two layers of heavy, insulated wire, and a secondary of many hundreds of turns of small insulated wire. The primary is wound about the iron core, over this a hard rubber tube or other insulating material is placed, and the secondary wound about the tube. The number of turns and the size of the wire used in the secondary are both dependent upon the desired voltage at the secondary terminals. The ratio of the number of turns in the primary to the number of turns in the secondary is the same as the ratio of the primary voltage to the secondary voltage. That is, if the number of turns in the primary is 100, the number of turns in the secondary 10,000 and the voltage of the primary 10, then the voltage of the secondary may be calculated as follows:

$$\frac{10,000}{10} = \frac{X}{10}$$

Where 10,000 equals turns in secondary.
100 equals turns in primary.
X equals voltage in secondary.
10 equals voltage in primary.

X must equal 1,000 volts. In other words, 10,000 divided by 100 is equal to 1,000 divided by 10.

47. To make and break the circuit of the primary, a device called the **vibrator or interrupter** is used. There are several different kinds of interrupters used with induction coils, but the vibrator is the only type that will be discussed in this course.

As shown in Fig. 23 the vibrator is placed at one end of the iron core. A flat spring fastened at one end has its free end just opposite the core, and has on the side next to the core a small piece of soft iron and on the other side a platinum contact. This contact makes connection with an adjusting screw held by a bracket. As seen in the figure when the circuit is closed the current flows from the battery through the key, primary coil, spring of vibrator, adjusting screw and then back to the battery. When key is depressed, the current magnetizes the core, which attracts spring of vibrator, thus breaking the contact with the adjusting screw. The current, on account of this break in the circuit, dies to zero, and due to the core losing its magnetism, the spring flies back to its normal position, again making contact with the adjusting screw. This completes the circuit once more and the same series of events occur again. This type of vibrator interrupts the circuit about 60 to 100 times per second. On account of the extra current of self-induction in the primary a very hot spark occurs at the vibrator contacts. This extra current not only melts the contact points but reduces the voltage at the secondary terminals. A high voltage at the secondary terminals is dependent on a quick decrease in the value of the current in the primary, when the circuit is broken at the vibrator.

48. If a condenser is connected across the contacts, as shown in Fig. 23, the extra current will be absorbed, preventing fusing of the contacts, and also allowing the current in the primary to die out quickly.

This condenser is usually made of tinfoil and paper. A large number of sheets of tinfoil of the same size are placed one above the other, separated by sheets of paper of larger size than the tinfoil sheets. Alternate sheets of tinfoil are connected to one conductor, while the remaining sheets of tinfoil are connected to the other conductor. These two main conductors are connected across the vibrator contacts.

When the circuit is closed the currents builds up in the primary to its maximum value, inducing a current of high voltage in the secondary, and when the circuit is broken by the vibrator spring, a reverse current is produced in the secondary of much greater value than that produced at instant circuit was closed. The higher voltage induced at the break is due to the quick demagnetization of the core.

49. The induction coil was used very widely in the early days of wireless, but has been superseded by a device called the step-up transformer. The **disadvantages of the induction coil are:..First, that only about one kilowatt of power can be handled efficiently, and second, that it**

gives considerable trouble, on account of contacts of vibrator melting and sticking.

50. In the mechanical production of electricity, the principle of electromagnetic induction is used. Under the heading of principles of electromagnetic induction we learned that there are two principal ways of inducting a current in a coil, in one method the coil remains stationary and the magnetic field about the coil is varied, while in the other method a coil is rotated through a stationary field. The later method, illustrated in Fig. 24, is the one used in the commercial production of electricity.

51. The **alternator** is the most simple form of the mechanical generator of electricity. Such a generator produces a current flowing first in one direction and then in the other, reversing the direction of flow many times per second. Electricity flowing in this manner is termed alternating current. The alternator does not really produce electricity, but merely creates an electromotive force or pressure, which causes electricity to flow against the resistance in a circuit.

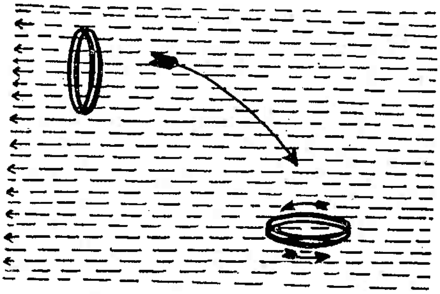

Fig. 24—Electromagnetic Induction.

The earth seems to be a vast reservoir of electricity and the alternator merely creates the pressure necessary to cause electricity to flow in the circuits provided for it.

52. A simple form of alternator consists of a north and south magnetic pole, such as the poles of a horse shoe magnet, between which, a rectangular loop of wire is caused to revolve. Such an arrangement is shown in Fig. 25. **The fundamental principle of the alternator is: If a coil wire is caused to rotate through a magnetic field of uniform strength, so as to cause the number of lines of force enclosed by the coil to increase or diminish uniformly, an e. m. f. will be induced. Fig. 26—Right Hand Rule for Finding Direction of Induced Current in the coil, the magnitude of which will depend upon the rate at which the lines of force are cut.**

In Fig. 25 the loop of wire is in a vertical position, and the lines of force are being cut at a minimum rate. Hence in this position the voltage in the loop will be zero, but in the horizontal position, as shown by the dotted lines in the figure, the rate of cutting will be maximum, the voltage in the loop being also at a maximum value.

53. The two ends of this loop are connected to two metal rings on

the shaft. They are known as **collector rings**, and make an electrical connection with two **brushes** which bear on the rings. The brushes are connected to the outside circuit. **The function of the collector rings is to convey the current from the revolving coil to the external circuit.**

As the loop of wire revolves from the vertical position to the horizontal position, the current rises from a zero to a maximum value, and in the next quarter revolution of the loop, to a second vertical position, the current dies back to a zero value. As the loop continues to revolve, the current reverses, rises to a maximum value and dies back to zero, being again in its original vertical position. Thus in one revolution the current flows first in one and then in the opposite direction. The rise of voltage from zero to a maximum and decrease to zero in the first half revolution is called an alternation, the second half revolution also produces an alternation, and the two taken together are termed a cycle.

54. This simple form of alternator, therefore, consists of **magnets, a revolving coil, collector rings and brushes.** The magnetic field may be produced by permanent magnets or by electromagnets. The number of poles may vary, but are always an even number, there being a north and south pole alternately. The coil in this simple form has only one wire, but in practical machines, consists of many turns in series. The direction of flow in the loop may be determined by the **right hand rule,** illustrated in Fig. 26. **If the thumb points in the direction of the lines of force, and the fingers point in the direction the conductor is moving, the index finger will point in the direction of current flow in the conductor.** It will be seen that as one branch of the loop goes down past one pole, the other branch will be moving upward, and the current induced in each branch will be in such a direction that they will not oppose each other.

55. **Alternating current may be defined as a current that increases**

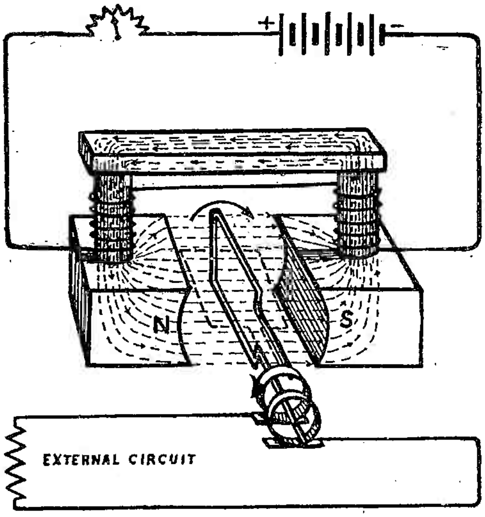

Fig. 25—Simple Alternator.

from zero to a maximum value in one direction, decreases to zero, rises to a maximum in the opposite direction and again decreases to zero.

The fact that alternating current is continuously changing in strength and pressure, with an accompanying change in the electromagnetic induction effects, renders its calculation different and more difficult than that of direct current.

In Fig. 27 we have a diagram of the curve of an alternating current. The straight line represents time, while the greatest height of the curve from this line represents the amplitude, that is, the greatest value attained by the current or voltage during the passage of the loop or coil past a field pole. The complete curve in Fig. 27 represents a cycle or two alternations.

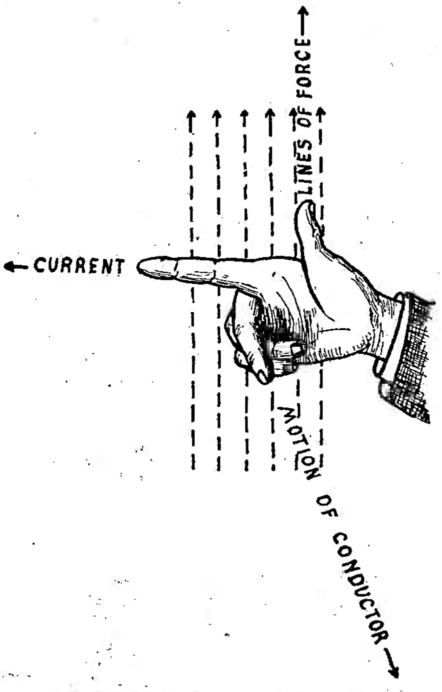

Fig. 26—Right Hand Rule for Determining Direction of Induced Current.

56. The number of cycles produced by the alternator per second is termed frequency. The two-pole alternator described above has one cycle produced per revolution. If the loop were revolved at 2,400 revolutions per minute or 40 per second, the frequency would be 40 cycles.

The frequency used in commercial practice is usually 60 cycles, and in some cases 25 cycles. The simple alternator would need to have its loop or armature revolved 60 times per second or 3,600 revolutions per minute in order to produce a 60 cycle current. Alternators used in commercial practice have more than two poles in order that the speed may not be so high. It is well for the student to remember that a cycle is produced by the revolving armature passing a north and south pole of the field.

57. The number of cycles produced per revolution by an alternator may be found by dividing the number of poles by two. Thus, in the simple alternator described above, the number of poles is two, and hence the frequency per revolution will be one. The rule for determining the frequency of an alternator may be stated as follows:

$$F = \frac{N \times S}{2}$$

Where F equals cycles per second.
N equals number of field poles.
S equals revolutions per second.

The frequencies employed in the generators producing current for wireless apparatus are: 60, 120, 240, 480, 500 and 600 cycles.

Example—An alternator has a speed of 2,000 revolutions per minute, the frequency is 500 cycles. What is the number of poles?

Solution—If the speed is 2,000 per minute, the speed per second is 2,000 divided by 60 or 33 1-3 revolutions per second, therefore, in one revolution there are 500 divided by 33 1-3 or 15 cycles produced per revolution. If two poles are needed to produce one cycle, there must be 2×15 or 30 poles in such a generator, instead of two as in the simple alternator.

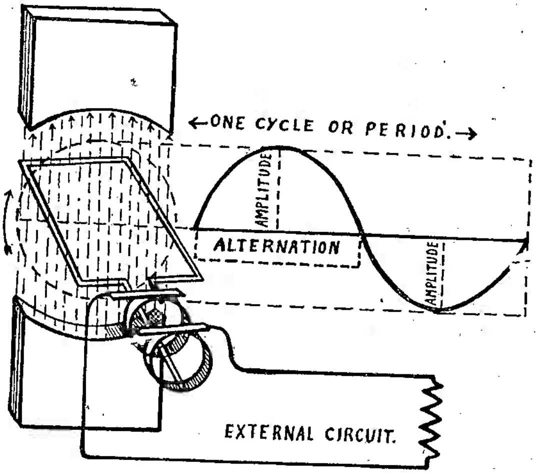

Fig. 27—Production of One Cycle of Current in an Alternator.

58. The frequency of an alternator may be varied by regulation of the speed of the armature.

59. **Inductance may be defined as that property of an electrical circuit by which energy may be stored up in electromagnetic form.**

Inductance, or the co-efficient of self-induction, may also be defined as the property of an electric circuit by which it produces induction within itself.

ELECTROMAGNETIC INDUCTION

Inductance and self inductance are practically synonomous.

The **unit of inductance** is the **henry** and **is** that **inductance possessed by a circuit which has an induced e. m. f.** of one volt, **when the current is changing at the rate** of one ampere **per second.**

That is, if the current increases from zero to a value of one ampere through a coil of wire having an inductance of one henry during one second of time, the change in the number of lines of force set up about it will cause an induced pressure of one volt.

The henry is too large a unit for practical use, except in special cases, so a smaller unit called the millihenry is used. The millihenry is one thousandth of a henry. Another subdivision is the centimeter which is one billionth of a henry.

CAPACITY.

Capacity is a very important subject in connection with wireless apparatus and a very thorough grounding in its principles is essential. We will give only a brief discussion in this instruction paper, touching principally on those parts of the subject which affect the flow of alternating current.

Capacity may be defined as that property of a circuit by which energy is stored up in electrostatic form.

Every circuit has more or less capacity, depending upon its dimensions, its form and the nature of the surrounding medium.

A device having concentrated capacity is termed a condenser. The Leyden Jar is an example of the type used in wireless circuits.

Another form of condenser is made of sheets of tinfoil separated and insulated from each other by paper. The construction of such a condenser may be described as follows: Sheets of paper 8 inches by 12 inches of tinfoil, 6 inches by 10 inches are piled alternately one above the other.

Suppose that 100 sheets of tinfoil and 100 sheets of paper are used. The sheets of tinfoil are considered as numbered one to a hundred. All even numbers are connected to one terminal and the odd numbers to the other terminal.

In the discussion of electromagnetic induction we learned that, when a circuit composed of a coil of wire and battery is closed, that is takes considerable time for the current to reach its maximum valve, due to the inductance of the circuit. The inductance of a circuit prevents the current from reaching its maximum valve as quickly as it would otherwise.

The effect of a condenser on alternating current is just the opposite to that of inductance. If the inductance and the capacity of the circuit are in the correct proportions, the one will neutralize the other, and the current flowing in the circuit will behave the same as if the circuit had no capacity of inductance. The unit of capacity is the farad. A condenser has a capacity of one farad if one volt potential will place a charge of one coulomb (one ampere for one second) within it.

The farad is a very large unit and a smaller unit called the microfarad is used. The microfarad is one millionth of a farad.

The material insulating the plates from each other is called the dielectric and may be paper, glass, mica, air or other insulator.

ELECTROMAGNETIC INDUCTION

The capacity of a condenser depends upon the dielectric material, the thickness of the dielectric and the size of the plates. By the dielectric is meant the material used to insulate the condenser plates.

Some dielectrics conduct static lines of force with greater ease than others. The ability of the air to conduct the lines of force is taken as one and that of castor oil is 4.8. That is, a condenser with castor oil as a dielectric will have 4.8 times the capacity of a like condenser having air as the dielectric. The number representing the ability of a substance to carry these lines of force is called its specific inductance capacity, or dielectric constant.

A very simple and familiar illustration which will form a deep and lasting impression is the case of a common rubber balloon such as one buys at the circus. Its ability for holding air depends upon three things: First, the size of the rubber sheet used to make it; second, the quality of the rubber and third, upon the thinness of the rubber provided it is not so thin as to break. These same things are true regarding the capacity or holding power of a condenser. The quality of the dielectric which might be rubber, mica, glass, oil, etc., will effect its capacity. The capacity will increase if the dielectric is made thinner but it must not be so thin that it will not withstand the electric pressure put upon it. Should the dielectric be too thin or too poor in quality the electric force (in volts) or strain will break down or rupture the substance as in the case with the rubber balloon.

60. Mutual induction has been discussed in a previous article. **It may be further defined as that induction between two circuits when the current through one of the circuits varies in strength.**

The inductance of a circuit depends on the size of the coil.

61. Due to the property of inductance, if an alternating current of a certain value is desired it will be necessary to have a higher voltage than would be required for a direct current of the same value. That is, inductance acts as a resistence in the circuit and must always be taken into consideration when calculating the dimensions of a circuit which is to carry a certain given current.

This opposing action of inductance in a circuit is called the spurious resistance and does not cause heat in the conductor.

The inductance of a circuit is termed reactance, and a coil having large self-induction used to regulate the flow of current by reason of its spurious resistance is known as a reactance coil.

The reactance of a circuit is measured in ohms.

Impedance is the sum of the true ohmic resistance and that due to the reactance.

A condenser also possesses a reactance, which is opposite in its effect to that of inductance.

That reactance due to induction is known as positive reactance, while that due to a condenser as negative reactance. If these two reactances are of the proper values they neutralize each other, the circuit behaving the same as it would in carrying direct current.

ELECTROMAGNETIC INDUCTION

*Answer the questions immediately following and send your answers to this Institute for grading. There is no code work to be submitted with this lesson.

QUESTIONS

THEORY LESSON NO. 3

52. How do we know that a current is accomplished by a magnetic field?
53. How may the polarity of a solenoid be determined?
54. What effect does an iron core have on a solenoid?
55. Give three methods of inducing a current in a coil of wire.
56. Define self-induction.
57. What causes the spark at contact when key is opened?
58. State the principle of self-induction.
59. Define mutual induction.
60. How does mutual induction differ from self-induction?
61. Name and describe briefly each of the two types of induction coils.
62. What is the purpose of the condenser connected across the vibrator contacts?
63. What is the function of the collector rings in an alternator?
64. Name the principal parts of an alternator.
65. Define alternating current.
66. Define frequency, alternation and cycle.
67. Give the rule for determining the frequency of an alternator.
68. Define inductance.
69. What is the unit of inductance?
70. What does the inductance of a coil depend upon?
71. Define capacity.
72. What is the unit of capacity?
73. What is meant by dielectric constant?
74. What does the capacity of a condenser depend upon?
75. Define reactance.
76. What effect does capacity reactance and inductance reactance have upon a circuit?

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Student No. 13794 Lesson No. 3

Ques. no.

52 We know that a current is accompanied by a magnetic field by this simple experiment, a compass is placed in a north and south position, The wire of the circuit with the current turned off is now placed accross the compass, also in a north and south position, when the current is turned on the needle will be deflected if the current is strong enough, at right angles to the current carrying conductor.

53 The polarity of a solenoid is determined by grasping the coil in the right hand with the fingers pointing in the direction of the current flow, the thumb will then point to the North pole.

54 The effect of an iron core on a solenoid is to greatly increase its power of magnetism, this is due to the greater permeability of iron than of air.

55 Three methods of inducing a current in a coil of wire are, 1st. a bar magnet is thrust into a coil of wire which is connected to a galvanometer a deflection of the galvanometer needle will be seen. no deflection of the needle will be shown if the magnet is held stationary but when the bar is pulled out a deflection again will be noted but in the opposite direction of the first.

2nd a current is induced in a coil also by mooving the coil through stationary lines of force, the current is induced by causing the coils to move through the field in such a manner that the lines of force cutting through it are varied.

3rd. Another way is to place a primary coil connected to a battery and key within a secondary connected to a galvanometer, no current is induced into the secondary if the primary becomes stationary, but when the key is opened the current falls from maximum to zero inducing a current into the secondary a current is also induced when the key is clozed.

56 Self induction is that property of a circuit which tends to stop any change in the strength of a current flowing through it.

57 The spark at contact when key is opened is caused by the electromotive force of self induction, that is, when the key is closed the current due to the opposing current does not reach the maximum value at once, but when the key is opened the current decreases from maximum to zero, the induced current being then in the same direction increases the current flow and causes the spark at contacts.

58 The principle of self induction is

The production of an extra current in a coil is dependent upon a change in the strength of the current flowing through the windings, and therefore a change in the number of lines of force cutting through the turns of the coil.

59 Mutual induction is defined as the induction between two circuits,

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when the current in one is changed in value.

60 Mutual induction differs from self induction in that it is the inductive action which occours between two circuits while self induction is the ~~inductiar~~ induction action of a current carrying circuit upon its self.

61 The two types of induction coils are primary and secondary.

A primary coil is made up of an iron core around which many layers of fairly heavy wire is wound, the iron due to its great permeability the field about the coil is much greater for a given current than an air core, this device makes use of the principle of self induction.

A secondary coil is made up of a core of iron, a primary wound with one or more layers of heavy wire according to the strength of the current to be used, and a secondary made up of many hundreds of turns of fine wire. The secondary is wound on an insulated tube which is slipped over the primary, this device makes use of the principle of mutual induction.

62 The purpose of the condensor connected accross the vibrator contacts is to absorb the extra current and stop the spark and to prevent sticking of the contacts it also helps the current in the primary to die out quickly.

63 The function of the collector rings in an alternator is to carry the current from the revolving coil to the external circuit.

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64 The principle parts of an alternator are magnets (either permenant or electro magnets) collector rings, revolving coil and brushes

65 Alternating current may be defined as current which increases from zero to maximum in one direction, decreases to zero, rises to maximum in the opposite direction and again decreases to zero.

66 Frequency is defined as the term applied to express the number of complete cycles taking place per second of time.

Alternation of a current is one half cycle or the rise and fall of a current in one direction.

A cycle is a complete reversal of current or two alternations.

67 The rule for determining the frequency of an alternator is

$$F = \frac{n X S}{2}$$

F = No. of cycles per. second
n = No. of field poles
S = No. of revolutions per. second.

68 Inductance is defined as that property of an electrical circuit by which ~~energy~~ may be stored up in an electromagnetic form.

69 The unit of inductance is the henry

It is that inductance of a circuit which has an induced voltage of one volt when the current is changing at the rate of 1 ampere per. second.

70 The inductance of a coil depends upon the rise of the current from zero to maximum and from maximum back to zero, or the rise and fall of the current in the coil

(over)

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71 Capacity may be defined as that property of a circuit by which energy may be stored up in electrostatic form.

72 The unit of capacity is the farad, this unit is very large so a unit called the micro farad is often used, this unit is one millionth of a farad.

73 Dielectric constant means the ability of a substance to carry the lines of force, since some Dielectrics carry the lines of force with greater ease than others, air is taken as the standard and is rated as one.

74 The capacity of a condenser depends upon the size of the plates and the thickness of the dielectric material

75 Reactance is the term applied to express the resistance of a wire to changes of current established in it.

76 The effect of capacity reactance and inductance reactance upon a circuit is when the two reactances are of proper values they neutralize each other, that is the circuit would be the same as it would be in carrying direct current.

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Answers to Lesson Test No. 3

52. If a wire carrying current has a cardboard at right angles about it and iron filings are scattered on it, they will arrange themselves in concentric circles about the wire.
53. Grasp the coil with the right hand so the fingers point in the direction of current flow and the thumb points in the direction of flow of the lines.
54. An iron core greatly increases the number of lines produced and makes it an electro-magnet.
55. First, by moving a magnet in the coil; second, by moving one coil, carrying a current in another coil; third, by changing the current in one coil which is surrounded by another coil.
56. Self induction is the inducing of a pressure within the coil of wire itself which opposes any change of current.
57. A current due to self-induction.
58. A change of current in a coil will change the number of lines linked with the coil and thus induce a new current (called self-induction).
59. Mutual induction is the inducing of current in one wire from the changing current in another wire close to it.
60. Self-induction occurs within the wire itself, while with mutual induction it is within another wire.
61. A spark or primary induction coil consists of one coil which has a high potential induced in it due to self-induction, while the regulation induction coil with a vibrator has two coils—a primary and secondary. A make or break in primary induces a high potential in the secondary due to mutual induction.
62. The condenser absorbs the current due to self-induction and reduces the sparking on the vibrator contacts.
63. The collector rings form a rubbing contact with the brushes to convey the current from the armature coil to the external circuit.
64. Magnets or poles, the armature with its coils, the collector rings and brushes.
65. An alternating current is one which goes thru periodic changes, starting with zero value, increasing to a maximum value in one direction; decreasing to zero and increasing to a maximum in the opposite direction, then decreasing to zero; repeating this change many times each second.
66. A cycle is one complete change in current, an alternation is one-half a cycle, and frequency is the number of cycles per second of time.
67. Frequency in cycles equals the number of pairs of poles passed per second by the armature coils.

$$F = \frac{N \times S}{2} \qquad F = \text{frequency}, \quad \frac{N}{2} = \text{no pairs of poles} \quad S = \text{Rev. per sec.}$$

68. Inductance is that property of a circuit which objects to a change in the current.
69. The Henry is the unit of inductance.
70. The inductance of a coil depends on the size of the coil and number of turns.
71. Capacity is the property for storing electricity.
72. The Farad is the unit, and for practical use the Micro-farad.
73. The Dielectric constant is a number which indicates how much better dielectric a certain substance is than air.
74. Size of plates, quality of dielectric (dielectric constant of substance) and the thinness of the dielectric.
75. Reactance is the property of a piece of electrical apparatus which reacts on the circuit, causing the electric pressure and current to be placed out of phase relations.
76. There are two reactance effects. First, Capacity reactance, causing the current to lead the pressure. Second, Inductance reactance, which causes the current to lag behind the pressure.

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LESSON TEXT No. 4

OF A

Complete Course in Radio Telegraphy

Electromagnetic Induction
Part II

REVISED EDITION

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THEORY AND CODE LESSON NO. 4

Do you know the International Code symbols for the alphabet?

Do you know the symbols for the punctuation marks?

In the first assignment we emphasized that frequent reviews were quite beneficial to the thorough mastery of wireless. Although we leave to you the advisability of doing so, we would suggest that you read through the first three theory lessons right now and compare our model answers with your answers, which no doubt you have received. Also practice the code work once more.

Now you are ready to learn the numerals. Practice these symbols until they are firmly fixed in your mind.

1	●▬▬▬▬	2	●●▬▬▬	3	●●●▬▬	4	●●●●▬
5	●●●●●	6	▬●●●●	7	▬▬●●●	8	▬▬▬●●
9	▬▬▬▬●	0	▬▬▬▬▬				

The bar indicating a fraction (/) is sent after the whole number and after the numerator of the fraction; i. e., 2½ would be sent thus:

●●▬▬▬ ▬●●▬● ●▬▬▬▬ ▬●●▬● ●●▬▬▬

Try these numbers without referring to the symbols for the numerals given above:

1456	9383	13,678.25	6234 1/2	76.51 2/3	.0020	1/2
7210	6899	2/3	4976 3/4	13.05 1/4	.1027	5/8
3/4	7/8	34,678 1/10	1/10	6.5	.0001	5/6

For additional practice in sending numbers, turn to your telephone directory, an arithmetic, the stock columns of your newspaper, etc.

It is a good idea to send from newspapers, including the words, punctuation marks and numerals. You may now turn to the following theory discussion.

THEORY LESSON NO. 4

62. **Transformers**:—In the early days of wireless, the necessary high voltage currents for the production of electromagnetic waves were produced by the induction coil. This coil, described in the last instruction paper, makes use of low voltage direct current in the primary, producing a potential of 50,000 volts or more at the secondary terminals.

As the interrupter used to make and break the primary current cannot handle large powers, and is a source of continual trouble, on account of sticking of contacts, the induction coil is now obsolete in wireless work.

The transformer, a device operating on the same principle as the induction coil, has been adopted almost universally and has numerous advantages over the latter. The amount of power, that the transformers can handle is unlimited. Traisformers handling 500 K. W. are not uncommon in high power wireless transmission.

The transformer operates on either pulsating or alternating current, We learned under the heading of Principles of Electromagnetic Induction, that a current flowing in one circuit, would induce a current in a neighboring circuit, provided, the current in the first circuit was changing in value.

ELECTROMAGNETIC INDUCTION

In the operation of an induction coil, this change in current strength is brought about by the making and breaking of the current at the vibrator contacts. The current through the primary rises from zero to maximum when the circuit is closed, and drops from a maximum to zero when the circuit is broken.

If the transformer is operated by alternating current, the current is continually rising and falling, and also reversing its direction of flow periodically. In modern wireless sets, the frequency of the alternating current used to operate the transformer varies from 60 to 600 cycles. A frequency of 500 cycles has found favor among wireless engineers and most sets now put on the market are of that frequency.

The alternator giving the required frequency is driven by an electric motor, the combination of the two being called a motor generator.

The transformer consists of an iron core, a primary winding and a secondary winding. An induction coil and an open core transformer are identical in their construction, except that the transformer does not need an interrupter.

The current from the alternator, periodically increasing and decreasing in value, flows through the primary of the transformer, first in one direction and then in the other. This change in current value causes a varying magnetic flux to flow through the secondary windings, inducing either a low or a high voltage current depending upon the ratio of the turns in the secondary to the turns in the primary. The greater the number of turns in the secondary, the higher the voltage. This process of transformation may be expressed by the following:

$$\frac{V}{V1} = \frac{T}{T1}$$

Where V. equals voltage of primary current.
V1. equals voltage of secondary current.
T. equals number of turns in primary.
T1. equals number of turns in Sec. winding.

That is, if the voltage in the primary is 10, the voltage in the secondary 10,000 and the number of turns in the primary 100, then the number of turns in the secondary may be found by substituting the above values in the formula. Substituting:

$$\frac{10}{10,000} = \frac{100}{T\text{-}1}$$

Therefore, T1 would need to be 1000 times 100 or 100,000 turns in the secondary.

$$\frac{10}{10,000} = \frac{100}{100,000}$$

If the current in the primary is 10 amperes, and the voltage 10, the power would be 10x10 or 100 watts. (See formula for Power, paper Number 2.)

The power at the secondary terminals will be less than 100 watts, depending upon the percentage of efficiency, and would be equal to the product of secondary voltage and amperage.

The current at the secondary would be about 1-100 ampere, because as the voltage increases, the amperage must decrease proportionately.

63. Types of Transformers:—Many types of transformers are in use in electrical installations.

The two main types are the step-up and the step-down transformer.

The first type raises the voltage from a low value to a high and is much used in wireless transmitters.

The step-down type lowers the voltage from a high to a low value, being of very little interest to the student of wireless.

Transformers may be classified as to construction as follows:

Open core, closed core, air core and auto transformer.

In the open core type of transformer we have the same construction as in the induction coil. This type gives practically constant current at all times, whether the secondary is short circuited or open.

The secondary winding is divided into sections in order to make easy any repair, due to short or open circuit. In case of a burnout in one of the sections or pancakes, all that is necessary to effect a repair, is to short circuit the section or replace it with a spare.

This type of transformer is illustrated in Fig. 28.

The closed core transformer, shown in Fig. 29, is so constructed that there is a complete path through the secondary for the magnetic lines of force set up by the primary, and is more efficient than the open core type.

The core is made of rectangular strips of soft iron, built up to the proper thickness and then wrapped with empire cloth.

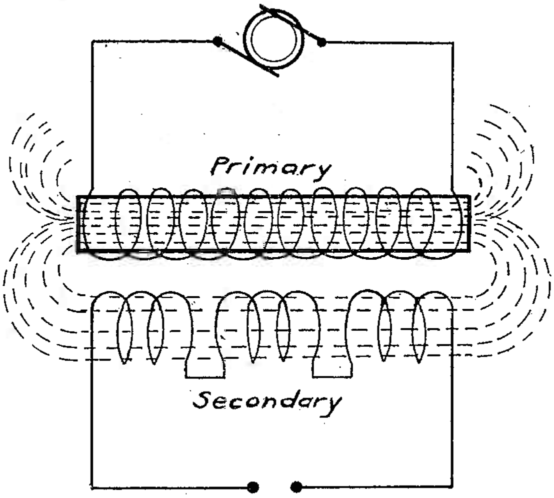


Fig 28. Diagram of Open Core Transformer

The primary winding consists of one or two layers of coarse wire, such as No. 10 or No. 12 gauge, wound on one leg of the core, while the secondary consists of hundreds of turns of No. 28 to 32, wound in sections on the opposite leg of the core.

This transformer will give constant current if an adjustable magnetic leakage gap is provided, as shown in Fig. 29.

This gap allows the magnetic reaction set up by the secondary to dissipate itself and not affect the primary winding. The induction from the secondary if allowed to flow through the primary core would neutralize the self induction of the primary and allow more current to flow.

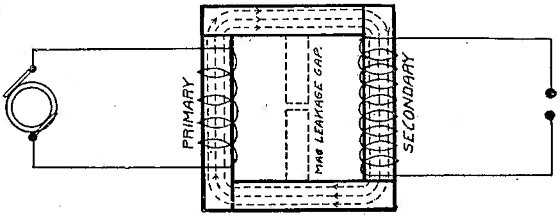


Fig. 29. Diagram of Closed Core Transformer.

The magnetic leakage gap prevents this and consequently the change of load on the secondary will cause no change in current flow.

In building the core of a closed core transformer, the sheets of iron are insulated from each other by shellac, in order to reduce the eddy currents. These eddy or Foucault currents are set up in the iron by induction, causing heating of the core and represent a considerable loss of energy.

The open and closed core transformers used in wireless telegraphy are designed to raise the voltage from 110 or more to various voltages ranging from 10,000 to 30,000 volts. The tendency at the present time is to make use of low voltage transformers.

The air core transformer is used extensively in radio circuits, both in sending and receiving. This type will be discussed in another instruction paper.

The auto transformer is a single winding having either an air or iron core. It is used to reduce alternating current to lower voltages. It was employed to a considerable extent in wireless apparatus of past years but is now practically obsolete. This type of transformer is illustrated in Fig. 30.

64. The Dynamo:—In Instruction paper No. 3, the principle of the alternating current generator is explained. All mechanical generators produce an alternative or pulsating current and to obtain direct current it is necessary to attach a device called a commutator to the alternator.

This commutator takes the place of collector rings, and a machine so equipped is called a dynamo.

ELECTROMAGNETIC INDUCTION

The function of the commutator of a dynamo is to so vary the connection of the brushes to the armature coils that the flow of current in the external circuit is in a constant direction.

The action of the commutator will be better understood, by studying the action of a simple two pole machine having a two segment commutator connected to a single loop, as illustrated in Fig. 31.

The principal parts of the dynamo are:—

1. The field magnets.
2. The armature.
3. The commutator.

The field magnets may be either permanent magnets or electro-magnets and their function is to create a magnetic field about the armature. The armature loop revolving through this field, has an alternating electric current induced in it, which is converted into a direct current by the action of the commutator.

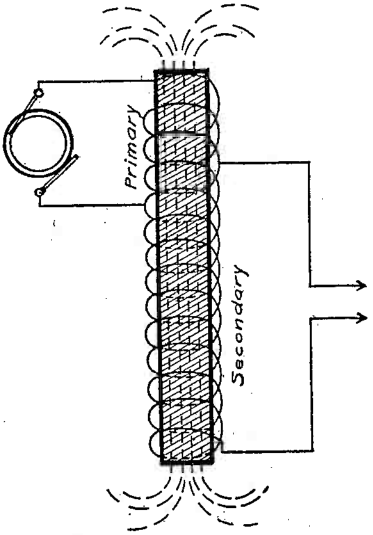


Fig. 30. Diagram of Auto Transformer

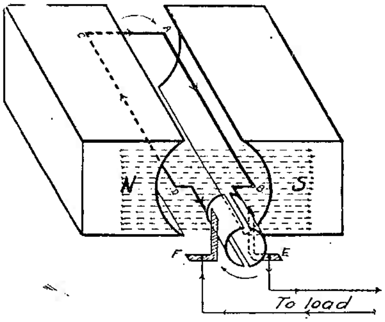


Fig. 31. Diagram Showing Function of Simple Commutator

As shown in Fig. 31, the machine has two field poles of opposite polarity, between which the loop of wire revolves. This loop has its ends connected to the two semi-cylindrical segments. These two segments are insulated from each other, and are located on one end of the revolving shaft. Two brushes are so arranged, that one brush makes contact with one segment, and the other with the other segment. Hence there is a complete path from one brush through the loop and back through the remaining segment to the other. The two brushes are also connected to the external circuit. According to the right hand dynamo rule, as the upper branch AB of the loop revolves down past the south pole the direction of current will be toward the segment of the commutator connected to this branch. As the branch AB goes down past the south pole, the branch CD revolves up past the north pole, causing a current to flow away from the segment connected to that branch. Therefore, the current during this half revolution flows out on the brush marked E, through the external circuit and back through the brush marked F.

The student should observe that the current is flowing to the external circuit through the brush E and to the loop through the brush F. During the next half revolution which brings the loop back to its original position, the branch AB will have the current reversed in it. That is, it is now moving up past the north pole and having a current induced in it, which flows away from the segment, and the branch CD is moving down past the south pole, having a current induced which flows to the remaining segment. Take note, however, that the current is still flowing from brush E to the external circuit and back to the loop through brush F.

Therefore, the commutator switches the brushes from one branch of the loop to the other in this simple type of machine. The current flow in the external circuit, when using a commutator of few segments will be direct, but of varying strength, or in other words, a pulsating current.

It will be observed that the brushes change segments at the position of zero current flow in the armature loop, that is, when the loop is at right angles to the direction of the lines of force.

In practical machines, the armature consists of many loops or coils wound over an iron core, the ends of the loop being connected to a commutator having many segments. Such machines are called multipolar dynamos, as they have more than two field poles.

In large machines the commutator has 150 or more segments, but in small machines, commutators having 20 or 30 segments are common. In the construction of a commutator, many copper bars or segments, separated by strips of mica are arranged in the form of a cylinder. This cylinder is placed on one end of the shaft, the two terminals of each armature coil being soldered to the ends of two segments. The commutator is insulated from the shaft of the armature by some insulating material.

65. Armatures.—Armatures for dynamos are made in two principal types, the ring-wound and the drum-wound.

The ring-wound armature is used very little in generators designed for wireless work. It consists of a ring of iron about which is wound the coils of the armature winding. Owing to this type of armature being practically obsolete, it will not be further discussed.

The drum-wound type is used in most modern dynamos and motors. In this type of armature all the wire is placed in slots cut into the outer surface of the iron core. The magnetic field of the dynamo is produced by two or more field poles arranged so that adjacent poles are of opposite polarity. The outstanding feature of the drum winding is that the two branches of each turn of wire lie under adjacent field poles. The iron core is made usually of many sheets of soft iron insulated from each other by shellac. These sheets are bolted together very tightly so that they form practically one piece of metal. A core of this type is said to be laminated.

The size of wire used on the armature of a motor or generator is determined from the current value for which the machine is designed. Large enough wire must be employed to prevent heating of the wire to a point where the temperature will melt the fiber insulation and ruin the windings.

66. **Brushes.**—The brushes which rest on the commutator and lead the current from the revolving armature to the external circuit are usually made of carbon. They usually bear at a slight angle or in the case of some types of small dynamos, directly against the face of the commutator. These brushes must be of proper hardness and bear against the commutator with proper pressure to prevent undue wear of the surface of the commutator. In many dynamos, the brushes are held by a rocker-arm. This device is merely a holder which allows shifting of the brushes from one point to another on the surface of the commutator. The position of the brushes must be adjusted to a critical position called the neutral point. In this position there is a minimum of sparking, due to the fact that the coils connected to the segments on which the brush is bearing, at this point in their revolution, have little or no current induced in them. That is, the coils are cutting the lines of force at a minimum rate.

67. **Types of Dynamos.**—Dynamos are divided into three main types:

1. The shunt wound.
2. The series wound.
3. The compond wound.

The shunt wound type of dynamo, shown in Fig. 32, has a field winding in shunt to the armature winding. The wire wound about the field poles has its terminals connected to the brushes bearing on the commutator. Therefore, part of the current flowing from the armature will pass through the field windings and keep the magnetic field at the proper strength.

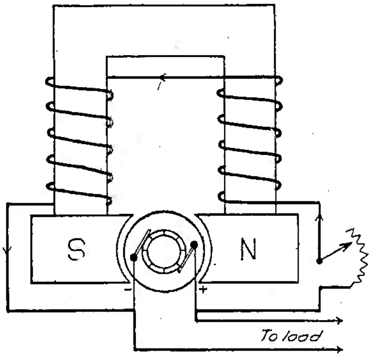


Fig. 32. Diagram of Shunt Wound Generator.

In starting a dynamo, the magnetic field is of very low value, being merely that due to the residual magnetism remaining in the field poles after being magnetized. However weak this field may be, the coils of the armature in passing through it have a small current induced in them, which flowing through the shunt field windings, gradually strengthens and builds up the field between the poles. This increase in the number of lines of force induces a stronger current in the armature and finally the dynamo is supplying full voltage.

The shunt field windings are made of fairly high resistance wire which prevents too great a flow of current, and allows the greater part of the current from the armature to flow out on the external circuit. A variable resistance, called a field rheostat is usually connected in series with the shunt winding to regulate the strength of the field and consequently the voltage of the current delivered to the external circuit. It is well to remember that the voltage induced in the armature depends upon the rate of cutting of the lines of force. Hence, if we vary the current through the field windings, we vary the number of lines of force cut by the armature coils.

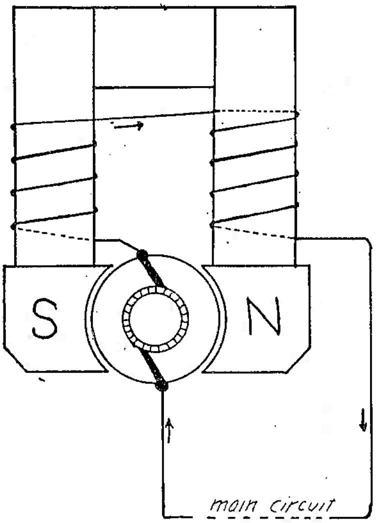


Fig. 33. Diagrams Showing Connections of Series Wound Generator

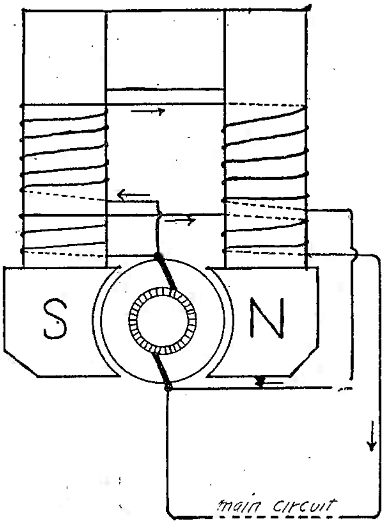


Fig. 34. Diagram Showing Connections of Compound Wound Generator.

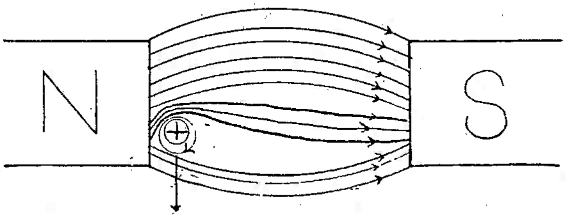


Fig. 35. Diagram Showing Effect of Magnetic Field on Current Carrying Conductor

In the **series wound dynamo**, illustrated in Fig. 33, the field magnets are in series with the armature, and consequently all the current induced in the armature must flow through the field windings. In order that this heavy current may not be held back, the field coils are wound with heavy wire. This winding will then carry the full output of the dynamo without heating. The series wound machine is practically obsolete.

In the **compound wound dynamo,** shown in Fig. 34, there is a shunt winding and also one in series with the armature. The series coil is of large wire, its function being to increase the magnetic field when the load varies. That is, in case a heavier load is put on the dynamo the increased flow of current will, in flowing through this series winding, increase the number of lines of force cut by the armature and thus maintain the voltage.

The **voltage** of dynamos may be regulated either by means of the field rheostat or by varying the speed. The former is the practical method used in controlling the voltage of all types of dyanmos.

68. The Electric Motor.—The direct current electric motor is almost identical in construction with the dynamo. In fact, most dynamos will act as motors if supplied with direct current. The electric motor converts electrical energy into mechanical energy and takes a very important part in modern industry.

The principle of the electric motor is: If a conductor free to move in a stationary magnetic field, has a current flowing through it, it will have a magnetic field of its own. The reaction of these two fields causes the conductor to move in a certain direction, depending upon the direction of current flow.

This principle is illustrated in Fig. 35. The direction of the lines of force about the conductor is found by means of the thumb rule. If the conductor is grasped by the right hand, so that the thumb points in the direction of current flow, the lines of force will be about the wire in the same direction as the fingers.

As shown in Fig. 35, due to the field about the wire, the lines of force are more dense on one side of the conductor, thus causing a distortion of the lines of force extending between the north and south poles. The lines of force in trying to straighten exert a pressure on the conductor, causing it to move in a certain direction.

The left hand or motor rule can be used to determine the relation between the field, the conductor, and the current flowing. This rule may be stated as follows: **If the forefinger of the left hand points in the direction of current flow in the conductor, and the thumb points in the direction of the lines of force, then the middle finger at right angles to the thumb and forefinger, will point in the direction of motion of the conductor.**

If we supply current to a simple machine, such as shown in Fig. 31, it will act as a motor. According to the left hand rule, the current flowing in the branch AB, if near the south pole, will cause this branch to go down, while the branch CD near the north pole will have a tendency to move upward. When the loop has reached a vertical position the brushes move from one segment to the other, reversing the direction of current flow in the loop. This causes another semi-revolution again placing the loop in a vertical position. The segments exchange brushes and the loop makes another half revolution. This action continues indefinitely as long as current is supplied to the motor.

The commutator of two segments plays a very important part in the action of this simple type of motor.

ELECTROMAGNETIC INDUCTION

The function of the commutator of any type of direct current motor is to maintain the polarity of the armature (loop) in such relation to the field poles, that there will be a constant attraction and repulsion, and therefore rotation.

That is, the function of the commutator is to maintain the current flow through the coils of the armature in such a direction, that the lines of force between the field poles will exert a pressure on the armature windings, thus causing rotation.

Practical motors have more than two poles. Four and six pole motors are quite common. The armatures have many coils and the commutator many segments like the dynamo. We learned that for generation of current in a dynamo it was necessary to cause coils of wire to rotate through a magnetic field. In a motor, we have this same situation, as the motor, at the same time it is a motor, has also the action of a dynamo.

Since the direct current motor is identical in construction with the dynamo, it has coils of wire revolving in a magnetic field. Therefore, while the armature is revolving and delivering mechanical power, it also has an electromotive force or voltage induced in its turns. This voltage will flow in an opposite direction to that of the current which drives the motor. This back or counter electromotive force has a decided effect on the action of the motor. It can never be as great as the applied voltage since in that case the motor would stop, but it does act as a resistance to the current entering the motor and proper control of the back e. m. f. will influence the speed.

In the dynamo, a series variable resistance may be inserted in the field windings and used to vary the voltage at the terminals. A variable resistance is also used in the motor field windings and used to regulate the value of the back e. m. f. If the e. m. f. is increased by allowing more current to flow through the field windings, the current entering the armature will be reduced in value, and the motor will slow down. When a larger current flows through the fields the number of lines of force cut by the armature is greater, inducing a larger e. m. f. This e. m. f. will oppose the applied e. m. f. from the source of power, thus reducing the speed.

The variable resistance connected in series with the motor field windings is called a motor field rheostat and its function is to control the speed of the motor.

60. **The Starting Box:**—The winding of the armature is made of large insulated wire. The large wire has very low resistance and if, in starting the current is connected directly to the motor, the current through the armature will be of great value. This will cause heavy sparking at the commutator and may cause the armature to burn out.

To prevent such an action a device, such as shown in Fig. 36, called a starting box, is employed. It is a variable resistance mounted in such a way, that when starting, the current will flow through all of the resistance. A low value of current flows through the armature causing it to revolve slowly, generating a slight counter e. m. f. The handle of the starter is pulled over slowly, cutting out resistance and allowing more and more current to flow through the windings of the armature. As the motor gains speed, the counter electromotive force increases in value and offers resistance to the applied voltage. Hence, at full speed the resistance of the starter is unnecessary. In the next instruction paper, the actual construction of the starting box will be fully explained and illustrated.

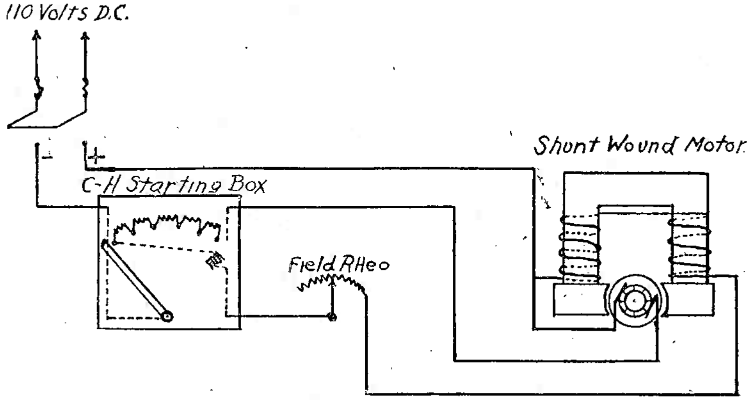


Fig. 36. Diagram of Cutler Hammer Starting Box with Connections to Motor

70. **Measuring Instruments.**—In order to control the action of electrical machinery, it is necessary to know the strength and pressure of the electric currents used in their operation. Instruments employed to indicate potential, current strength, power and frequency are called meters. These instruments take various forms and are based on different principles. The presence of an electric current is made known by the production of heat, magnetic action and chemical changes. The construction of almost all meters are based either on heating or magnetic effects.

The **galvanometer** is a very sensitive indicator of the presence of electric currents, being capable in some types of measuring as small a current as one-millionth ampere.

A galvanometer of the magnetic type takes the form of a permanent horseshoe magnet, between which a rectangular coil of wire is suspended in such a way that it may revolve and enclose the magnetic lines of force extending between the north and south poles.

As illustrated in Fig. 37, if a current flows through the coil of wire, it acts similar to a motor armature, in that the field of the permanent magnet reacts on the field of the coil, causing the coil to move. A pointer fastened to the moving element, passes over a scale which is marked in degrees or some other convenient unit. The extent of the rotation of this coil of wire will depend upon the strength of current and upon the sensibility of the instrument. In very sensitive instruments, the moving coil is supported in jewel bearings and held to the zero position by spiral springs. As shown in Fig. 37, a stationary cylindrical iron core is placed in the center of the moving coil. The function of this core is to increase

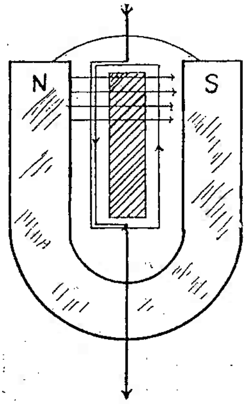


Fig. 37. Diagram of Simple Galvanometer

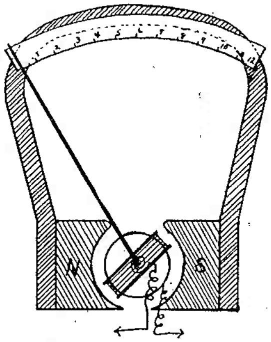


Fig. 38. Diagram of Voltmeter or Ammeter

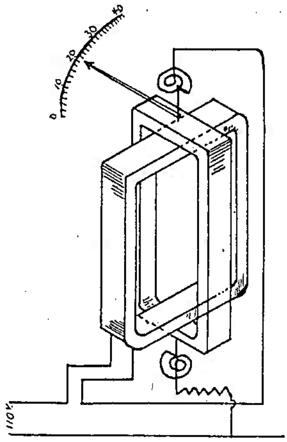


Fig. 39. Diagram of Wattmeter

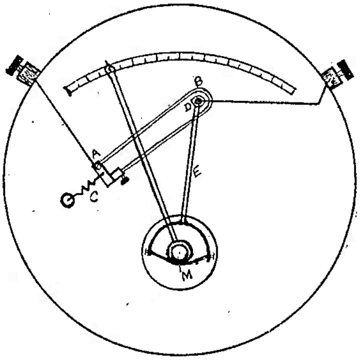


Fig. 40. Diagram of Hotwire Ammeter

the permeability of the path, which the lines of force take from the north to the south pole.

Taking the direction of the lines of force as being from the north to the south pole and the direction of the current as shown by the arrows, the left hand motor rule indicates that the direction of the part of the coil next to the north pole would be up, out of the paper.

The **voltmeter** for measuring direct current is merely a magnetic galvanometer, such as shown in Fig. 38, arranged in a certain way. As the voltmeter measures the pressure or potential difference between two points of a circuit, it is not connected in series but in shunt to a circuit, such as across the terminals of an armature. A high resistance coil is placed in series with the coil of the voltmeter to keep the current flow at a very low value.

The **ammeter** is an instrument for measuring the value of the current flow in a circuit. It is merely a galvanometer of special construction placed in series with the circuit, and is illustrated by Fig. 38. It has a low resistance moving coil connected in shunt to a path of low resistance. It only takes a small current to actuate the instrument, so a shunt is placed about the moving coil to carry the greater portion of the current.

The voltmeter and ammeter just described can only be used for direct current measurements.

The **wattmeter** is an instrument for measuring the power flowing in a circuit. The product of volts and amperes in direct current circuits equals the watts, but in alternating current circuits this it not always true, due to the fact that the amplitude of the current may lag behind the amplitude of the potential.

As alternating current is used in modern wireless transmitting sets, a wattmeter is necessary in order to know what power is being absorbed by the apparatus.

'In Fig. 39, one type of wattmeter is illustrated. It consists of two coils, one of which is connected in series with the line, while the other in series with a high resistance connected across the line. The wattmeter is practically an ammeter and a voltmeter combined, the voltage coil being movable while the current coil is stationary. As shown in the figure a spiral spring is used on the voltmeter coil to keep the needle at zero when no power is being used. When current is flowing, the magnetic fields set up in the two coils react on each other in such a manner that the movable coil tends to move into a parallel position with the stationary coil. The pointer on the voltage coil moves over a scale calibrated so as to measure either watts of kilowatts.

The **hot wire ammeter** is an instrument designed to utilize the heating effect of the current to be measured. This type of ammeter is employed in measuring the currents flowing in the wires leading to the aerial of a transmitting or sending set. The currents flowing in certain portions of a transmitter are of high frequency and high voltage, and the ordinary ammeter will not give true readings.

The principle of the Roller-Smith hot wire ammeter is, that a wire expands when a current flows through it. That is, a given length of wire will increase in length if a current flows through it. This increase in length of the wire is employed in causing a pointer to move over a scale. The more current flowing in this wire the greater the deflection of the needle. As shown in Fig. 40, the current flows on the wire from A to B. The resistance of this wire causes it to heat and therefore expand. The spring at C puts a tension on the two wires extending over the pulley D. If a current flows and expands the wire from A to B, due to the increase in length of the one branch the pulley D must rotate to make both branches the same length. This causes the arm E attached to the pulley to move to the left. Between the prongs of this arm a silk thread,

which passes around the shaft M, is stretched. As the arm E moves, the silk thread must move the shaft, carrying the pointer over the scale.

Another type of hot wire ammeter uses a thermo couple as the essential element.

A thermo couple is shown in Fig. 3, of instruction paper No. 1. If a junction of two dissimilar metals are heated by some means, a direct current will be produced. This current, while weak, will actuate a sensitive ammeter.

In this hot wire ammeter, the current to be measured is allowed to flow through several wires stretched between two copper blocks. On one of the wires a thermo couple is fastened, which is heated by the current flowing between the copper blocks. The direct current set up by this thermo couple flows to a magnetic ammeter. The necessity for the other wires between the copper blocks is to carry part of the heavy current flowing in the circuit. It acts as a shunt to the thermo couple junction.

This instrument is used by the Marconi Company and is manufactured by the Roller-Smith Company.

The **Frequency Meter** is an instrument used to indicate the frequency of an alternating current. In one common type a number of reeds having various vibration frequencies are arranged in such a manner that an alternating current flowing through it will cause the reed having a corresponding frequency to vibrate. The frequency in cycles per second will be indicated on a dial. This instrument is very little used in modern equipments.

QUESTIONS

INSTRUCTION PAPER No. 4

We suggest that you study this lesson over twice before attempting to answer the following questions. Send your answers to the Institute for grading. No code translation is included.

77. What is one advantage of the transformer over the induction coil?

78. What is the frequency of the alternating current employed in modern wireless sets?

79. What two main types of transformers are in use?

80. Name four other kinds of transformers.

81. Which is the more efficient, the open or closed core type of transformer?

82. What is the function of the magnetic leakage gap?

83. What is the function of the commutator of a dynamo?

84. Name the principal parts of a dynamo.

85. With what type of armature are most dynamos equipped?

86. Describe the type of brushes used on dynamos.

87. Give diagrams of three types of dynamos.

88. What is the principle of the electric motor?

89. Give the left hand or motor rule.

90. What is the function of the commutator of a motor?

91. What is the cause of the back or counter e. m. f. of a motor?

92. How is the speed of a motor controlled?

93. Explain the use of a starting box.

94. Upon what two effects of a current of electricity is the design of measuring instruments based?

95. Why is the voltmeter connected across the circuit rather than in series?

96. What is the wattmeter?

97. Upon what principle does the hot wire ammeter operate?

98. Describe the thermo-couple.

99. What is a frequency meter?

100. What size of wire is used on the armature of a motor or generator?

Student No
13794

George J. Guderjahn
West Salem, Ohio.

Lesson No 4.

Ques No.

77 One advantage of the transformer over the induction coil is the absence of an interrupter, whose contacts frequently become fused together, shorting the primary the inductance coil cannot handle very high voltage.

78 The frequency of the alternating current used in wireless sets ranges from 60 to 600 cycles. 500 cycles is much used at present on account of its high clear note it produces.

79 Step up and Step down.

80 Four others used are auto transformer, air core, closed core and open core.

81 The most efficient of the two is the closed core type of transformer

82 The function of the magnetic leakage gap is to prevent the magnetic reaction set up by the secondary from neutralizing the self induction of the primary and allowing more current to flow in the primary.

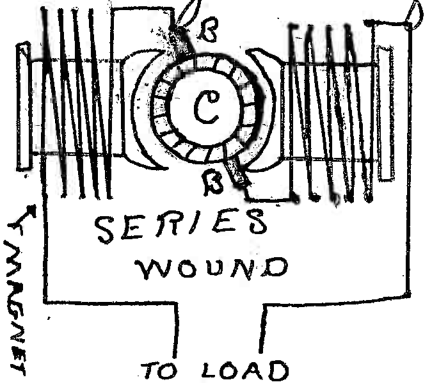
83 The function of the commutator of a dynamo is to so vary the connection of the brushes to the armature coils that the current flowing in the external circuit is in a constant direction.

84 The principal parts of a dynamo are armature, commutator and field coils or magnets.

85 most dynams are equipped with the drum wound type of armature.

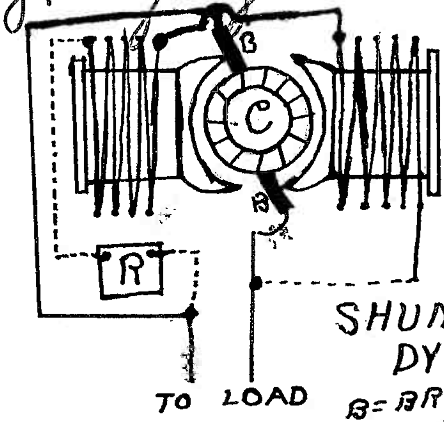
86 The brushes used on a dynamo are made of carbon set in a holder in such a position that they either bear at an angle or directly against the commutator, the brushes must be of the right hardness to prevent ruining the commutator by excessive wear

87 Diagrams of three types of dynamos are.



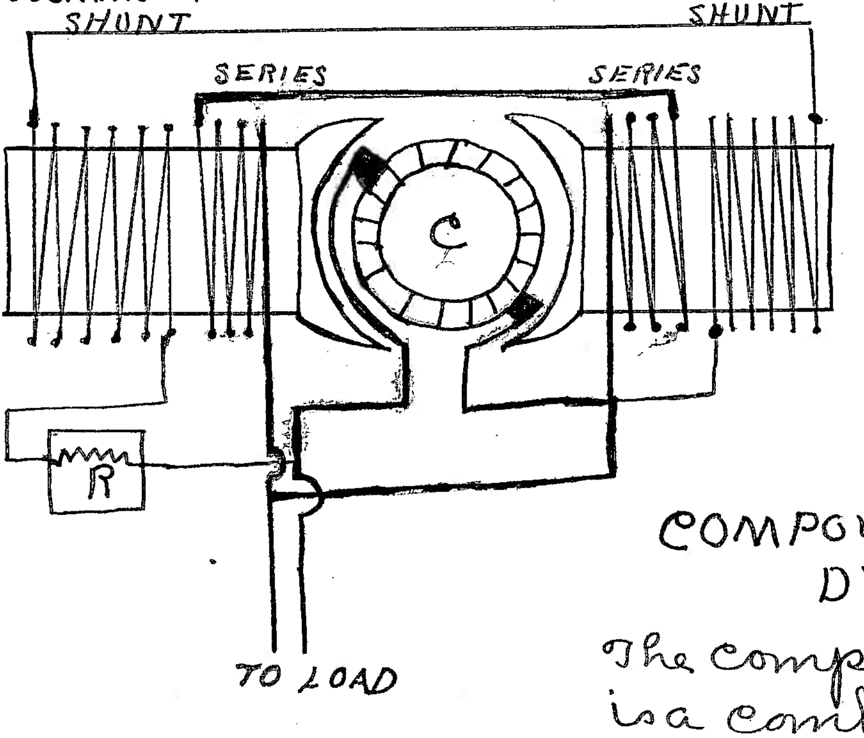
SERIES WOUND

B = BRUSHES
C = COMMUTATOR



SHUNT WOUND DYNAMO

B = BRUSHES
C = COMMUTATOR
R = REOSTAT



COMPOUND WOUND DYNAMO

The compound dynamo is a combination of the series and shunt types.

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88 The principle of the electric motor is: if a conductor is free to move in a stationary magnetic field, and has a current flowing through it. it has a magnetic field of its own, these two fields reacting upon each other causes the conductor to move in a certain direction, depending upon the direction of the current flow.

89 The left hand motor rule is.
If the forefinger of the left hand points in the direction of the current flow in the conductor, and the thumb points in the direction of the lines of force, then the middle finger at right angles to the thumb and forefinger. will point in the direction of motion of the conductor.

90 The function of the commutator in a motor using direct current is to maintain the polarity of the armature in such relation to the field coils that there will be a constant attraction and repulsion, which causes the rotation of the armature.

91 The back or counter E. M. F. of a motor is caused by the armatur revolving in a magnetic field which causes an electromotive force to be induced in its windings, this current flows in the opposite direction to the current which drives the motor, it is never as strong as the current used to drive the motor because if it was the motor would stop, however it does act as a resistance to the applied current and therefore the speed is influenced by it.

92 The speed of a motor is controlled by a reostat of variable resistances inserted in series with the field windings of the motor.

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93 The use of the starter box on a motor is to prevent the armatur from burning out and the motor ruined due to the very low resistance of the wire on the armatur, that is: if the current was connected directly to the motor the current in the armatur would be very great and causes the brushes to spark at the commutator, and may also burn the armatur out. The starting box prevents this, it is similar to a reostot and is placed in such a way that when the motor is started all the resistances are in series, the value of current in the armatur is cut down causing it to turn over slowly, generating a counter E. M. F. in the windings as the resistances are successifully cut out this back E. M. F. increases in value and offers a resistance to the applied current, so that when the motor is running at full speed the resistance of the starter is not needed.

94 The two effects of a current of electricity which are used in the designing of measuring instruments are heat and magnetism.

95 The voltmeter is connected across the circuit because it has to measure the pressure or P.D. between two points of a circuit, therefore it is equipped with a high resistance coil placed in series with the voltmeter coil to keep the current flow at a low value.

96 a wattmeter is an instrument to measure the current value flowing in a circuit

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97 The principle upon which the hot wire ammeter operates is. It is known that heat causes expansion and cold contraction, so it was found that a current flowing through a circuit causes the circuit to heat up, and in turn the circuit expanded. this expansion was then carefully measured and made to actuate a pointer over a scale, it was then possible to measure the amperage of a circuit by the heat imparted to the wire by the current flowing through it.

98 The thermo-couple is described as the production of direct current by the junction of two dissimilar metals when heated

This principle is made use of in a hot wire meter for measuring the amperage of a circuit

The current is allowed to flow through several wires stretched between two copper blocks. the thermo couple is connected to one of the wires, when the current is flowing in the circuit the wires heat up setting up a direct current in the thermo couple, which in turn is connected to a magnetic ammeter

99 A frequency meter is an instrument used to tell the frequency of an alternating current

100 The size of wire used on the armatur of a motor or generator is determined from the strength of the current for which the machine was designed. That is wire must be used that is large enough to prevent heating of the wire to a temperature high enough to destroy the insulation and ruin the coils

Correspondence Course

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Answers to Lesson Test No. 4

77. The transformer has the advantage of being able to handle large amount of power.
78. 500 cycles.
79. The step-up and the step-down transformer.
80. Air core, open core, closed core and auto-transformer.
81. The closed core transformer.
82. The leakage gap allows the secondary increased current to react thru it and tends to maintain a constant current in the primary.
83. The commutator of a dynamo rectifies the A. C. current generated in its armature coils as it passes out thru the brush to the external circuit, and thus delivers direct current to the load.
84. Field magnets, armature and commutator.
85. Most generators have a drum-wound armature.
86. Carbon brushes of the proper hardness bearing on the commutator at right angles to the surface or slanted a bit toward the direction of rotation.
87. See Figures 32, 33 and 34.
88. Electric current is supplied to the armature conductors which set up a field of their own and react on the lines of the field to cause a movement of the conductors.
89. Let the forefinger of the left hand point in the direction of the current and the thumb indicate the direction of field lines, then the middle finger at right angles to the thumb and forefinger will show the direction of motion.
90. The motor commutator changes the polarity of the armature coils so as to form a constant attraction and repulsion with the pole pieces, causing a rotation.
91. The counter E. M. F. of a motor is the pressure generated within the armature coils which react against the incoming or impressed voltage. It acts as a resistance to cut down the flow of current.
92. The motor speed is controlled by a field rheostat connected in series with the shunt field.
93. The starting box is a variable resistance put in series with the armature to prevent excessive currents on starting the motor. The counter E. M. F. takes its place when the armature comes up to speed.
94. Electrical instruments are designed to operate on the heating or magnetic effects of the electric currents.
95. A voltmeter measures the pressure between two points or wires, and must therefore be connected to these points. It contains a high resistance which cuts the current thru it to a small value, just enough to move the pointer to the correct value on the scale.
96. A wattmeter is an instrument for measuring the electric power in watts or kilowatts.
97. The hot-wire ammeter operates on the principle of the current causing an expansion or elongation of a special wire in the instrument. This elongation moves the pointer over a scale.
98. A thermo couple is formed by the junction of two different metals. When this junction becomes heated a direct current will be set up in a circuit connected across these two wires.
99. A frequency meter is an instrument to indicate the frequency in cycles for the current flowing in it. Some instruments have a pointer while another type has vibrating reeds. The reed corresponding to the frequency will vibrate and indicate, by a scale over it, the cycles per second.
100. The size of wire used on the armature of a motor or generator is determined from the current value for which the machine is designed. Large enough wire must be employed to prevent heating of the wire to a point where the temperature will melt the rubber insulation and ruin the windings.

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