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~~University of Wis~~

AUDELS ENGINEERS *AND* MECHANICS GUIDE 8

A PROGRESSIVE ILLUSTRATED SERIES
WITH QUESTIONS-ANSWERS
CALCULATIONS

COVERING

MODERN ENGINEERING PRACTICE

SPECIALLY PREPARED FOR ALL ENGINEERS
ALL MECHANICS AND ALL ELECTRICIANS.
A PRACTICAL COURSE OF STUDY AND
REFERENCE FOR ALL STUDENTS AND
WORKERS IN EVERY BRANCH OF THE
ENGINEERING PROFESSION

BY

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NOTE

This book is number eight of Audel's Engineers' and Mechanics' Guides. Its plan is to illustrate electricity in its many practical applications in the clearest and plainest manner, and in a way not to discourage the searcher for practical electrical knowledge, but to make an interesting, attractive, instructive and useful reference for all the electrical profession.

By a ***rigid economy*** *of words* the author has been able to give a vast amount of information on each of the many subjects which otherwise would have to be omitted.

The author is indebted to the various manufacturers for their co-operation in furnishing information relative to their products, and also credit is due to H. L. for supplying special wiring data.

Credit is also due to Mr. Harry E. Hershey, of the Automatic Electric Co., for valuable assistance in preparing the chapter on Automatic Telephones.

FRANK D. GRAHAM.

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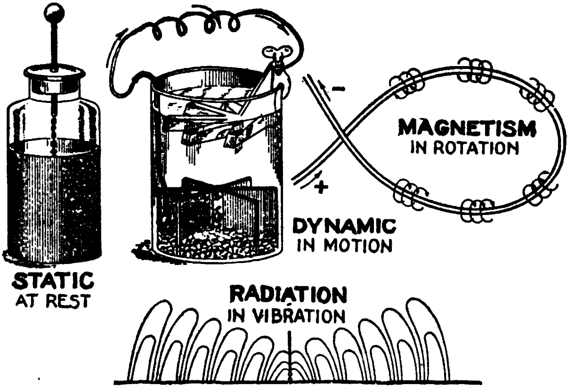
CHAPTER 91

Electricity

The name electricity is applied to an invisible agent known only by the effects which it produces, and the many ways in which it manifests itself. There are four principal forms of electricity:



FIGS. 6,103 to 6,106.—The four kinds of electricity.

1—Static electricity *at rest.*
2—Dynamic electricity *in lineal motion.*
3—Magnetism electricity *in rotation.*
4—Radiation electricity *in vibration.*

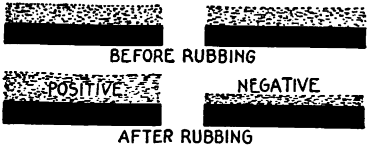
1. Static Electricity

If two unlike bodies be rubbed together, electricity will be concentrated on the surfaces and when in this condition they are said to be charged or electrified.

Thus, if a glass rod be rubbed with silk in dry air, it becomes *charged* with *electricity* called *positive* electricity, while a rod of sealing wax or other resinous substance rubbed with wool or fur becomes *negatively* charged.

Figs. 6,107 and 6,108.—The Leyden jar and discharger. Its discovery is attributed to the attempt of Musschenbrock and his pupil Cuneus to collect the supposed electric "fluid" in a bottle half filled with water. The bottle was held in the hand and was provided with a nail to lead the "fluid" down through the cork to the water from the electric machine. The invention of the Leyden jar is also claimed by Kleist, Bishop of Pomerania.

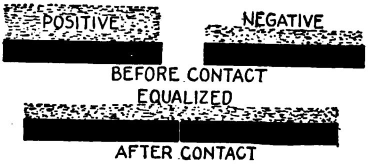
Positive and Negative Electricity.—These terms signify that one body is changed to a higher pressure than the other, that is, by rubbing some of the charge is taken from one body and transferred to the other as in figs. 6,109 to 6,112, the higher charge is arbitrarily called positive (+) and the lower negative (—) as in simile, *hot* and *cold*.



Figs. 6,109 to 6,112.—Positive and negative electricity. The rubbing process removes electricity from one body transferring it to the other.

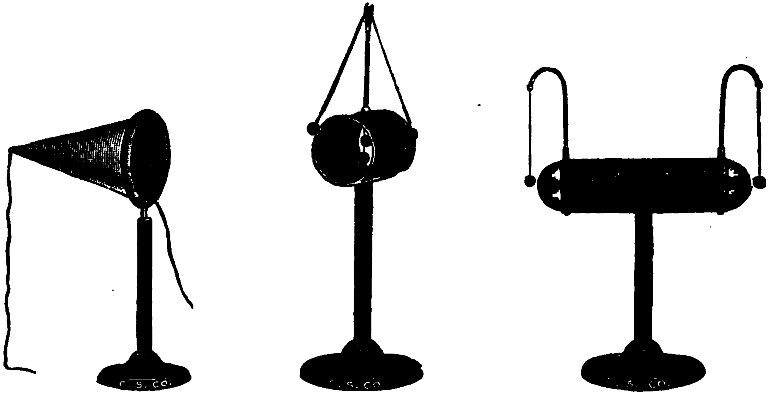
***Rule 1.**—If oppositely charged bodies be brought into contact with each other, the pressure will be equalized by the passing of the charge from the higher to the lower one.*

When the pressures are thus equalized the bodies are said to be discharged. Where the pressure difference is small, contact is necessary (figs. 6,113 to 6,115), but where it is great, it is only necessary to bring the bodies close together as in fig. 6,112.



Figs. 6,113 to 6,115.—Equilization of oppositely changed bodies by contact.

Electrical Attraction and Repulsion.—Two balls of light material as



Figs. 6,116 to 6,118.—Electrostatic apparatus. Fig. 6,116, Faraday's bag. When the bag is charged and pulled inside out, the static charge always remains on the outside. Fig. 6,117 hollow cylinder with pith balls, showing that electricity resides only on the outer surfaces of bodies. Fig. 6,118, induction cylinder with removable pith ball holders.

Figs. 6,119 to 6,121.—Electrostatic apparatus. Fig. 6,119 induction spheres so mounted on insulating support that they can be brought into contact. Useful in connection, with fig. 6,118 for showing the separation of positive and negative electricity by induction. Fig. 6,120, ellipsoidal conductor for showing unequal distribution. Fig. 6,121 Biot's hemispheres with pair of their nickel plated brass hemispheres with rubber handles. Charge on outside of globe may be removed by placing hemispheres in position shown.

pith are attracted to a charged glass rod, adhere to it, become charged, and then are repelled and fly off (as in figs. 6,124 to 6,126). They also repel each other but are attracted by a charged rod of sealing wax. From this follows:

***Rule 2.**—A body charged with one kind of electricity repels one charged with the same kind, and attracts one charged with the opposite kind.*

Whenever two bodies are rubbed together the body rubbed receives a charge unlike that of the rubbing body, as stated.

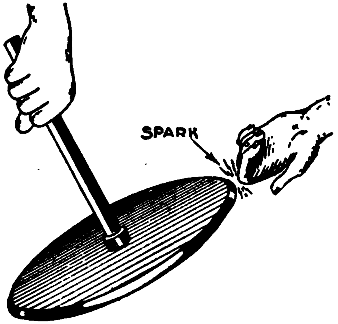
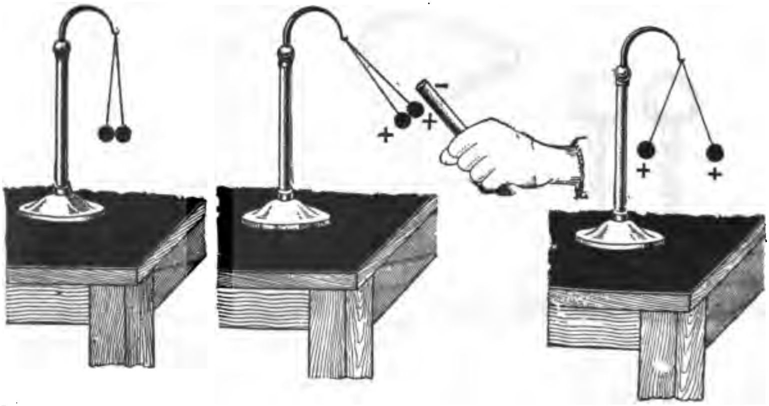


Fig. 6,122.—Production of spark with highly charged body.

Fig. 6,123.—Gold leaf electroscope; it consists of two strips of gold foil suspended from a brass rod within a glass jar. Used to detect the presence and sign of an electric charge.

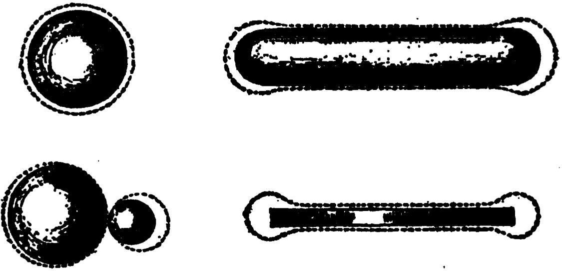


Figs. 6,124 to 6,126.—Electrical attraction and repulsion.

Rule 3.—Whenever a positive charge is developed an equal negative charge is developed, and vice-versa.

The Charge.—The quantity of electrification of either kind produced by friction or other means is called the *charge*.

Distribution of the Charge.—*This resides on the surface of the body* and hence depends on the *extent* of the surface and not on the mass of the body. Certain bodies, or material like glass, paper, etc., have the property of retaining this charge at whatever point attained; such are known as insulators.



FIGS. 6,127 to 6,130.—Distribution of the charge on conductors of various shapes.

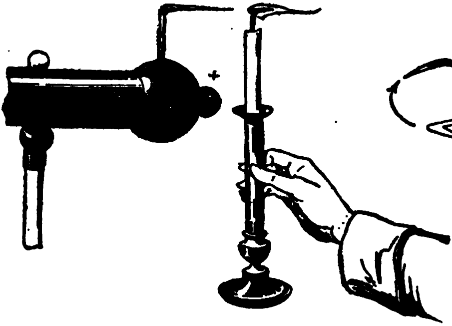


FIG. 6,131.—Experiment to illustrate the effect of pointed conductors.

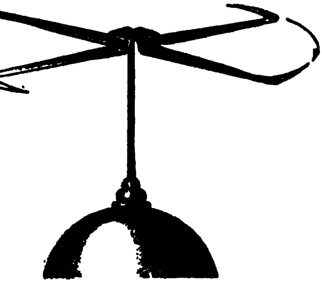


FIG. 6,132.—Electric wind mill which operates by the reaction due to the escape of the electric charge from the points.

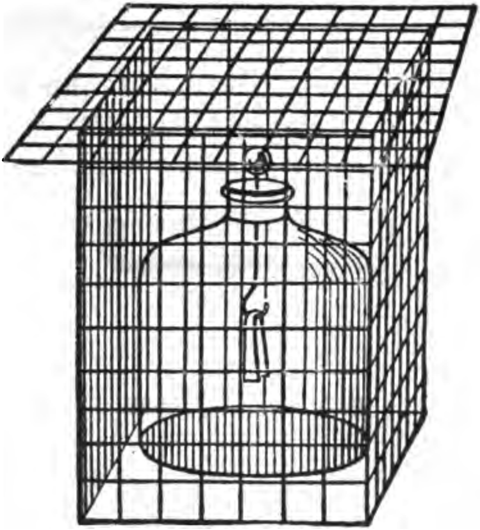


FIG. 6,133.—The electric screen. A screen of wire gauze surrounding a delicate electrical instrument will protect it from external electrostatic induction.

"Free" and "Bound" Electricity.—Electricity upon a charged conductor not in the presence of a charge of the opposite kind is called *free* and if a conductory path be provided, it will flow away to earth: if in the presence of a neighboring charge of opposite kind it is called *bound*.

Electric Screen.—Faraday showed that the charge on the outside of a conductor distributes itself in such a way that there is no electric force without the conductor.

Thus in fig. 6,133, the gold leaf electroscope covered with a bird cage failed to detect the pressure of powerfully charged bodies outside.

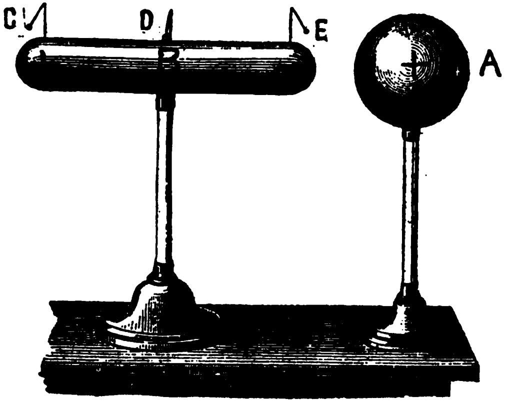
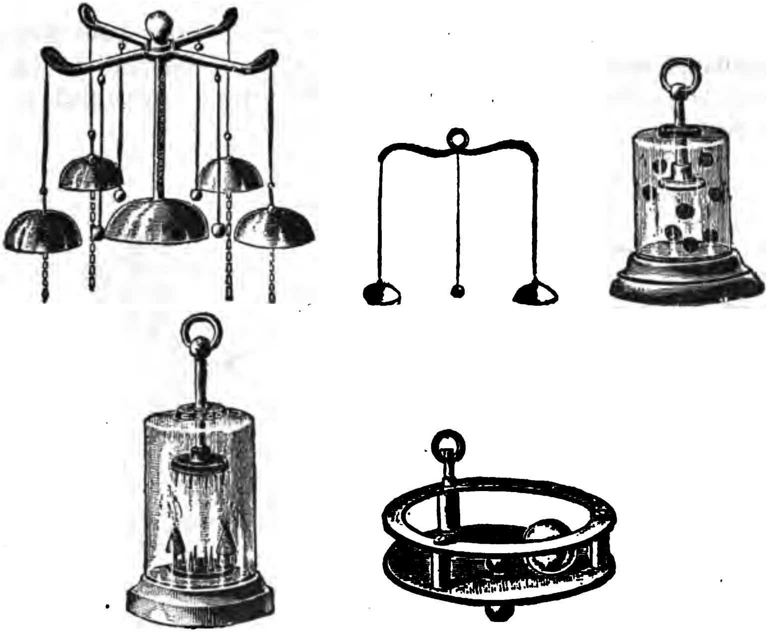
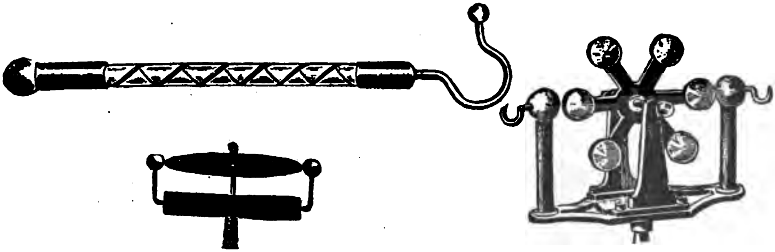


FIG. 6,134.—Experiment illustrating the nature of an induced charge. The apparatus consists of a metal ball and cylinder, both mounted on insulated stands, pith balls being placed on the cylinder at points C, D, and E.

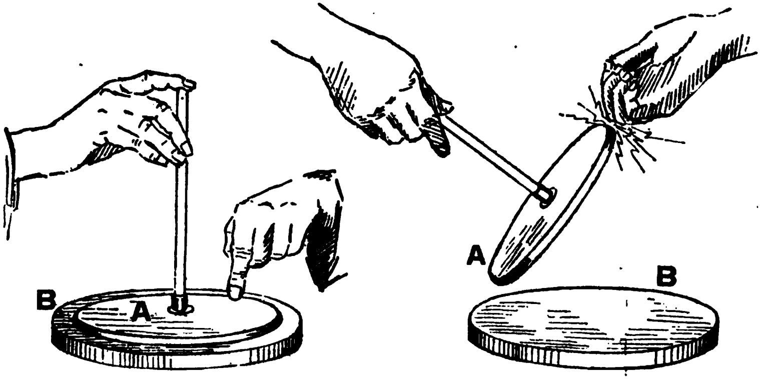


Figs. 6,135 to 6,139.—Electrostatic apparatus. Fig. 6,135, electrical chimes to illustrate attraction and repulsion of charge. Fig. 6,136, electrical chime arranged to be suspended from static machine. Fig. 6,137, Volta's hail storm or dancing balls. The charge from static machine causes balls to dance rapidly. Fig. 6,138, smoke condenser. The glass shade is filled with smoke from a punk candle, which is condensed upon the glass, when a charge from a static machine is applied. Fig. 6,139, electrical circus or racing ball. When connected with a static machine the glass races around the plate.



Figs. 6,140 to 6,142.—Electrostatic apparatus. Fig. 6,140, spiral tube. A charge sent through the tube will show a series of sparks where it crosses the gaps. Fig. 6,141, rotating disc. It will rotate rapidly when connected to a static machine. Fig. 6,142, electrostatic motor. It will rotate at high speed when connected to static machine.

Charge by Induction.—If two bodies, as brass balls both insulated and one electrified, the other not, be placed near together, the one not electrified will become electrified by *induction.*



FIGS. 6,143 and 6,144.—The electrophorus and method of using. Charge B; place A, in contact with B, and touch A (fig. 6,143). The disc is now charged by *induction* and will yield a spark when touched by the hand, as in fig. 6,144.

Condenser, Lyden Jar.—An apparatus for condensing a large quantity of electricity on a comparatively small surface. *It consists of two insulated conductors, separated by an insulator and the working depends on the action of induction.*

Electric Machines.—Various machines have been devised for producing electric charges such as

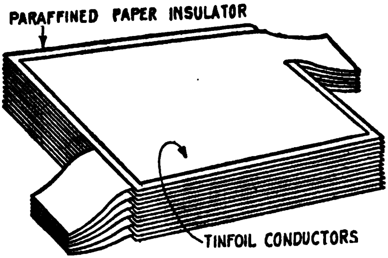
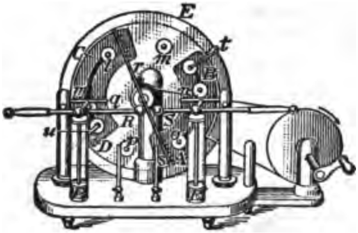


FIG. 6,145—Condenser for induction coil. ***In construction,*** numerous sheets of tin foil are prepared and placed on top of each other with a thin layer of insulating material between as shown.

have been described. The ordinary "static" or electric machine, is nothing but a *continuously acting erectrophorus*.

Fig. 6,146 represents the socalled Toepler-Holtz machine. Upon the back of the stationary plate E, are pasted paper sectors beneath which are strips of tinfoil AB, and CD, called inductors.

In front of E, is a revolving glass plate carrying disc *l*,*m*,*n*,*o*,*p*, and *q*, called carriers. To the inductors AB, and CD, are fastened metal arms *t*, and *u*, which bring B, and C, into electrical contact with the discs *l*, *m*,*n*,*o*,*p*, and *q*, when these discs pass beneath the tinsel brushes carried by *t*, and *u*. A stationary metallic rod *rs*, carries at its ends stationary brushes as well as sharp pointed metallic combs. The two knobs R, and S, have their capacity increased by the Leyden jars L, and L′A, small + charge to be originally placed on the inductor CD. Induction takes place in the metallic system consisting of the discs *l*, and *o*, and the rods *rs*, *l*, becoming negatively charged and *o*, positively charged.



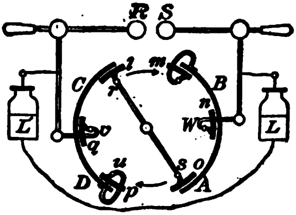


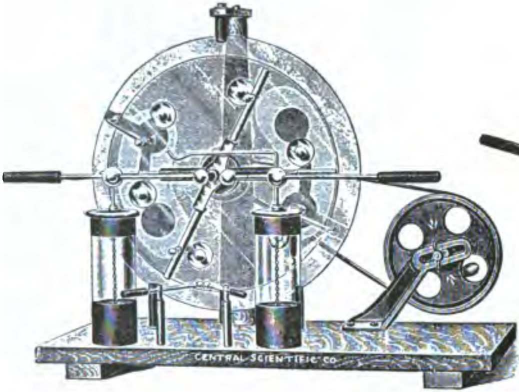
FIG. 6,146.—The Toepler-Holtz electric machine.

FIG. 6,147.—Principle of Toepler-Holtz electric machine.

As the plate carrying *l*,*m*,*n*,*o*,*p*,*q*, rotates in the direction of the arrow the negative charge on *l*, is carried over to the position *m*, where a part of it passed over to the inductor AB, thus charging it negatively. When *l*, reaches the position *n*, the remainder of its charge, being repelled by the negative electricity which is now on AB, passes over into the Leyden jar, L.

When *l*, reaches the position *o*, it again becomes charged by induction this time positively, and more strongly than at first, since now the negative charge on AB, as well as the positive charge on CD, is acting inductively upon the rod *rs*. When *l*, reaches the position *u*, a part of its now strong positive charge passes to CD, thus increasing the positive charge upon its inductor.

In the position *v*, the remainder of the positive charge on *l*, passes over to L′. This completes the cycle for *l*. Thus, as the rotation continues AB, and CD, acquire stronger and stronger charges, the inductive



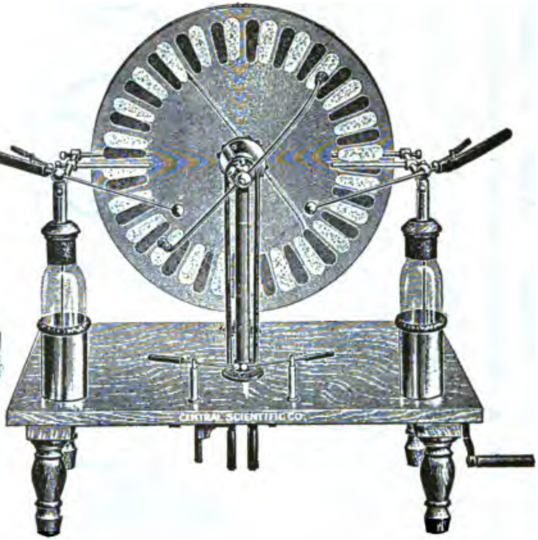


FIG. 6,148.—Mars Toepler-Holtz electric machine. ***In construction,*** **the belt tension is adjustable, the brushes are made of** tinsel, which is claimed to be superior to wire. The **condensers are of the Leyden jar type. There is a current breaker which** permits the intensity and rate of discharge to be varied. **The machine is equipped with a pair of nickel plated shocking handles** and chains and an attachment for holding accessories **such as bell chimes, image plates, etc. A 3 to 6 inch spark may be pro**duced, depending upon weather conditions. Revolving **plate 12 in.; stationary plate 14 in.**

FIG. 6,149.—Wimshurst self-charging static machine**, new design. The machine works without change of poles, and is accord**ingly more satisfactory than the Toepler-Holtz typ**e in which the poles may reverse at any moment. For this reason it is espe**cially adapted to X ray work. The machine is pro**vided with a spark gap attachment, and there is a current breaker, by means** of which the outer coils of the Leyden jar may be **either connected or disconnected, thus allowing either an intermittent spark** discharge or a continuous discharge. Spark range **from ¼ to ½ the plates diameter.**

action upon *rs*, becomes more and more intense, and positive and negative charges are continuously imparted to L′, and L, until a discharge takes place between the knobs R and S.

2. *Dynamic Electricity*

When static charges are equalized by means of a spark, the energy takes on the form of a *current*, but dynamic or current electricity is usually understood to mean energy of *considerable* current strength and *long duration* as compared with a static discharge.

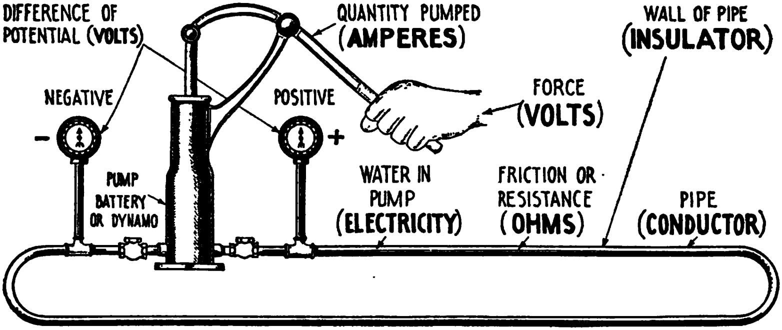
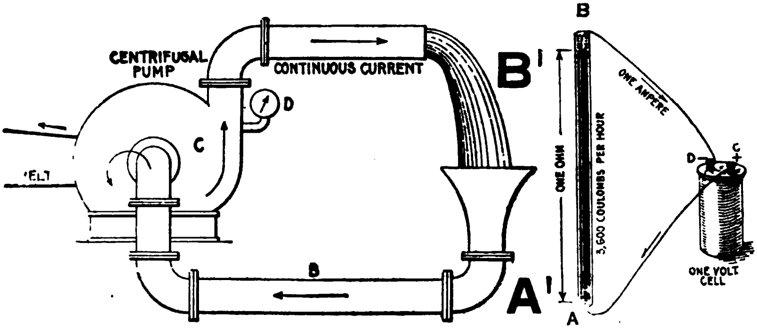


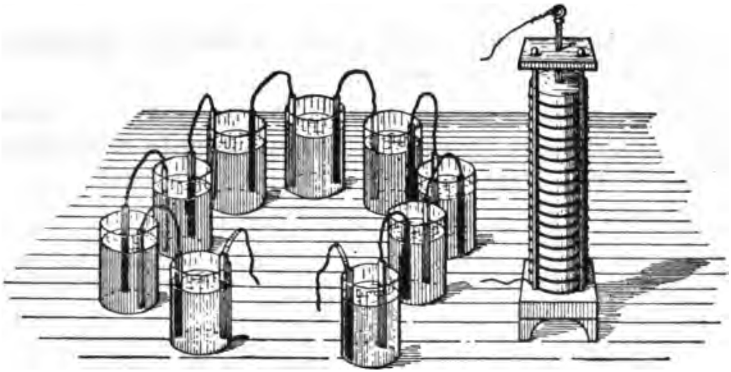
FIG. 6,150.—Hydraulic analogy of electric current.

Electrical currents are said to flow through conductors.

These offer more or less resistance (*ohms*) to the flow, depending on the material. Copper wire is generally used as it offers little resistance. It is now thought that the flow takes place along the surface and not through the metal. The current must have pressure volts to overcome the resistance of the conductor and flow along its surface. This pressure is called *voltage* caused by what is known as difference of potential between the source and terminal. An electric current has often been compared to water flowing through a pipe. The pressure under which the current flows is measured in *volts* and the quantity that passes in *amperes*. The resistance with which the current meets in flowing along the conductor is measured in *ohms*. The flow of the current is proportional to the voltage and inversely proportional to the resistance. The latter depends upon the material, length and diameter of the conductor. Since the current will always flow along the path of least resistance, it must be so guarded that there will be no leakage. Hence, to prevent leakage, wires are *insulated*, that is, covered by wrapping them with cotton, silk thread, or other insulating material. If the insulation be not effective, the current may leak, and so return to the source without doing its work. This is known as a *short circuit*. The conductor which received the current from the source is called the *lead*, and the one by which it flows back, the *return*. When wires are used for both lead and return, it is called a *metallic circuit;* when the ground is used for the return, it is called a *grounded circuit*.



FIGS. 6,151 and 6,152.—Diagrams showing hydraulic analogy illustrating the difference between amperes and coulombs. If the current strength in fig. 6,152 be one ampere, the quantity of electricity passing any point in the circuit per hour is 1×60×60=3,600 coulombs. The *rate* of current flow of one ampere in fig. 6,152 may be compared to the rate of discharge of a pump as in fig. 6,151. Assuming the pump to be of such size that it discharges a gallon per revolution and makes 60 revolutions per minute, the quantity of water discharged per hour (coulombs in fig. 6,152) is 1×60×60=3,600 gallons. Following the analogy further (in fig. 6,152), the pressure of one volt is required to force the electricity through the resistance of one ohm between the terminals A and B. In fig. 6,151, the belt must deliver sufficient power to the pump to overcome the friction (resistance), offered by the pipe and raise the water from the lower level A' to the higher level B'. The difference of pressure between A and B in the electric circuit corresponds to the difference of pressure between A' and B'. The cell furnishes the energy to move the current by maintaining a difference of pressure at its terminals C and D: similarly, the belt delivers energy to raise the water.



FIGS. 6,153 and 6,154.—Courane de Tasses and Volta's pile, the first of all batteries (1800). The Courone de tasses (crown of cups) was a battery of simple cells in series. Each cell was composed of a plate of silver or copper and one of zinc immersed in brine. Volta's pile consisted of a series of alternate discs of zinc and copper, separated by moistened felt. Surprising results were obtained with this pile.

OHM'S LAW

$$\text{CURRENT} = \frac{\text{ELECTROMOTIVE FORCE}}{\text{RESISTANCE}}$$

$$I = \frac{E}{R} \qquad \text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

$$\text{RESISTANCE} = \frac{\text{ELECTROMOTIVE FORCE}}{\text{CURRENT}}$$

$$R = \frac{E}{I} \qquad \text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

$$\text{ELECTROMOTIVE FORCE} = \text{CURRENT} \times \text{RESISTANCE}$$

$$E = IR \qquad \text{VOLTS} = \text{AMPERES} \times \text{OHMS}$$

A volt is that pressure which produces a current of one ampere against a resistance of one ohm.

An ampere is the current produced by one volt in a circuit having a resistance of one ohm. It is that quantity of electricity which will deposit .005084 grain of copper per second.

A conlomb is one ampere flowing for one second.

Rule 4.—OHM'S LAW. *In a given circuit, the amount of current in amperes is equal to the pressure in volts divided by the resistance in ohms, that is:*

$$\text{current} = \frac{\text{pressure}}{\text{resistance}} \text{ or, amperes} = \frac{\text{volts}}{\text{resistance}} \quad \ldots\ldots (1)$$

from which

$$\text{volts} = \text{amperes} \times \text{resistance; resistance} = \frac{\text{volts}}{\text{amperes}}$$

Equation (1) may be expressed by symbols, thus:

$$I = \frac{E}{R} \quad \ldots\ldots (2)$$

in which

I = current strength in *amperes*,
E = pressure in *volts*,
R = resistance in *ohms*.

from (2) is derived the following:

$$E = IR \quad \ldots\ldots (3)$$

$$R = \frac{E}{I} \quad \ldots\ldots (4)$$

Example.—A circuit having a resistance of 5 ohms is under a pressure of 110 volts. How much current will flow?

From Ohm's law, amperes = volts ÷ resistance (equation 2) = 110 ÷ 5 = 22 amperes.

Example.—If the resistance of a circuit be 10 ohms, what voltage is necessary for a flow of 20 amperes?

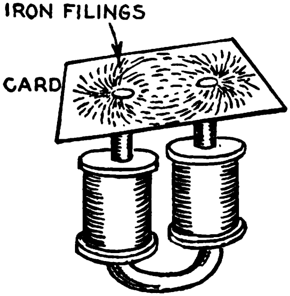
From Ohm's law, volts = amperes × resistance (equation 3) = 20 × 10 = 200 volts.

Example.—On a 110 volt circuit what resistance is necessary to obtain a flow of 15 amperes?

From Ohm's law, resistance = volts ÷ amperes (equation 4) = 110 ÷ 15 = 7⅓ ohms.

3. Magnetic Electricity

The latest theory of magnetism, well supported by facts,



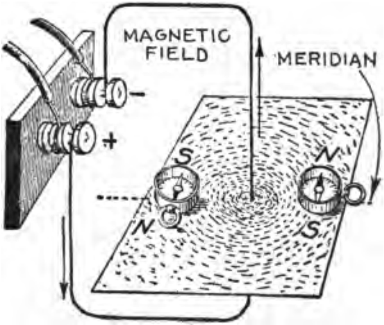


Fig. 6,155.—Ordinary horse shoe magnet with iron filings showing magneto field.

Fig. 6,156.—Electromagnetic field surrounding a conductor with current flowing.

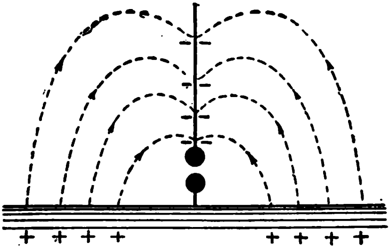


Fig. 6,157.—Electrostatic field about aerial pressures to spark discharge.

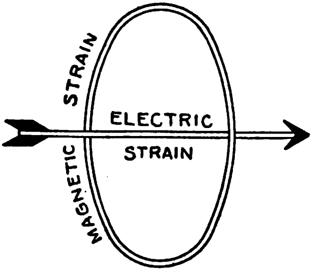


Fig. 6,158.—Strains in the ether.

assumes that the molecules of a magnetic substance are minute magnets by nature, each having two poles.

In a bar magnet, each molecule at the two ends may be supposed to have the attraction of its inward pointing pole neutralized more strongly than that of the outward pointing pole, which, therefore, is free to attract other bodies.

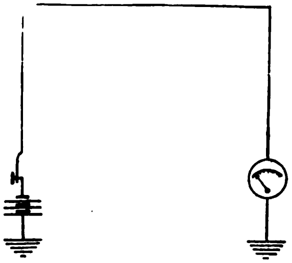


Fig. 6,159.—The wire telegraph.

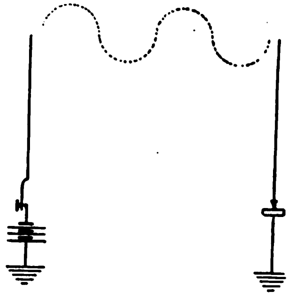


Fig. 6,160.—The wireless telegraph.

Rule 5.—Like poles repel, unlike poles attract each other.

A close relation exists between magnetism. Oersted, a Danish investigator, in 1819, ***announced that a compass needle is disturbed by the neighborhood of an electric current.*** If the wire through which the current flows be held above and parallel to the needle, the needle tends to set itself at right angles to the wire. The lines of this electromagnetic force must necessarily be concentric circles around the wire, as was shown in fig. 6,105.

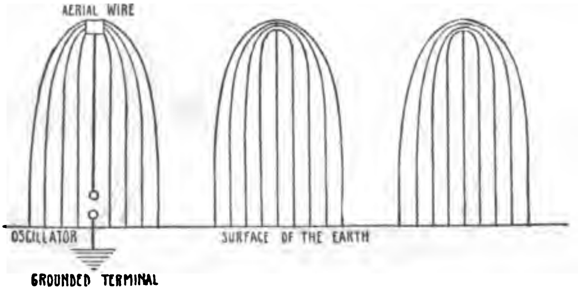


Fig. 6,161.—Fessenden sliding half waves; theory based on the experiment made by Hertz.

4. Radio Electricity

In wireless work the electric waves representing the messages are transmitted, or propagated, from the sending station to the receiving station through the ether, the latter performing the same functions as the wire does in ordinary telegraphy and telephony as in figs. 6,159 and 6,160.

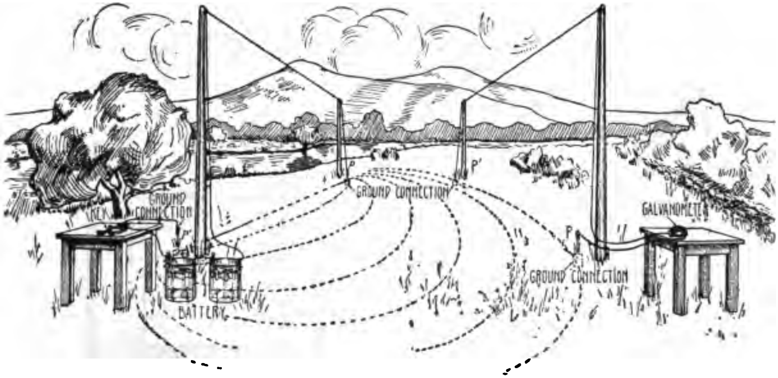
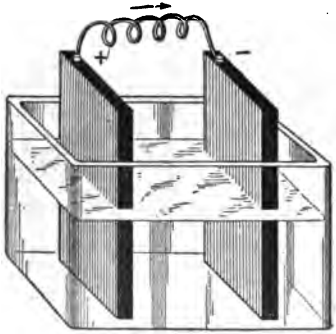


FIG. 6,162.—Conductivity method of wireless telegraphy; ***earth the medium***. Steinheil of Bavaria discovered that the earth could be utilized in place of the usual return conductor of a wire telegraph line as here shown. By placing earth plates *p p'* and P, P' connected together and having a galvanometer in circuit parallel with the first, which included a battery and a key, Steinheil found that there was enough leakage of current from one to the other to deflect the needles of the galvanometer. The dotted lines represent current in the earth.

CHAPTER 92

Primary Cells

Production of the Current.—To produce current electricity it is only necessary to immerse a piece of zinc and a piece of copper or carbon in an acid or salt solution called the ***electrotype***, thus forming a primary cell as in figs. 6,163 and 6,164.



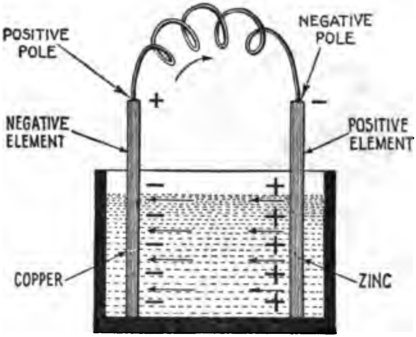
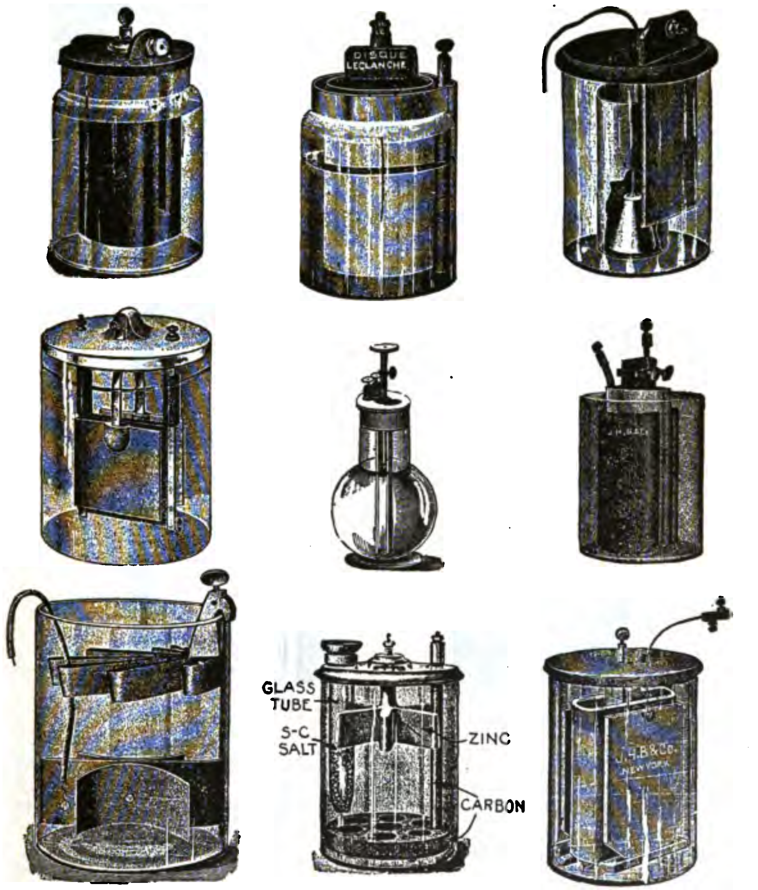


Fig. 6,163.—Simple primary cell. *It consists of* two dissimilar metal plates (such as copper and zinc which are called the *elements*) immersed in the electrolyte or exciting fluid contained in the glass jar.

Fig. 6,164.—Simple primary cell illustrating the terms poles and elements. *Carefully note that the negative element has a positive pole, and the positive element a negative pole.*

If the copper and zinc electrodes be connected with a wire, a current will flow from the copper to the zinc, the copper being positively charged and the zinc negatively charged, although ***inside the cell the action is reversed, the current flowing from the zinc to the copper***, as shown in fig. 3,164.

Primary cells may be classed: 1, according to their chemical features as, *a*, one fluid, and *b*, two fluid, and 2, according to service, as, *a*, open circuit, for intermittent work, and *b*, closed circuit, for furnishing current continuously as in telegraphy.



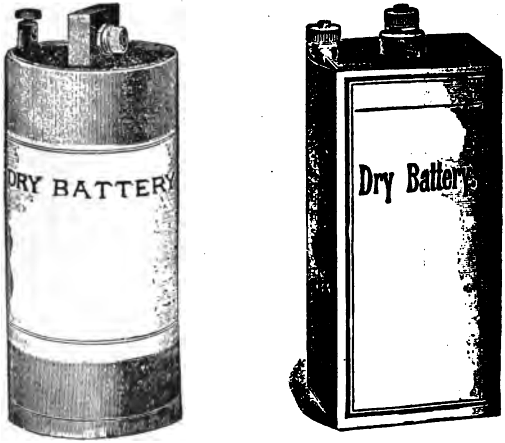
Figs. 6,165 to 6,173.—Various primary cells. Fig. 6,165, carbon cell; fig. 6,166, Disque Leclanche cell (single fluid with solid depolarizer); fig. 6,167, Fuller telephone standard cell (adapted to long distance telephoning); fig. 6,168, Edison single fluid cell (caustic soda electrolyte; suitable for ignition and R. R. signal work); fig. 6,169, Grenet cell (suitable for experimental work); fig. 6,170, Bunsen two fluid cell (suitable for experimental work); fig. 6,171, Daniell gravity "crow foot" pattern two fluid cell (*gravity* instead of a porous cup is depended upon to keep the liquids separate; suitable for closed circuit work); fig. 6,172, Partz acid gravity cell with depolarizer (the effective depolarizer permits both open and closed circuit work); fig. 6,173, Wheelock cell (carbon and zinc elements).

In *one fluid* cells both metal plates are immersed in the same solution.

In *two fluid* cells each metal plate is immersed in a separate solution, one of which is contained in a porous cup which is immersed in the other liquid.

Polarization.—In the operation of the simple primary cell *hydrogen is formed.*

Some bubbles of the gas rise to the surface of the electrolyte and so escape into the air, ***but much of it clings to the surface of the copper element which thus gradually becomes covered with a thin film of hydrogen***, this partly because the effective plate area is decreased and partly because the hydrogen tends to set up a reverse current, the output is considerably diminished and the cell is said to be polarized. Because of this, some cells are provided with a *depolarizer*, or substance, which prevents polarization by combining with the hydrogen.



Figs. 6,174 and 6,175.—Round and rectangular types of the so called "dry" cell.

So called "Dry" Cells.—A dry cell is composed of two elements, usually zinc and carbon, and a liquid electrolyte. A zinc cup closed at the bottom and open at the top forms the negative electrode; this is lined with several layers of blotting paper or other absorbing material.

Fig. 6,176.—Polarity indicator. It indicates the negative and positive poles when connected in circuit.

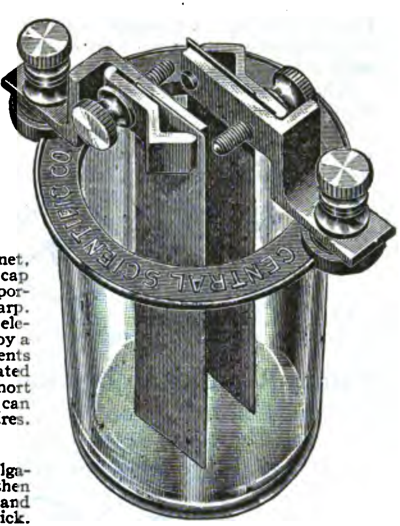


Fig. 6,177.—Students demonstration battery. An excellent battery for studying the laws of the voltaic cell, such as internal resistance, effects of amalgamating the zinc, use of various solutions, etc. With a complete set of elements the various forms of batteries in common use are readily assembled, namely; Simple voltaic, Bunsen, Grenet, Daniell gravity and LeClanche. The cap which fits the glass tumbler is made of porcelain, which is acid proof and will not warp. The clamps will hold either flat or round elements and, as they are attached to the cap by a swivel joint, the distance between the elements can be varied at will. The clamps are insulated from each other so that there can be no short circuit between the elements. The elements can be removed without disconnecting the lead wires.

BATTERY DIRECTIONS

Amalgamating.—A good method for amalgamating the zinc element is to dip it into acid, then pour a few drops of mercury on the surface and rub in with a piece of cloth attached to a stick. This is perhaps the best and quickest method although the most expensive.

Amalgamating Fluid.—Two-ounces mercury, 1 ounce acqua regia, 10 ounces water Dip zinc into solution and then wash with water. No need of brush or rag.

LeClanche Cell.—Place 6 ounces ammonium chloride into jar and fill with water to two-thirds its capacity. Stir well until the salt is entirely dissolved. Place elements with zinc outside porous cup as illustrated.

Carbon Cylinder Cell.—Directions furnished under LeClanche cell apply to this type of cell, except that zinc rod is placed inside carbon cylinder.

Samson Cell.—Directions furnished under carbon cylinder cell apply to this type of cell.

Grove Cell.—Outer cell contains amalgamated zinc plate dipping into dilute sulphuric acid (by weight 10 parts water to 1 part acid). In inner porous cup, a piece of platinum dips into nitric acid of full strength. Obnoxious nitrogen oxide fumes may be suppressed in a large measure by the addition of a small quantity of potassium dichromate.

Bunsen Cell.—This cell is merely a modification of the Grove cell, in which the expensive platinum is replaced by an electrode of gas carbon.

In both the Grove and Bunsen cells the nitric acid may be replaced by a chromic acid solution.

Grenet Cell.—In this cell the zinc plate between two carbon plates dips into a chromic acid solution (see below). When this cell is exhausted, the rich reddish color of chromic acid will be replaced by a muddy dark green color.

Chromic Acid Solution.—There are many different formulæ, but the most convenient method of making a generally useful acid is by simply dissolving prepared chromic acid salt in water. A useful formula is, 30 parts sodium dichromate, 100 parts water and 23 parts sulphuric acid (sp. gr. 1.845) all by weight.

Plunge Battery.—Elements and directions under Grenet type apply to this type of battery

Daniell Battery.—The zinc element is placed in a porous cup containing sulphuric acid (1 part acid to 20 parts water, by weight). The copper element encircles a porous cup and dips into saturated solution copper sulphate, kept continually saturated by the addition of an excess of copper sulphate crystals on bottom of jar. Solution is more effective by addition of few cubic centimeterx sulphuric acid.

The positive electrode consists of a carbon rod placed in the center of the cup; the space between is filled with carbon—ground coke and dioxide of manganese mixed with an absorbent material. This filling is moistened with a liquid, generally sal-ammoniac.

The top of the cell is closed with pitch to prevent leakage and evaporation. A binding post for holding the wire connections is attached to each electrode and each cell is placed in a paper box to protect the zincs of adjacent cells from coming into contact with each other when finally connected together to form a battery.

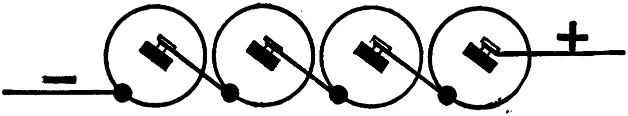


FIG. 6,178.—Series battery connection: The pressure between the (+) and (—) terminals of the *battery* is equal to *the product of the voltage of a single cell multiplied by the number of cells.*

Points Relating to Dry Cells.—The following items should be carefully noted:

1.—Never accept dry cells from a dealer without testing them with *your own* ammeter. 2.—Never use more cells in series than is necessary to do the work. 3.—Where there is vibration (as around gas engines) do not connect cell with heavy wire. 4.—If the cells be allowed to become moist or wet they will be ruined. 5.—Cells deteriorate with age, hence demand fresh cells, and do not fail to test them before buying. 6.—To strengthen weak cells in emergency, punch small holes in cup, place in sal-ammoniac solution, allowing cell to absorb all it will take up; close holes with shellac, or solder,

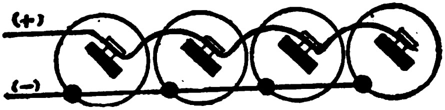


FIG. 6,179.—Multiple or parallel connection. The voltage *is the same as that of a single cell,* but the current is equal to the *amperage of a single cell multiplied by the number of cells.*

***BATTERY DIRECTIONS**—Continued*

Gravity Battery.—This type of battery is merely a form of Daniell cell, where the two solutions are kept separate by their difference in gravity. Place 2 pounds copper sulphate crystals in bottom of jar with copper element. Add clear water to fill the jar when elements are in position. Allow to stand for 2 hours, unless desired for use at once, in which case add 1 ounce zinc sulphate to solution and suspend zinc over edge of jar when liquids are sufficiently separated.

Fuller Cell.—Fill glass jar half full of chromic acid solution, place 1 teaspoonful mercury and 2 tablespoons full of common salt in the porous cup and fill with water to 1½ inches of top. The carbon element containing the porous cup is then placed in the glass jar, the zinc is placed in the glass jar and the cover over it. The solution should fill the glass jar to within an inch of the top.

Edison Cell.—Dissolve contents of can of caustic soda in jar filled with water to mark. Insert the elements, taking care that the copper oxide plate is at least 1 inch below the surface of the liquid. Carefully pour contents of bottle of oil on surface of solution. Oil excludes all air and keeps salts from forming.

wipe and replace in cover. 7.—A dry cell when new should show 1½ vots, and from 25 to 30 amperes. 8.—An ammeter test should be made as quickly as possible. 9.—An idea of the condition of a cell can be obtained by taking one terminal wire and snapping it across the other terminal and noting the intensity of the spark.

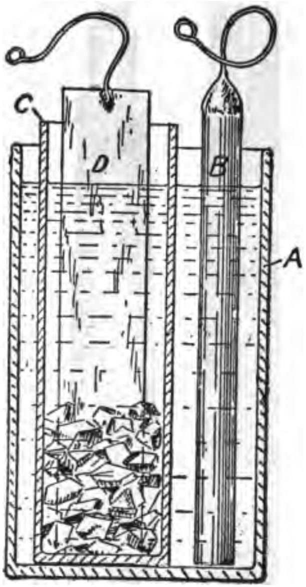


FIG. 6,180.—Simple Daniell cell for closed circuit work. To maintain a constant current for an indefinite time, it is only necessary to maintain the supply of copper crystals and zinc. ***Directions for making:*** The outer vessel A, consits of a glass jar (an ordinary glass jam jar will do) containing a solution of sulphuric acid (1 part in 12 to 20 parts of water), and a zinc rod B. Inside the jar is placed a porous pot C, containing a strip of thin sheet copper D, and a saturated solution of sulphate of copper (also called "blue stone" and "blue vitrol"). The zinc is preferably of the Leclanche form. The porous pot should be dipped in melted paraffin wax, both top and bottom to prevent the solution mingling too freely and "creeping." A few crystals of copper sulphate are placed in the pot as shown. In mixing the sulphuric acid and water, ***the acid should be added to the water—never the reverse.*** Zinc sulphate is sometimes used instead, as it reduces the wasteful consumption of the zinc, but it should be pure. With care a cell will last for weeks. When it weakens or "runs down" an addition of sulphuric acid to the outer jar and a few more crystals placed in the porous pot will renew its energy.

Battery Connections.—When two or more cells are connected together, the arrangement is called a *battery; most people persist in* ***erroneously*** *calling a single cell a battery.* Cells may be connected in several ways, as:

1. In series.
2. In parallel.
3. In series parallel.

These methods of connecting cells are illustrated in the accompanying cuts.

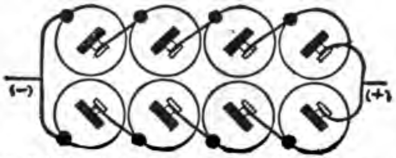
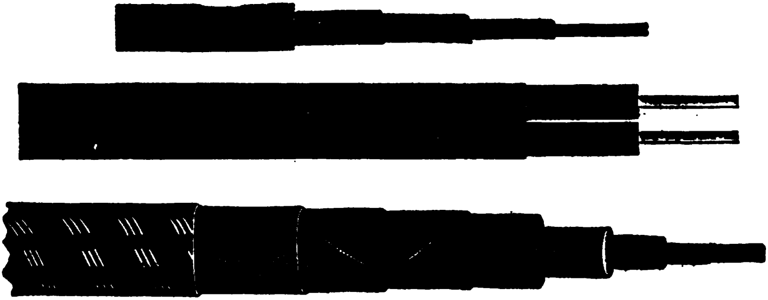


FIG. 6,181.—Series parallel connection. The pressure equals *the voltage of one cell, multiplied by the number of cells in one battery*, and the amperage, *that of one cell multiplied by the number of batteries.* This form of connection is objectionable unless all the cells be of equal strength.

CHAPTER 93

Conductors and Insulators

A conductor is a substance which permits the flow of electricity especially one which conducts electricity with great ease.



FIGS. 6,182 to 6,184.—Various covered wires. Fig. 6,182, single; fig. 6,183, duplex; fig. 6,184, automobile high tension cable.

Conductors offer more or less *resistance* to the flow depending upon the material. Copper wire is generally used as it offers but little resistance.

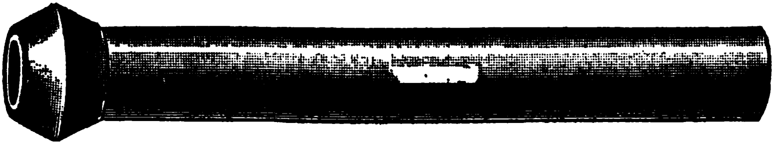
An insulator is a material (*erroneously called non-conductor*) which offers great resistance to the flow of the current

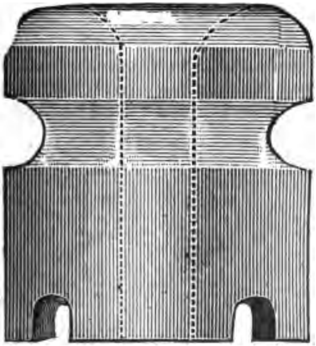
There is, however, no substance so good a conductor as to be devoid of resistance, and no substance of such high resistance as to be a *non-conductor*.

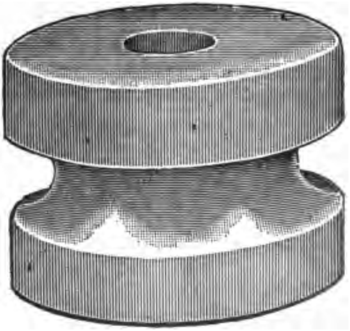
A conductor is said to be insulated when it is supported or insulated in such a way that it does not touch any other conductor and hence so that electricity cannot flow from it.

The series in the following table possess conducting power in different degrees in the order in which they stand, the most efficient conductor being first, and the most efficient insulator being last in the list.

Good Conductors	**Fair Conductors**	**Partial Conductors**	***Insulators***
Silver	Charcoal and coke	Water	Slate
Copper	Carbon	The body	Oils
Aluminum	Plumbago	Flame	Porcelain
Zinc	Acid solutions	Linen	Dry paper
Brass	Sea water	Cotton	Silk
Platinum	Saline solutions	Mahogany	Sealing wax
Iron	Metallic ores	Pine	Gutta percha
Nickel	Living vegetable substances	Rosewood	Ebonite
Tin		Lignum Vitæ	Mica
Lead	Moist earth	Teak	Glass
		Marble	*Dry* air







Figs. 6,185 to 6,187.—Standard porcelain insulators. Fig. 6,185, tube type; figs. 6,186, and 6,187, grooved insulators.

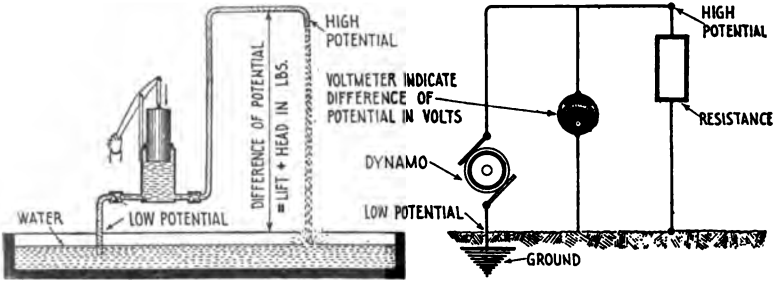
Resistance and Conductivity.—A current of electricity always flows in a conducting circuit when its ends are kept at different pressures in the same way that a current of water flows in a pipe when a certain pressure is supplied.

The same electrical pressure does not, however, always produce a current of electricity of the same strength, nor does a certain pressure of water always produce a current of water of the same volume or quantity. In both cases the strength or volume of the currents is dependent not only upon the pressure applied, but also upon the *resistance* which the conducting circuit offers to the flow in the case of electricity, and on the friction (which may be expressed as resistance) which the pipe offers to the flow in the case of water.

FIG. 6,188.—Hydraulic analogy of *resistance*. The hydraulic pump here shown with its steam cylinder of very large diameter as compared with the water cylinder is capable of pumping water against great pressure, caused by something, as a valve nearly closed, placed in the path of the flowing water which *opposes* its flow and thus is the cause of the pressure pumped against. ***Similarly,*** a dynamo pumps electricity through a circuit which opposes more or less its flow, this opposition being called *resistance*.

Resistance is that property of a substance that opposes the flow of an electric current through it.

The unit of resistance is the ohm already defined. The inverse of resistance is known as conductance or *conductivity*. That is if a conductor have a resistance of R ohms, its conductivity is equal to 1 ÷ R.



FIGS. 6,189 and 6,190.—Hydraulic analogy illustrating *potential*. When the pump is operated the water is forced up from a low level (low potential) to a high level (high potential) whence energy for the end of the pipe it falls back by gravity to the low level. ***Similarly,*** in fig. 6,190, the dynamo forces up electricity from a low potential to a high potential by interposing a resistance in the circuit passing through the resistance its potential falls to low potential. *The author* ***objects*** *to the term "potential" as the simple word* ***pressure*** *is more easily understood.*

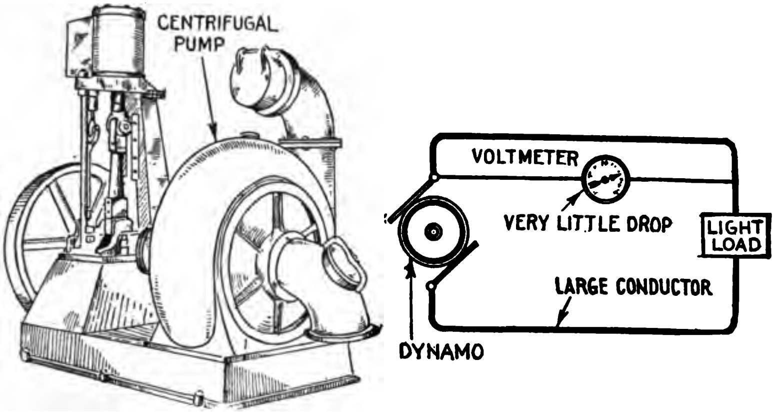
The unit of conductance is the ***mho***, which is the conductance offered by a column of pure mercury 106.3 *cm.* long and 14.4521 grams in mass at the temperature of melting ice.

Rule 6.*—Resistance varies directly as the length of a conductor.*

Example.—If the resistance of 15 ft. of wire be 5 ohms, what is the resistance of 1,000 ft. of the same wire?

$$\text{resistance 1,000 ft. of the wire} = 5 \times \frac{1{,}000}{15} = 333\tfrac{1}{3}\text{ ohms}$$

Rule 7.*—The resistance varies inversely as the cross section of a conductor.*



Figs. 6,191 and 6,192.—Hydraulic analogy of *conductivity*. The direct connected centrifugal pump set (fig. 6,191) with its small engine and large pump suggests the pumping of a large volume of water against low pressure—*easy flow*. *Similarly*, in fig. 6,192, a dynamo having an external circuit of very large copper wires "pumps" the electricity against very little resistance, thus a voltmeter connected as shown would show very little drop indicating high conductivity. Now if resistance wires were substituted for the copper wires, the voltmeter would show a large drop indicating low conductivity.

Example.—A conductor .01 sq. in. in cross sectional area has a resistance of .075 ohm per ft. What is the resistance of a conductor of the same material .04 sq. in. and one foot long?

The ratio between the two areas is $.04 \div .01 = 4$, hence, since the resistance varies inversely with the areas

$$\text{resistance of large wire} = .075 \div 4 = .01875$$

Conductivity or Conductance.—This is *the inverse of* *resistance.* The term expresses *the capability of a substance to conduct the electric current.*

Good conductors of heat are also good conductors of electricity.

Specific Conductivity.—By definition this is *the figure which indicates the relation between one substance and another as to their capacity to conduct electricity.*

The following table gives the data for a few metals:

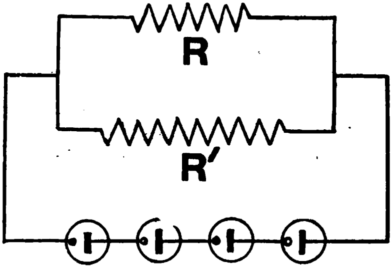


FIG. 6,193.—Divided circuit with two conductors *in parallel.*

Substance	**Specific resistance in microhms**	**Specific conductivity**
Silver	1.609	100.
Copper	1.642	96.
Gold	2.154	74.
Iron (soft)	9.827	16.
Lead	19.847	8.
German silver	21.470	7.5
Mercury (liquid)	96.146	1.6

Divided Circuits.—If a circuit be divided, as in fig. 6,193, into two branches R and R′, the current will also be divided, part flowing through one branch and part through the other.

Rule 8.—In a divided circuit the relative strength of the current in the several branches is proportional to their conductivities.

Example.—If, in fig. 6,193, the resistance of R = 10 ohms, and R′ = 20 ohms, the current through R, will be to the current through R′, as $^1/_{10}$ is to $^1/_{20}$; or, as 2:1, or, in other words, $^2/_3$ of the total current will pass through R, and $^1/_3$ through R′. The joint resistance of the two branches will be less than the resistance of either branch singly, because the current has increased facilities for travel. In fact, the joint conductivity will be the sum of the two separate conductivities.

Taking again the resistance of R = 10 ohms and R′ = 20 ohms, the joint conductivity is

$$\frac{1}{10} + \frac{1}{20} = \frac{3}{20}$$

and the joint resistance is equal to the reciprocal of $^3/_{20}$ or 6 $^2/_3$.

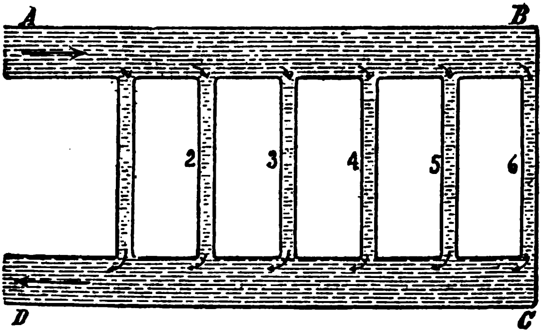


FIG. 6,194.—Hydraulic analogy for divided circuits. ***In the system*** of pipes shown, water flows from A B to CD through the six vertical pipes 1 to 6, the greatest amount going through the one which offers the least resistance. The electrical circuit presents the same conditions. the greater the number of parallel connections (corresponding to the pipes 1 to 6) the less is the resistance encountered by the current.

Example.—A current of 42 amperes flows through three conductors in *parallel* of 5, 10 and 20 ohms resistance respectively. Find the current in each conductor.

$$\text{joint conductance} = \frac{1}{5} + \frac{1}{10} + \frac{1}{20} = \frac{7}{20}$$

Supposing the current to be divided into 7 parts, 4 of these parts would flow in the first conductor, 2 in the second and 1 in the third.

The whole current is 42 amperes.

$^4/_7$ of 42 = 24 Current in first conductor = 24 amperes.
$^2/_7$ of 42 = 12 " " second " = 12 "
$^1/_7$ of 42 = 6 " " third " = 6 "
} Ans.

CHAPTER 94

Electrical and Mechanical Energy

The production of electricity is simply *a transformation of energy from one form into another.*

The electrical unit of work is the volt coulomb to amount of work performed *when* **one ampere** *of current flows for* **one second** *in a circuit whose resistance is* **one ohm,** *when the pressure is* **one volt.**

The Ampere-Hour.—A gallon of water may be drawn from a hydrant *in a minute* or *in an hour;* it is still one gallon. So in electricity, a given amount of the current, say one *coulomb*, may be obtained in a second or in an hour.

The ampere is the unit **rate** *of flow*, that is

one ampere = one coulomb per second

For commercial purposes the *ampere hour* which is a larger unit of electrical quantity than the coulomb is used. An ampere hour is the quantity of electricity passed by one ampere of current in one hour, or its equivalent, that is, since one

ampere = one coulomb × one second, and one hour = 60 × 60 = 3,600 sec.

$$\begin{aligned} \text{one ampere hour} &= 1 \text{ ampere} \times 3{,}600 \text{ seconds} \\ &= 60 \text{ amperes} \times 60 \text{ seconds} \\ &= 3{,}600 \text{ amperes} \times 1 \text{ second} \end{aligned}$$

which means that one ampere hour = one ampere flowing one hour, or 60 amperes flowing one minute, or 3,600 amperes flowing one second, or any other equivalent.

Example.—It is sometimes estimated that the quantity of electricity in a flash of lightning is $^1/_{10}$ coulomb, and the duration of the discharge $\frac{1}{20,000}$ part of a second. What is the current in amperes?

Now since

$$\text{coulombs} = \text{amperes} \times \text{seconds} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

solving (1) for the current,

$$\text{amperes} = \frac{\text{coulombs}}{\text{seconds}} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

substituting the given values in (2),

$$\text{amperes} = \frac{^1/_{10}}{\frac{1}{20,000}} = 2,000$$

Watts and Kilowatts.—One watt is the *power due to a current of one ampere flowing at a pressure of one volt.*

$$\begin{aligned}\text{That is, one watt} &= \text{one ampere} \times \text{one volt}\\ &= (\text{one coulomb} \times \text{one second}) \times \text{one volt}\\ &= (\text{one coulomb} \times \text{one volt}) \times \text{one second}\end{aligned}$$

and since one *joule* is the amount of work done when one coulomb of electricity flows under a pressure of one volt,

$$\text{one watt} = \text{one joule per second}$$

Since the watt is too small a unit for convenience in some commercial ratings, as for instance the output ratings of dynamos, motors, etc., a thousand watts or one kilowatt (abbreviated *kw.* is used), thus a 50,000 watt dynamo is called a 50 *kw.* dynamo.

The Watt Hour.—*This unit represents the amount of work done by an electric current of one ampere strength flowing for one hour under a pressure of one volt; that is,*

$$\begin{aligned}\text{One watt hour} &= \text{One ampere} \times \text{one hour} \times \text{one volt;}\\ &= 3,600 \text{ coulombs} \times \text{one volt.}\end{aligned}$$

Example.—An incandescent lamp taking one-half an ampere of current on a circuit having a pressure of 100 volts, or a lamp taking one ampere on a circuit having a pressure of 50 volts, would each be consuming 50 watts of energy, and this multiplied by the number of hours would give the total number of watt-hours for any definite time.

Electrical Horse Power.—One watt is equivalent to one joule per second or 60 joules per minute. One joule in turn, is equivalent to .7374 ft. lbs., hence 60 joules equal:

$$60 \times .7374 = 44.244 \text{ ft. lbs.}$$

Since one horse power = 33,000 ft. lbs. per minute, the electrical equivalent of one horse power is

$$33{,}000 \div 44.244 = 746 \text{ watts.}$$

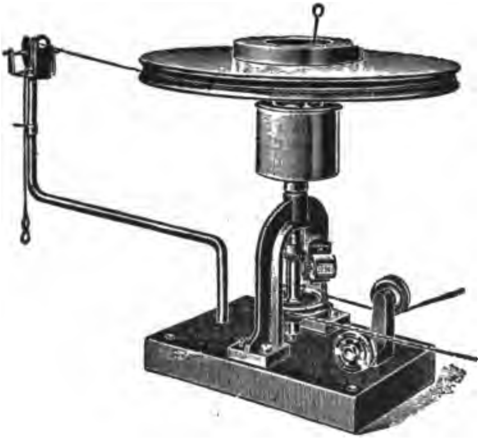


Fig. 6,195.—Callendar's mechanical equivalent of heat apparatus (Central Scientific Co.) With this apparatus a lecturer can obtain in about ten minutes in the presence of a class of students, a value of "J" correct to ½ per cent. Joules experiments 1843-50, gave the figure 772, known as "Joules equivalent," more recent experiment by Prof. Rowland (1880) and others give high figures: 778 is generally accepted. Marks and Davis value is 777.54 ft. lbs.

or,

$$\frac{746}{1{,}000} = .746 \text{ kilowatts}$$

Again one kilowatt (*kw.*) or 1,000 watts is equivalent to

$$1{,}000 \div 746 = 1.34 \text{ horse power.}$$

Heat.—By definition, ***heat*** is a form of energy. Heat is produced in the agitation of the molecules of matter—the energy expended in agitating these molecules is transformed into heat.

Heat is measured in *calories* or British thermal units (abbreviated *B.t.u.*).

A calorie is the ***amount of heat necessary to raise the temperature of one gram of water from*** 0° ***to*** 1° ***Centigrade;*** sometimes called the ***smaller calorie*** or ***therm.***

A British thermal unit (*B.t.u.*) is $\frac{1}{180}$ of the heat required to raise 1 lb. of water from 32° to 212° Fahr. (*Marks and Davis.*)

The calorie is used for calculation in Physics and the British thermal unit for commercial calculation.

CHAPTER 95

Current Effects

Electricity being *an invisible agent, known only by its effects*, it is important to note these effects. They are:

1. Thermal effect.
2. Magnetic effect.
3. Chemical effect.
4. Mechanical effect.

Thermal Effect.—The conductor along which the current

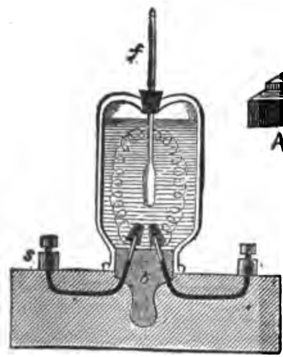


FIG. 6,196.—Lenz's apparatus for measuring the heat given off by an electric current. It consisted of a wide mouthed stoppered bottle fixed upside down, with its stopper, *b* in a wooden box; the stopper was perforated so as to give passage to two thick platinum wires, connected at one end with binding screws, *s*, while their free ends were provided with platinum cones by which the wires under investigation could be readily affixed; the vessel contained alcohol, the temperature of which was indicated by a thermometer fitted in a cork

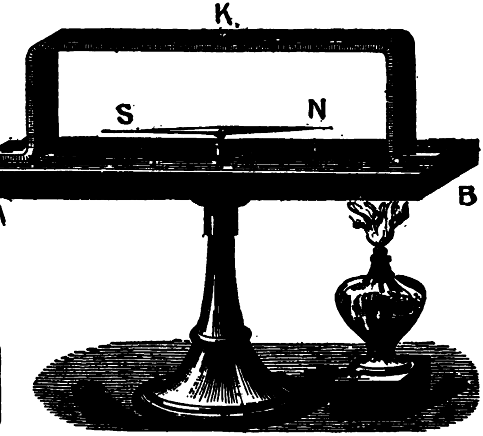


FIG. 6,197.—The Seebeck effect: If, in a complete metallic circuit having junctions of dissimilar metals, the junctions be at different temperatures, then a steady current will flow in the circuit as long as the differences of the temperatures of the junction is maintained. To demonstrate this, a piece of copper K, bent in the shape seen in the figure, was placed on a block of bismuth AB, carrying a pivoted magnetic needle NS. As soon as the equality flows becomes heated. The rise of temperature may be small or great according to circumstances, but some heat is always produced.

Rule 9.—JOULE'S LAW:—*The heat generated in a conductor by an electric current is proportional to: 1, the resistance of the conductor, 2, the time during which the current flows, and 3, the square of the strength of the current.*

Case 1.—Volts given.

The quantity of heat in calories may be calculated by use of the equation,

$$\text{calories per second} = \text{volts} \times \text{amperes} \times .24^{*} \qquad (1)$$

The total number of calories developed in a given interval of time is found by the equation,

$$\text{heat} = \text{volts} \times \text{amperes} \times \text{seconds} \times .24 \qquad (2)$$

Example.—If a current of 10 amperes flow in a wire whose terminals are at a pressure difference of 12 volts, how much heat will be developed in 5 minutes?

Substituting in equation (2):

$$10 \times 12 \times (60 \times 5) \times .24 = 8{,}640 \text{ calories}$$

Case II.—Volts not given.

Since by Ohm's law the pressure difference, or

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

Substituting in equation (2)

$$\text{heat} = \text{amperes}^{2} \times \text{ohms} \times \text{seconds} \times .24 \qquad (3)$$

FIG. 6,196.—*Text continued.*

inserted in a hole made in the bottom of the vessel. The current was passed through the platinum wires, and its strength measured by means of a galvanometer interposed in the circuit.

FIG. 6,197.—*Text continued.*

of temperatures was altered by either heating or cooling one of the junctions of the two metals, the needle indicated a current which continued to flow as long as the difference of temperature was maintained at the junctions.

---

*NOTE.—Heat amounting to .24 calorie equals the work represented by one joule.

Example.—An incandescent lamp of 150 ohms resistance uses one ampere. How much heat does it give off in one half hour in calories and in *B.t.u.?*

Substituting in (3)

$$\text{heat} = 1^2 \times 150 \times (60 \times 30) = 64{,}800 \text{ calories}$$

and since 1 calorie = 3.968 *B.t.u.*,

$$\text{heat} = 64{,}800 \times 3.968 = 257{,}126 \ B.t.u.$$

Heat Produces Electricity.—When a rod, say of bismuth is soldered, end to end, to a rod of antimony, and the two free ends are connected to a wire, then when the junction is heated, a current will flow through the whole circuit in the direction from bismuth to antimony. If the junction be cooled, the current will flow from antimony to bismuth.

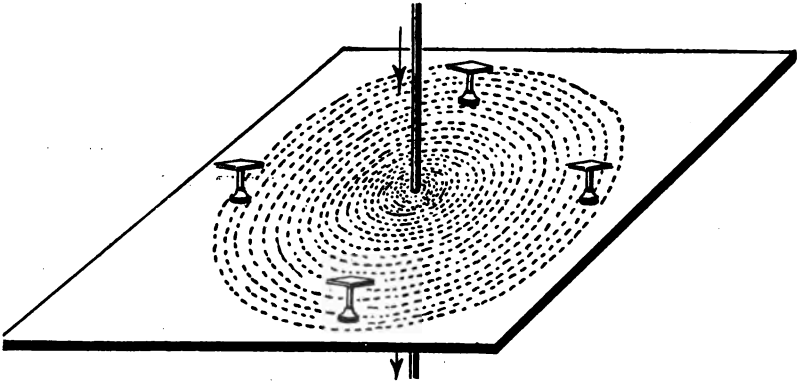


FIG. 6,198.—Magnetic field surrounding a wire in which a current is flowing. The magnetic field consists of lines of force which are circles concentric with the wire as indicated by a compass which will point in a direction perpendicular to the radius joining the compass and wire.

Again, if a current be sent through such a rod in the direction from bismuth to antimony, the junction becomes cooled; when from antimony to bismuth, the junction is heated. Two dissimilar metals soldered together is called a *thermo-electric couple.*

Magnetic Effect.—The space both outside and inside the substance of the conductor, but more especially the former, becomes a "magnetic field" in which delicately pivoted or suspended magnetic needles will take up definite positions and magnetic materials will become magnetized.

Chemical Effect.—If the conductor be a liquid which is a chemical compound of a certain class called *electrolytes*, the liquid will be decomposed at the places where the current enters and leaves it.

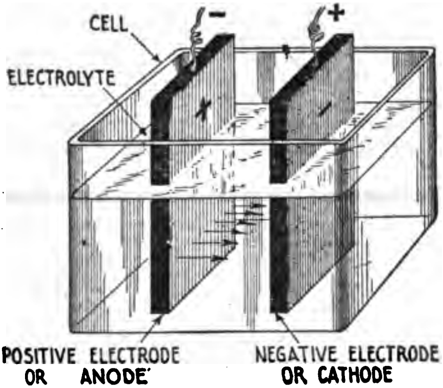


Fig. 6,199.—Electrolyte cell showing essential parts.

Rule 10.—GROTTHUSS' THEORY (announced in 1806). *The molecules in an electrolyte have their individual electro-positive and electro-negative atoms charged positively and negatively respectively.*

Faraday stated several laws of electrolysis as follows:

Rule 11.—LAW NO. 1.—*The quantity of an ion liberated in a given time is proportional to the quantity of electricity that has passed through the voltameter* in that time.*

Rule 12.—LAW NO. 2.—*The quantity of an ion liberated in a voltameter is proportional to the electro-chemical equivalent of the ion.*

Rule 13.—LAW NO. 3.—*The quantity of an ion liberated is equal to the electro-chemical equivalent of the ion multiplied by the total quantity of electricity that has passed.*

Mechanical Effect.—*Like poles repel each other and unlike poles attract each other, thus producing mechanical movement.* Upon these phenomena depend the operation of motors, dynamos and most other electrical apparatus.

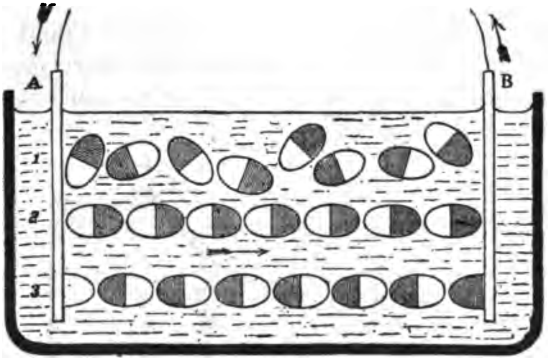
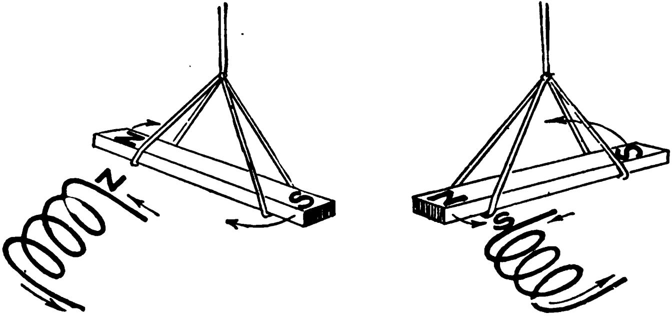
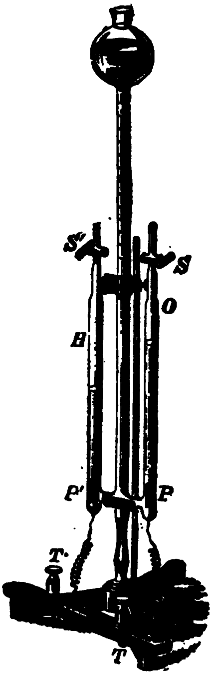


FIG. 6,200.—Electrolytic cell, illustrating Grotthuss' theory. In an ordinary liquid, for instance in water, the molecules are arranged indifferently, like row 1, with their positive and negative ends pointing in all directions. When the charged plates A and B connected to the + and — poles of a battery are inserted in the water, the molecules turn as shown in row 2, so that all the hydrogen or shaded ends (+) are turned towards the (—) plate B and all the oxygen or unshaded ends (—) towards the (+) plate A. All along the row the electrical forces are supposed to tear the molecules asunder, depositing H, on B, and O, on A. The atoms in the middle of the liquid, however, recombine, for the hydrogen atoms in their journey towards B, meet the oxygen atoms traveling in the opposite direction, and we get the state of affairs represented in row 3. The next step is to rotate once more the atoms into the positions shown in row 2, and so on. In this way the theory accounts for the products only appearing at the electrodes and not in the body of the liquid.



FIGS. 6,201 and 6,202.—Mechanical effect of the current: *Like poles repel each other; unlike poles attract each other.*



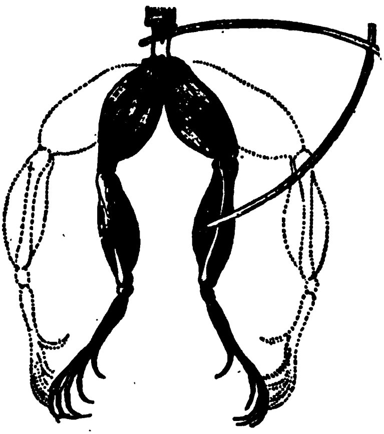


Fig. 6,203.—Galvani's experiment upon frogs' legs illustrating ***muscular contractions.*** It was discovered in 1678 that when a portion of a muscle of a frog's leg, hanging by a thread of nerve bound with a silver wire, was held over a copper support so that both nerve and wire touched the copper, the muscle immediately contracted.

Fig. 6,204.—Decomposition of water by electrolyses. Fill apparatus with acidulated water through central tube allowing air to escape through cocks S and S'. Now if terminal T, be attached to the positive and T', to the negative pole of a suitable battery, bubbles of gas will be observed to rise from the plates P and P', and finding their way to the top of the respective tubes, will displace the liquid, which will be driven into the open central tube. The gas rising from the anode P, is oxygen (O), and that rising from the kathode P', is hydrogen (H). If the tubes be graduated, the latter will be found to occupy about twice the volume of the former. The proportion is theoretically 2 to 1.

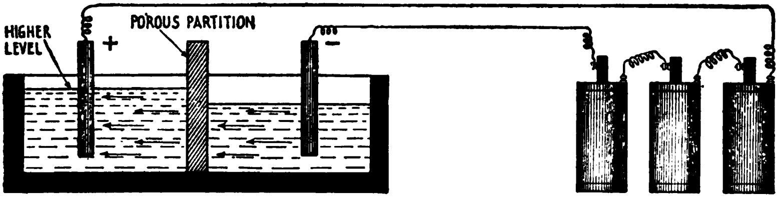


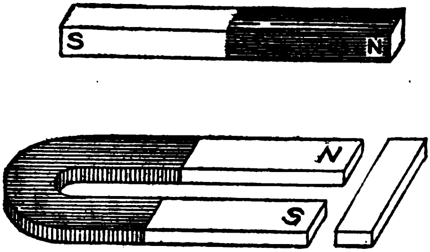
Fig. 6,205.—Electrolyte cell with porous partition illustrating ***electric osmosis.*** Porret observed that if a strong current be led into certain liquids, a porous partition being placed between the electrodes, the liquid is carried by the current through the porous partition, until it is forced up to a higher level on one side than on the other. This electric action is most pronounced when the experiment is made with liquids, which are poor conductors. The movement of the liquid takes place in the direction of the current.

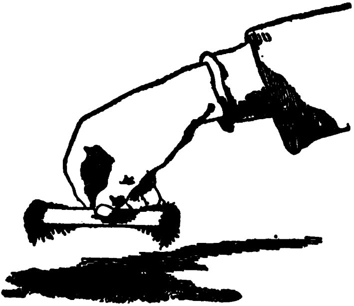
CHAPTER 96

Magnetism

Nobody knows what magnetism really is, but the latest and generally accepted theory assumes that *the molecules of a magnetic substance are minute magnets by nature, each having two poles.*

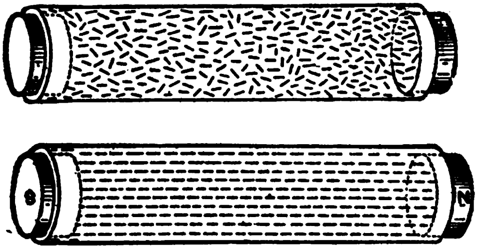
A magnet has two kinds of magnetism residing in the ends of the magnet. These ends are called the *poles*. These poles are distinguished as ***north*** and ***south***, because if the magnet were suspended by a thread or balanced on a pivot free to turn, the north pole would point approximately to the earth's geographical north, while the south pole would point approximately to the earth's geographical south. The north pole is the *positive* (+) pole and the south pole the negative (—) pole.





FIGS. 6,206 and 6,207.—Simple *bar magnet* and *horse shoe magnet* with *keeper*. These are known as *permanent magnets* in distinction from *electro-magnets*. The horse shoe magnet will attract more than the bar magnet because both poles act together. A piece of soft iron, or keeper is placed across the ends of a horse shoe magnet to assist in preventing the loss of magnetism.

FIG. 6,208.—***Magnetic poles.***—If a bar magnet be plunged into iron filings and then lifted, as illustrated in the figure, a mass of filings will cling to the ends of the magnet but not to the middle. The ends are called the *poles* of the magnet.



Figs. 6,209 and 6,210.—Experiment illustrating the molecular theory of magnetism. Coarse steel filings are placed inside a small glass tube and the contents magnetized. It will be found that filings which at first had no definite arrangement will rearrange themselves under the influence of magnetic force, and assume symmetrical positions, each one lying in line with, or parallel to its neighbor, as shown in fig. 6,210.

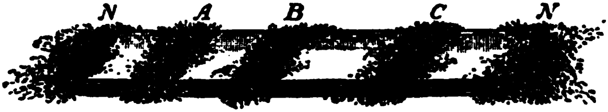
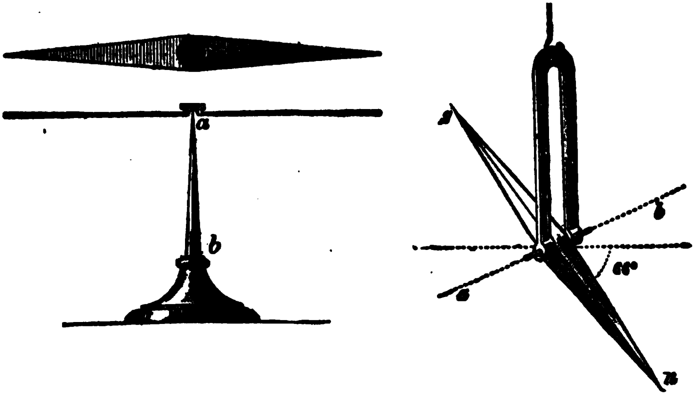
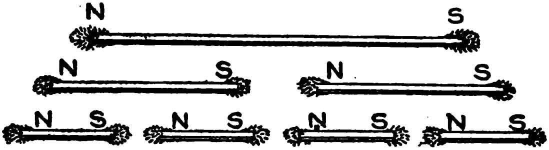


Fig. 6,211.—Badly magnetized bar. If an abnormal magnet with more than two poles be dipped into iron filings, the latter will adhere at places other than the two ends, as shown. The polarities are alternately N and S; that is, the regions N, B, N, have north polarity, while A and C, have south polarity. These are known as *consequent poles*.



Figs. 6,212 and 6,213.—Horizontal magnetic needle and magnetic *"dip"* needle. The horizontal needle indicates the magnetic meridian, and the dip needle indicates the angle which the lines of force make with the horizontal. In the northern hemisphere the N pole of the needle is depressed, in the southern hemisphere the S pole is similarly affected.



FIGS. 6,214 to 6,220.—Effect of breaking a magnet into several parts. ***Each part*** will be found to be a complete magnet having an N and S pole. The sub-division may be continued indefinitely, but always with the same result. This is evidence of the correctness of the molecular theory of magnetism, which states that ***the molecules of a magnet are themselves minute magnets arranged in rows with their opposite poles in contact.***

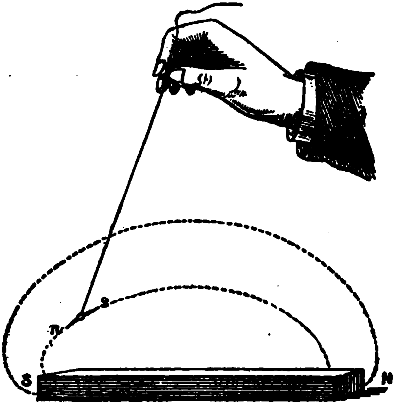


FIG. 6,221.—Tracing lines of force. If a small magnetic needle, suspended by a thread, be held near a magnet, it will point in some fixed direction depending on the proximity of the poles of the magnet.

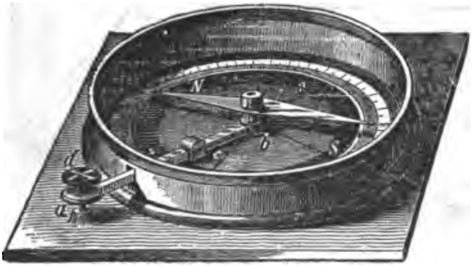


FIG. 6,222.—Simple compass. ***It consists of*** a magnetic needle resting on a steel pivot, protected by a brass case covered with glass and a graduated circle marked with the letters N, E, S, W, to indicate the cardinal points. *ab* is a lever which asserts the needle by pushing it against the glass when the button *d* is pressed.

Magnetic Field.—*This comprises the region around a magnet through which magnetic forces act.*

The magnetic field is said to be composed of *lines of force;* these lines are of circular form. The field is most intense near the poles of the magnet, becoming weaker and weaker as the distance from the magnet is increased until they finally disappear.

Magnetic Force.—*This is the force with which a magnet attracts or repels on the magnet another piece of iron or steel.*

Rule 14.*—Like magnetic poles repel one another; unlike magnetic poles attract one another.*

Rule 15.*—The force exerted between two magnetic poles varies inversely as the square of the distance between them.*

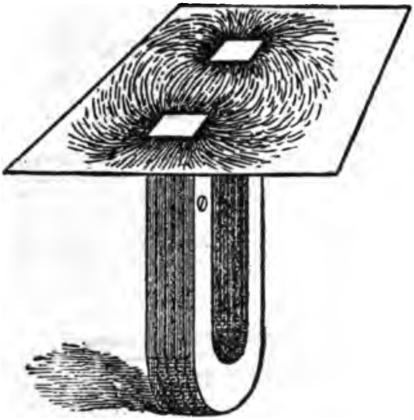
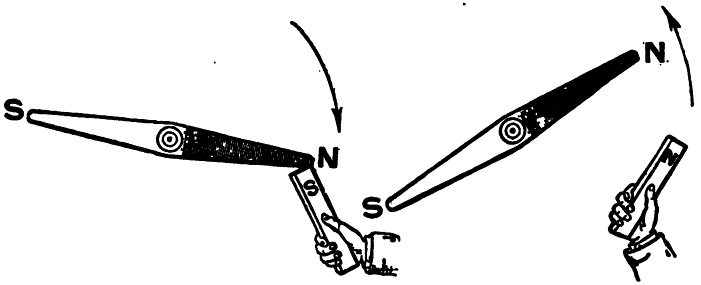


Fig. 6,223.—***The Magnetic Field.***—This may be represented graphically by sprinkling iron filings on a cardboard placed over a magnet and shaking the card. These will place themselves in curves reaching from pole to pole, these curves being called *lines of force*, and the space in which a magnet may create such lines is called the *magnetic field*.



Figs. 6,224 and 6,225.—Mutual action of poles: 1, ***unlike poles attract each other*** (fig. 6,224); ***like poles repel each other*** (Fig. 6,225).

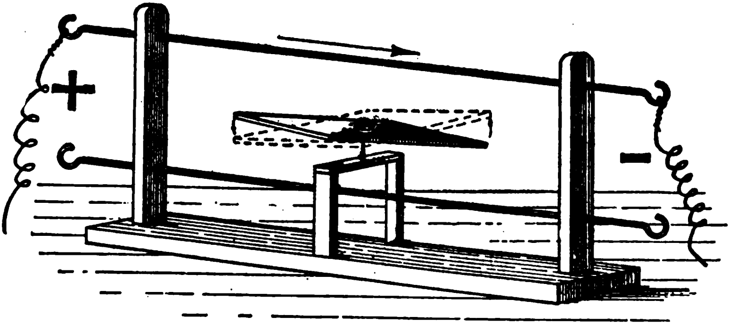


FIG. 6,226.—Oersteds discovery. In 1820 Hans Christian Oersted (1777-1851), found that *a magnetized needle was affected by the action of an electric current.* In 1813 Oersted stated: "It must be determined whether electricity in its most latent state has any action upon the magnet as such." Oersted found that the magnetic property of the current did not depend upon the kind or form of metal he employed and that the magnetic needle would be deflected by using any conductor, even a litre of mercury being effectual, the only difference being in the quantity of effect produced, and the results were obtained even if the conductor be interrupted by water, unless the interruption be of great extent.

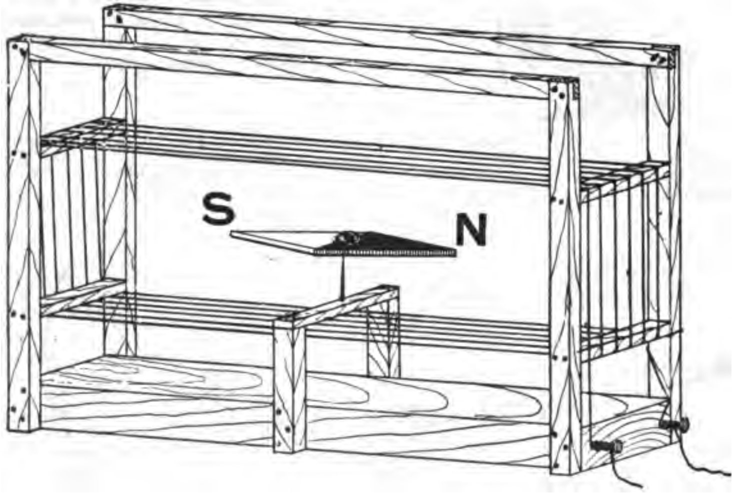


FIG. 6,227.—Schweigger's experiment, showing effect of several turns of wire. In 1821 Schweigger placed a compass needle in the center of a parallelogram and wound several turns of wire around it, as shown, each turn being insulated. Movable magnet galvanometers utilize the principle of Schweigger's apparatus for their operation. Schweigger's apparatus was called Schweigger's multiplier.

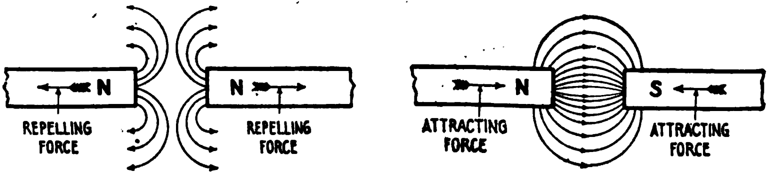
Magnetic Circuit.—*The path taken by the magnetic lines of force is called the magnetic circuit;* the greater part of such a circuit is usually in magnetic material, but there are often one or more air gaps included.

The following definitions should be carefully noted:

***Magnetic Flux.**—The total number of lines of force in the magnetic circuit*

***Reluctance.**—The resistance offered to the magnetic flux by the substance magnetized; magnetic resistance.* It is equal to the ratio of the magnetic force to the magnetic flux.

***Oersted.**—The unit of reluctance being the reluctance offered by a cubic centimeter of vacuum.*



FIGS. 6,228 and 6,229.—Mutual effect of *like* and *unlike* poles; *like poles repel each other; unlike poles attract each other*

***Maxwell.**—The amount of magnetism passing through every square centimeter of a field of unit density.*

****Gauss.**—The intensity of field which acts on a unit pole with a force of one dyne. It is equal to one line of force per square centimeter.*

Magnetic Effect of the Current.—Much is due to Hans Christian Oersted, who made numerous experiments in magnetism.

Rule 16.—OERSTED'S DISCOVERY—*A magnet tends to set itself at right angles to a wire carrying an electric current.*

Oersted also found that the way in which the needle turns, whether

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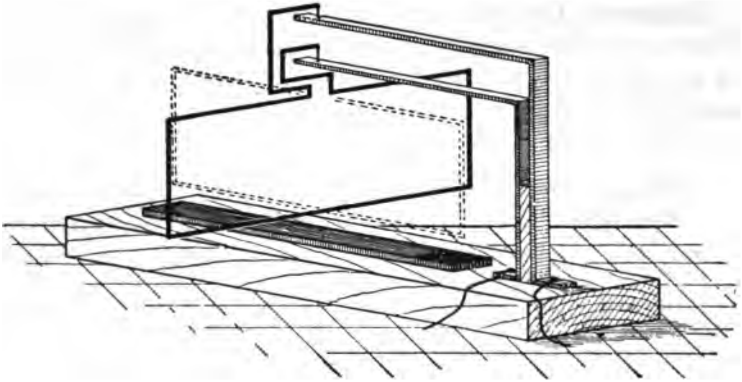
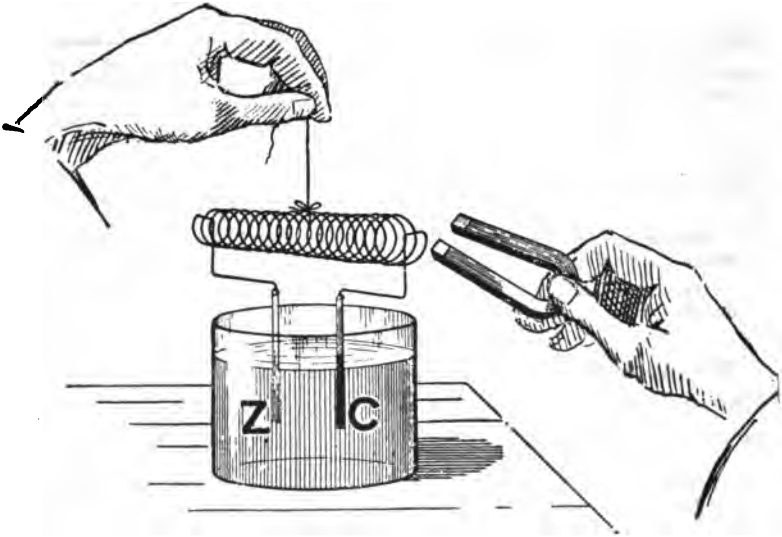
NOTE.—***Hans Christian Oersted,*** born 1777, died 1851, the Danish physicist, was noted for his experiments on the magnetic needle with the electric current.

*NOTE.—***Karl Friedrich Gauss,*** born 1777, died 1855. He was a German mathematician, founder of the mathematical theory of electricity and inventor of the bifilar magnetometer. The unit *gauss* was named after him.

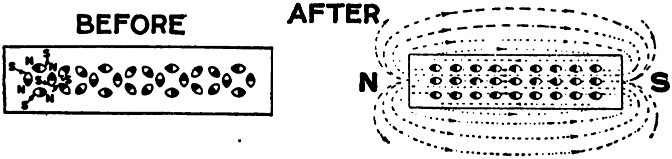




FIGS. 6,230 and 6,231.—Ampere's experiments. Following Oersted's discovery, Ampere began his investigations. He reversed Oersted's experiment (fig. 6,230) and showed the action of a magnet on a movable circuit by means of a rectangular movable frame suspended from mercury cups. When a magnet is placed near this frame and current is flowing, the frame will be attracted by the magnet. Another experiment performed by Ampere was with a solenoid whose ends were attached to copper and zinc electrodes immersed in an acid solution thus forming a cell as in fig. 6,231. When suspended as shown one end of the solenoid will be attracted by a magnet.

to the right or left of its usual position, depends: 1, upon the position of the wire that carries the current, whether it be above or below the needle, and 2, on the direction in which the current flows through the wire.

Rule 17.—CORKSCREW RULE—*If the direction of travel of a right handed corkscrew represent the direction of the current in a straight conductor, the direction of rotation of the corkscrew will represent the direction of the magnetic lines of force.*



FIGS. 6,232 and 6,233.—Arrangement of molecules in iron bar *before* and *after* magnetization according to the generally accepted theory.

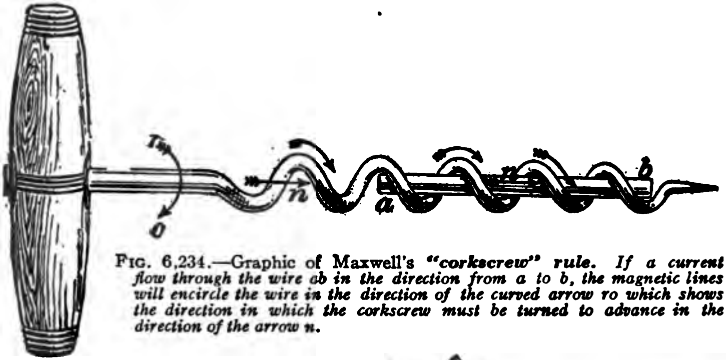
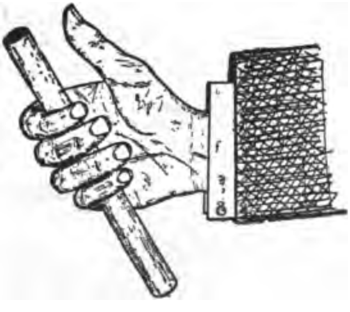


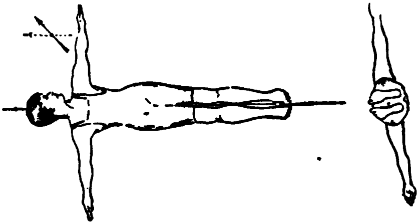
FIG. 6,234.—Graphic of Maxwell's **"corkscrew" rule.** *If a current flow through the wire ab in the direction from a to b, the magnetic lines will encircle the wire in the direction of the curved arrow ro which shows the direction in which the corkscrew must be turned to advance in the direction of the arrow n.*

FIG. 6.235.—***Right hand rule*** for direction of magnetic field around a conductor carrying a current. *The thumb of the right hand is placed along the conductor, pointing in the direction in which the current is flowing, then, if the fingers be partly closed, as shown in the illustration, the finger tips will point in the direction of the magnetic whirls.*



Rule 18.—RIGHT HAND RULE—*The thumb of the right hand is placed along the conductor, pointing in the direction in which the current is flowing —then, if the fingers be partly closed, the finger tips will point in the direction of the magnetic whirls.*

Rule 19.—AMPERE'S RULE—*Suppose yourself to be in the wire, floating with the current and facing the needle; its north pole will turn toward your left hand.*



FIGS. 6,236 and 6,237.—Amperes left hand rule: *Suppose a man swimming in the wire with the current, and that he turn so as to face the needle, then the N.-seeking pole of the needle will be deflected towards his left hand.*

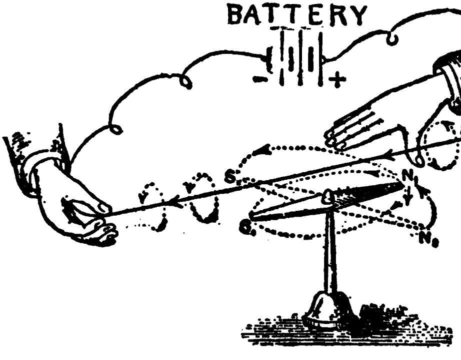


FIG. 6,238.—Right hand palm rule to determine the direction of the magnetic field around a conductor carrying a current. *Place the palm of the outstretched right hand above and to the right side of the wire with the fingers pointing in the direction of the current and the thumb extended at right angles, that is, pointing downward. The direction in which the thumb points will indicate the direction of the magnetic whirls.*

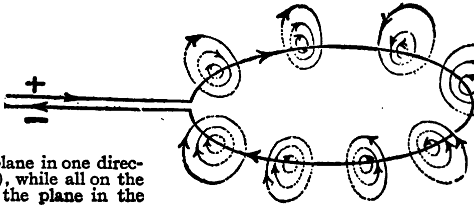


FIG. 6,239.—Lines of force of a circular loop. If a current flow through the loop in the direction indicated the lines of force both inside and outside the loop, will cross the plane of the loop at right angles, and all those which cross the loop on the inside will pass through the plane in one direction (downward in the figure), while all on the outside will return through the plane in the opposite direction.

***Rule 20.**—Magnetic lines of force tend to occupy a position in which they are parallel with each other and run in the same direction.*

Solenoids.—A solenoid consists of a spiral of conducting wire wound cylindrically so that, when an electric current passes through it, its turns are nearly equivalent to a succession of

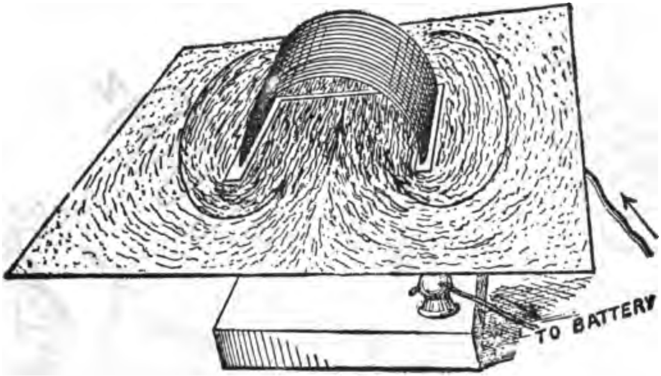


FIG. 6,240.—Magnetic field of a solenoid. If iron filings be sprinkled on the cardboard and a current passed through the solenoid, the character of the field is as indicated.

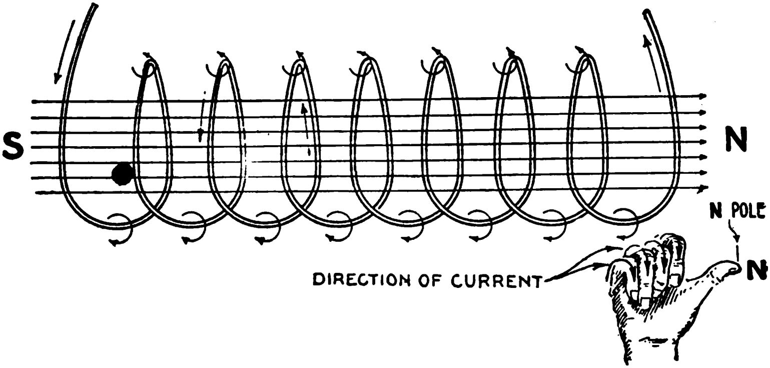
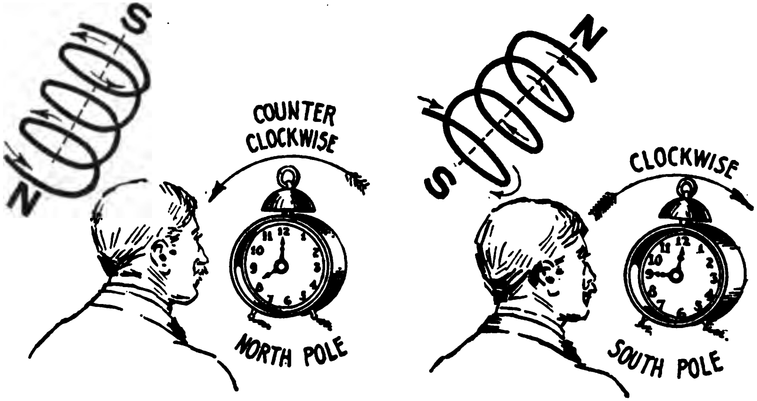


FIG. 6,241.—***Right hand palm rule*** to determine the direction of the magnetic field around a conductor carrying a current: *Place the palm of the outstretched right hand above and to the right side of the wire with the fingers pointing in the direction of the current, that is, pointing downward, and the thumb extended at right angles. The direction in which the thumb points will indicate the direction of the magnetic field.*

parallel circular circuits, and it acquires magnetic properties similar to those of a bar magnet.

Rule 21.*—Upon the direction in which the current flows through a solenoid depends its polarity.*

The rule which follows is the most conveniently applied rule for polarity of solenoids.



FIGS. 6,242 and 6,243.—Application of the clock rule for polarity of solenoids. ***It will be noted*** that the polarity depends upon the direction of the current and the *order* of winding.

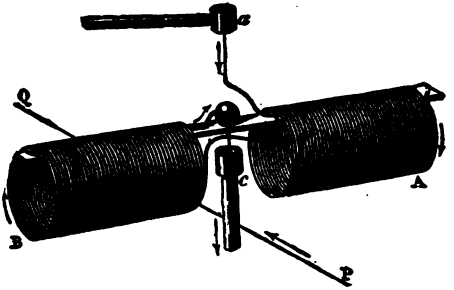
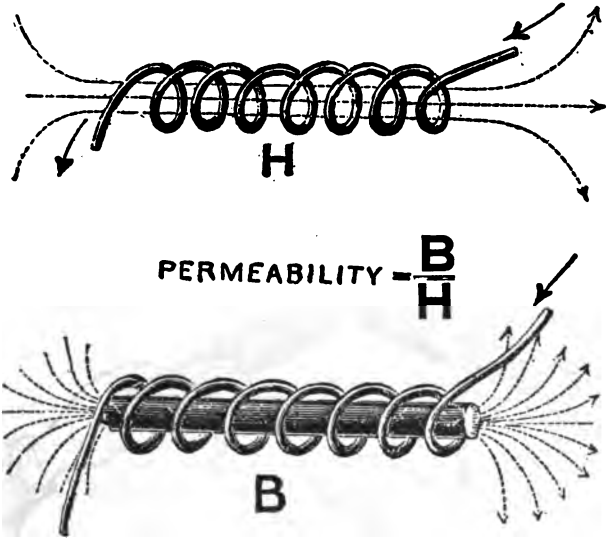


FIG. 6,244.—Action of currents on solenoids. ***To demonstrate*** this fact experimentally, a solenoid is constructed as shown, so that it can be suspended by two pivots in the cups *a* and *c*. The solenoid is then movable about a vertical axis, and if a rectilinear current QP, be passed beneath it, which at the same time traverses the wires of the solenoid, the latter is seen to turn and set at right angles to the lower current; that is, in such a position that its circuits are parallel to the fixed current; moreover, the current in the lower part of each of the circuits is in the same direction as in the rectilinear wire. If, instead of passing a rectilinear current below the solenoid, it be passed vertically on the side, an attraction or repulsion will take place, according as the two currents in the vertical wire, and in the nearest part of the solenoid, are in the same or in contrary directions.

Rule 22.—RIGHT HAND RULE—*If the solenoid be grasped in the right hand, so that the fingers point in the direction in which the current is flowing in the wires, the thumb extended will point in the direction of the north pole.*

Rule 23.—CLOCK RULE—*For a person standing at the south pole of a solenoid, the current flows in the direction in which the hands of a clock turn*, from the left *over* to the right; if he stand at the north pole, the current *will flow counter clockwise.*

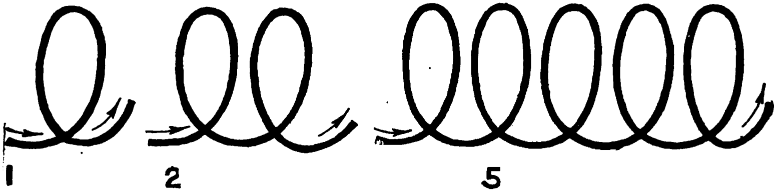


Figs. 6,245 and 6,246.—Illustrating the effect of introducing an iron core into a solenoid. Few lines pass through the air core, while many pass through the iron core. The number of lines B, passing through a unit cross section of the iron core divided by the number of lines H, passing through a unit cross section of the air core is called the *permeability* and designated by the Greek letter μ.

Permeability.—This is a measure of the ease with which magnetism passes through any substance. It is defined as: *the ratio between the number of lines of force per unit area passing through a magnetizable substance, and the magnetizing force which produces them.*

***Rule 24.**—The permeability of any piece of material increases with the increase of cross section and decreases with the increase of length.*

Magnetic Saturation.—For all practical purposes, magnetic saturation may be defined as: *That point of magnetism where a very large increase in the magnetizing force does not produce any perceptible increase in the magnetization;* that is, the state of a magnet which has reached the highest practical degree of magnetization.



FIGS. 6,247 to 6,249.—***Ampere turns. By definition*** the ampere turns is equal to the *product of the current passing through a coil multiplied by the number of turns in the coil.* Thus, in fig. 6,247, ampere ×1 turn = 1 ampere turn; in fig. 6,248, 5 amperes ×2 turns =10 ampere turns; in fig. 6,249, 2 amperes ×5 turns =10 ampere turns.

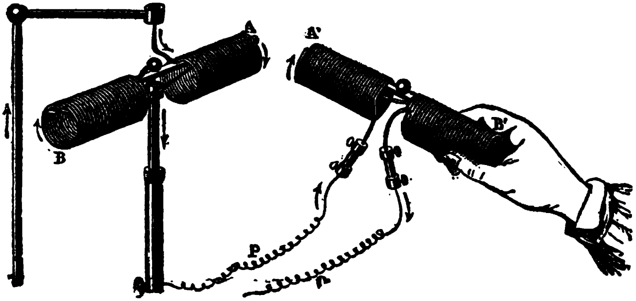


FIG. 6,250.—Mutual action of solenoids. When two solenoids traversed by a current are allowed to act on each other, one of them being held in the hand and the other being movable about a vertical axis, as shown in the figure, attraction and repulsion will take place just as in the case of two magnets (see figs. 6,224 and 6,225).

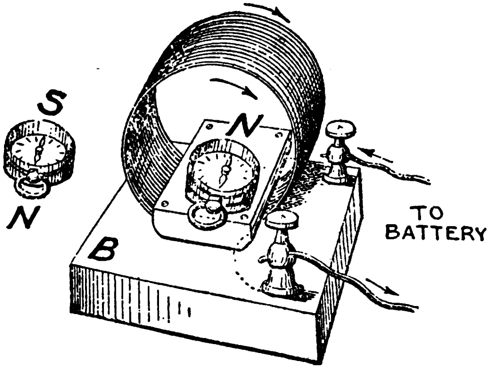
Ampere Turns.—When a coil passes around a core several times, its magnetizing power is proportional both to the strength of the current and to the number of turns in the coil. *The product of the current passing through the coil multiplied by the number of turns composing the coil is called the* ***ampere turns.***

By experiment, one ampere turn produces 1.2566 units of magnetic pressure, hence:

magnetic pressure = 1.2566 × turns × amperes

The unit of magnetic pressure is the *gilbert* (named after William Gilbert, the English physicist) and is equal to

1 ÷ 1.2566 ampere turn = .7958 ampere turn



FIGS. 6,251 and 6,252.—Magnetic conditions inside and outside of a solenoid. If magnetic needles be placed inside and outside the solenoid as shown and a current be passed through the coil, it will be found that the magnetic force inside the coil is in a direction opposite to that outside the coil as indicated by the magnetic needles.

Comparison of Electric and Magnetic Circuits.—The total number of magnetic lines of force, or magnetic flux, produced in any magnetic circuit will depend on the magnetic pressure (*m.m.f.*) acting on the circuit and the total reluctance of the circuit, just as the current in the electrical circuit depends upon the electrical pressure and the resistance of the circuit, that is:

NOTE.—***William Gilbert,*** born 1540, died 1603. He was an English physicist, noted for his experiments in magnetism, and for the publication in 1600 of his chief work "De Magnete" which marked an epoch in the science of magnetism, and earned for its author the title of the "founder of the science of magnetism and electricity." *The practical unit of magnetic force* (the ***gilbert***) was named after him.

Electric circuit	**Magnetic circuit**
amperes $= \dfrac{\text{volts}}{\text{ohms}}$	maxwells $= \dfrac{\text{gilberts}}{\text{oersteds}}$

It should be noted that in the electric circuit, resistance causes heat to be generated and therefore energy to be wasted, but in the magnetic circuit *reluctance does not involve any similar waste of energy.*

Rule 25.*—The reluctance is directly proportional to the length of the circuit, and inversely proportional to its cross sectional area.*

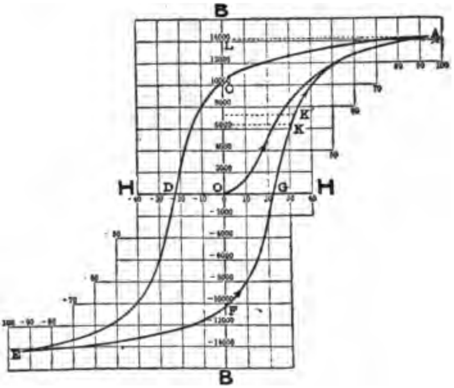


FIG. 6,253.–Hysteresis loop or curve showing how *B*, changes when *H*, is periodically varied. ***In the figure*** H = number of lines of force per sq. cm. (strength of field) and B = number of lines of induction per sq. cm. If now H, be gradually diminished to zero, it is found that the value of B, for any given value of H, is considerably greater when that value of H, was reached by *decreasing* H, from a higher value, than when the same value was reached by *increasing* H, from a lower value; that is, to say, the curve AC, when H, is decreased, is very different from the curve OA, when it is increased. Take for instance, the value H = 20. When this is reached by increasing H, from 0 to 20, the corresponding value of B, is 5,100, but when it is reached by decreasing H, from 94 to 20, the value of B, is 12,200. It may be noted, too, that when H, is reduced to zero, B, still has a value OC, or 10,300, which is nearly three quarters the value it had when H, was 94. This induction is the "residual magnetism" mentioned already. ***In soft iron*** it will nearly all disappear on tapping, but without this it can also be removed by reversing the current in the magnetising coil, so as to demagnetise the iron. The curve shows that a demagnetising force of H = 23 is required to make B, zero at the point D. This force is called the *coercive force* of the iron, and measures the tenacity with which it holds the residual magnetism. As the magnetising force is still further increased in reverse direction, the curve goes from D, to E, where the iron becomes saturated negatively. On gradually returning, H, to zero, the curve goes from E, to F, along a similar but opposite path to AC, OF, being again the residual magnetism. The magnetising force has now passed round a cycle from O, to a positive value, back to O, to a negative value, and again back to O, and if this cycle be repeated several times, the B-H curve becomes a loop *FGACDE*, which is symmetrical about the center O.

The reluctance of a magnetic circuit is calculated according to the following equation:

$$\text{reluctance} = \frac{\text{length in centimetres}}{\text{permeability} \times \text{cross section in square centimetres}}$$

Hysteresis.—The term hysteresis has been given by Ewing to the subject of *lag of magnetic effects behind their causes*.

It is a peculiar quality of an iron core, such as an armature core undergoing rapid reversals of magnetism, by which there occurs an expenditure of energy which is converted into heat. This loss of energy is due to the work required to change the position of the molecules of the iron and takes place both in the process of magnetizing and demagnetizing; the magnetism in each case lagging behind the force: *static* hysteresis as distinguished from *viscous* hysteresis.

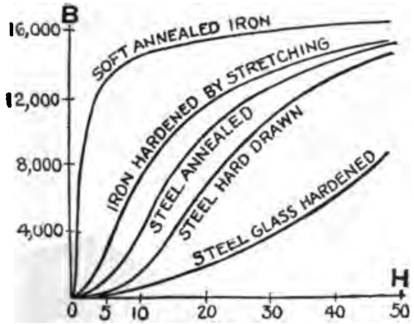


FIG. 6,254.—*BH* curves for iron and steel.

Residual Magnetism.—When a mass of iron has once been magnetized, it becomes a difficult matter to entirely remove all traces when the magnetizing agent has been removed, and, as a general rule, a small amount of magnetism is permanently retained by the iron. This is known as *residual magnetism*, and it varies in amount with the quality of the iron.

Residual magnetism in iron is of great importance in the working of the *self-exciting* dynamo, and is, indeed the essential principle of this class of machine.

Without residual magnetism in the field magnet core, the dynamo when started would not generate any current unless it received an initial excitation from an external source.

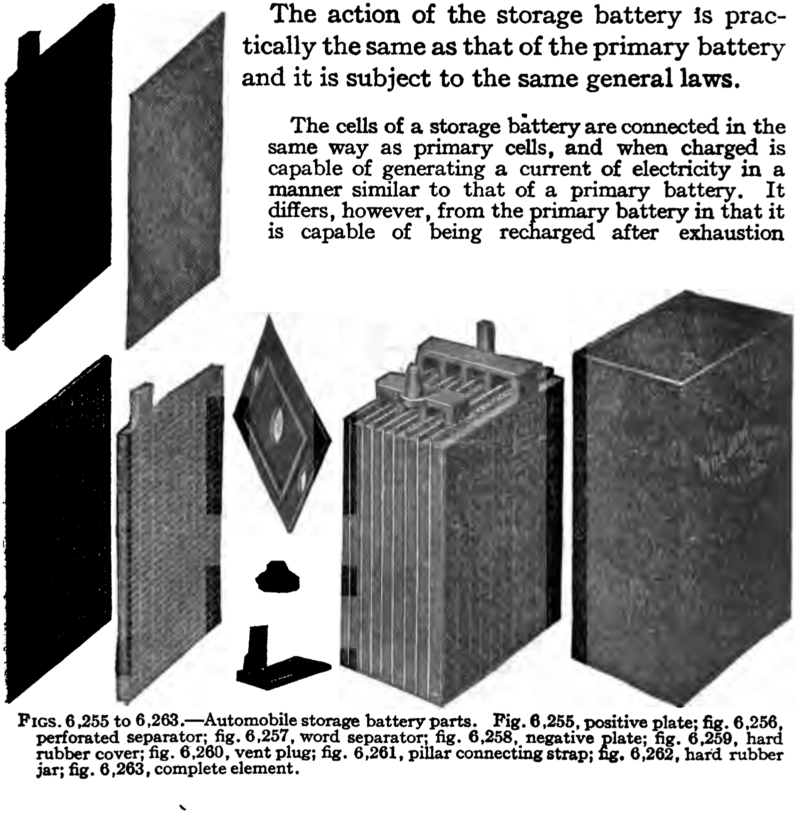
NOTE.—***Ewing's theory of magnetism.***—A theory of magnetism advanced by Ewing, that molecular magnets are held together, not by friction but by mutual magnetic attraction, their poles pointing in every direction till some outside magnetic force draws them into a common direction.

CHAPTER 97

Storage Batteries

The action of the storage battery is practically the same as that of the primary battery and it is subject to the same general laws.

The cells of a storage battery are connected in the same way as primary cells, and when charged is capable of generating a current of electricity in a manner similar to that of a primary battery. It differs, however, from the primary battery in that it is capable of being recharged after exhaustion



Figs. 6,255 to 6,263.—Automobile storage battery parts. Fig. 6,255, positive plate; fig. 6,256, perforated separator; fig. 6,257, word separator; fig. 6,258, negative plate; fig. 6,259, hard rubber cover; fig. 6,260, vent plug; fig. 6,261, pillar connecting strap; fig. 6,262, hard rubber jar; fig. 6,263, complete element.

by passing an electric current through it in a direction opposite to that of the current on discharge. This difference constitutes the principal advantage of the storage battery over the primary battery.

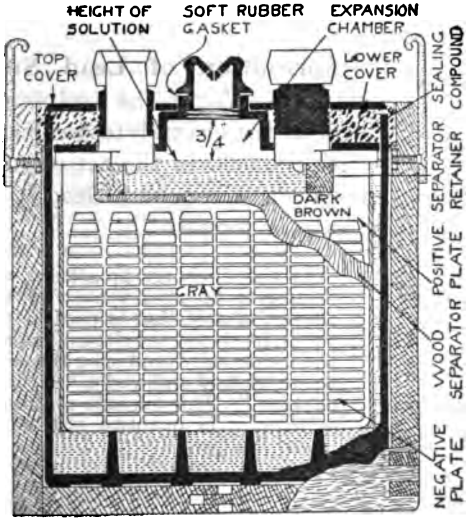
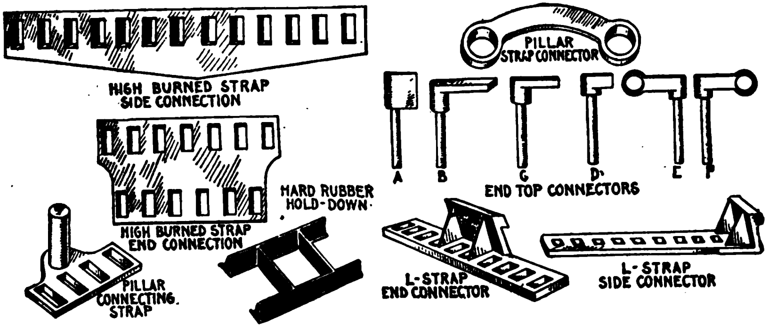


Fig. 6,264.—Sectional view of Gould cell showing various parts.

General.—A storage battery consists of one or more cells. A cell consists essentially of positive and negative plates immersed in electrolyte.

The electrolyte generally used consists of a mixture of sulphuric acid and water. The voltage of one cell is about two volts.



Figs. 6,265 to 6,277.—Willard connecting straps and connectors.

When a cell is put on discharge, the current is produced by the acid in the electrolyte going into and combining with the lead of the porous part of the plates called "active material." In the positive plate, the active material is lead peroxide, and in the negative plate, it is metallic lead in a spongy form.

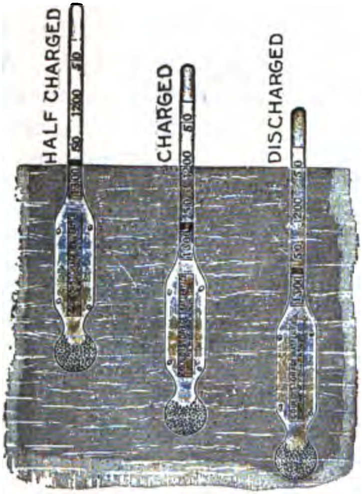
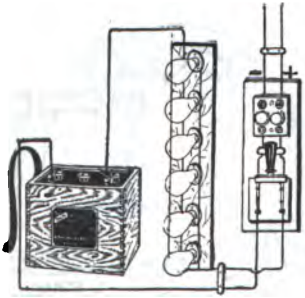


Fig. 6,278.—State of charge as indicated by hydrometer reading of density of the electrolyte.

Formation of Lead Sulphate.—When the sulphuric acid in the electrolyte combines with the lead in the active material, a compound, lead sulphate, is formed.

As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is used in the plates, producing the electric current and incidentally producing the compound of acid and lead called "lead sulphate." This sulphate continues to increase in quantity and bulk,



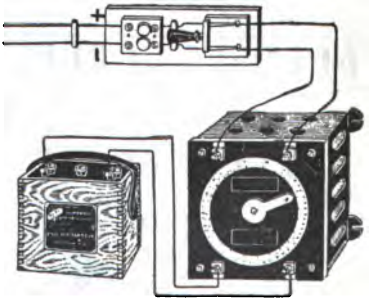
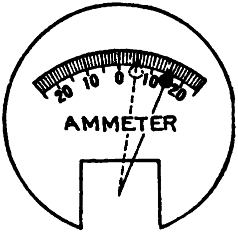


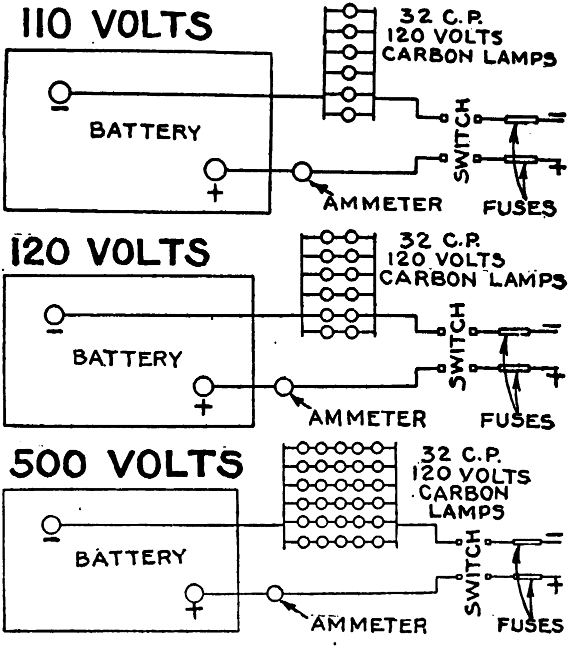
Fig. 6,279.—Diagram illustrating method of charging with lamps in parallel or direct current circuit.

Fig. 6,280.—Diagram illustrating method of charing with rheostat on direct current circuit.



thereby filling the pores of the plates. As the pores of the plates become thus filled with the sulphate, the free circulation of acid into the plates is retarded; and since the acid cannot then get into the plates fast enough to maintain the normal action, the battery becomes less active, as is indicated by the drop in voltage.

Fig. 6,281.—Method of reading ammeter when the current is unsteady. Owing to the irregularity of the explosion in a hit-and-miss engine, it is almost impossible to maintain a steady reading of the ammeter, as the ammeter hand will swing forward at each impulse of the engine and drop back until the next explosion. In this case, adjust the rheostat so that the ampere reading will be equal to the designated charging rate. If the hand oscillate for instance, between 5 to 15, the current value is ½ (5+15) = 10 amperes.



Figs. 6,282 to 6,284.—Charging through bank of lamps on 110, 220, and 500 volt circuit.

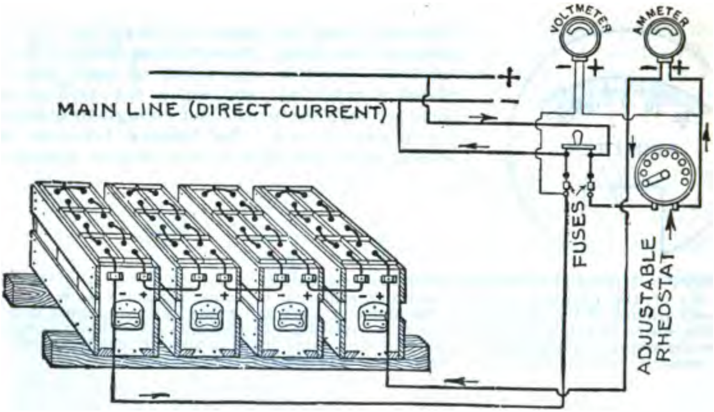


FIG. 6,285.—Charging several batteries, **rheostatic control.** *The trays are first connected in series. The current flows from the positive wire of the current supply, into the positive terminal of the first tray (in this case on the right); through the positive and out the negative of each cell and each tray in turn and returns to the current supply from the negative of the last cell. The voltmeter is connected between the resistance and the battery in order to show battery voltage.*

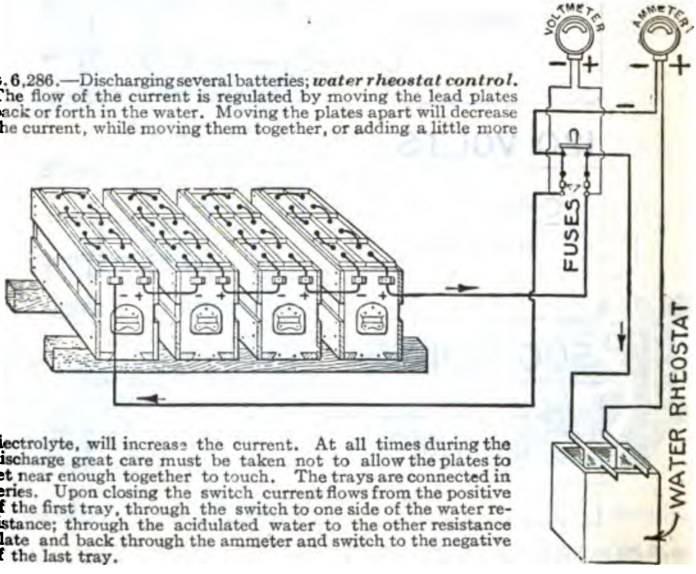


FIG. 6,286.—Discharging several batteries; *water rheostat control.* The flow of the current is regulated by moving the lead plates back or forth in the water. Moving the plates apart will decrease the current, while moving them together, or adding a little more electrolyte, will increase the current. At all times during the discharge great care must be taken not to allow the plates to get near enough together to touch. The trays are connected in series. Upon closing the switch current flows from the positive of the first tray, through the switch to one side of the water resistance; through the acidulated water to the other resistance plate and back through the ammeter and switch to the negative of the last tray.

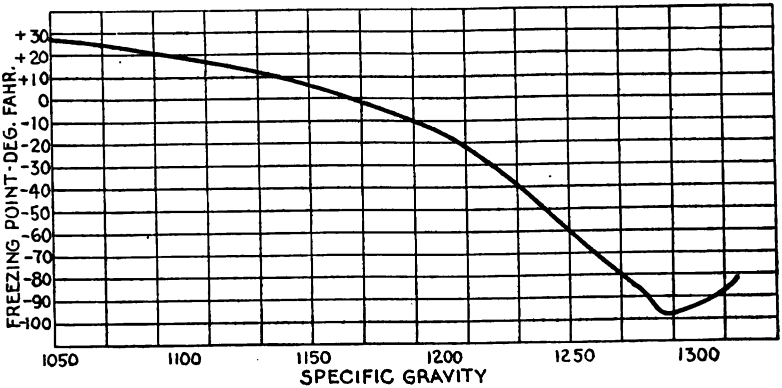


FIG. 6,287.—Freezing points of electrolyte. The freezing point of a battery depends upon its strength. For instance, a solution with a strength or specific gravity of 1.250 will not freeze until cooled to a temperature of 62° below zero Fahr. A strength of 1.150 will freeze at 5° above zero, hence there is little danger of freezing except when the battery is completely discharged. Moreover, at these freezing points, the solution is slushy and does not become hard until the temperature goes still lower. ***If water be added*** to a battery in freezing weather and then not stirred in with the solution by charging the battery, it will remain on top of the solution and may freeze.

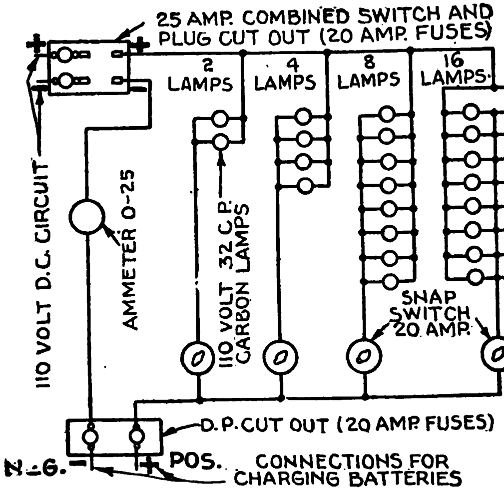
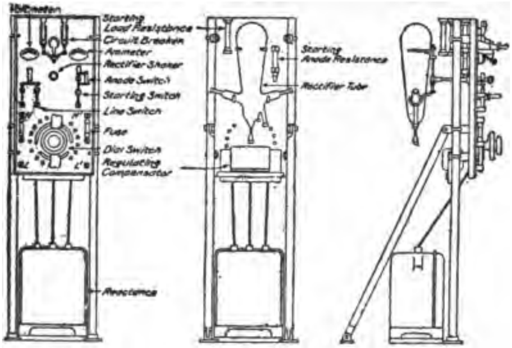


FIG. 6,288. — Trickle charge. When a number of batteries are to be held in wet storage, the most satisfactory results can be obtained by charging continuously at a very low rate, which is so low that gassing is avoided and yet gives enough charge. to maintain the batteries in good condition. This charge is called a *trickle charge* and in many cases will be found more convenient to arrange for them the perodic charge. It has the added advantage of keeping the batteries in condition for putting into use at any time on short notice. ***To apply trickle charge;*** 1, give bench charge; 2, Connect a tungsten lamp or lamps of appropriate resistance, in series with the cells, across a charging system adapted for continuous charging. 3, Every two months interrupt the trickle charge, remove filling plug, add water to bottom of filling tubes, replace and tighten filling plug and continue trickle charge.

Specific Gravity Drop During Discharge.—During a normal complete discharge, the amount of acid used from the electrolyte in a cell will cause the specific gravity to drop about 150 points (.150 sp. gr.)

Thus if the gravity of a fully charged cell be 1.300, it will, at the end of discharge, be about 1.150. The battery should receive charge before it is discharged below this point.

Charging.—To charge, direct current is passed through the cells in a direction opposite to that of discharge.

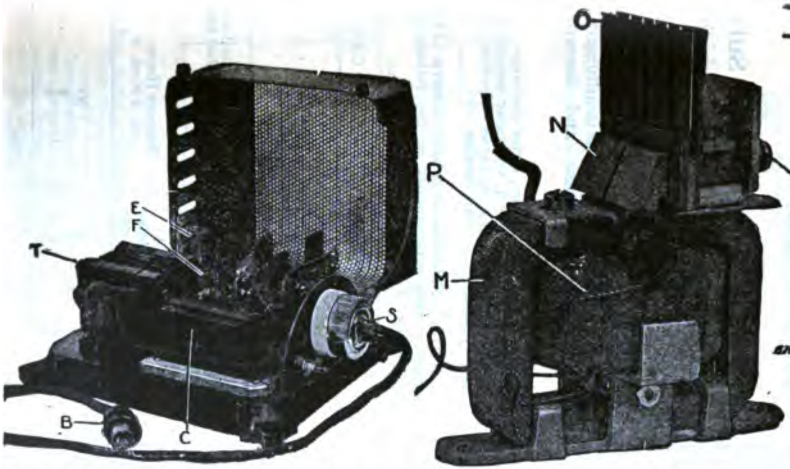


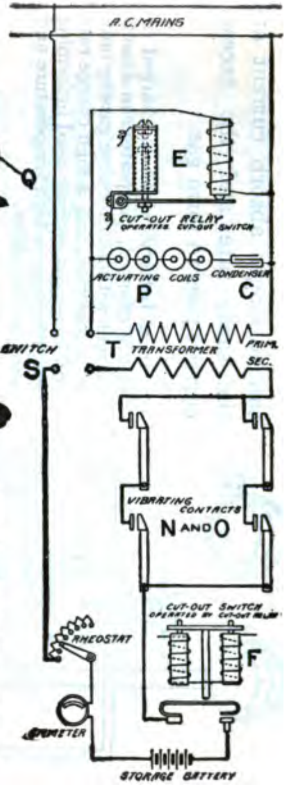
FIGS. 6,289 to 6,291.—Mercury arc rectifier outfit, or charging set. The cut shows front, rear, and side views of the rectifier, illustrating the arrangement on a panel, of the rectifier tube with its connection and operating devices.

This current, passing through the cells in the reverse direction, will reverse the action which took place in the cells during discharge.

Object of Charging.—*The acid absorbed by the plates during discharge is, during charge, driven from the plates by the charging current and restored to the electrolyte. This is the whole object of charging.*

Gassing.—When a battery is fully discharged, it can absorb current at the highest rate. As the charge progresses, the plates





FIGS. 6,292 to 6,294.—Edison rectifier and diagram of connections. ***In operation,*** the primary circuit taken from the alternating current mains by the cord B, embraces the primary winding of the transformer T, a condenser C, and the coils P, of the vibrating units, fig. 6,293. The secondary circuit from the transformer embraces the massive carbon and copper contacts (N and O, fig. 6,294) which pass only the positive waves of the alternating current for charging batteries or other duty. An ammeter and rheostat may be placed in this charging circuit if the current is to be varied, or a fixed connection may be substituted on the base of the rectifier if it is to be used for the maximum duty of 8 or 16 amperes. The vibrating unit (fig. 6,293), which operates in a manner similar to the well known action of a polarized relay, includes a permanent magnet M; the coil in the primary circuit P; the vibrating armature of steel with removable carbon contact N; the stationary copper contact with comb top for heat radiation O, and the screw Q, for adjusting the amplitude of the armature vibration. The vibrating armature of each unit is divided into two parts, which gives flexibility, affords increased current capacity and minimizes sparking, the two leads shown being connected together in one circuit. A primary relay and a secondary switch (E and F, figs. 6,292 and 6,294), close their contacts when current is flowing. Upon failure of the main alternating current line they operate to open the charging circuit. A storage battery is thus prevented discharging through the rectifier. Upon resumption of the main alternating current, the rectifier starts automatically.

can no longer absorb current at the same rate and the excess current goes to form gas.

In a battery which is charged or nearly charged, the plates can absorb current without excessive gassing only at a low rate, and a high charge rate will be almost entirely used in forming gas, resulting in high temperature and wear on the plates.

Normal and Abnormal Sulphating.—The sulphating which takes place during an ordinary discharge is entirely normal.

If, however, charging be insufficient, the sulphate increase and become

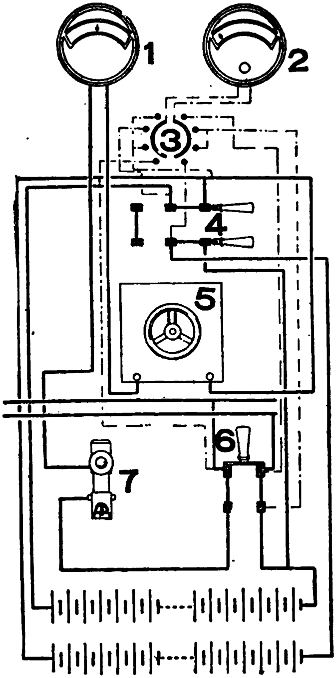


FIG. 6,295.—Parallel charge, series discharge. 1, ammeter; 2, voltmeter; 3, voltmeter switch; 4, series parallel switches; 5, battery rheostat; 6, battery switch; 7, circuit breaker.

NOTE.—*Selection of proper battery.* The number of *cells* is determined by the voltage of the system. Thus, according to Gould:

Voltage of System	Number of Cells	Voltage of System	Number of Cells
110	60	220	120
115	64	230	126
125	70	250	138

NOTE.—The size of a 110 volt battery can be determined thus, assuming that the battery will be charged at any time during the day convenient to operate the dynamo and that the battery will be able to furnish current for lamps as follows:

Time	Number of Lamps	3 Amperes	4 Number of hours	Ampere Hours col. 3 ×col. 4
5 p.m. to 10 p.m.	Twenty 16 *c.p.*	10	5	50
10 p.m. to 6 a.m.	Two 8 *c.p.*	½	8	4
6 a.m. to 8 a.m.	Six 16 *c.p.*	3	2	6
				Total 60

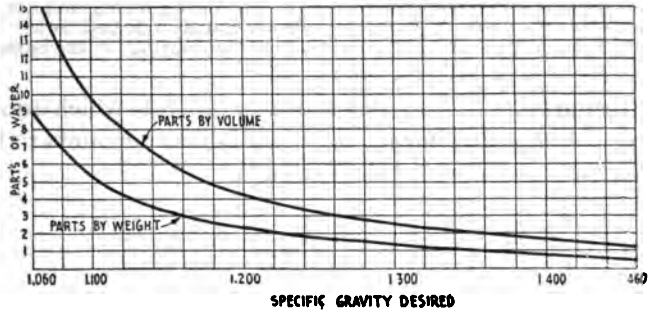


FIG. 6,296.—Curves for mixing full strength acid and water. Full strength or concentrated sulphuric acid is a heavy, oily liquid, having a strength (specific gravity) of about 1.835. If put into the battery, it would quickly ruin it, and must therefore *first* be diluted with pure (distilled) water to the proper strength for the particular type of battery, to which it is to be added. ***In mixing,*** take the following precautions: 1, Use a glass, china, earthenware, rubber or lead vessel; never metallic other than lead. 2, *Carefully pour the acid into the water;* ***not*** the water into the acid. 3, Stir thoroughly with a wooden paddle and allow to cool before taking a hydrometer reading. The electrolyte like most substances expands with rise of temperature; this affects the hydrometer reading. ***Correction for hydrometer reading;*** *Add one point to hydrometer reading for every 3° Fahr. increase in temperature above 70°.*

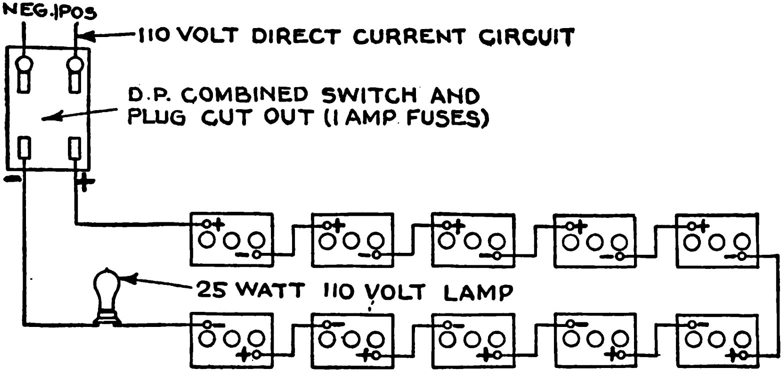


FIG. 6,297.—Wiring diagram for charging one to twelve 6-volt batteries from 110 volt bus. With this equipment regulation of the current through various numbers of batteries is obtained by means of the switches. Instead of lamps, *resistance units*, of approximately 35 ohms resistance and 3.3 amperes capacity each may be used. This equipment will occupy less space than the lamps and serve the same purpose, each resistance unit replacing two lamps. Instead of either a lamp resistance or unit resistance panel, a special form of *rheostat* may be used. However lamps are advisable where the light for same may serve for illumination, otherwise the energy spent in heating the resistance is a total loss.

hard and the plates become lighter in color, lose their porosity and are not easily charged; this is the abnormal condition usually referred to as "sulphated." This condition is usually the result of "starvation" of the battery.

Overdischarge.—It is not ***discharge*** at any rate which injures a battery, but ***overdischarge,*** or, what in time amounts to the same thing, undercharge or "starvation."

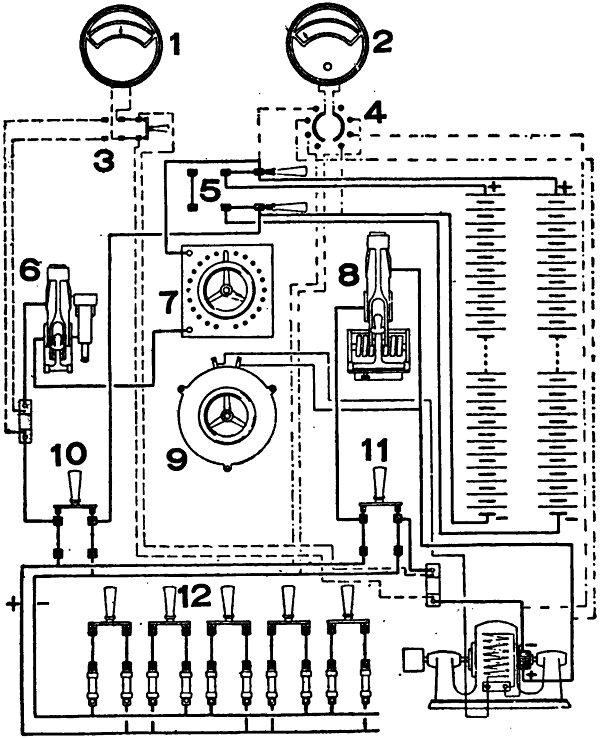


FIG. 6,298.—Parallel charge, series discharge including dynamo and distribution circuits. 1, ammeter; 2, voltmeter; 3, ammeter switch; 4, voltmeter switch; 5, series parallel switches; 6, battery circuit breaker; 7, battery rheostat; 8, overload and reverse current circuit breaker (discriminating cut out); 9, dynamo field rheostat; 10, battery switch; 11, dynamo switch; 12, switches to distribution circuits.

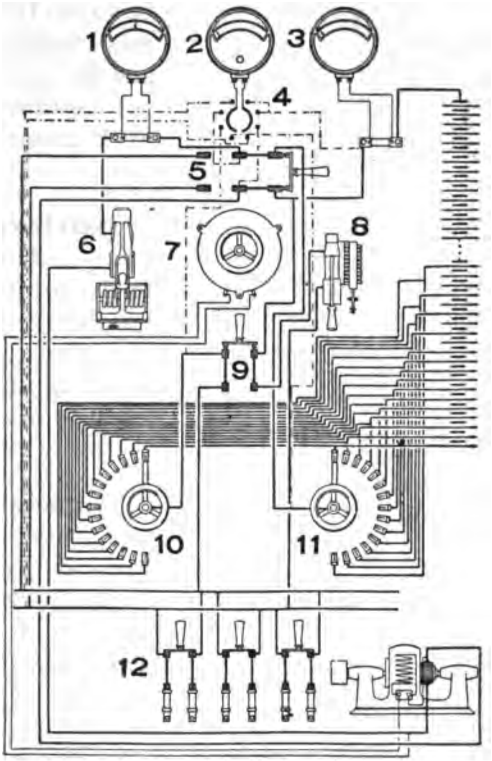
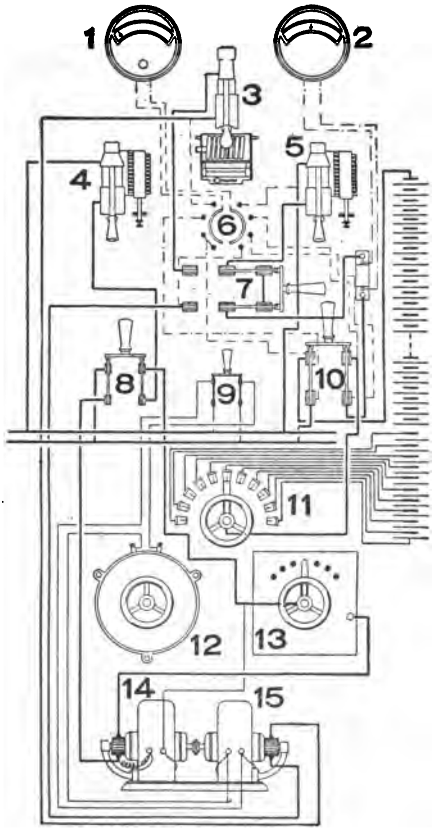


Fig. 6,299.—High voltage charge. End cell regulation. 1, dynamo ammeter; 2, voltmeter; 3, battery ammeter; 4, voltmeter switch; 5, dynamo switch; 6, dynamo circuit breaker over load and reverse; 7, dynamo field rheostat; 8, battery circuit breaker; 9, battery switch; 10, discharge end cell switch; 11, charging end cell switch; 12, switches to distributing circuits. The battery is charged in one series directly from the dynamo, which has a pressure range to 155 volts, and the charging current is controlled by the dynamo field rheostat. Two end cell switches are required so that the lighting circuits may be supplied while the battery is charging, the power voltage for the lamps being obtained by adjusting the position of the end cell switch connected to the lighting circuit. This is an overload breaker in the battery circuits and an overload breaker with reverse current trip in the dynamo circuit, the latter protecting the dynamos against overload and reversal of current.



Starvation.—In automobile batteries, if a car be so run that the battery gets insufficient charge and be "starved," it cannot be expected to do its work properly.

Overcharge. — Persistent overcharging not only tends to wash out the positive active material, but also acts on the positive grids, giving them a scaly appearance.

Temperature. — Low temperature temporarily both lessens the ampere hour capacity which can be taken out of the battery and lowers the discharge voltage.

FIG. 6,300.—Shunt booster charge, and cell discharge. 1, voltmeter; 2, ammeter; 3, under load circuit breaker; 4, booster motor circuit breaker; 5, battery circuit breaker; 6, voltmeter switch; 7, booster switch; 8, booster motor switch; 9. booster field switch; 10, battery switch; 11, end cell switch; 12, booster field rheostat; 13, motor starter; 14, motor; 15, dynamo.

NOTE.—***Charging rates.*** In selecting the size of battery to give a certain discharge rate, care should be taken that the dynamo is large enough to charge the battery at a rate not lower than the normal eight hour rate. In the case when two halves of a battery are charged in parallel each half taking the normal rate, the dynamo must have a current capacity double that at which each half is to be charged. Moreover the dynamo should have capacity to charge the battery occasionally at a higher rate, as this not only improves the condition of the cells, but permits a shorter charging period.

*Keep battery **unusually** well charged in winter and not expose it unnecessarily to low temperatures.* There is no danger of the electrolyte freezing in a fully charged cell; but in one which is over discharged or has had water added without subsequent charging this is liable to occur.

High temperature is to be avoided from the standpoint of life. 110 degrees Fahr. is usually given as the limiting temperature, and even this would be harmful if maintained steadily. Heating is ordinarily the result of charging at too high a current rate.

The effects of continued high temperature are to distort and buckle the plates, to char and weaken the wood separators, to soften and sometimes injuriously distort the jars and covers.

Points on Storage Battery Care.—The following should be specially noted:

1. Add nothing but pure distilled water to the cells and do it often enough to keep the plates covered.
2. Take frequent hydrometer readings.
3. Give the battery a special charge whenever the gravity readings show it to be necessary.
4. Charge at the proper rate.
5. Keep the filling plugs and connections tight and the battery clean.
6. To prevent corrosion of terminals and connections, wipe with a rag moistened with household ammonia solution.
7. Keep battery well charged in cold weather.

BATTERY REPAIRS

1. Double Cover Batteries

The type battery here considered to illustrate battery repair methods is a ***Gould*** 6 volt 81 ampere hour size of the double cover sealed type. Before starting to dismantle a battery a sketch should be made showing the inter-cell connections and position of terminals for guidance in reassembling.

NOTE.—The author is indebted to the Gould Storage Battery Co. for the accompanying instructive series of cuts illustrating *Storage Battery Repairs*.

Battery Repairs

FIG. 6,301.—***Battery repairs. 1.*** Gould 6 volt 81 ampere hour storage battery as received for repairs.

FIG. 6,302.—***Battery repairs 2.*** To remove terminal or connecting link, center punch the tops of terminals and connectors over the terminal posts and drill down to a depth of ¾ inch, using a ⅝ inch drill for ¾ inch posts and a ⅞ inch drill for 1 inch posts. Do not drill deeper than necessary so as to minimize the labor of building up the post.

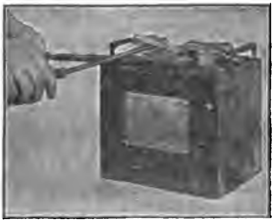


FIG. 6,303.—***Battery repairs 3.*** In removing the top connectors place a file or a flat piece of steel along the edge of the case. Place an ordinary screw driver underneath the connector and pry it off. The object of the file or piece of steel is to protect the wood case from breakage.

FIG. 6,304.—***Battery repairs 4.*** Brush off the accumulation of lead and dirt from the top of the battery. Care should be exercised to keep foreign substances from the inside of the battery, especially metal which may become lodged between the plates and separators and eventually cause short circuiting.

FIG. 6,305.—***Battery repairs 5.*** Unscrew and remove the vent plugs. In all cases be sure that the vent plugs are removed before using a flame around the battery. As hydrogen gas is generated in a battery its presence may result in an explosion. This gas can be quickly expelled by blowing into the cells with a bellows. As the vent plugs are made of hard rubber, which is easily broken, do not attempt to remove them with a pair of pliers.

FIG. 6,306.—***Battery repairs 6.*** Soften the sealing compound around the edges of the covers by playing a gas or torch flame over the compound. Care must be taken that the flame does not burn or scorch the covers. It is best to play the flame back and forth and not steadily in one place.

FIG. 6,307.—***Battery repairs 7.*** Using a heated screw driver, chisel or a plumber's lead scraper dig out the compound around the edges of the covers.

FIG. 6,308.—***Battery repairs 8.*** Again using a flame, heat the top of the covers to soften the underlying compound. Insert a screw driver under the covers and pry them off gently. Do not attempt to force them off but use more heat until they lift easily.

FIG. 6,309.—***Battery repairs 9.*** After the top covers have been removed, heat the underlying compound with the illuminating gas flame or blow torch. Do not allow the flame to play in one place long as this would cause the compound to melt and run. A small flame used for several minutes will bring better results than a strong flame. After softening the compound it may be removed by using a heated screw driver.

FIG. 6,310.—***Battery repairs 10.*** Apply the gas flame to the inside of the jar for an instant, then run a hot putty knife around the edges between jar and cover. Now place the battery on the floor, and holding it firmly between the feet, grasp the terminal posts with two pairs of pliers and lift the element and inside cover out together.

FIG. 6,311.—***Battery repairs 11.*** Let the elements rest at an angle on top of the jars to drain. While the elements are draining apply a flame around the terminal posts and remove covers. The covers may have warped from the heat. If so, they should be placed in boiling water and flattened out on a smooth surface to cool.

FIG. 6,312.—***Battery repairs 12.*** If separators be in good condition, and a jar replacement only is to be made, set the element, with bottom cover, in electrolyte or water till ready to replace. If separation is to be renewed and plates examined, separate the positive and negative groups. Grasp the elements firmly and work the groups gently back and forth.

FIG. 6,313.—***Battery repairs 13.*** Remove separators. Take a putty knife and run it between the plate and the separator. It is always best to renew the separators. When a new battery is received for replacement of a leaky jar the separators will generally be found in good condition so as not to require renewal. Separators should never be allowed to dry but should be kept immersed in water.

FIG. 6,314.—***Battery repairs 14.*** Plates should be inspected to determine whether or not they require replacement. If battery has been overheated through overcharging or short circuiting this will be indicated by brittle and buckled plates with active material granular and falling away from the grid. Plates in this condition will have to be replaced. If electrolyte has not been kept above the plates the tops of the plates will show a white substance known as sulphate. If the battery has been allowed to remain in a discharged condition for any length of time it will be indicated by sulphated plates. This sulphation is susceptible to removal by charging at a low rate for a long period. This rate should be about one-half the normal charging rate continued until the specific gravity and voltage reaches a maximum value.

FIG. 6,315.—***Battery repairs 15.*** Positive group showing buckled plates. A group of buckled plates which, when reassembled, will not go into the jar readily, should be replaced with a new group. Buckled plates if otherwise serviceable can be strengthened thus: Insert boards of suitable thickness between the plates and over each outside plate; place the pile in a vise, apply a gradual pressure, exercising care that the plates are not subjected to a severe strain. The condition of the negative plates is sometimes such that they may be used again with new positives. In this case the negative group should be immersed in water to prevent the plates drying out through heating or exposure to the air. If the positive plate be fairly hard, and has not lost much of its surface, it may be used again. Occasionally it happens that one or two plates in a group require replacement while the balance of the plates are in good condition. In this case new plates may be used in replacement.

FIG. 6,316.—***Battery repairs 16.*** Having examined the groups, pour the electrolyte into a large jar or vessel. A glass jar is best adapted to the purpose so as to disclose the sediment which will settle at the bottom. Sometimes impurities get into the electrolyte, and as a precautionary measure it is not advisable to use old solution.

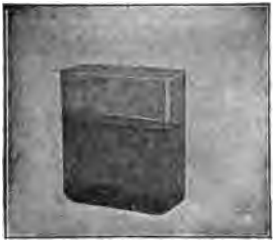


FIG. 6,317.—***Battery repairs 17.*** Note the sediment which has settled at the bottom of the jar containing electrolyte. Under normal usage this sediment will not be considerable. A large amount of it indicates that the cell has been overheated, and that the solution has not been kept above the plates by adding distilled water at regular intervals.

FIG. 6,318.—***Battery repairs 18.*** This shows the pouring off of the clear electrolyte. Never allow the sediment to get into the battery as it would impair the efficiency of the separators.

FIG. 6,319.—***Battery repairs 19.*** Invert the case over a sink and thoroughly clean the cells by inserting a hose and injecting a stream of water upward into each cell. Be sure that all sediment and foreign matter is removed from the cells before installing the plates.

FIG. 6,320.—***Battery repairs 20.*** Inspect the jars carefully for cracks or other imperfections. Jars exhibiting such defects should be replaced with new ones.

FIG. 6,321.—***Battery repairs 21.*** To remove a jar fill it with boiling water and allow it to stand for at least five minutes. This will loosen the sealing compound surrounding the jar.

FIG. 6,322.—***Battery repairs 22.*** Grasp the edges of the jar to be removed with two pairs of pliers as illustrated and pull it straight up. Care should be exercised so as not to damage adjacent jars.

FIG. 6,323.—***Battery repairs 23.*** Before putting in a new jar examine the space in the case and remove the shims and sealing compound so as not to hinder the jar being placed properly.

FIG. 6,324.—***Battery repairs 24.*** The jar should be heated before being placed in the case. This may be accomplished by pouring boiling water in the jar. If hot water be not available play a light flame around the outside of the jar.

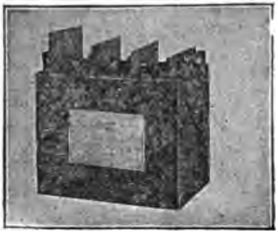


FIG. 6,325.—***Battery repairs 25.*** When the jar has been heated it should be pushed into place, taking care to see that the top of the jar is level with the others. If the tops are not lined up, the top connectors will be uneven, and as a result present a very poor looking job.

FIG. 6,326.—***Battery repairs 26.*** To secure the proper spacing and a tight fit, place a paraffined wood veneer shim between the jars.

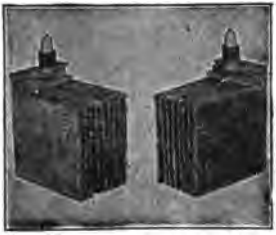


FIG. 6,327.—***Battery repairs 27.*** To replace an element the first step is to take the positive and negative groups to a clean, flat table. Always make sure that the work table is free from lead scrapings or foreign substances of any kind as these substances will adhere to wet separators, and if not removed will cause short circuiting of the plates.

FIG. 6,328.—***Battery repairs 28.*** Intermesh the positive and negative group. As the negative group contains one more plate than does the positive, both outside plates will be negative.

FIG. 6,329.—***Battery repairs 29.*** This illustrates a complete element ready to receive separators.

FIG. 6,330.—***Battery repairs 30.*** Lay the element on its side and put the separator retainers in position. Insert the separators between each pair of plates. If wood separators only be used, the grooved side of the separator should be next to the positive plate. If wood separators and rubber sheets be used, they should be inserted together, the rubber sheet between the positive plate and the grooved side of the wood separator. See that the separators are against the retainers and that they extend equally on either side of the element. Carefully check up separators after assembling as to omit a separator would cause considerable trouble

FIG. 6,331.—***Battery repairs 31.*** A complete element. Grasping the element by the pillar posts, lower gently into the jar. This should be done very carefully to avoid breaking the jar.

FIG. 6,332.—***Battery repairs 32.*** To clean the covers, heat a putty knife.

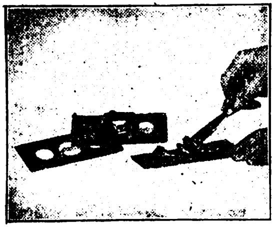


FIG. 6,333.—***Battery repairs 33.*** After heating the putty knife clean all the compound off the covers.

FIG. 6,334.—***Battery repairs 34.*** Sometimes the bottom cover will not fit properly over the element. By using a pair of pliers in the manner illustrated, it will be an easy matter to locate the centers.

FIG. 6,335.—***Battery repairs 35.*** If the bottom cover do not fit close to the terminal posts, or the wall of the jar, the openings should be calked with hemp twine or tow to prevent the melted sealing compound flowing into the jar.

FIG. 6,336.—***Battery repairs 36.*** Small gas stove and ordinary coffee pot used for melting and pouring sealing compound.

FIG. 6,337.—***Battery repairs 37.*** Always pour the compound so that it will fill all spaces and reach to a height level with the top of the case. Also see that it flows evenly over the whole surface.

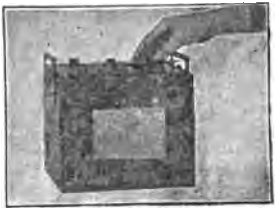


FIG. 6,338.—***Battery repairs 38.*** Before putting on the top cover slightly heat it with a gas flame. Also heat the surface of the compound.

FIG. 6,339.—***Battery repairs 39.*** Wooden form used for properly holding the covers down while the compound is cooling.

FIG. 6,340.—***Battery repairs 40.*** Place the wooden form over the covers and place a heavy weight on top of the form. The battery should stand for ten or fifteen minutes until the sealing compound has set.

FIG. 6,341.—***Battery repairs 41.*** After the form is removed there is always an excess of sealing compound. This can be scraped off with a hot putty knife.

FIG. 6,342.—***Battery repairs 42.*** Before applying terminals see that the terminal posts are scraped clean of all compound and dirt. It is practically impossible to do a good job of burning if all parts are not properly cleaned.

FIG. 6,343.—***Battery repairs 43.*** Using an ordinary pocket knife, clean the inside of the connectors, removing all dirt and oxides. Clean the tops of the connectors with a rasp file to remove dirt and oxide.

FIG. 6,344.—***Battery repairs 44.*** Before applying the terminal connectors test all cells with a voltmeter to see if they be set up properly. If a voltmeter be not handy, scrape the rubber bushings on each post. The red bushing is positive and the black is negative. The connectors should be applied so that the positive of one cell is connected to the negative of the next cell.

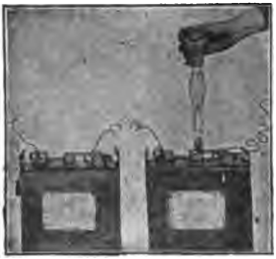


FIG. 6,345.—***Battery repairs 45.*** In burning connectors and terminals to the posts, melt the top of the post, then the edges of the hole in the connector. Melt strips of antimonious lead and allow the molten metal to run into the hole in the connector. Care must be taken to see that the top of post and inside edges of the connector are melted together before applying additional lead. If this be not done, the connection will surely pull loose. Care should also be taken not to melt the outer edges of the connector. Practice will be found necessary.

FIG. 6,346.—***Battery repairs 46.*** After burning, the connectors and terminals, mark the positive terminal with a stamp "POS" and the negative "NEG." If a stamp be not available use a blunt instrument and mark the positive (+) and the negative (—).

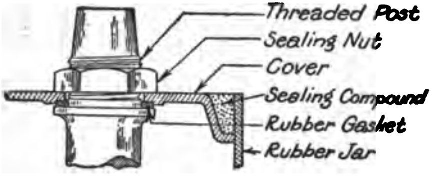
Repairing Batteries With Single Covers

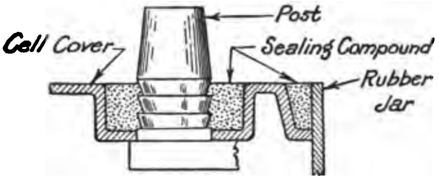
A great many batteries are now constructed with single moulded covers with a depression around the edge into which the sealing compound is poured.

In order to remove the elements from such cells it is only necessary to remove the connecting links as previously described and remove the compound from the channel around the jar formed by the depression of the cover. The element can then be removed with the cover attached to the posts.

Removal of the cover from the element can be effected according to the means by which it is attached and sealed to the posts.

The most usual methods are shown in the accompanying cuts.





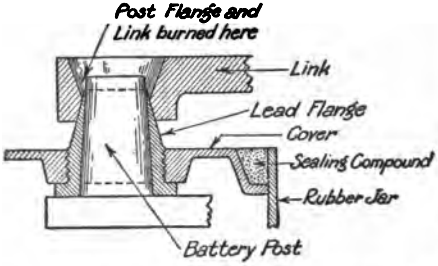


FIG. 6,347.—***Battery repairs 47.*** The battery post is threaded and provided with a flange on which the cover rests, with a soft rubber sealing gasket between. A lead or hard rubber nut secures the cover to the post. To remove cover simply unscrew the nuts on positive and negative post. In replacing a cover of this type the nut should be prevented backing off by breaking the thread in the post, just above the nut, by means of a prick punch.

FIG. 6,348.—***Battery repairs 48.*** Sealing around posts is made by means of sealing compound. There are several designs of this kind but it is in any case necessary to remove the compound or to soften it by heating before cover can be removed.

FIG. 6,349.—***Battery repairs 49.*** A lead flange is screwed into the cover from the lower side. The inside of this flange fits the battery post and the outside tapers above the top of the cover so that when the cell connector is placed in position the three parts, namely—post, flange and connecting link—are burned together at the top. When the connecting links are removed from both posts by drilling, the cover is free and can be lifted off. In replacing the cover on such a battery great care must be taken that the edge of the lead flange is burned into the joint; a new flange being used if necessary. Aside from the points described above repairs to a single cover battery are to be handled as before described.

GLOSSARY

Acid: Term frequently used to describe the liquid in cells, in place of the more correct one —*Electrolyte.*

Active Material: The "formed" paste which fills the grid.

Ampere: The unit of measure of quantity of electric current.

Ampere-Hours: Product of amperes and hours.

Battery: Any number of cells when connected and used together.

Bridge (*or rib*): Wedge-shaped vertical projection from bottom of rubber jar on which plates rest and by which they are supported.

Burning: A term used to describe the operation of joining two pieces of lead by melting them at practically the same instant so they may run together as one continuous piece. Usually done with mixture of oxygen and hydrogen gases, hydrogen and compressed air, or oxygen and illuminating gas.

Cadmium: A metal used in about the shape of a pencil for obtaining voltage of positive or negative plates. It is dipped in the electrolyte but not allowed to come in contact with plates.

Capacity: The rating of cell or battery in ampere-hours, qualified by the rate or time of discharge.

Case: The box which holds the cells of a battery

Cell: Unit of storage battery practice; consists of element, electrolyte and jar.

Charge: Passing direct current through a battery, in order to replace energy used on discharge.

Charging Rate: The proper rate of current, expressed in amperes, to use in charging a battery.

Connector: Solid or flexible part for connecting positive pole of one cell to negative pole of another, etc., or to terminal.

Cover: Cover for cell to retain electrolyte and exclude foreign material.

Cycle: One charge and discharge.

Density: Specific gravity.

Developing: The first cycle or cycles of a new or rebuilt battery to bring about proper electro-chemical conditions to give rated capacity

Diffusion: Pertaining to movement of acid within the pores of plates. (See *Equalization.*)

Discharge. The flow of current from a battery through a circuit, opposite of "charge."

Dry: Term frequently applied to cell containing insufficient electrolyte.

Electrolyte: The conducting fluid of electro-chemical devices; for lead-acid storage batteries consists of about two parts of water to one of chemically pure sulphuric acid, by weight.

Element: Positive group, negative group and separators.

Equalization: The result of circulation and diffusion within the cell which accompanies charge and discharge. Difference in capacity at various rates is caused by the time required for this feature.

Equalizing: Term used to describe the making uniform of varying specific gravities in different cells of the same battery, by adding or removing water or electrolyte..

Evaporation: Loss of water from electrolyte from heat or charging.

Forming: Electro-chemical process of making pasted grid or other plate types into storage battery plates. (Often confused with *Developing.*)

Foreign Material: Objectionable substances.

Freshening Charge: A charge given to a battery which has been standing idle, to keep it fully charged.

Gassing: The giving off of oxygen gas at positive plates and hydrogen at negatives, which begins when charge is something more than half-completed—depending on the rate.

Gravity: Common term for specific gravity.

Grid: Cast or stamped frame-work in which active material is retained.

Group: Any number of positive *or* negative plates properly joined together.

Hold-down: Device for keeping separators from floating or working up.

Jar: Container for element and electrolyte. Usually of hard rubber.

Lug. Vertical projection from grid for connecting with and burning to strap.

Mud: (See *Sediment.*)

Over-Charge: Continuance of charge beyond that apparently or supposedly necessary to improve condition of cells.

Over-Discharge: The carrying of discharge beyond proper cell voltage; shortens life if carried far enough and done frequently

Paste: The mixture of lead oxide or spongy lead and other substances which is put into grids

Plate. The combination of grid and paste properly "formed." Positives are reddish brown and negatives slate gray

Polarity: An electrical condition. The positive terminal (or pole) of a cell or battery or electrical circuit is said to have positive polarity; the negative, negative polarity

Post: The vertical cylindrical part of strap which receives connector.

Potential Difference: Abbreviated P.D. Found on test curves. Synonymous with voltage

Rate: Number of amperes for charge or discharge Also used to express *time* for either

Rib: (See *Bridge.*)

Ribbed: (See *Separator.*)

Reversal: That which occurs to voltage readings when cells are discharged below a certain critical point or charged in the wrong direction.

Sealing: Making tight joints between jar and cover: usually with a black, thick, acid-proof compound.

Sediment: Loosened or worn out particles of active material fallen to the bottom of cells; frequently called "mud."

Sediment Space: That part of jar between bottom and top of bridge.

Separator: An insulator between plates of opposite polarity; usually of wood, rubber or combination of both. Separators are generally corrugated or ribbed to insure proper distance between plates and to avoid too great displacement of electrolyte.

Spray. Fine particles of electrolyte carried up from the surface by gas bubbles. (See *Gassing.*)

Strap: That part to which all plates of one group are burned.

Sulphate. Common term for lead sulphate. (Pb SO4.)

Sulphated: Term used to describe cells in an under-charged condition, from either over-discharging without corresponding long charges or from standing idle some time and being self-discharged.

Sulphate Reading: A peculiarity of cell voltage when plates are considerably sulphated, where charging voltage shows abnormally high figures before dropping gradually to normal charging voltage.

Terminal: Part to which outside wires are connected.

Vent or *Vent-Cap:* Hard or soft rubber part inserted in cover to retain atmospheric pressure within the cell, while preventing loss of electrolyte from spray.

Voltage: Electrical pressure or potential difference, expressed in volts.

Wall: Jar sides and ends.

Washing: Removal of sediment from cells after taking out elements; usually accompanied by rinsing of groups, replacement of wood separators and renewal of electrolyte.

Watts: Product of amperes and volts.

Watt-Hours: Product of amperes, volts and time in hours.

CHAPTER 98

Electrolysis

This term signifies the *decomposition of a chemical compound in solution, called the* **electrolyte,** *into its constitutent elements*, called ***ions,*** by the *passage of an electric current through it.*

There are two kinds of ions: 1. The electro-positive ions called *cations* and, 2. The electro-negative ions called *anions*.

The former appear at the cathode and the latter at the anode. The current may be regarded as being carried through the electrolyte by the ions; since an ion is capable of carrying a fixed charge only of + or — electricity, any increase in the current strength necessitates an increase in the number of ions.

Alkali and Bleach.—When an electric current is passed through a solution of sodium chloride in water, using electrodes which are not attacked by the chloride or by free clorine, the *chloride is split up into its constituent parts, the metal sodium is separated at the cathode, while the gas chlorine forms in minute bubbles at the surface of the anode and rises to the surface of the liquid in the cell.*

The metal sodium, however, has a great affinity for the hydroxyl constituent of water, and it at once enters into union with this, and produces sodium hydrate and hydrogen gas at the surface of the cathode. These changes are the basis of all the patented processes and cells for the production of alkalies and chlorine products by electrolysis.

Aluminum.—The process of aluminum manufacture consists in the *electrolysis of a fused mixture of the fluorides of sodium*, *calcium and aluminum, in which alumina (aluminum oxide) is dissolved.*

When an electric current is passed through such a mixture of fused salt, using carbon electrodes, aluminum separates as drops of molten metal at the cathode, while oxygen is liberated at the anode and at once unites with it to form carbonic acid gas. The bath is kept in the fused state by the heating action of the current. The action taking place in the electrolytic bath is therefore, virtually, a reduction of the alumina or aluminum oxide by the carbon of the anode; but this reduction would be impossible without the aid of the current to first separate the oxygen and aluminum, which have great affinity one for the other.

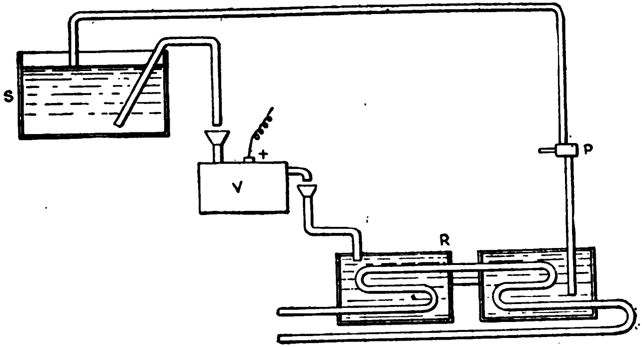
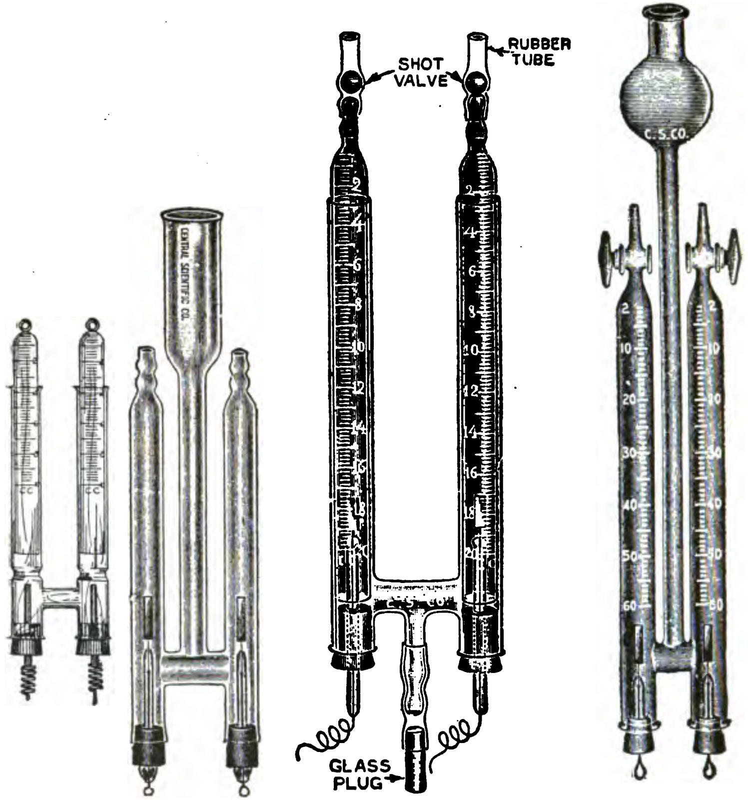


FIG. 6,350.—Arrangement of Gibb's process. The process *consists in* the electrolysis of potassium chloride solutions, using a copper or iron cathode and a platinum anode. S is the supply tank; V, the electrolytic cell; R, the refrigerators; and P, the pump by means of which the exhausted electrolyte is returned to the supply tank, while the chlorate precipitates out as crystals.

The aluminum separated at the cathode is in the molten state and falls to the bottom of the bath, and it is allowed to collect there, being removed at stated intervals, either by a syphon or by tilting. Fresh alumina is fed into the bath at short intervals to replace that which has been decomposed by the current; and the process is, therefore, a continuous one.

Bullion Refining.—The general principle of electrolytic bullion refining is *to use the alloy of previous metals, or bullion, as an anode in an electrolyte which dissolves only one of the two metals to be separated, and to use a sheet of the pure metal that is being deposited, as cathode.*

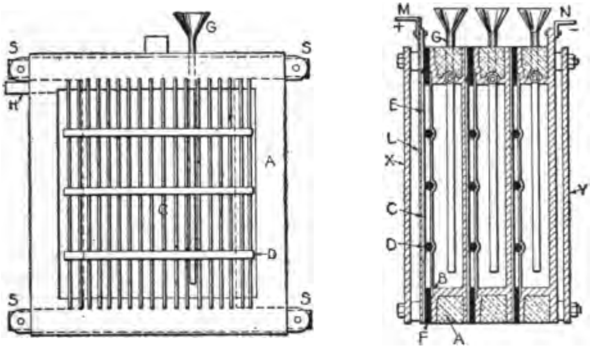


FIGS. 6,351 to 6,354.—Electrolysis apparatus. Fig. 6,351, electrolysis of water, simple form with sliding graduated tubes and platinum electrodes. Fig. 6,352, electrolysis of water, improved form with platinum electrodes that may be easily replaced by copper electrodes or by carbon electrodes for electrolysis of hydrochloric acid. Fig. 6,353, electrolysis apparatus (Osborne form), for study of conductivity of liquids, ionization, electroplating, electrolysis of water, and principles involved in the theory of electrolytic dissociation. ***It consists of*** an outer U tube with graduated sliding tubes, shot valves, glass plug and platinum electrodes which are easily replaced by carbon or copper electrodes. Fig, 6,354, Hoffman's improved form of electrolysis of water apparatus with graduated tubes, glass stop cocks and removable platinum electrodes

For silver deposition an acid solution of nitrate is employed as the electrolyte (the Moebius process), while for gold an acid solution of gold chloride is found to yield the best results (the Wohlwill process).

Chlorates.—Chlorate of potash or of soda is produced electrolytically by the electrolysis of the corresponding chloride.

The electrolytic and chemical changes which first occur when a solution of sodium or potassium chloride is electrolyzed by the aid of electrodes not acted on by the products of the electrolytic decomposition, have been already described under *Alkali and Bleach* (page 3,442-82).



FIGS. 6,355 and 6,356.—Gibb's cell and battery of three cells. The cells ***consists of*** a wooden frame A, covered with some metal B, such as lead, not attacked by the electrolyte. The cathode consists of a gird of vertical copper wire C, kept in position by cross bars D, of some insulating material. The grid is placed in a vertical position against one side of the cell frame, and kept in place by the anode of the adjoining cell, from which it is insulated by the strips, F, and bars D. The opposite side of the cell from that occupied by the cathode is partially closed by the anode indicated by dotted lines. This consists of a thick lead plate L, covered with platinum foil on the outer side E, (fig. 6,356), and is held in position by the cathode and framework of the following cell. G, is a pipe, reaching to the bottom of the cell, by which the potassium chloride is continuously supplied, and it is the overflow pipe to convey the mixed solution of the chloride and chlorate as well as the liberated hydrogen gas away from the cell. S,S,S,S, are lugs projecting from the framework by means of which any number of cells can be bolted together to form a series of cell. In fig. 6,356, the heavy plates X and Y, are used to close the ends of the wooden framework and form a fully closed series of cell with only the openings at the various supply and overflow points. Current connections are made at the points M and N.

Hypochlorite.—If the cell designed for chlorate production be worked with a low current density, and at a temperature which does not rise above 68° Fahr., little chlorate will be produced. and sodium hypochlorite will be formed in its place.

Ozone.—This can be produced by chemical methods, but it is also produced by *the sparkless discharge of electricity through dry air or oxygen from conductors charged at a high pressure and it is always formed when a frictional electric machine of the old plate type is worked with an air discharge.*

Oxygen and Hydrogen.—Dilute sulphuric acid is employed in one form of apparatus as electrolyte, namely, that patented by Schoop, the more customary electrolyte being a solution of caustic soda.

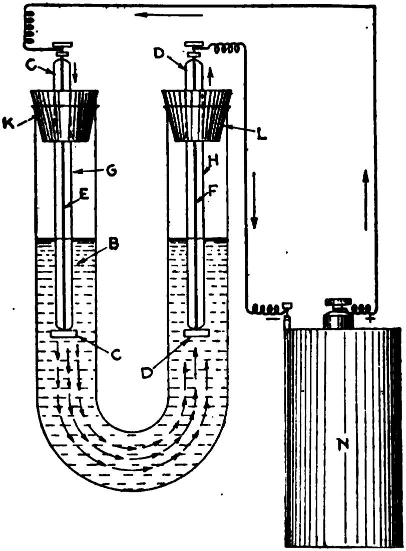


FIG. 6,357.—Electrolysis of copper. Fill the U shaped glass tube shown above, with a solution B, made by dissolving some crystals of copper sulphate or bluestone. Immerse in the solution two platinum electrodes C and D, attached to the copper wires E and F, sealed in the glass tubes G and H, which are held in the tube openings by loosely fitting rubber corks K and L. Attach the positive pole of the battery N, to the terminal of the electrode C, and the negative pole of the battery to the upper terminal of the electrode D. The electric current from the battery will then pass from the platinum *anode* C, through the copper sulphate electrolyte B, to the platinum *cathode* D, thence to the negative terminal of the battery. The passage of the current through the electrolyte will result in the liberation of the constituent ions of the latter, oxygen gas being liberated at the anode C, metallic copper deposited on the cathode D, and the copper sulphate solution B, changed to sulphuric acid.

The primary products of electrolysis in this case are hydroxyl (OH) and the metal sodium (Na) but these immediately enter into secondary chemical changes which produce oxygen gas at the anode and hydrogen gas at the cathode. The gases obtained in this way are not quite free from impurity, but for industrial requirements they are sufficiently pure, and this method of manufacture is much cheaper and more cleanly than the usual chemical methods of production.

Sodium and Potassium.—It is necessary to work with *a fused electrolyte in place of an aqueous solution in this case.*

Owing to the readiness of sodium and potassium to enter into combination with water, the difficulties of operating the process upon a commercial scale are chiefly due to this great chemical activity of the alkali metals.

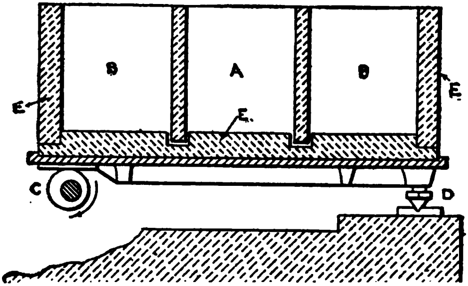


FIG. 6,358.—Castner cell. ***The parts are:*** A, cathode chamber; BB, anode chambers; C, eccentric for producing a rocking movement of cell; D, pivot support for framework of cell; E, slate walls of cell. The Castner cell is of the mercury type in which advantage is taken of the property possessed by mercury of forming an alloy with sodium, fluid at the ordinary temperature, this alloy being known chemically as an amalgam. When the amalgam is heated with water it is decomposed, and a solution of sodium hydrate is formed, while the mercury is restored to its original condition of purity. Hence, if a layer of mercury be employed as cathode on the floor of a cell in which a solution of sodium chloride is being decomposed by the current, the sodium liberated at the surface of the mercury will at once enter into union with it, and will be kept safe from further chemical or electrolytic changes. The layer of mercury, in fact, acts as a reservoir for the sodium atoms, or ions, brought to its surface, and stores up these until they are wanted.

Wet Extraction Process for Metals.—Copper, nickel, tin and zinc have all been extracted from their ores or slags by the use of electrolytic processes, and in many cases these processes are still being worked upon an industrial scale.

Copper.—The principle of the wet copper extraction processes is as follows: The ore is roasted to drive off the sulphur, and then leached in suitable vats with a solution which will dissolve the copper and leave the other metals and impurities undissolved. This solution is then electrolyzed in order to recover the copper as a cathode deposit.

Nickel.—The roasted ore is leached with a solution containing both copper and calcium salts as chlorides, and the copper is first deposited by electrolysis. The last traces of copper are then removed from the electrolyte by chemical means, and the nickel is in turn deposited by use of a higher voltage from the remaining solution.

Tin.—The Böhne process depends upon the use of sulphuric acid as a leaching agent and upon electrolytic deposition of the tin, from the sulphate solution so obtained. In the recovery of tin from old tin cans and tin scrap by electrolysis, sodium hydrate is used as the electrolyte.

Zinc.—A great amount of investigation and large sums of money have been spent upon processes for extracting zinc from its ores, by aid of electrolysis, but only two of these have achieved any industrial success. The Hoepfner process depends upon the use of the waste calcium chloride solution from ammonia soda works, and was worked out chiefly as a process for recovery and utilization of the chlorine from this waste product; zinc, testing 99.96 per cent. purity, and bleach being the products finally obtained. The Swinburne-Ashcroft method (the other successful process) is not a wet extraction process, but depends upon the electrolytic separation of zinc from fused zinc chloride.

FIG. 6,359.—Electrolysis in lower New York. The figure illustrates current movements as discovered. The power house is located near the navy yard in Brooklyn. A portion of the returning currents, as shown by arrows, flows over the New York and Brooklyn bridge to Manhattan, thence north to Williamsburg bridge via underground mains, subway structures, and other metals, and passes over that bridge back to Brooklyn, thence through mains to rails and negatives, to power house. In this case damage may be expected at three points: 1, where currents leave bridge metals on the Manhattan side; 2, where they leave pipes to enter Williamsburg bridge; 3, where they leave same bridge for pipes in Brooklyn side. When the two bridge structures are connected in Manhattan as proposed, then there will be further changes in the direction of current. Before the Williamsburg bridge was built, these currents recrossed through the river bed, leaving mains all along the docks in the Manhattan side, for the river, and leaving the river for mains or other metals along the docks of the Brooklyn side. Traces of these currents have been found as far north as 23rd St., a distance of over two miles from the Brooklyn bridge. Since the Williamsburg bridge has been built, nearly all traces of these currents flowing north of it have disappeared, showing that the mass of metal composing the structure acts as a short circuit or path of lower resistance which carries practically all of the returning currents flowing from Manhattan back to Brooklyn.

CHAPTER 99

Electro-plating

This process consists in obtaining *an electro-deposit of one metal, used as an anode, upon some metallic article which is connected to form the cathode in an electrolytic bath*, that is the substance upon which it is desired to deposit the metal is connected with the negative pole of the source of current, and the metal which is to be plated upon is connected with the positive pole.

The chemical nature of the *electrolyte* employed depends upon the kind of plating. For plating with gold or with silver, the electrolyte is always alkaline, for plating with nickel or with copper, it is usually acid.

Substances other than metal can be electroplated by first coating their surfaces with powdered graphite or plumbago, as in the case of *electrotyping*.

An essential condition in electroplating is cleanliness.

The merest trace of grease or dirt is sufficient to completely spoil the plating; in fact, the presence of even the small amount of grease caused by handling the article with the naked hand is often sufficient to prevent an adherent deposit.

The articles to be plated are cleaned by means of emery paper or wet sand, and by scrubbing with a scratch brush.

Next they are treated with caustic soda and then thoroughly rinsed in running water.

Sometimes they are dipped in acid, partly for cleansing purposes, and partly to slightly roughen or frost the surfaces.

Stripping.—Worn articles of electro-plate, which are to be re-plated, require therefore to have the whole of the previous plating removed before receiving a new coat. This process of removal, which is accomplished by various acids, is technically known as *stripping*.

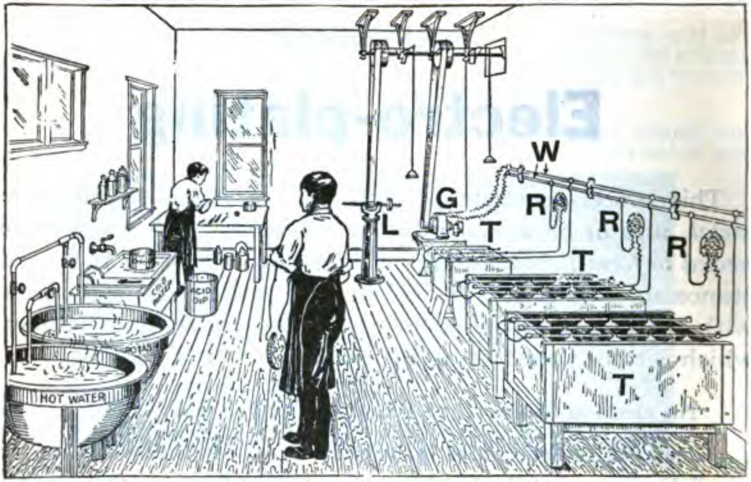


FIG. 6,360.—Electro-plating outfit with ***two wire*** system of distribution.

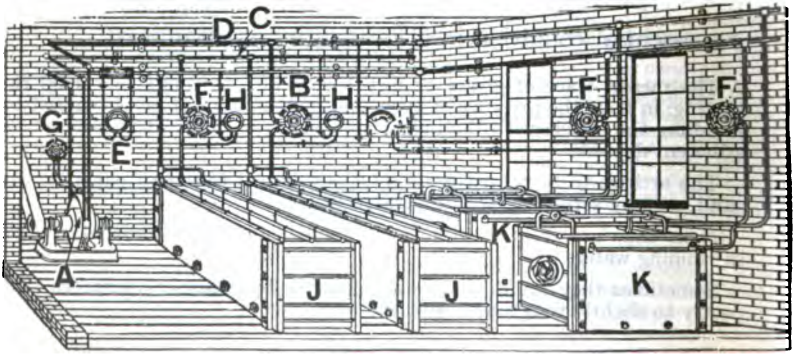


FIG. 6,361.—Electro-plating outfit with ***three wire*** system of distribution. The apparatus consists of: A, multipolar dynamo; B, positive line; C, neutral line; D, negative line; E, ammeter; F, tank rheostat; G, field rheostat; H, tank volt-meters; I, Starrett volt-meter; J, still solution; K, plating apparatus.

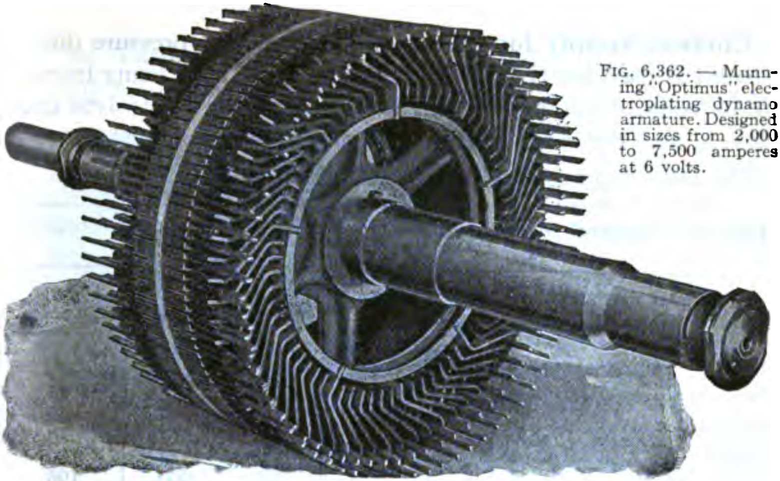


FIG. 6,362. — Munning "Optimus" electroplating dynamo armature. Designed in sizes from 2,000 to 7,500 amperes at 6 volts.

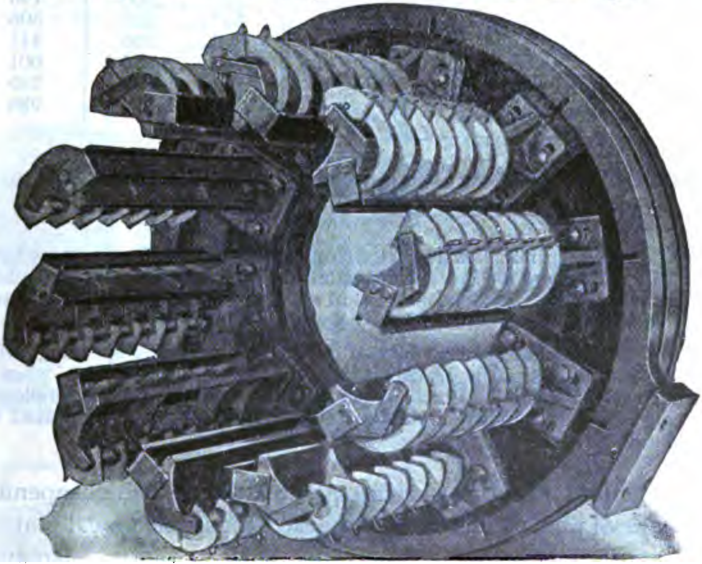


FIG. 6,363.—Munning "Optimus" electroplating dynamo brush yoke with brush rigging, 5,000 ampere size.

Current Supply for Electro-plating.—Low pressure direct current is used for this purpose, the pressure used being from 1 to 16 volts, depending upon the nature of the electrolyte employed, and the rate at which the plating is accomplished.

The following tables will be found useful:

Amperes required to plate one square foot.

Solution and metal.	Average amperes.
Nickel	4
Brass	6 to 8
Bronze	6 to 8
Copper	6 to 8
Acid copper	10 to 12
Silver	2
Gold	1½
Zinc	10

Carrying capacity of copper wire.

Size.	Amperes.
1/16″... .0625	3
1/8″... .125	12
3/16″... .1875	27
1/4″... .250	49
5/16″... .3125	76
3/8″... .375	110
1/2″... .500	196
5/8″... .625	306
3/4″... .750	441
7/8″... .875	601
1″...1.000	785
1 1/8″...1.125	994

Current Density.—The current density is important and varies with different metals.

With a high current density the deposit may be crystalline or powdery, and will not adhere well to the cathode. What is required is to regulate the current so that the deposited metal may be smooth and adherent, and capable of being burnished without being detached.

Hard and fast lines cannot be laid down, but, generally speaking, with high current densities the deposit is powdery, and of a dark color, when it is said to be "burnt." Much higher current densities can be employed if the solution be rapidly circulated by means of a pump or agitated by blowing in air.

Mechanical Electro-plating Apparatus.—The cheapening in the cost of plating has been so marked that mechanical plating apparatus is now recognized as a necessity in the metal manufacturing industry.

The Tanks, or Vats.—These vessels are for holding the plating solutions, and should be made of well seasoned wood, liquid tight, and lined with some suitable material which will not be acted upon by the solution the tank is intended to contain.

Fig. 6,364.—Heating tanks. Small shops usually depend upon gas or oil stoves placed under the various tanks or jars containing solutions that must be kept hot, such as lye, rinsing water, gold solutions, etc., as either offers a means of keeping up the desired temperature with very little trouble or expense. Larger establishments, however, find it cheaper and better in every way to use steam jacketed tanks, as here shown.

Dipping Vessels.—These are employed for holding the articles and dipping them into the various solutions used in cleaning the articles preparatory to the plating.

All dipping vessels used in acid solutions should be made of vitrified or glazed stoneware or glass.

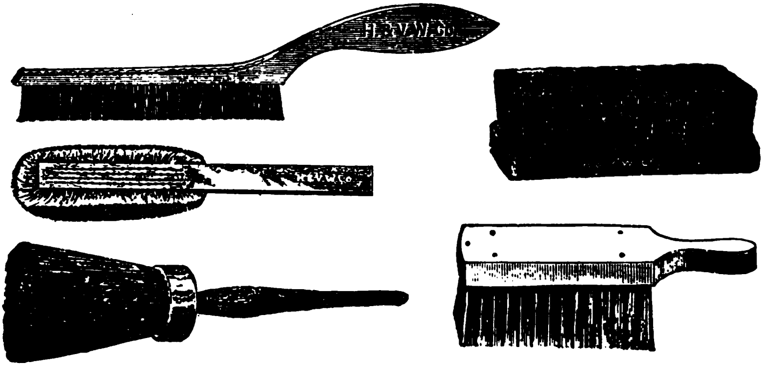
Figs. 6,365 to 6,371.—Various dipping baskets.

Scouring, Swilling and Rinsing Troughs.—These are usually made of wood, lined with lead and divided in the middle by a partition, one part being used for scouring and the other for holding clean water for rinsing the articles after they have been scoured clean.

Tumbling or Rattling Barrels.—Small objects, such as small castings, stampings, etc., that are not required to have square edges, are best cleaned by tumbling, or rattling, as it is called in foundries.

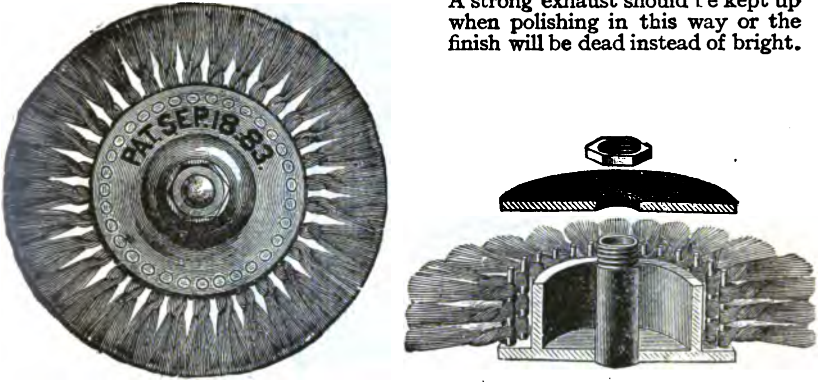
Figs. 6,372 and 6,373.—Various dipping vessels. Fig. 6,372, deep glazed earthenware dipping basket; fig. 6,373, shallow glazed earthenware dipping basket. The aluminum basket is adapted for use in washing and dipping in all acid solutions, but cannot be used in potash solutions. Different shapes and sizes of basket are required for various kinds of work. Successful dipping depends, however, chiefly upon quick and careful handling rather than upon the shapes of the dip, therefore, the holes in these baskets should be as large as possible, so as to allow the acid or cyanide solution to drain out quickly.

Large quantities of work are thus easily and cheaply cleaned without much manual labor, which is the expensive item in polishing. If rough castings are being worked, the sand, scale, etc., adhering to them is allowed



Figs. 6,374 to 6,378.—Various brushes. Fig. 6,374, jeweler's shoe handle wash out hand brush; fig. 6,375, flat scouring brush; fig. 6,376, cotton potash brush; fig. 6,377, sawdust brush; fig. 6,378, wire foundry brush.

to remain in the barrel, where it acts as a polishing powder, brightening the parts which are not reached by the metal of other castings; but when tumbling for a bright finish, the sand, dirt, etc., are exhausted by means of the blower, so that the surfaces are finely polished by friction only—burnished, as it were, by rubbing against other metal of the same kind. A strong exhaust should be kept up when polishing in this way or the finish will be dead instead of bright.



Figs. 6,379 and 6,380.—Hanson and Van Winkle swing type, circular steel wire, casting brush. The steel wires are twisted in knots and the knots are hung on rods around the hub, as shown in fig. 6,379, so that they will turn around the rods if the work be held too close to the brush wheel. In using the brush the work should be held so as to be just in contact with the ends of the wires. The brush shown is about 15 inches in diameter, and should not be run much faster than 1,000 *r.p.m.*

Fig. 6,381.—Hanson and Van Winkle tumbling barrel with convex head for dry tumbling. The type of barrel is especially adapted for removing burrs and for smoothing small castings. This barrel gives three distinct motions to the articles: rolling, shaking, and spreading.

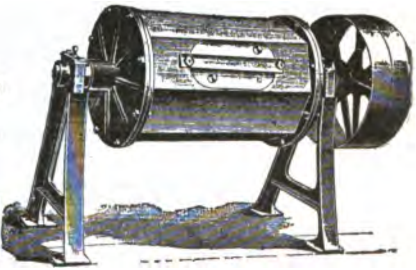


Fig. 6,382.—Hanson and Van Winkle tumbling barrel for wet grinding or polishing. It is intended for sand and water grinding, washing out core sand, etc., and is adapted for brass castings. The barrel is provided with a gland for connecting a water pipe to supply a constant flow of water.

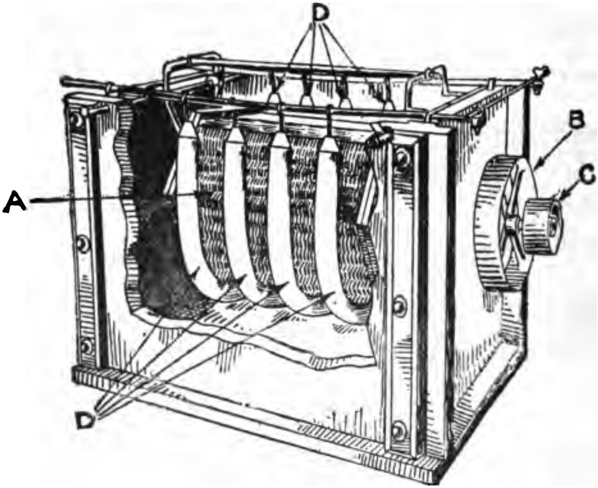


FIG. 6,383.—Mechanical electro-plating apparatus. ***It consists of*** a barrel A, in which are placed the articles to be plated. This barrel is revolved by belt device over the pulleys B or C, which provide two speeds. The barrel is removable at any time without interfering with the device. The anodes D, D, are curved to fit the periphery of the revolving barrel, and when the anodes are hung at each side of the tank, as shown, the work is always equidistant from the anodes, thereby insuring a regular deposit of even depth. ***In setting up and operating*** the mechanical electro-plating apparatus, connect the anode rod to the positive wire of the main line, and the cathode rod to the negative wire. Use suitable size wires for this purpose, as shown by the branch holes in the rod connections. Insert a rheostat in the negative line between the tank and the main line. When the barrel is being filled or emptied move the rheostat lever to the *off* point, so as to prevent the burning or blackening of the work when it is being removed from the tank. This should receive particular attention when a high voltage current is used. All contact points should be kept perfectly clean. A strip of thin sheet lead, or a split length of rubber hose, bent into the shape of a U, should be placed over the entire length of the anode rod to prevent the slop and dirt from the solution impairing the contact of the anode hooks with the positive rod. The revolving barrel may be operated at two speeds. In order to obtain the correct speeds, the countershaft should be driven at the rate of 10 revolutions per minute. ***The following voltages should be used*** with the various solutions: Acid copper solution, 18° Baume, 2½ to 5 volts; cyanide copper and brass solution, 12°–15° Baume, 4 to 5 volts; nickel solution, 10° Baume, 4 to 5 volts; zinc solution, 20° Baume, 6 to 10 volts. ***With the lower speed,*** almost any kind of article which will not hang to the periphery of the barrel, may be handled with the lower voltages. ***The higher speed*** and the higher voltages should be used for round articles, or those having no sharp edges or corners, with a consequent shortening of the time of deposition. The best results are obtained when the articles fill about one-half the barrel. The average length of time required to obtain a good deposit of the different metals under proper working conditions is approximately as follows: Acid copper solution, 20 to 40 minutes; cyanide copper and brass solutions, 30 to 45 minutes; nickel solution on brass, 15 to 30 minutes; nickel solution on steel, 45 to 60 minutes; zinc solution, 1½ to 2 hours. In the case of all solutions, the crystallization of the salts during cold weather tend to give a great deal of trouble. Therefore, all solutions should be kept at a temperature of 70 to 80 degrees Fahr., thereby permitting the use of denser and more highly conductive solutions, with a consequent shortening of the time of deposition. A loop of bare steam pipe immersed in the solution will serve to supply the necessary heat.

Bright work can only be obtained by long continued tumbling, and the bright finish comes rather quickly after all the pieces in the barrel become smooth, accordingly, it is necessary not to add any pieces once the barrel is charged, or the work will not finish evenly.

Steel Ball Burnishing Barrels.—Burnishing with steel balls is done both on small articles preparatory to plating and also on articles that have been plated and require a highly burnished finish.

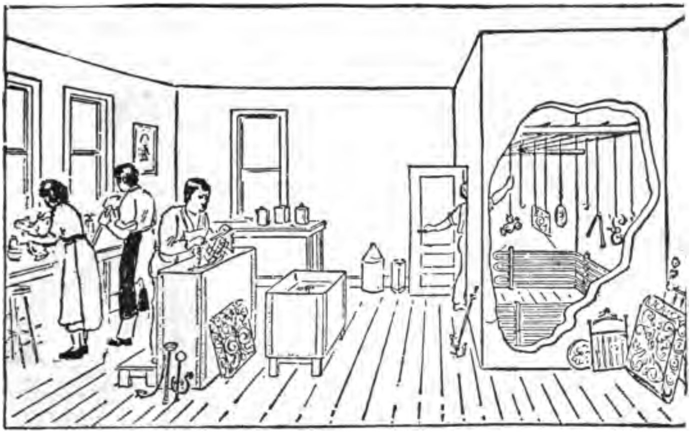


FIG. 6,384.—The lacquer room. When possible, a separate room should be used for lacquering, or a portion of the shop may be partitioned off for the purpose in order to avoid all dust or moisture. If the room be heated by steam pipes, it is advisable to have the regulating valves outside. The lacquer room should be light, dry, and well ventilated. When it is necessary to use artificial light, it is safer and better to use incandescent lamps. Do not have a stove or gas light near the lacquer room, as both the lacquer and thinner, as well as the gases which arise from them, are very inflammable.

Polishing Powders.—In order to hold fine powders on the wheels and buffs, they must be mixed with some medium that will perform this office and at the same time act as a lubricant to the work.

The polishing compositions generally employed are various preparations of rouge, tripoli, crocus, white rouge. Vienna lime and powdered pumice stone.

Solutions for Electro-plating with Different Metals.—These may contain the necessary constituents in various percentages. The following solutions are considered the best in general practice.

A good 14 carat gold plating solution is composed of water, 1 gallon; potassium cyanide, 10 ounces; gold chloride, 10 pennyweights; and a sufficient amount of carbonate of copper to give the desired shade. A 14 carat gold anode should be employed, composed of fine gold and the latter being composed of 80 parts of copper, 83 parts zinc, and 6 parts nickel.

The best solution for silver plating is the double cyanide of silver and potassium solution.

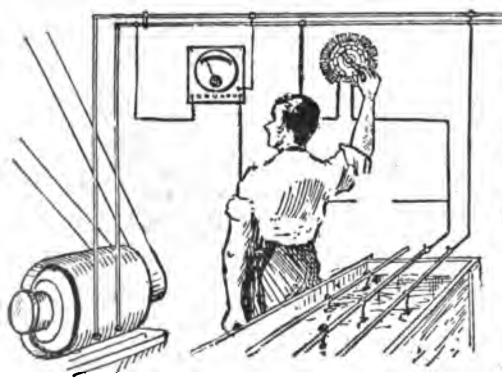


Fig. 6,385.—Connections and manipulation of rheostat on large copper, brass, and bronze solutions where variations of voltage are necessary to secure different colors.

Fig. 6,386.—Dipping or immersion; a method of chemically cleaning many articles consisting of dipping them in solutions which dissolve the grease scale, etc. Successful dipping depends chiefly upon quick and careful handling rather than upon the dips themselves, and the holes in these baskets should be as large as possible to allow the rapid escape of acid or cyanide. The usual sizes of hole in dipping baskets are 1/8, to 1 inch in diameter.

The single cyanide of silver is prepared by adding a solution of cyanide of potassium to a solution of nitrate of silver until a precipitate ceases to form.

The double cyanide of silver and potassium is prepared by dissolving an equivalent of silver cyanide (134 parts) in a solution containing an equivalent of cyanide of potassium (65 parts). The silver plating solution is made up with distilled water, the proportion by weight of silver per gallon of water varying from ½ ounce to 5 ounces or more.

The best nickel plating solution is that which is made up of the double sulphate of nickel and ammonium, in the proportion of 12 ounces to one pound of the double salt to each gallon of solution. The crystals should be dissolved in boiling water in a wooden tub, frequently stirred and cold water added to make up the desired quantity. After the solution has become cool it should be filtered through a large volume, 1,000 gallons or more, held in large lead lined tanks.

Electro-plating with copper is employed chiefly to form a coating on iron, steel, tin, zinc, lead, Brittania metal and pewter articles preparatory to silver plating the same, for the reason that silver will not adhere perfectly to those metals, while on the other hand, silver will adhere perfectly to copper and copper to the soft metals.

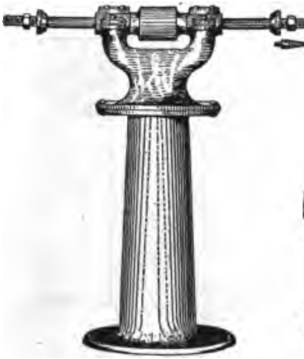
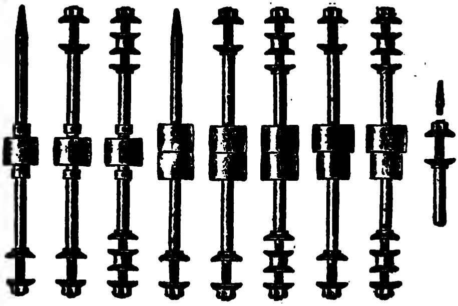


FIG. 6,387.—Polishing and buffing head. Polishing and buffiing heads range in size from those sufficiently strong to run wooden polishing wheels up to 16 inches in diameter, and those designed to run 9 or 10 inch buffs at 3,000 revolutions per minute, to those known as light polishing heads, capable of being operated on a bench without the use of a counter shaft.



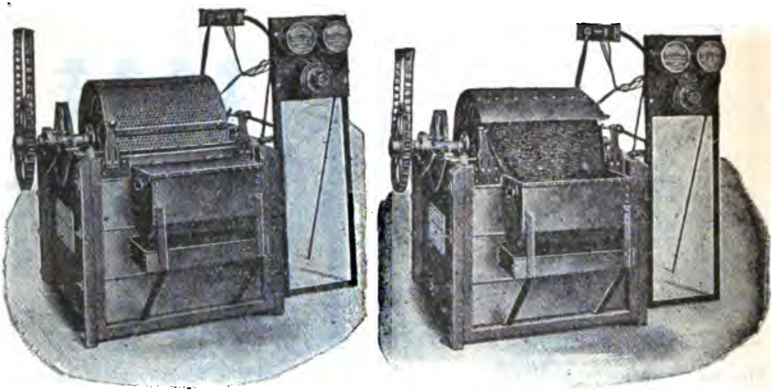
FIGS. 6,397 to 6,388.—Steel spindles used with polishing head.

The copper plating solutions employed for this purpose, and for electrotyping are acid solutions of copper sulphate.

Polishing and Grinding Machines.—These machines, or heads consist of a stand carrying a small pulley between two bearings with shaft extended at each end to take the various buffing, polishing and grinding wheels, brushes, etc.

Polishing Wheels.—These are made of canvas, wood, felt, leather, and walrus hide. Rough heavy castings are first ground upon coarse solid emery or carborundum wheels, usually run at a slow speed, not exceeding 1,000 revolutions per minute

Canvas wheels are used for roughing out. Felt wheels can be used for roughing, grinding, polishing and finishing. Walrine wheels are used chiefly in giving a fine polish to silverware, brass goods, etc. They can be used with crocus, emery, rouge, or rotten stone, and] give a smooth fine finish to the work.



FIGS. 6,398 and 6,399.—U.S. electro-plating barrel. Fig. 6,398, view while plating; fig. 6,399, view while emptying. It empties by lifting a lever which reverses the motion of the barrel.

Pickles and Dips.—While the best polish is secured by grinding and wheel polishing, many articles are best cleaned chemically by *immersing them in solutions which dissolve the scale, grease, etc., adhering to them, leaving a clean but rough surface which must be polished afterwards.*

Black Pickle for Iron:—Sulphuric acid 66° Baume, 1 part; water, 15 parts. Used chiefly for removing scale from castings and forgings.

Bright Pickle for Iron:—Water, 10 quarts; concentrated sulphuric acid, 28 oz.; zinc, 2 oz.; nitric acid, 12 ozs. Mix in the order named. The pickle leaves the metal bright.

Dip for Copper, Brass, etc.:—Sulphuric acid, 66° Baume, 50 parts by weight; nitric acid, 36° Baume, 100 parts by weight; common salt, 1 part by weight; lamp black, 1 part by weight. Forgings, punchings, etc., are pickled in dilute sulphuric acid to remove scale, and then cleaned and brightened by dipping in the above solution.

Cyanide Dip for Brass:—Potassium cyanide in ten times its weight of water is used as a preliminary dip when plating articles that would have the polish injured by the acid dips. The work must be allowed to remain longer in this than in the acid solutions.

Pickle for German Silver:—German silver may be cleaned in the bright dip for brass, or in a preliminary pickle of dilute nitric acid and water (12 to 1), followed by a dip of equal parts of sulphuric and nitric acids, and then by rinsing in boiling water and drying in sawdust. Use sawdust that contains no tannin.

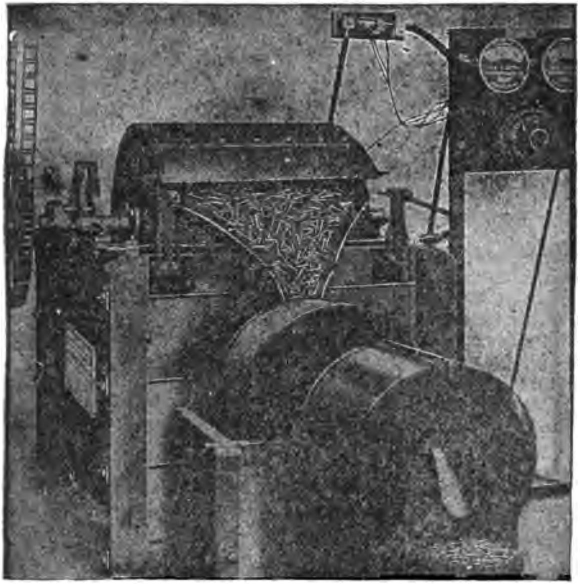


Fig. 6,400.—U. S. electro-plating and self-emptying barrel for brass, nickel, copper, tin, zinc, etc. ***Method of galvanizing:*** After pickling and cleaning the material, the galvanizing barrel is then filled by means of pails, shovels, etc., with from 150 to 200 lbs. of material at a time and is then started to turn slowly "in the galvanizing direction," and in about 40 to 50 minutes the material is finished. Upon reversing the motion of the barrel, it thereupon empties the galvanized material (in from three to four minutes) into the washing drum of the washing and drying apparatus and gradually goes into draining drum, from there to drying drum, from there into whatever receptacle is placed for receiving the material ready for shipment. ***Quality and thickness of coating:*** The thickness of the coating can be regulated according to requirements, and depends upon the length of time the material is allowed to remain in the galvanizing barrel while galvanizing. The coating deposited consists of chemically pure zinc, uniformly smooth. With the apparatus, one laborer can attend to two barrels and turn out from 3,000 to 5,000 lbs. of material per day; two men and a boy will be able to attend to about six barrels. ***Range of the barrel:*** The barrel will galvanize any kind of small material as, for instance: bolts and nuts (from the smallest size to 8 in. long), nails, rivets, spikes, screws, small castings and fittings, stampings, sash pulleys, lag screws, washers, springs, etc., in fact all such material excepting that having very deep recesses or hollow material which requires inside galvanizing.

Nickel Plating.—Nickel does not adhere very well to iron or steel articles, and furthermore, if after being plated upon steel, the article becomes scratched, the steel rusts, and the rust, getting beneath the nickel film, causes it to peel off.

It is, therefore, very usual to first coat the iron with a film of copper, which, being a soft metal, is not readily removed by scratching. The nickel is then deposited upon the copper coating. Nickel cannot be deposited from solutions containing more than a trace of acid; most nickel plating solutions consist of a solution of the double salt of ammonium sulphate and nickel sulphate, which is rendered alkaline with ammonia.

In order to obtain a thoroughly satisfactory and brilliant deposit of nickel, the articles which are to be plated must be very carefully prepared, and should have a burnished surface.

Electrotyping.—In preparing electrotypes *a wax impression is taken of the form, which is made up usually of type, or illustrations, or both.*

In order to do this a metal plate is evenly coated with a wax composition, and this is placed with the wax face downward upon the form. The form with the wax upon it is then placed in a hydraulic press and subjected to a steady pressure of about two tons to the square inch. To prevent the type adhering to the wax, it is dusted over with finely powdered graphite. After being taken out of the press, the wax is carefully removed from the form. The mould is next coated with black lead to give it a metallic surface, as the wax is a non-conductor; the mould is then subjected to the process of electro deposition, resulting in the formation of a film of copper on the prepared surface.

A battery or dynamo is used to generate the current. The positive terminal of the source of current is connected to a rod extending across a trough or tank containing the plating bath. Suspended from the rod are anodes of copper, from which a deposit is desired. The other terminal of the source is connected with another rod across the trough, to which are suspended the articles to be plated.

The copper shell is removed from the mould by applying hot water; the shell is then backed up with electrotype metal to render it strong enough for use.

Galvanizing.—A bath containing zinc sulphate, which must only be slightly acid, is employed; as the electrolysis proceeds the solution becomes acid by the zinc being deposited out, and in order to keep the strength of the solution constant, it is circulated through a filter bed containing zinc dust.

Zinc anodes are not generally used because they are apt to disintegrate; the anodes usually employed are of lead, but iron is sometimes used. In fact, the presence of a trace of iron in the bath improves the deposit.

CHAPTER 100

Alternating Currents

An alternating current is defined as: *A current which reverses its direction in a periodic manner, rising from zero to maximum*

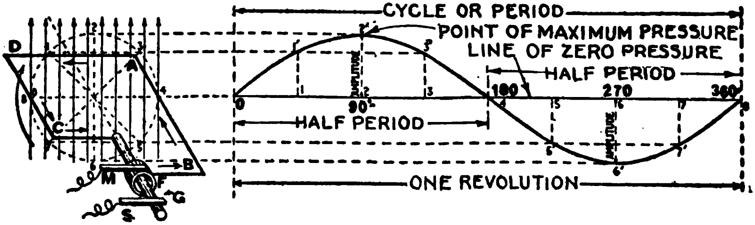


Fig. 6,401.—Alternating current represented by the ***sine curve.*** As the elementary alternator rotates the induced electric pressure will vary in such a manner that ***its intensity at any point of the rotation is proportional to the sine of the angle corresponding to that point.*** Hence, on the horizontal line which passes through the center of the dotted circle, take any length as 08, and divide into any number of equal parts representing fractions of a revolution, as 0°, 90°, 180°, etc. Erect perpendiculars at these points and from the corresponding points on the dotted circle project lines (parallel to 08) to the perpendiculars; these intersections give points, on the sine curve. The curve lies above the horizontal axis during the first half of the revolution and below it during the second half, which indicates that the current flows in one direction for a half revolution, and in the opposite direction during the remainder of the revolution.

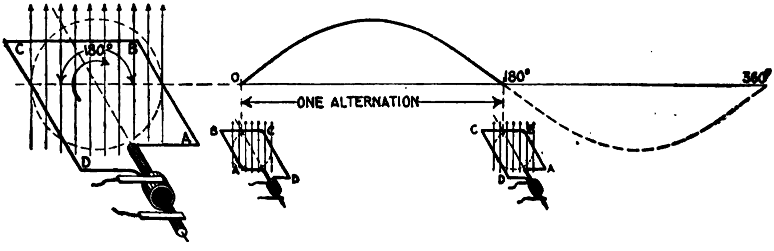


Fig. 6,402.—Diagram showing one *alternation* of the current in which the latter varies from zero to maximum and back to zero while the generating loop ABCD makes one half revolution.

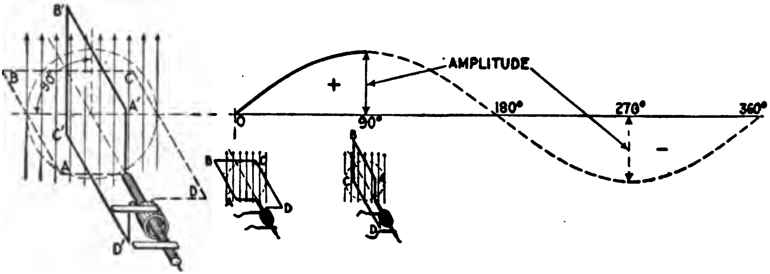


FIG. 6,403.—Diagram illustrating *amplitude* of the current. The current reaches its amplitude or maximum value in one quarter period from its point of zero value, as, for instance, while the generating loop moves from position ABCD to A'B'C'D'. At three-quarter revolution, the current reaches its maximum value in the opposite direction.

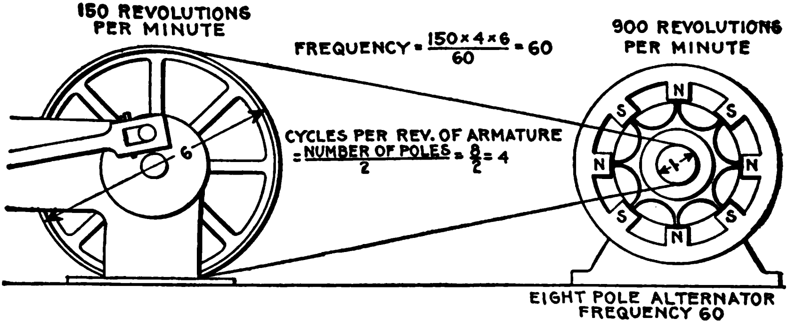


FIG. 6,404.—Diagram illustrating *frequency*. The frequency or *cycles per second* is equal to *the revolutions of armature per second* × ½ *number of poles per phase.*

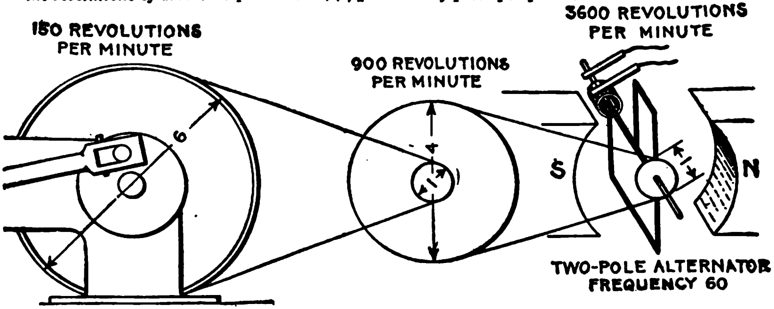
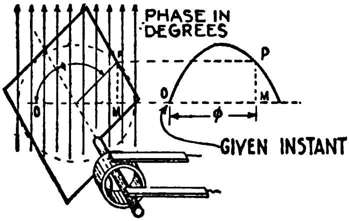


FIG. 6,405.—Diagram illustrating *why alternators are built* **multi-polar.** Evidently the excessive speed of the bi-polar alternator would require such great velocity reduction that an intermediate reduction gear would be necessary requiring extra space and adding complication.

strength, returning to zero, and then going through similar variations in strength in the opposite direction; these changes comprise the *cycle* which is repeated with great rapidity.



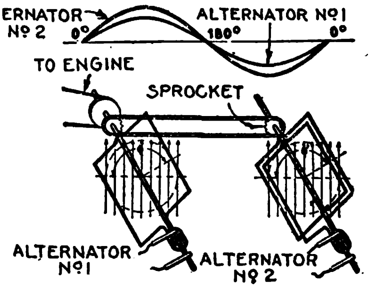
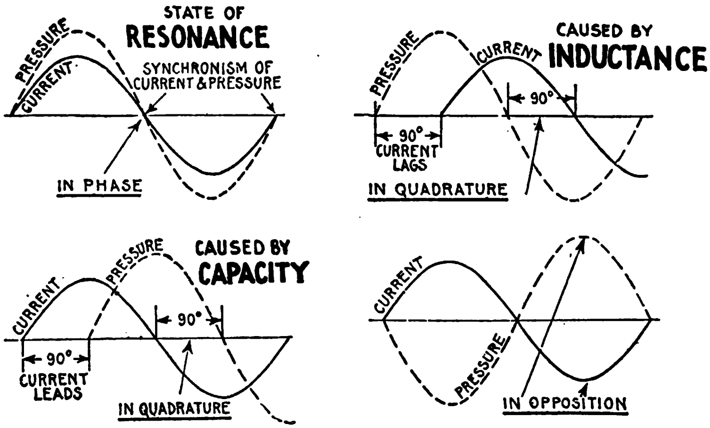


FIG. 6,406.—Diagram illustrating **phase.** By definition *phase is the angle turned through by the armature reckoned from a given instant.*

FIGS. 6,407 and 6,408.—Diagrams illustrating ***in phase*** or ***synchronism.*** If two alternators with coils in parallel planes be made to rotate "in step" with each other as by chain connection, they will then operate *in phase* or *in synchronism*, and the alternating pressure or current in one will vary in step with that in the other.



FIGS. 6,409 to 6,412.—Phase relations of the current.

The advantage of alternating current (*a.c.*) over direct current (*d.c.*) lies in the reduced cost of transmission by use of high voltages and transformers, greater simplicity of alternators and *a.c.* motors, facility of transforming from one voltage to another (either higher or lower) for different purposes.

The disadvantages of alternating current are: 1, the high pressure at which

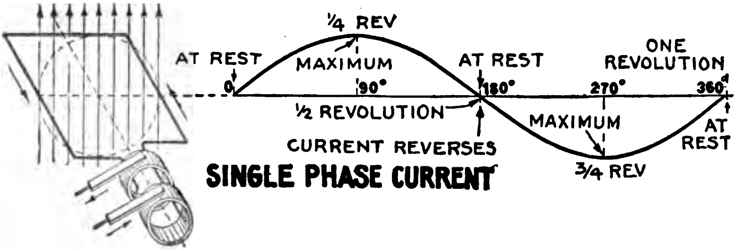


Fig. 6,413.—***Single phase current.***—There are three points during the cycle at which there is no current and no pressure: 0°, 180°, and 360°. The current reaches a maximum at 90°, reverses at 180°, and reaches a maximum in the reverse direction at 270°.

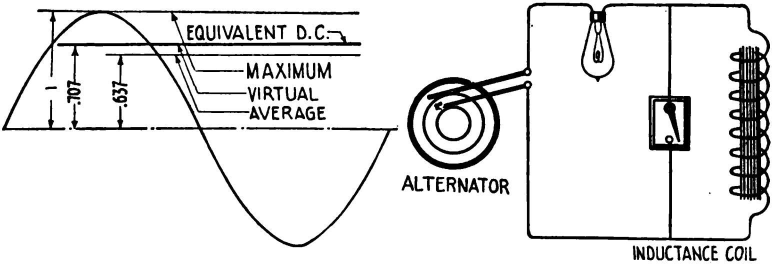


Fig. 6,414.—Maximum, ***virtual*** and average volts. *The* ***virtual*** *value of an alternating pressure or current is equivalent to that of a direct pressure or current which would produce* ***the same effect.*** If a Cardew voltmeter be placed on an alternating circuit in which the volts are oscillating between maxima of + 100 and — 100 volts, it will read 70.7 volts, though the arithmetical mean is really only 63.7; 70.7 steady volts would be required to produce an equal reading. The word ***effective*** *is commonly used* ***erroneously*** *for* ***virtual.***

Fig. 6,415.—Diagram illustrating ***virtual*** and ***effective*** pressures. When switch is closed the whole of the impressed pressure will be effective in causing current to flow around the circuit. In this case the virtual and effective pressures will be equal. If the coil be switched into circuit, the reverse pressure due to self induction will oppose the virtual pressure; hence, the effective pressure (which is the difference between the virtual and reverse pressures) will be reduced, the virtual or impressed pressure remaining constant all the time.

NOTE.—*A* ***Cardew voltmeter*** indicates electric pressure by the passage of the current through a slender wire of platinum silver which thereupon expands and moves the index needle upon the scale.

it is used renders it dangerous, requiring more efficient insulation, alternating current cannot be used for such purposes as electroplating, charging storage batteries, etc.

The various terms relating to alternating current illustrated in the accompanying cuts should be thoroughly understood.

Single or Monophase Current.—This is produced by an

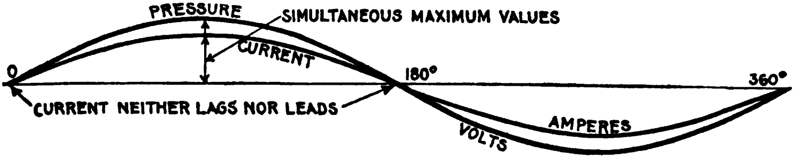


FIG. 6,416.—Pressure and current curves illustrating the term "in phase." The current is said to be *in phase* with the pressure when it *neither* lags nor leads.

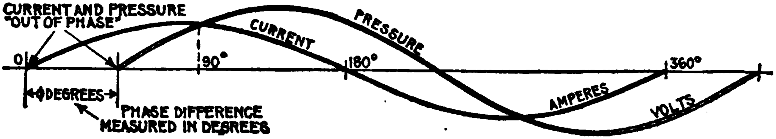


FIG. 6,417.—Pressure and current curves illustrating the term "out of phase." The current is said to be *out of phase* with the pressure when it *either* lags or leads, that is when the current is not in synchronism with the pressure. In practice the current and pressure are nearly always out of phase.

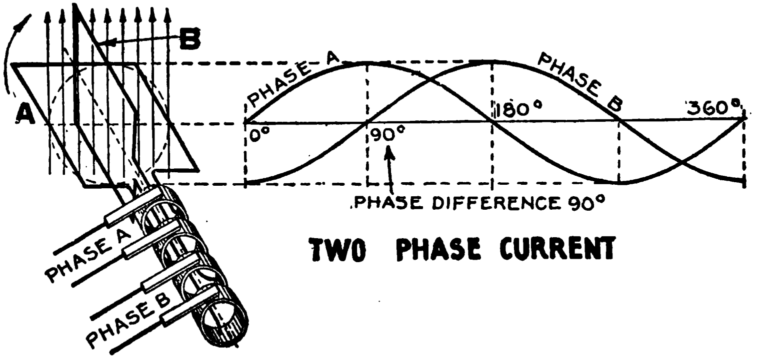
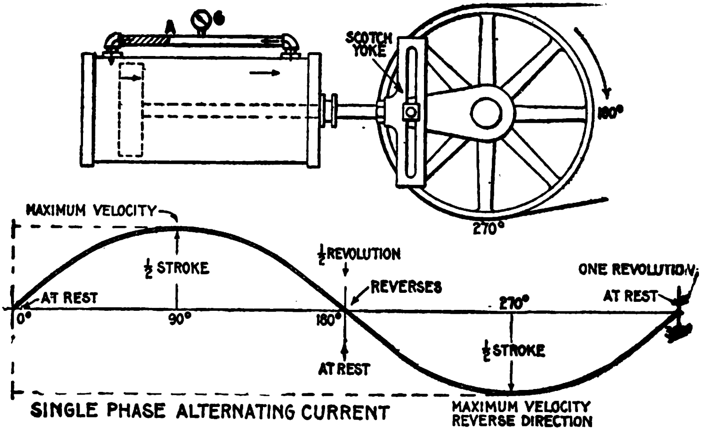
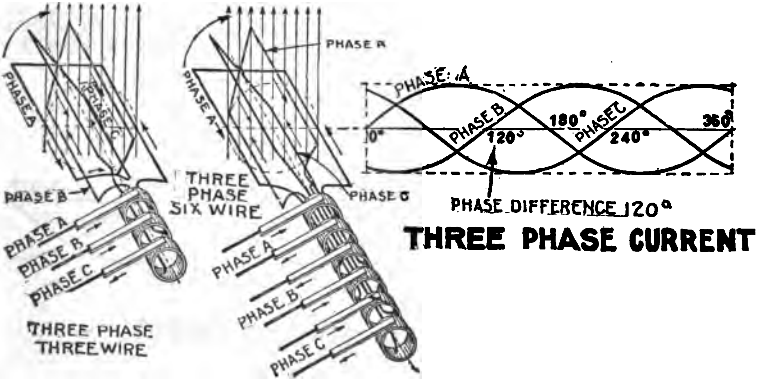


FIG. 6,418.—***Two phase current.***—If the loops be placed on the alternator armature at 90 magnetic degrees, a single phase current will be generated in each of the windings, the current in one winding being at its maximum value when the other is at zero. In this case four transmission conductors are generally used, two for each separate circuit.



FIGS. 6,419 and 6,420.—Hydraulic analogy of single phase current. If the cylinder and pipe be full of water, a current of water will begin to flow through the pipe in the direction indicated as the piston begins its stroke, increasing to maximum velocity at one-quarter revolution of the crank, decreasing and coming to rest at one-half revolution, then reversing and reaching maximum velocity in the reverse direction at three-quarter revolution, and coming to rest again, at the end of the return stroke. A pressure gauge at G, will register a pressure which varies with the current. Since the alternating electric current undergoes similar changes, the sine curve will apply equally as well to the pump cycle as to the alternating current cycle.

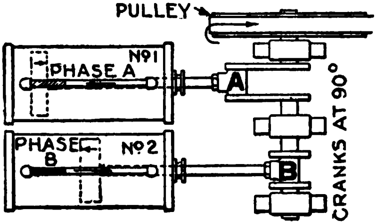


FIGS. 6,421 and 6,422.—*Three phase current* with three and six wire alternators. If the loops be placed on the alternator armature at 120 magnetic degrees from one another, the current in each will attain its maximum at a point one-third of a cycle distant from the other two. The arrangement shown in fig. 6,422 gives three independent single phase currents and requires six wires for their transmission. A better arrangement and the one generally used is shown in fig. 6,421. Here the three ends (one end of each of the loops) are brought together to a common connection as shown, and the other ends, connected to the collector rings giving only three wires for the transmission of the current.

alternator, whose armature has a single winding as in fig. 6,413. Two wires, a lead and return are used.

Two-Phase Current.—Usually these are two distinct single phase currents flowing in separate circuits. There is often no electrical connection between them.

They are of equal periods and amplitude but differ in phase by ¼ of a period, as shown in fig. 6,418. With this phase relation one of them will be at a maximum when the other is at zero.



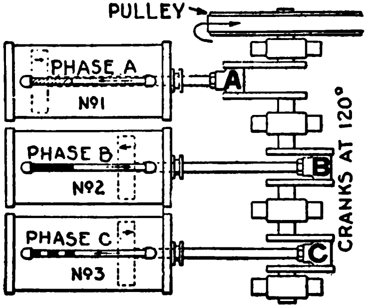


FIG. 6,423.—Hydraulic analogy of two phase current. The same cycle of water flow takes place as in figs. 6,419 and 6,420. Since the cranks are at 90°, the second piston is one-half stroke behind the first; the flow of water in No. 1 (phase A) is at a maximum when the flow in No. 2 (phase B) comes to rest, the current conditions in both pipes for the entire cycle being represented by two sine curves whose phase difference is 90°.

FIG. 6,424.—Hydraulic analogy of three phase current. Three cylinders are here shown with pistons connected through Scotch yokes to cranks placed 120° apart. The same action takes place in each cylinder as in the preceding cases, the only difference being the additional cylinder, and difference in phase relation.

Three Phase Currents.—This consists of *three alternating currents of equal frequency and amplitude, but differing in phase from each other by ⅓ of a period.*

When any one of the currents is at its maximum the other two are of half their maximum value and are flowing in the opposite direction.

Induction.—Each time a current is started, stopped or

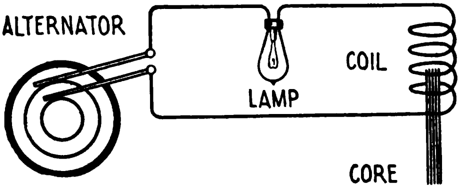


FIG. 6,425.—*Self-induction* in *a.c.* circuit. Lamp burns dimly before core is inserted into the coil, and assuming the coil to be made of one pound of No. 20 magnet wire, lamp will go out when core is inserted owing to the self-induction of the coil which is greatly increased by the presence of the iron core.

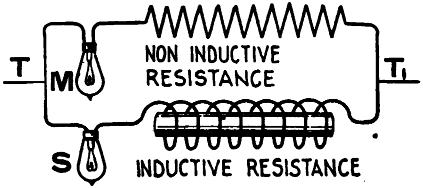
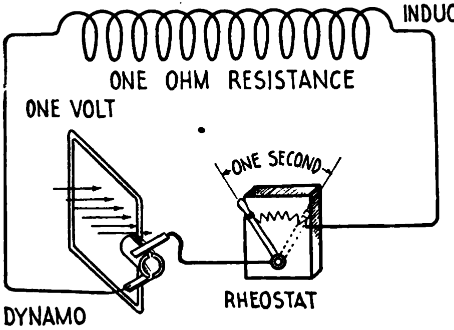


FIG. 6,426.—***Non-inductive*** and ***inductive resistances***. If *d.c.* be applied at TT′ (the two ohmic resistances being the same) the lamps M and S, will burn with equal brilliancy. If *a.c.* be applied at TT′, M, will burn brightly while S, will give little or no light owing to the inductance of the inductive resistance.



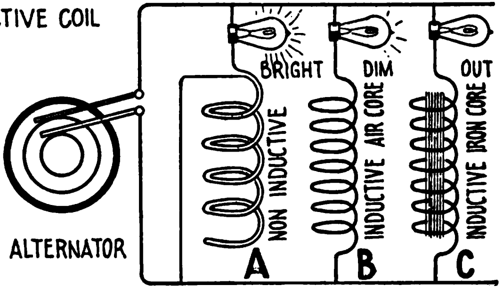
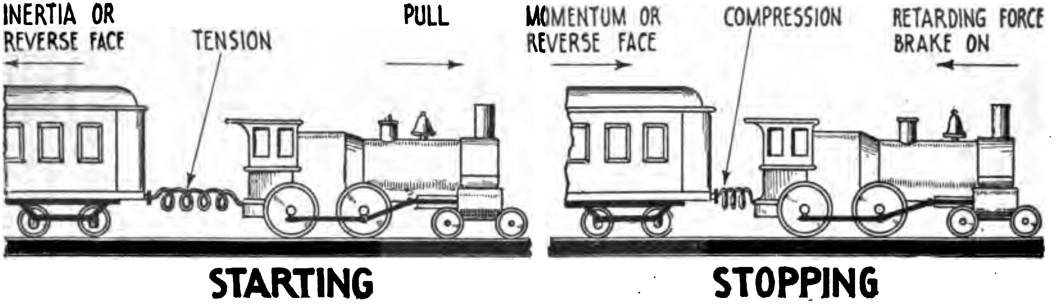


FIG. 6,427.—Diagram illustrating the ***henry***. By definition: *A circuit has an inductance of one henry when a rate of change of current of one ampere per second induces a pressure of one volt.* It is assumed that the resistance of the dynamo and connecting wires is zero.

FIG. 6,428.—Effect on *a.c.* of various coils. Assuming each coil has the same (ohmic) resistance, a lamp will burn brightly, be dimmed, or go out when joined in series with coils A, B, or C respectively. Note the method of winding coil A, to make it ***non-inductive***.



FIGS. 6,429 and 6,430.—Mechanical analogy of self-induction in an *a.c.* circuit. ***In starting,*** the locomotive first moves and stretches the spring before the car begins to move thus producing an initial force necessary to overcome the opposition or inertia of matter which resists the effort to change it from a state of rest to a state of motion. ***In stopping,*** the opposite conditions obtain. ***Similarly,*** like conditions are present each time electricity is set in motion or brought to rest. This opposition is visibly presented on opening a switch, the current momentarily ***arcing the gap***, against the enormous resistance thus introduced.

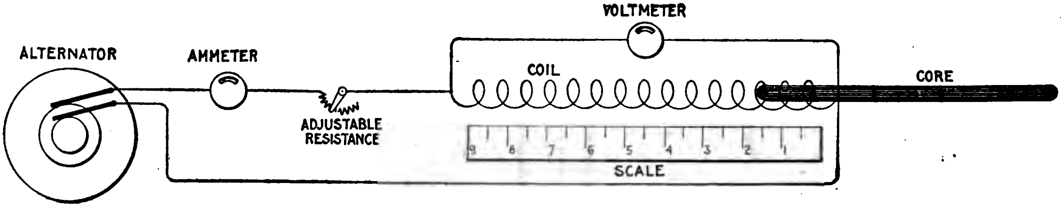
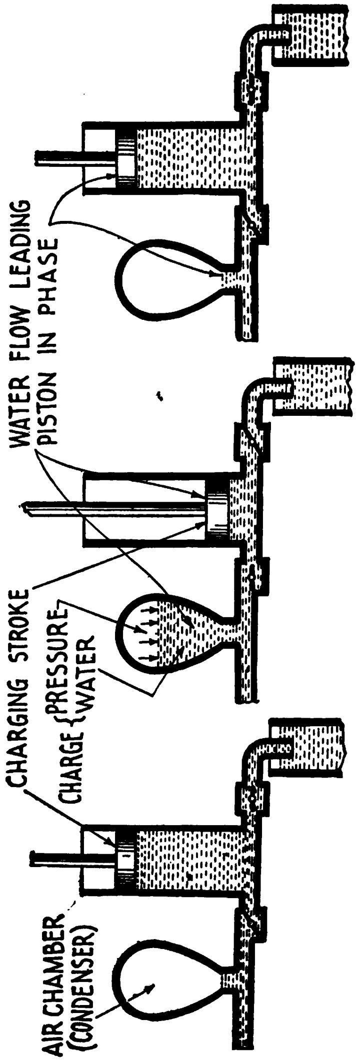


FIG. 6,431.—Inductance test, illustrating the self-induction of a coil which is gradually increased by moving an iron wire core inch by inch into the coil. The current is kept constant with the adjustable resistance throughout the test and readings taken first without the iron core, and again when the core is put in the coil and moved to the 1, 2, 3, 4, etc., inch marks. By plotting the voltmeter readings and the position of the iron core on section paper, a curve is obtained showing graphically the effect of the self-induction.



FIGS. 6,432 to 6,434.—Hydraulic analogy of **capacity**. The pressure pump on the down stroke (figs. 6,432 and 6,433) forces (*impressed pressure*) the water into the air chamber (*condenser*) charging [illegible] against an increasing back pressure, which, at the end of the stroke is *in excess* of the pressure due to the head (*resistance*) pumped against. This accumulation of pressure in the air chamber keeps the water (*current*) flowing while the piston is on the return stroke (figs. 6,433 and 6,434), and the impressed pressure (volts) is zero, the *water flow* (current) *leading* in phase the power stroke (*volts*) of the pump.

varied in strength, *the magnatism changes, and* ***induces*** *a reverse pressure that opposes the pressure which produces the current.*

This self-induced reverse pressure tends to weaken the main current at the start and prolong it when the circuit is opened.

Evidently since an alternating current is continually varying in strength and reversing, there will always be more or less opposition due to the reverse pressure, this opposition being called the ***spurious*** *resistance* as distinguished from the ***ohmic*** *resistance* or *true* resistance. Hence in the flow of alternating current in a circuit there will be two retarding effects, due to the spurious and ohmic resistances.

The spurious resistance depends upon the frequency, shape of the conductor, and nature of the surrounding medium.

The expression *inductance* is frequently used in the same sense as *coefficient of self-induction*, or the capacity which an electric current has of producing induction within itself. ***The unit of inductance is the henry,*** named after Joseph Henry.* The ohmic equivalent of inductance, or

$$X_i = 2\pi f L \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which f = frequency; L = henrys.

Capacity.—When an electric pressure is applied to a condenser, the current plays in and out, charging the condenser in alternate directions.

As the current runs in at one side and out at the other, the dielectric becomes charged, and tries to discharge itself by setting up an opposing electric pressure. This opposing pressure rises just as the charge increases.

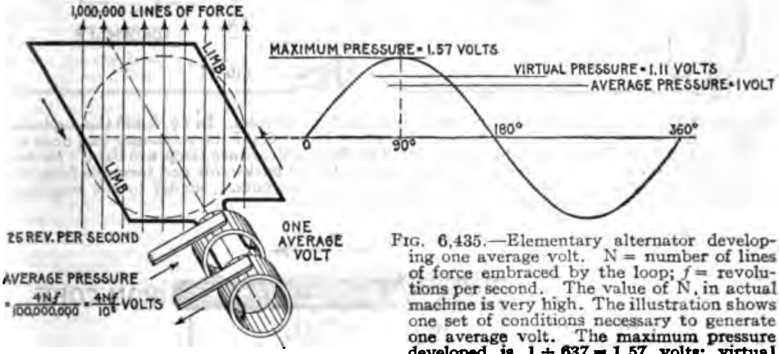


FIG. 6,435.—Elementary alternator developing one average volt. N = number of lines of force embraced by the loop; f = revolutions per second. The value of N, in actual machine is very high. The illustration shows one set of conditions necessary to generate one average volt. The maximum pressure developed is 1 ÷ .637 = 1.57 volts; virtual pressure = 1.57 × .707 = 1.11 volts.

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*NOTE.—***Joseph Henry,*** the American physicist, was born 1797, died 1878. He was noted for his researches in electromagnetism. In 1831, he employed a mile of fine copper wire with an electromagnet, causing the current to attract the armature and strike a bell, thereby establishing the principle employed in modern telegraph practice. He was made a professor at Princeton in 1832, and during his experimenting then, he devised an arrangement of batteries and electromagnets embodying the principle of the telegraph relay which made possible long distance transmission. ***He was the first to observe magnetic self-induction,*** and performed important investigations in oscillating electric discharges (1842), and other electrical phenomena. Henry enjoyed an international reputation, and is acknowledged to be one of America's greatest scientists.

NOTE.—"I adhere to the term *virtual*, as it was in use before the term *efficace* which was recommended in 1889 by the Paris Congress to denote the *square root of mean square* value. The corresponding English adjective is *efficacious;* but some engineers mistranslate it with the word *effective*. I adhere to the term *virtual* mainly because the adjective *effective* is required in its usual meaning in kinematics to represent the resolved part of a force which acts obliquely to the line of motion, the effective force being the whole force multiplied by the cosine of the angle at which it acts with respect to the direction of motion. Some authors use the expression 'R. M. S. value' (meaning 'root mean square') to denote the virtual or quadratic mean value."—*S. P. Thompson.*

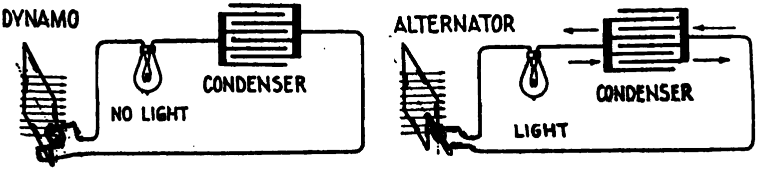
The effect of capacity is the opposite of inductance, that is, ***it assists the current to rise to its maximum sooner than it would otherwise.***

A condenser is said to have a capacity of one farad *when one coulomb of electricity stored in the plates of the condenser will cause a pressure of one volt across its terminals.* Every alternating current circuit acts as a condenser.

The ohmic equivalent of capacity or capacity reactance

$$X_c = \frac{1}{2\pi f C} \quad \text{.......................(2)}$$

in which f = frequency; C = capacity of standard condenser.



Figs. 6,436 and 6,437.—Effect of condenser on *d.c.* and *a.c.* circuits. In fig. 6,436 the condenser prevents the flow of direct current, hence no light. In fig. 6,437 the condenser gap does not hinder the flow of *a.c.* in the metallic portion of the circuit, hence lamp will light. *In fact* the alternator produces a continual surging of electricity backwards and forwards from the plates of the condenser around the metallic portion of the circuit, similar to the surging of waves against a bulkhead which projects into the ocean.

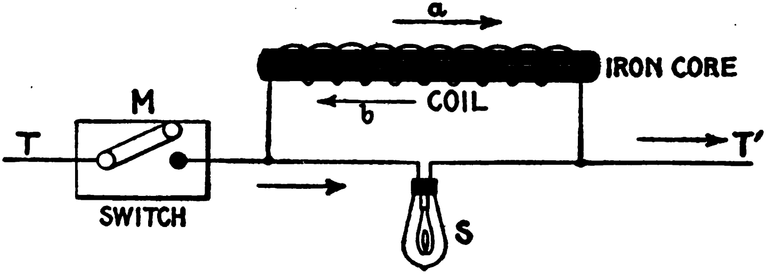
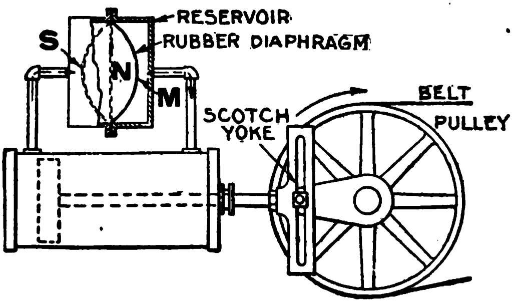


Fig. 6,438.—Inductance experiment with intermittent direct current. A lamp is connected in parallel with a coil of fairly fine wire having a removable iron core, and the terminals T, T' connected to a source of direct current, a switch M, being provided to interrupt the current. The voltage of the current and resistance of the coil are of such values that when a steady current is flowing, the lamp filament is just perceptibly red. *At the instant of making the circuit, the lamp will momentarily glow more brightly than when the current is steady; on breaking the circuit the lamp will momentarily flash with great brightness.* In the first case, the reverse pressure, due to inductance, as indicated by arrow *b*, will momentarily oppose the normal pressure in the coil, so that the voltage at the lamp will be momentarily increased, and will consequently send a momentarily stronger current through the lamp. On breaking the main circuit at M, the field of the coil will collapse, generating a momentary much greater voltage than in the first instance, in the direction of arrow *a*, the lamp will flash up brightly in consequence.



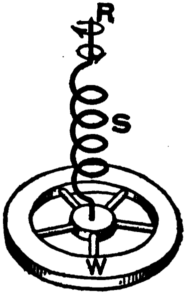


Fig. 6,439.—Hydraulic analogy illustrating capacity in an alternating current circuit. A chamber containing a rubber diaphragm is connected to a double acting cylinder and the system filled with water. *In operation,* as the piston moves, say to the left from the center, the diaphragm is displaced from its neutral position N, and stretched to some position M, in so doing offering increasing resistance to the flow of water. On the return stroke the flow is reversed and is assisted by the diaphragm during the first half of the stroke, and opposed during the second half. The diaphragm thus acts with the flow of water one-half of the time and in opposition to it one-half of the time. This corresponds to the electrical pressure at the terminals of a condenser connected in an alternating current circuit, and it has a maximum value when the current is zero and a zero value when the current is a maximum.

Fig 6,440.—Mechanical analogy illustrating effect of capacity in an alternating circuit. If an alternating twisting force be applied to the top R, of the spring S, the action of the latter may be taken to represent capacity, and the rotation of the wheel W, alternating current. The twisting force (impressed pressure) must first be applied *before* the rotation of W (current) will begin. The resiliency or rebounding effect of the spring will, in time, cause the wheel W, to move (amperes) in advance of the twisting force (voltage), thus representing the current *leading in phase.*

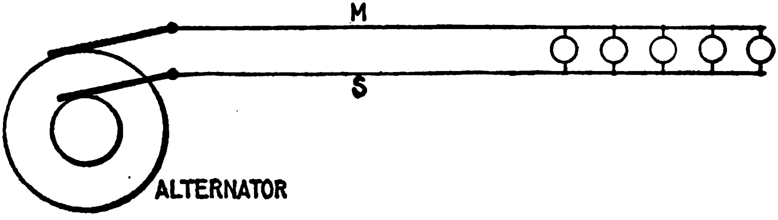


Fig. 6,441.—Diagram illustrating effect of capacity in an alternating circuit. Considering its action during one cycle of the current, the alternator first "pumps", say from M to S; electricity will be heaped up, so to speak, on S, and a deficit left on M, that is, S will be + and M −. If the alternator be now suddenly stopped, there would be a momentary return flow of electricity from S, to M, through the alternator. If the alternator go on working, however, it is obvious that the electricity heaped up on S, helps or increases the flow when the alternator begins to pump from S, to M, in the second half of the cycle, and when the alternator again reverses its pressure, the + charge on M, flows round to S, and helps the ordinary current. The above circuit is not strictly analogous to the insulated plates of a condenser, but, as is verified in practice, that with a rapidly alternating pressure, the condenser action is not perceptibly affected if the cables be connected across by some non-inductive resistance as for instance incandescent lamps.

Example.—What is the resistance equivalent of a 50 microfarad condenser to an alternating current having a frequency of 100?

Substituting in formula (2), the given values in the expression for ohmic value

$$X_c = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 100 \times .000050} = \frac{1}{.031416} = 31.8 \text{ ohms.}$$

If the pressure of the supply be, say 100 volts, the current would be 100 ÷ 31.8 = 3.14 amperes.

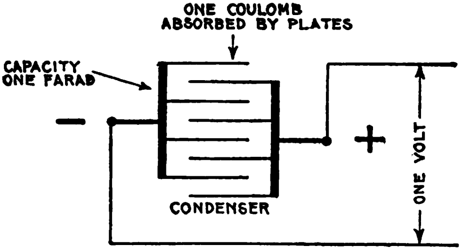
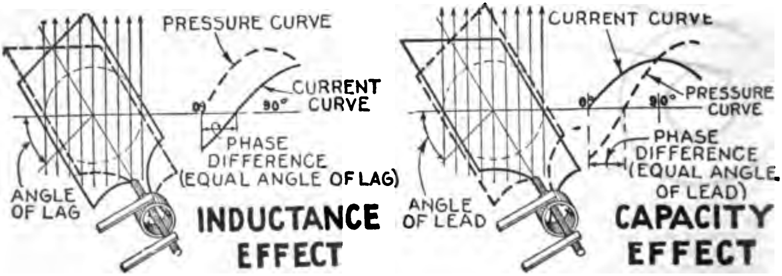


Fig. 6,442.—Diagram illustrating the ***farad.*** By definition, *a condenser is said to have a capacity of one farad if it will absorb one coulomb of electricity when subjected to a pressure of one volt.* This is a unit of large size and for convenience the ***microfarad,*** or one millionth of a farad is generally used.

Lag and Lead.—The alternating current does not always keep in step with the alternating volts which produce the current.



Figs. 6,443 and 6,444.—Diagrams illustrating ***lag*** and ***lead.*** The effect of inductance is to retard the current cycle, that is to say, if the current and pressure be in phase, the introduction of inductance will cause a phase difference, the current wave "lagging" behind the pressure wave as shown in fig. 6,443. The effect of capacity is to cause the current to rise to its maximum value sooner than it would otherwise do, as in fig. 6,444; capacity produces an effect exactly the opposite of inductance.

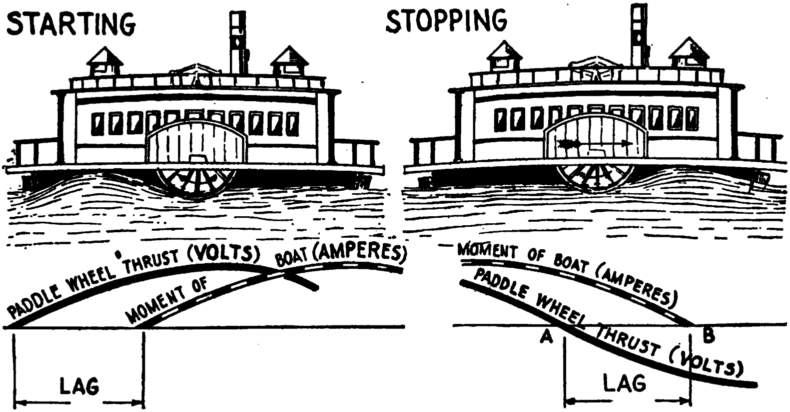
If there be ***inductance*** *in the circuit, the current will* ***lag;*** *if there be* ***capacity*** *the current will* ***lead*** *in phase.*

Lag and lead are measured in degrees. The angle of lag (symbol ϕ) is the angle where the tangent of the angle of the lag is equal to the quotient of the spurious resistance divided by the ohmic resistance, that is

$$\tan\phi = \frac{\text{spurious resistance}}{\text{ohmic resistance}} = \frac{2\pi f L}{R} \qquad (3)$$

in which f = frequency; L = inductance in henrys; R = ohmic resistance.

Example.—An alternating circuit has an inductance of 6 ohms and a resistance of 2.5 ohms. What is the angle of lag?



Figs. 6,445 to 6,448.—Ferry boat analogy of ***lag.*** ***In starting,*** the paddle wheels make an appreciable movement (*volts*) before the boat begins to move (*amperes*). Thus the movement of the boat (*amperes*) ***lags*** behind the thrust of the paddle wheels (*volts*). ***In stopping,*** the paddle wheels make several reverse turns (*reversal of a.c. volts*) before the movement of the boat (amperes) ceases, thus lagging behind the thrust of the paddles (*volts*).

Substituting in formula (1)

$$\tan\phi = \frac{6}{2.5} = 2.4$$

Referring to a table of natural tangents, the corresponding angle is approximately 67°.

The angle of lag may be anything up to 90°.

Reactance.—The *spurious resistance or inductance as* *distinguished from the ohmic resistance is called reactance and is expressed in ohms.*

Example.—If an alternating current whose frequency is 60, have an inductance of .5 henry, what is the reactance?

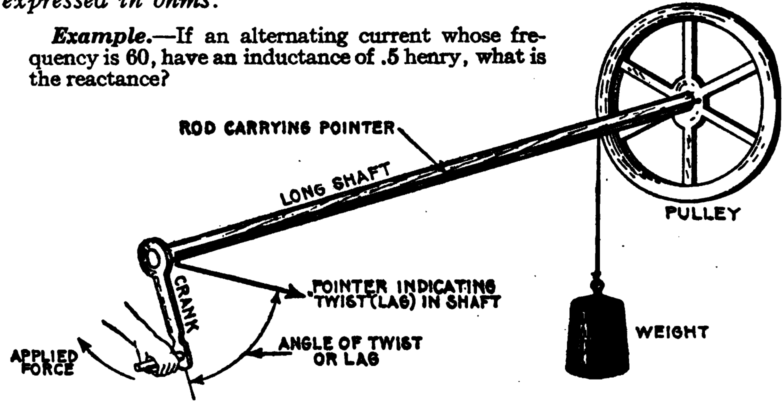


FIG. 6,449.—Mechanical analogy of lag. If at one end force be applied to turn a very long shaft, having a loaded pulley at the other, the torsion thus produced in the shaft will cause it to twist an appreciable amount which will cause the movement of the pulley to *lag* behind that of the crank. This may be indicated by a rod attached to the pulley and terminating in a pointer at the crank end, the rod being so placed that the pointer registers with the crank when there is no torsion in the shaft. The angle made by the pointer and crank when the load is thrown on, indicates the amount of lag which is measured in degrees.

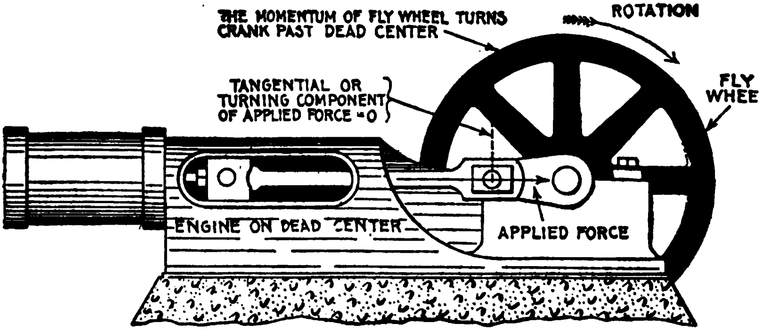
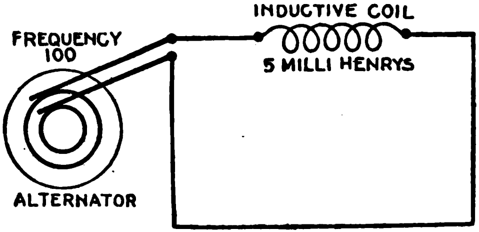


FIG. 6,450.—Steam engine analogy of current flow at zero pressure. When the engine has reached the dead center point the full steam pressure is acting on the piston, the valve having opened an amount equal to its lead. The force applied at this instant, indicated by the arrow is perpendicular to the crank pin circle, that is, the tangential or *turning* component is equal to zero, hence there is no pressure tending to turn the crank. The latter continues in motion past the dead center because of the momentum previously acquired. Similarly, the electric current, which is here analogous to the moving crank, continues in motion, though the pressure at some instants be zero, because it acts as though it had weight, that is, it cannot be stopped or started instantly.



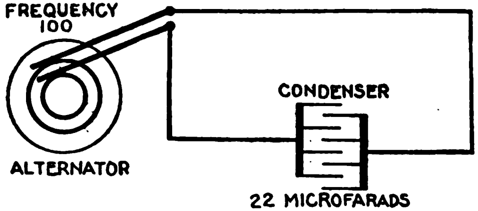
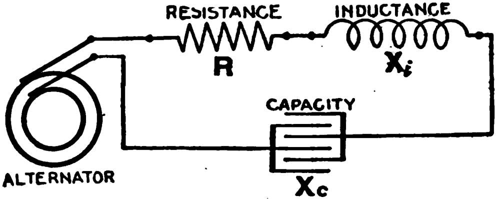


Fig. 6,451.—Diagram showing alternating circuit containing inductance. Formula for calculating the ohmic value of inductance or "inductance reactance," is $X_i = 2\pi fL$ in which X_i = inductance reactance; π = 3.1416; f = frequency; L = inductance *in henrys* (not Millihenrys). L 15 = millihenrys = 15 ÷ 1000 = .015 henrys. Substituting, $X_i = 2 \times 3.1416 \times 100 \times .015 = 9.42$ ohms.

Fig. 6,452.—Diagram showing alternating circuit containing capacity. Formula for calculating the ohmic value of capacity or "capacity reactance" is $X_c = 1 \div 2\pi fC$, in which X_i = capacity reactance; π = 3.1416; f = frequency; C = capacity *in farads* (not microfarads). 22 microfarads = 2 ÷ 1,000,000 = .000022 farad. Substituting, $X_c = 1 \div (2 \times 3.1416 \times 100 \times .000022) = 72.4$ ohms.



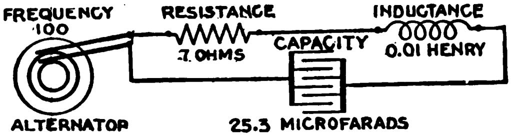


Fig. 6,453.—Diagram showing alternating circuit containing resistance, inductance, and capacity. Formula for calculating the impedance of this circuit is $Z = \sqrt{R^2 + (X_i - X_c)^2}$, in which Z = impedance; R = resistance; X_i = inductance reactance X_c = capacity reactance. Example: What is the impedance when R = 4, X_i = 92.4, and X_i = 72.4. Substituting $Z = \sqrt{4^2 + (94.2 - 72.4)^2} = 22.2$ ohms. Where the ohmic values of inductance and capacity are given as in this example, the calculation of impedance is very simple, but when inductance and capacity are given in millihenrys and microfarads respectively, it is necessary to first calculate their ohmic values as in figs. 6,451 and 6,452.

Fig. 6,454.—Diagram of a resonant circuit. A circuit is said to be resonant when the inductance and capacity are in such proportion that the one neutralizes the other, the circuit then acting as though it contained only resistance. In the above circuit $X_i = 2\pi fL = 2 \times 3.1416 \times 100 \times .01 = 6.28$ ohms; $X_c = 1 \div (2 \times 3.1416 \times 100 \times .000253) = 6.28$ ohms whence the resultant reactance $= X_i - X_c = 6.28 - 6.28 = 0$ ohms. $Z = \sqrt{R^2 + (X_i - X_c)^2} = \sqrt{7^2 + 0^2} = 7$ ohms.

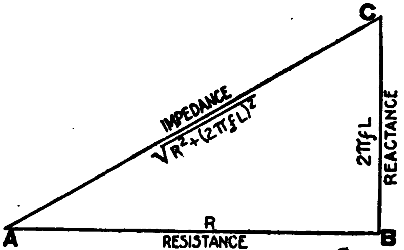
Substituting in formula (1)

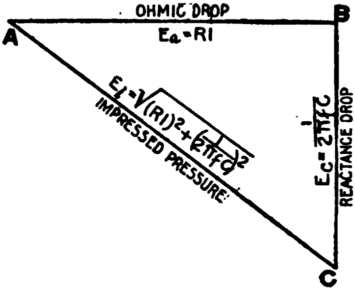
$$X_l = 2\pi f L = 2 \times 3.1416 \times 60 \times .5 = 188.5 \text{ ohms}$$

Impedance.—This term means *the total opposition in an electric circuit to the flow of an alternating current.*

1. When the circuit contains only resistance and reactance.

$$\text{impedance} = \sqrt{\text{resistance}^2 + \text{reactance}^2} \ldots\ldots\ldots\ldots\ldots (4)$$





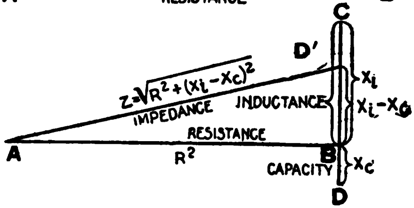


FIG. 6,455.—Graphical method of obtaining the impedance in circuits containing resistance and inductance, having given the resistance and reactance, that is, the ohmic resistance and spurious resistance. With any convenient scale lay off AB = *resistance*, and erect the perpendicular BC = *reactance* (using the same scale); join AC, whose length (measured with the same scale) will give the *impedance.*

FIG. 6,456.—Graphical method of obtaining the impressed pressure in circuits containing resistance and capacity, having given the ohmic drop and reactance drop due to capacity. With any convenient scale, lay off AB = *ohmic drop*, and at right angles to AB draw BC = *reactance drop* (using the same scale). Join AC, whose length (measured with the same scale) will give the *impressed pressure.* The mathematical expressions for the three quantities are given inside the triangle, and explained in the text.

FIG. 6,457.—Impedance diagram for circuit containing resistance, inductance and capacity. The symbols corresponding to those used in equation (1) below. In constructing the diagram from the given values, lay off AB = resistance; at B, draw a line at right angles, on which lay off above the resistance line, BC = inductive reactance, and below, BD = capacity reactance, then the resultant reactance = BC − BD = BD'. Join A and D' then AD' = impedance.

Example.—If an alternationg pressure of 100 volts be impressed on a coil of wire having a resistance of 6 ohms and inductance of 8 ohms, what is the impedance of the circuit and how many amperes will flow through the coil? In the example here given, 6 ohms is the resistance and 8 ohms the reactance. Substituting these in equation (4)

$$\text{impedance} = \sqrt{6^2 + 8^2} = \sqrt{100} = 10 \text{ ohms}$$

The current in amperes which will flow through the coil is, by Ohm's law using impedance in the same way as resistance.

$$\text{current} = \frac{\text{volts}}{\text{impedance}} = \frac{100 \text{ volts}}{10 \text{ ohms}} = 10 \text{ amperes.}$$

2. When the circuit contains resistance, reactance and capacity.

$$\textit{impedance} = \sqrt{\textit{resistance}^2 + (\textit{inductance reactance} - \textit{capacity reactance})^2}$$

or using symbols,

$$Z = \sqrt{R^2 + (X_i - X_c)^2} \ldots\ldots\ldots\ldots\ldots (5)$$

Example.—A current has a frequency of 100. It passes through a circuit of 4 ohms resistance, of 150 milli-henrys inductance, and of 22 microfarads capacity. What is the impedance?

a. The ohmic resistance R, is 4 ohms.

b. The inductance reactance, or

$$X_i = 2\pi f L = 2 \times 3.1416 \times 100 \times .15 = 94.3 \text{ ohms.}$$

150 milli-henrys are reduced to .15 henry before substituting in the formula.

c. The capacity reactance, or

$$X_c = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 100 \times .000022} = 72.4 \text{ ohms.}$$

22 microfarads are reduced to .000022 farad before substituting in the formula.

Substituting values as calculated in equation (5),

$$Z = \sqrt{4^2 + (94.2 - 72.4)^2} = \sqrt{491} = 22.2 \text{ ohms.}$$

Resonance.—Inductance and capacity oppose each other *when the effect of inductance neutralizes that of capacity the circuit is in a state of* ***resonance;*** that is, when X_i and X_c are equal in formula (5) the circuit is resonant.

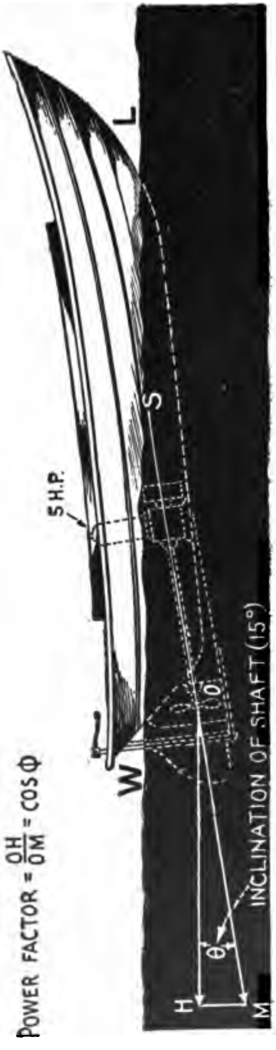


FIG. 6,458—Marine analogy of *power factor*. **Usually the propeller shaft in a dory is at a considerable angle to the surface of the water,** hence the full thrust of the propeller wheel is not effective in propelling the dory. The power of the engine then must be multiplied by a coefficient (less than unity) called the *power factor* to obtain the true or net power. On MS, take OM = thrust and draw from M, a vertical line to meet a horizontal line from O, at H. OH, then is the active component of the thrust serving to move the boat. the power of the engine being reduced in the proportion of OH ÷ OM, but this is the *cosine* of angle φ, hence power factor = *cos* φ. ***Example,*** The dory has a 5 *h.p.* engine (*kva*÷746) with shaft inclined 15° (angle φ), what is the power factor, and net power (*true watts*÷746) effective in propelling the dory? Power factor = cos φ = (from table), .966. Net power = (*kva*÷746 × *power factor*) = 5×.966 = 4.83 *h.p.*, 5−4.85 = .17 *h.p.* being lost because of inclination of shaft; this loss corresponds to the *wattless* components. The foregoing neglects the additional loss due to inefficiency of the propeller.

CHAPTER 101

Power Factor

When the alternating current is not in phase with the pressure, the product must be multiplied by a coefficient called the *power factor* in order to obtain the *true watts*, or actual power available.

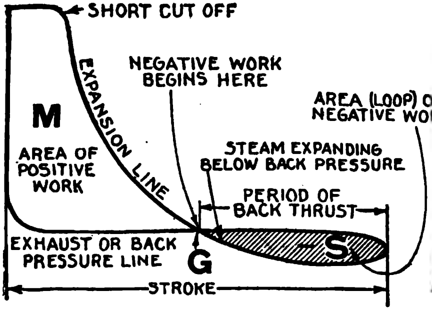
By definition the power factor is: ***the number of watts indicated by a watt meter, divided by the product of the ammeter reading, multiplied by the volt meter reading.***

The watt meter reading gives the ***true watts*** and the product of the ammeter and volt meter readings, the ***apparent watts.***

The power factor depends upon the relative amount of resistance, inductance and capacity in the circuit, and it may vary from one to zero.

When the current and pressure are in synchronism, the power factor is unity; *when there is lag or lead the power factor is less than unity.* Its usual value is slightly less than one. *The power factor is numerically equal to the cosine of the angle of phase difference between current and pressure.*

Example.—A circuit having a resistance of 3 ohms, and a resultant reactance of 4 ohms, is connected to a 100 volt line. What is: 1, the impedance, 2, the current, 3, the apparent power, 4. the angle of lag, 5, the power factor, and 6, the true power?



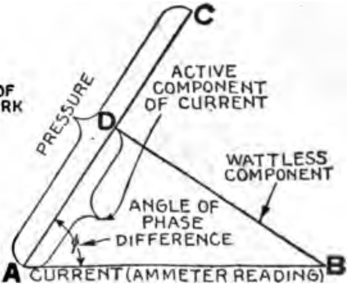


Fig. 6,459.—Steam engine analogy of power factor. In the card, the steam distribution is such that the steam is expanded below the back pressure line, that is below the pressure of the exhaust. This results in *negative work* which must be overcome by the *momentum* or *kinetic energy* previously stored in the fly wheel, and which is represented on the diagram by the shaded loop S. If the exhaust valve had opened at G, the amount of work done during the revolution would be represented by the area M, but continuing the expansion below the back pressure line, the work done is M – S. This latter case as compared with the first when expansion does not continue below the back pressure line gives an efficiency (power factor) of (M – S) + M, the shaded area representing so much loss.

Fig. 6,460.—Method of obtaining the *active component* of the current; diagram illustrating why the power factor is equal to cos ϕ. If AB and AC be respectively the given current and pressure, or readings of the ammeter and voltmeter, and ϕ the angle of phase difference between current and pressure, then drawing from B, BD perpendicular to AC will give AD the active component. Now, true power = AC × AD, but AD = AB cos ϕ, hence true power = AC × AB cos ϕ. Again, apparent power = AC × AB, and since true power = apparent power × power factor, the power factor = cos ϕ.

1. *The impedance of the circuit.*

$$Z = \sqrt{3^2 + 4^2} = 5 \text{ ohms.}$$

2. *The current.*

current = volts ÷ impedance = 100 ÷ 5 = 20 amperes.

3. *The apparent power.*

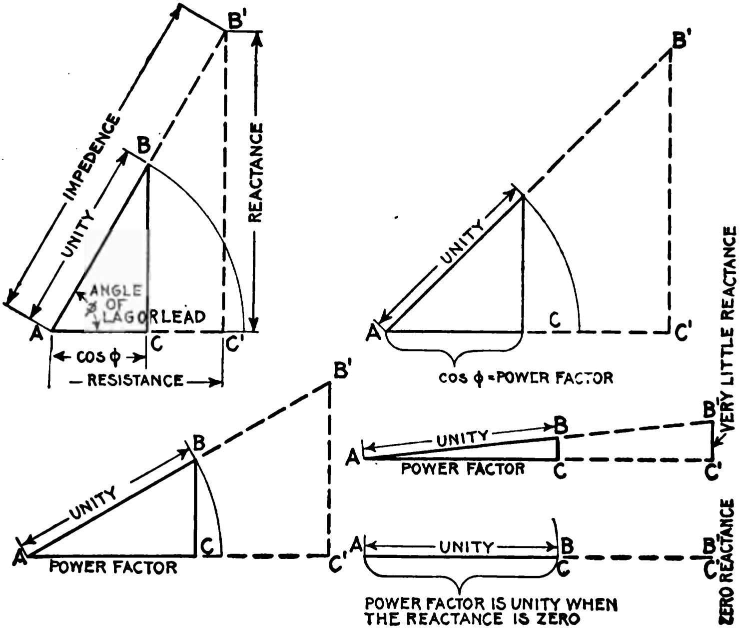
apparent power = volts × amperes = 100 × 20 = 2,000 watts.

4. *The tangent of the angle of lag.*
   tan ϕ = reactance ÷ resistance = 4 ÷ 3 = 1.33. From table of natural tangents (page 451) ϕ = 53°.

5. *The power factor.*
   The power factor is equal to the cosine of the angle of lag, that is, power factor = cos 53° = .602 (from table).

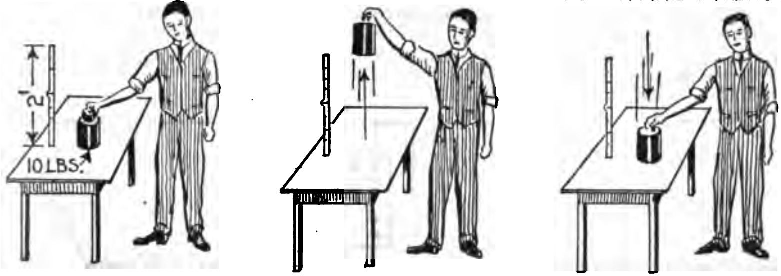
6. *The true power.*
   The true power is equal to the apparent watts multiplied by the power factor, or

$$\begin{aligned}\text{true power} &= \text{volts} \times \text{amperes} \times \cos\phi \\ &= 100 \times 20 \times .602 = 1{,}204 \text{ watts.}\end{aligned}$$



FIGS. 6,461 to 6,465.—Diagrams illustrating *why the power factor is unity* when there is no resultant reactance in the circuit, that is, when the circuit is resonant, or has only resistance. The power factor is equal to the cosine of the angle of lag (or lead). In the figures this angle is BAC or ϕ and the value of the *natural cosine* AC gives the power factor. ***By inspection*** of the figures, it is evident that decreasing the reactance decreases the angle ϕ and increases cos ϕ or the power factor. The circular arc in each figure being at unity distance from the center A, the power factor with decreasing reactance evidently approaches unity as its limit, this limit being shown in fig. 6,465 where the reactance B'C' = 0.

“Wattless Current”; Power Factor Zero.—When the power factor is zero, it means that the phase difference between the current and the pressure is 90°.



FIGS. 6,466 to 6,468.—Mechanical analogy of wattless current. If a man lift a weight any distance as from the position of fig. 6,466 to position of fig. 6,467, he does a certain amount of work on the weight giving it potential energy. When he lowers it to its original position, as in fig. 6,468, the weight loses the potential energy previously acquired, that is, it is given back to the man, the "system" (man and weight) having returned to its original condition as in fig. 6,466. During such a cycle, the work done by the man on the weight is equal to the work done by the weight on the man and no useful external work has been accomplished.

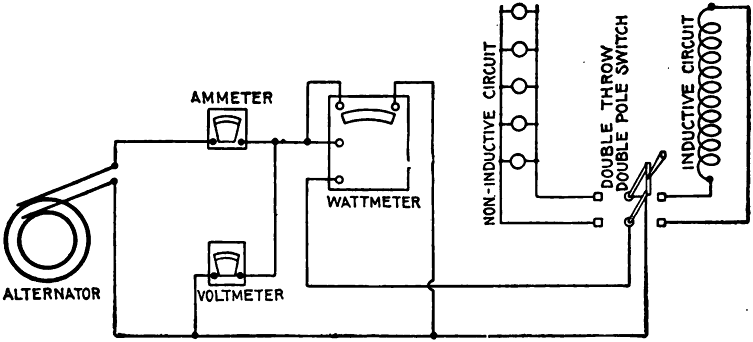


FIG. 6,469.—Diagram illustrating power factor test, when on non-inductive and inductive circuits. The instruments are connected as shown and by means of the double throw switch can be put on either the non-inductive or inductive circuit. First turn switch to left so that current passes through the lamps; for illustration, the following readings are assumed: ammeter 10, voltmeter 110, and wattmeter 1,100. The power factor then is wattmeter reading ÷ volts × amperes = 1,100 actual watts ÷ 1,100 apparent watts = 1, that is, on non-inductive circuit the power factor is unity. Now throwing the switch to the right connecting instruments with the inductive circuits, then for illustration the following readings may be assumed: ammeter 8, voltmeter 110, and wattmeter 684. Now, as before, power factor = wattmeter reading ÷ volts × amperes = 684 ÷ (8 × 110) = 684 ÷ 880 = .78.

The term *wattless current*, as understood, does not indicate an absence of electrical energy in the circuit; its elements are there, but not in an available form for external work. The false power due to the so-called wattless current pulsates in and out of the circuit without accomplishing any useful work.

If an alternator supply current to a circuit having a very small resistance and very large inductance, the current would lag nearly 90° behind the pressure. The primary current of a transformer working with its secondary on open circuit is a practical example of a current which represents very little energy.

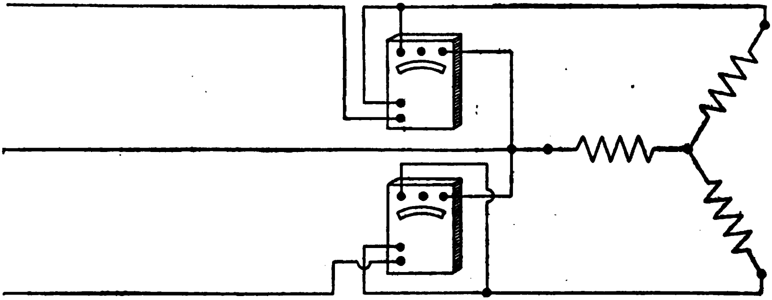


FIG. 6,470.—Wattmeter method of three phase power measurement. Two wattmeters are required in unbalanced systems as shown in the illustratior. The total power transmitted is then the algebraic sum of the readings of the two wattmeters. If the power factor be greater than .5, the power is the arithmetical sum, and if it be less than .5, the power is the arithmetical difference of the readings.

Power Factor in Station Operation.—Commercially, it is desirable to keep the power factor as near unity as possible, because with a low power factor, while the alternator may be carrying its full load and operating at a moderate temperature, the consumer is paying only for the actual watts which are sent over the line to him.

NOTE.—*To avoid disputes* manufacturers usually rate their alternators in kilovolt amperes (*kva.*) instead of watts, a kilovolt ampere being a unit of apparent power in an *a.c.* current which is equal to one kilowatt when the power factor is equal to one.

NOTE.—*A power factor meter* is important in station operation when rotary converters are used on *a.c.* lines for supplying direct current and the sub-station operators are kept busy adjusting the field rheostat of the rotary to maintain a high power factor and prevent over heating of the alternators during the time of day when there is the maximum demand for current that is at the time of the peak of the load.

For instance, if a large alternator supplying 1,000 kilowatts at 6,600 volts in a town where a number of induction motors are used on the line be operating with a power factor of say .625 during a great portion of the time, the switchboard instruments connected to the alternator will give the following readings:

Voltmeter 6,600 volts; ammeter 242.4 amperes; power factor meter .625.

The apparent watts would equal 1,600,000 watts or 1,600 kilowatts, which, if multiplied by the power factor .625 would give 100,000,000 watts or 1,000 kilowatts which is the actual watts supplied. The alternator and line must carry 242.4 amperes instead of 151 amperes and the difference 242.4 — 151 = 91.4 amperes represents a *wattless current* flowing in the circuit which causes useless heating of the alternator.

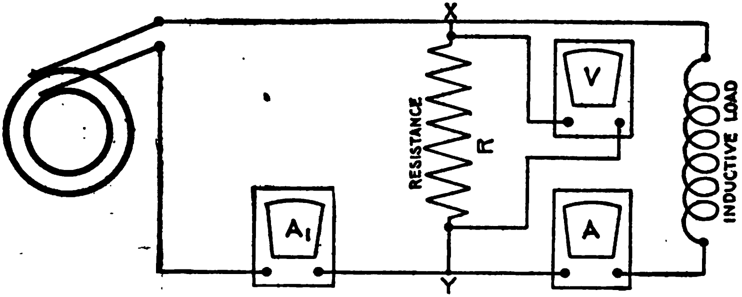


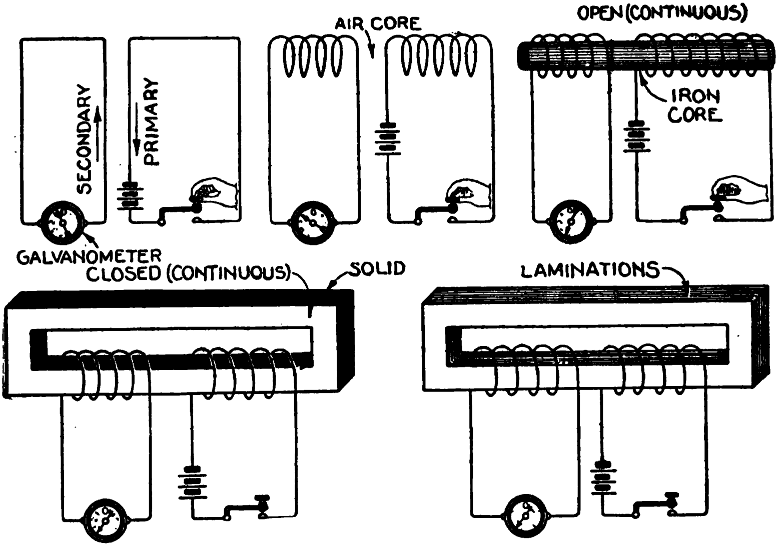
FIG. 6,471.—Fleming's combined voltmeter and ammeter method of measuring power in alternating current circuits. It is quite accurate and enables instruments in use to be checked. In the figure, R is a non-inductive resistance connected in shunt to the inductive load. The voltmeter V measures the pressure across the resistance XV. A and A_1 are ammeters connected as shown. Then true watts $= \left(A_1^2 - A^2\left(\frac{V}{R}\right)^2\right) \times \frac{R}{2}$. If the volt meter V take an appreciable amount of current, it may be tested as follows: disconnect R and V at Y, and see that A and A_1 are alike; then connect R and V at Y again, and disconnect the load. A_1 will equal current taken by R and V in parallel.

In station operation the power factor is determined, not by calculation, but by reading a power factor meter.

CHAPTER 102

Transformers

The transformer is one of the essential devices in effecting the economical distribution of electric energy, and may be defined as *an apparatus used for changing the voltage and current of an alternating circuit.* A transformer consists essentially of:



Figs. 6,472 to 6,476.—Elementary transformers illustrating basic principles. Fig. 6,472, primary and secondary windings of only a single turn—induction very feeble; fig. 6,473, coils with air core—induction feeble; fig. 6,474, coils with *open* iron core—induction strong; fig. 6,475, coils with *closed* iron core—induction stronger; fig. 6,476, coils with closed *laminated* iron core to prevent eddy currents and resulting loss through heating.

1. A primary winding; 2. secondary winding; 3. An iron core.

Basic Principle.—The working of a transformer is due to what is known as ***mutual induction*** *between two circuits when an intermittent or alternating current flows in one of the circuits.*

The effect of mutual induction may be explained by the aid of fig. 6,472. Whenever circuit **A**, is closed by the switch allowing a current to pass in a given direction, a momentary current will be induced in circuit **B**, as indicated by the galvanometer.

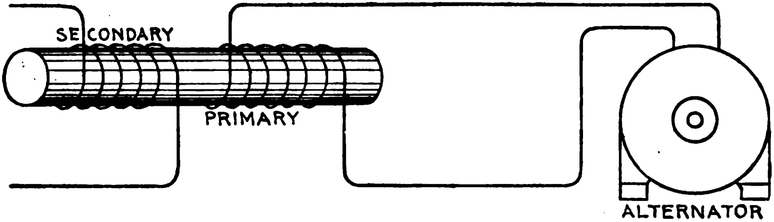


Fig. 6,477.—Diagram of elementary transformer with non-continuous core and connection with single phase alternator. The three essential parts are: primary winding, secondary winding, and an iron core.

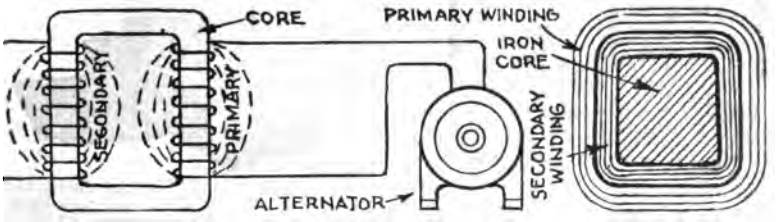


Fig. 6,478.—Diagram of elementary transformer with continuous core and connections with alternator. The dotted lines show the leakage of magnetic lines. To remedy this the arrangement shown in fig. 6,479 is used.

Fig. 6,479.—Cross section showing commercial arrangement of primary and secondary windings on core. One is superposed on the other. This arrangement compels practically all of the magnetic lines created by the primary winding to pass through the secondary winding.

A similar result will follow on the opening of circuit **A,** the difference being that the momentary induced current occurring at closure moves in a direction opposite to that in the battery circuit, while the momentary

FIGS. 6,480 to 6,483.—General Electric core construction. Fig. 6,480, two part distributed core partially assembled; fig. 6,481, three part distributed core, fig. 6,482, four part distributed core; fig. 6,483, four part distributed core partly assembled. ***The two part*** distributed cores are assembled from straight laminations so that the center leg is of cruciform section and the two outer legs of rectangular section. The end laminations are inserted after the windings have been assembled. These cores are strongly clamped by means of structural steel parts which are also utilized in securing the core and coils in the tanks. ***The three and four part*** cores are built up using L shaped laminations assembled in such a manner as to secure a comparatively large center section with magnetic circuits radiating at 120 degrees or 90 degrees, respectively. These laminations are interlocked in the center section. The use of L shaped punchings materially improves the designs by reducing the number of joints in the magnetic circuit to two, and thus materially lowering the exciting current. The three part core is so assembled that a nine sided center leg is produced which gives practically a circular form on which the coils are wound. In the four part core, a center leg having four sides with well rounded corners is secured so that the winding makes no sharp bends, and is either circular or nearly circular in form depending on the details of design of the core. The outer laminations closing the magnetic circuits are assembled after the winding operation is completed. The three part core is clamped by means of metal plates being held together by a bolt passing through the center of the core. In the four part core metal straps around the outer legs serve to hold these clamping plates together. These clamping plates in addition serve as a means of clamping the core and coils in the tank.

current at opening moves in the same direction. Currents besides being induced in circuit **B**, at *make* or *break* of circuit **A**, are also induced when the current in circuit **A**, is fluctuating in intensity. This intermittent or alternating current is necessary for the operation of a transformer.

With intermittent current most marked results are observed when the make or break is sudden. Since the current can be stopped quicker than it can be started, the induction is greatest at *break*, hence ignition apparatus is designed to produce a spark at break.

In fig. 6,472 the inductive effect is very feeble and successively better results are obtained in figs. 6,473 to 6,476.

In fig. 6,472, circuit **A**, in which a current is passed is called the *primary circuit*, and circuit **B**, in which a current is induced, the *secondary circuit*. Similarly, in fig. 6,476 the coil of circuit **A**, is called the *primary winding*, and that of circuit **B**, the *secondary winding*.

FIGS. 6,484 and 6,485.—Assembled coils of Westinghouse 10 and 15 *kva*. transformers; views showing ventilating ducts.

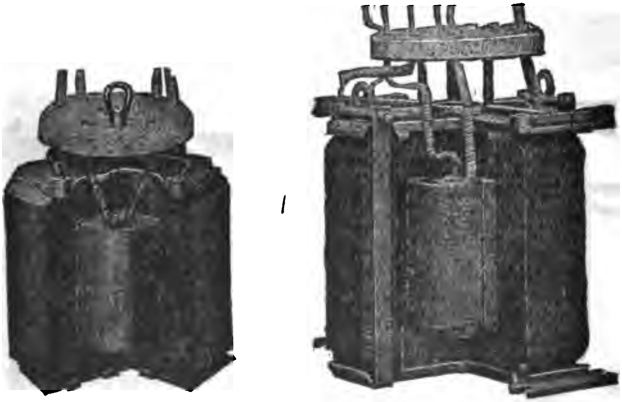
The property of a transformer that makes it of great value for most purposes is that *the voltage of the induced currents may be increased or diminished to any extent depending on the relation between the number of turns in the primary and secondary winding.*

Rule 26.—The voltage of the secondary current is (approximately) to the voltage of the primary current as the number of turns of the secondary winding is to the number of turns of the primary winding.

Example.—If ten amperes flow in the primary winding and the transformation ratio be 10, then 10 × 10 = 100 amperes will flow through the secondary winding.

Thus, a direct proportion exists between the pressures and turns in the two windings and an inverse proportion between the amperes and turns, that is:

primary voltage: secondary voltage = primary turns: secondary turns
primary current: secondary current = secondary turns: primary turns



FIGS. 6,486 and 6,487.—General Electric Core and windings assembly. Fig. 6,486, single phase, 60 cycle 2,300 volt, transformer using three part distributed core; fig. 6,487, core and coils of single phase, 2,300 volt transformer using four part distributed core. ***Windings.*** These are of two general types, those wound directly on the core, and those wound on forms, and later assembled on the core. Windings made directly on the core have the advantage of rigid support, the insulations being placed in final fixed positions by the winder and not disturbed or distorted by an assembly process. These advantages are especially desirable in the small units as here the clearances required by economical design are smallest. The coils of the three part distributed core transformers are wound on the core. One half of the low voltage coils are usually wound directly over the core insulation. The high voltage coils and outer low voltage coils are in turn wound over the inner low voltage coils with an insulating pad between all coils. The windings are provided with suitable coil ducts for uniform cooling—the number and location of the ducts varying with the size of the transformer. The coils of the four part distributed core transformers may be either core wound or form wound, depending upon the size and voltage of the transformer. Those wound on the core are wound in the same manner as those of the three part distributed core transformers.

From the above equations it is seen that the watts of the primary circuit equal the watts of the secondary circuit.

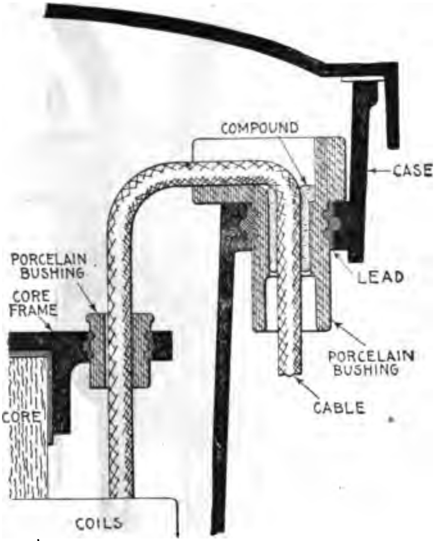


FIG. 1,954.—Method of bringing out the secondary leads in Wagner central station transformers. Each primary lead is brought into the case through a similar bushing. Observe the elimination of al possibility of grounding the cable on the case or core.

In the above example, the total wattage in the primary circuit is 1,000 × 10 = 10 *kw.*, and that in the secondary circuit is 100 × 100 = 10 *kw.* Hence, while both volts and amperes are widely different in the two circuits, the watts for each are the same in the ideal case, that is, assuming perfect transformer action or 100% efficiency. Now, the usual loss in commercial transformers is about 3% at full load, so that the actual watts delivered in the secondary circuit is (100 × 100) × 97% = 9.7 *kw.*

The No Load or Exciting Current.—When the secondary winding of a transformer is open or disconnected from the secondary circuit no current will flow in the winding, but a very small current called the *no load or exciting current* will flow in the primary circuit.

The reason for this is as follows: The current flowing in the primary winding causes repeated reversals of magnetic flux through the iron core. These variations of flux induce pressures in both coils; that induced in the primary called the *reverse pressure* is opposite in direction and very nearly equal to the impressed pressure, that is, to the pressure applied to the primary winding. Accordingly the only force available to cause current to flow through the primary winding is the difference between the impressed pressure and reverse pressure, the *effective pressure.*

The Magnetizing Current.—The magnetizing current of a transformer is sometimes spoken of as that current which the primary winding takes from the mains when working at normal pressure. The ***true magnetizing current*** is that component of this total no load current which is in quadrature with the supply pressure. The remaining component has to overcome the various iron losses, and is therefore "in phase" with the supply pressure. The relation between these two components determines the power factor of the "no load current."

This component is very small if the transformer be well designed, and be worked at low flux density.

Action of Transformer with Load.—If the secondary winding of a transformer be connected to the secondary circuit

FIG. 6,489.—Rear view of Fort Wayne distributing transformer showing hanger irons for attaching to pole cross arms.

FIG. 6,490.—Top view showing core and coils in place of Westinghouse distributing transformer. The coils are wound from round wire in the smaller sizes of transformers and from strap copper in the larger sizes. Strap wound coils allow a greater current carrying conductor section than coils wound from large round wire, as there is little waste space between the different turns of the conductor. The coils are arranged concentrically with the high tension winding between the two low tension coils, the object being to improve the *regulation*. The low tension coils are wound in layers which extend across the whole legnth of the coil opening in the iron, while the high tension coils are wound in two parts and placed end to end. This construction reduces the normal voltage strains to a value which will not give trouble under any condition of service. Leads with means of preventing creeping of oil by capillary action are attached to these studs and brought out of the core through porcelain bushings.

by closing a switch so that current flows through the secondary winding, the transformer is said to be *loaded*.

The action of this secondary current is to oppose the magnetizing action of the slight current already flowing in the primary winding, thus decreasing the maximum value reached by the alternating magnetic flux in the core, thereby decreasing the induced pressure in each winding.

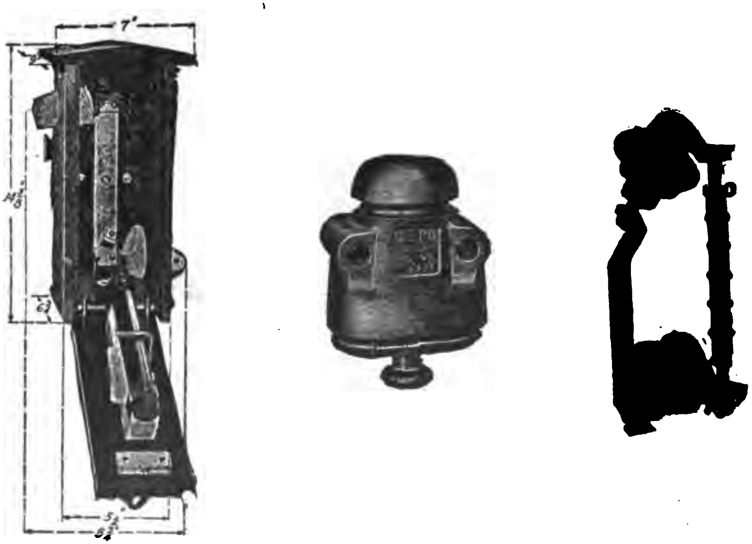
Figs. 6,491 and 6,492.—Westinghouse transformer terminal blocks for high and low tension conductors.

The amount of this decrease, however, is ***very small***, inasmuch as a very small decrease of the induced pressure in the primary coil greatly increases the difference between the pressure applied to the primary coil and the opposing pressure induced in the primary coil so that the primary current is greatly increased. In fact, ***the increase of primary current due to the loading of the transformer is just great enough*** (*or very nearly*) ***to exactly balance the magnetizing action of the current in the secondary coil;*** that is, the flux in the core must be maintained approximately constant by the primary current whatever value the secondary current may have.

Figs. 6,493 to 6,496.—Porcelain bushing for Westinghouse transformers.

When the load on a transformer is increased, the primary of the transformer automatically takes additional current and power from the supply mains in direct proportion to the load on the secondary.

When the load on the secondary is reduced, for example by turning off lamps, the power taken from the supply mains by the primary coil is automatically reduced in proportion to the decrease in the load. This automatic action of the transformer is due to the balanced magnetizing action of the primary and secondary currents.



Figs. 6,497 to 6,499.—General Electric transformer cut outs. Fig. 6,497, expulsion cut out for 6,600 volts; fig. 6,498, plug cut out; fig. 6,499, expulsion cut out for pressures above 6,600 volts. ***The plug cut out*** **is suitable for mounting on the cross arm and may be used on 2,500 volt circuits for currents up to 30 amperes, or 3,500 volt circuit for currents, up to 15 amperes.** ***The expulsion cut out,*** **is suitable for installation on the cross arm and is used for voltages and currents higher than those for which the plug type cut out is suitable. One type of expulsion cut out consists of a box of treated ash with hinged door and a tubular fuse holder which is supported on a porcelain fastened to the door, making connection with the line through springs when the door is closed. Upon opening the door the fuse holder is automatically disconnected from the circuit. A card holder is provided on the bottom of the box just beneath the gas outlet of the fuse holder. When the fuse blows, the expulsion of the gas either punctures the card or forces it out of the holder, thus indicating a blown fuse. This indication may be seen from the ground, making it unnecessary for linemen or inspectors to climb the pole to determine if the fuse be blown. These cut outs are suitable for use on circuits of 6,600 volts and below, 100 amperes and less. A modification of this cut out is made for circuits of 15,000 to 45,000 volts and currents up to 50 amperes. Although no covering is provided with this cut out, it is suitable for outdoor installation.**

Classification of Transformers.—As in the case of motors, the great variety of transformer makes it necessary that a classification, to be comprehensive, must be made from several points of view, as:

1. With respect to the transformation, as

   - *a.* Step up transformers;
   - *b.* Step down transformers.

2. With respect to the arrangement of the coils and magnetic circuit, as

   - *a.* Core transformers;
   - *b.* Shell transformers;
   - *c.* Combined core and shell transformers.

3. With respect to the kind of circuit they are to be used on, as

   - *a.* Single phase transformers;
   - *b.* Polyphase transformers.

4. With respect to the method employed in cooling, as

   - *a.* Dry transformers;
   - *b.* Air cooled transformers { natural draught; forced draught, or air blast;
   - *c.* Oil cooled transformers;
   - *d.* Water cooled transformers.

5. With respect to the nature of their output, as

   - *a.* Constant pressure transformers;
   - *b.* Constant current transformers;
   - *c.* Current transformers;
   - *d.* Auto-transformers.

6. With respect to the kind of service, as

   - *a.* Distributing;
   - *b.* Power.

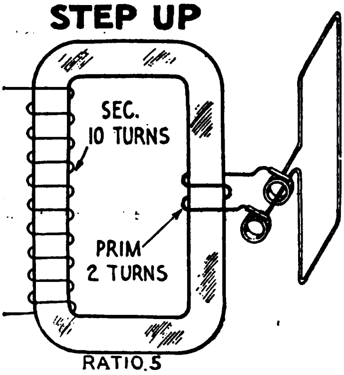
7. With respect to the circuit connection that the transformer is constructed for, as

a. Series transformers; *b*. Shunt transformers.

8. With respect to location, as

a. Indoor, *b*. Outdoor.

Step Up and Step Down Transformers.—At the station the low voltage current from the alternators is transformed to high voltage current so that it may be transmitted to considerable distances with small wires, and at each point of distribution it is stepped down to low voltage as is required for lighting, etc. In this way there is a considerable saving in copper as must be evident.



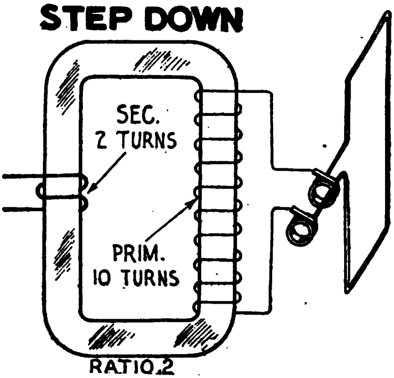
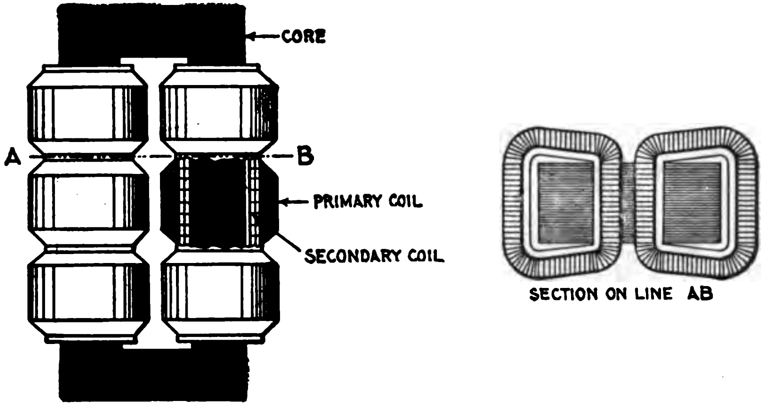


FIG. 6,500.—Diagram of elementary *step up* transformer. As shown the primary winding has two turns and secondary 10 turns, giving a ratio of voltage transformation of 10 ÷ 2 = 5. Since only ⅕ as much current flows in the secondary winding as in the primary, the latter requires heavier wire than the former.

FIG. 6,501.—Diagram of elementary step down transformer. As shown the primary winding has 10 turns and the secondary 2, giving a ratio of voltage transformation of 2 ÷ 10 = .2. The current in the secondary being 5 times greater than in the primary will require a proportionately heavier wire.

Thus, since watts = amperes × volts (from which amperes = watts ÷ volts) to transmit say 1,000 watts at 1,000 volts the wire must be large enough to carry 1,000 ÷ 100 = 10 amperes, whereas if the pressure be increased to 1,000 volts, the wire would only have to carry 1,000 ÷ 1,000 = 1 ampere, hence a much smaller wire could be used.

Core Transformers.—This type of transformer may be defined as one having an iron core, upon which the wire is wound in such a manner that the iron is enveloped within the coils, the outer surface of the coils being exposed to the air as shown in figs. 6,502 and 6,503.



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Figs. 6,502 and 6,503.—Core type transformer. *It consists of* a central core of laminated iron, around which the coils are wound. A usual form of core type transformer consists of a rectangular core, around the two long limbs of which the primary and secondary coils are wound, the low tension coil being placed next the core.

Shell Transformers.—In the shell type of transformer, as shown in fig. 6,504, the core is in the form of a shell, being built around and through the coils. A shell transformer has, as a rule, fewer turns and a higher voltage per turn than the core type.

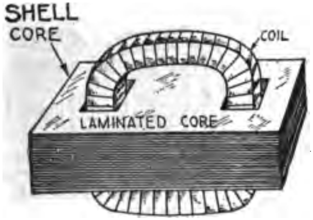
Comparison between Shell and Core Transformers.—The choice between shell and core transformers depends upon manufacturing convenience rather than upon operating characteristics.

The major insulation in a core type transformer consists of several large pieces of great mechanical strength.

In the shell type, there are required an extremely large number of relatively small pieces of insulating material, which necessitates careful workmanship to prevent defects in the finished transformer, when thin or fragile material is used.

Both core and shell transformers are built for all ratings. For small ratings the core type possesses certain advantages with reference to insulation, while for large ratings, the shell type possesses better cooling properties, and has less magnetic leakage than the core type.

Distributed Core Transformers.—An improved type of transformer has been introduced which can be considered either as two superposed shell transformers with coils in common, or as a single core type transformer with divided magnetic circuit and having coils on only one leg.



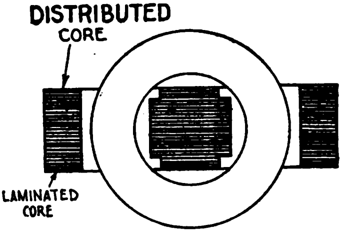


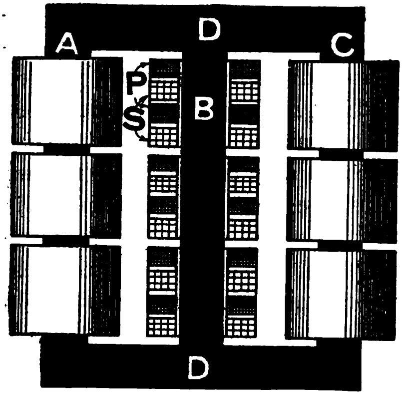
FIG. 6,504.—Shell type transformer. ***In construction,*** the laminated core is built around and through the coils as shown. For very heavy current ratings at low voltage this type has some advantages with respect to mechanical construction of windings whereas in other ratings, especially at high voltages, the core type is preferable, both in this respect and with respect to insulation.

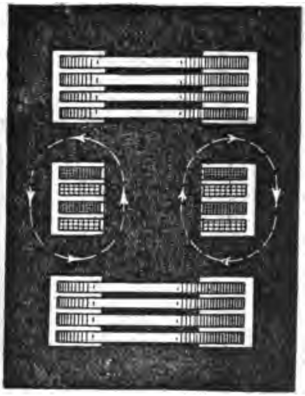
FIG. 6,505.—Plan of core of General Electric distributed core type transformer. The core used contains four magnetic circuits of equal reluctance, in parallel; each circuit consisting of a separate core. In this construction one leg of each circuit is built up of two different widths of punchings forming such a cross section that when the four circuits are assembled together they interlock to form a central leg, upon which the winding is placed. The four remaining legs consist of punchings of equal width. These occupy a position surrounding the coil at equal distances from the center, on the four sides; forming a channel between each leg and coil, thereby presenting large surfaces to the coil and allowing its free access to all parts of the winding. The punchings of each size transformer are all of the same length, assembled alternately, and forming two lap joints equally distributed in the four corners of the core, thereby giving a magnetic circuit of low reluctance.

It is best considered however, as a distributed core type transformer, and for small sizes it possesses most of the advantages of both types. It can be constructed at less cost than can either a core or a shell transformer having the same operating characteristics and temperature limits.

Single and Polyphase Transformers.—A single phase transformer may be defined as *one having only one set of primary and secondary terminals, and in which the fluxes in the one or more magnetic circuits are all in phase*, as distinguished from a polyphase transformer, or combination in one unit of several one phase transformers with separate electric circuits but having certain magnetic circuits in common.

In polyphase transformers there are two or more magnetic circuits through the core, and the fluxes in the various circuits are displaced in phase.





FIGS. 6,506 and 6,507.—Core and shell types of three phase transformer. ***In the core type,*** fig. 6,506, there are three cores A, B, and C, joined by the yokes D and D′. This forms a three phase magnetic circuit, since the instantaneous sum of the fluxes is zero. Each core is wound with a primary coil P, and a secondary coil S. As shown, the primary winding of each phase is divided into three coils to ensure better insulation. The primaries and secondaries may be connected *star* or *mesh.* The core B, has a shorter return path than A and C, which causes the magnetizing current in that phase to be less than that in A and C phases. This has sometimes been obviated by placing the three cores so their corners form an equilateral triangle (as in fig 6,481), but the extra trouble involved is not justified, as the unbalancing is a no load condition, and practically disappears when the transformer is loaded. ***The shell type,*** fig. 6,507, consists practically of three separate transformers in one unit. The flux paths are here separate, each pair of coils being threaded by its own flux, which does not, as in the core type, return through the other coils. This gives the shell type an advantage over the core type, for should one phase burn out, the other two may still be used, especially if the faulty coils be short circuited. The effect of such short circuiting is to prevent all but a very small flux threading the faulty coil.

Polyphase current may be transformed either by a polyphase transformer or by using a single phase transformer for each phase. The polyphase transformer is however preferable, because less iron is required than would be with the several single phase transformers. The polyphase transformer therefore is somewhat lighter and also more efficient.

Cooling of Transformers.—There are various methods of cooling transformers, the cooling mediums being

1. Air. 2. Oil. 3. Water.

The means adopted for getting rid of the heat which is inevitably developed in a transformer by the waste energy is one of the important considerations with respect to its design.

Air Cooled Transformers.—In this type of transformer there are two methods of circulating the air as by, 1, natural draught, and 2, forced draught or blast. As designed for natural draught, the case containing the windings is open at the top and bottom. The column of air in the case expands as its temperature rises, becoming lighter than the cold air on the outside and is consequently displaced by the latter, resulting in a circulation of air through the case. The process is identical with furnace draught.

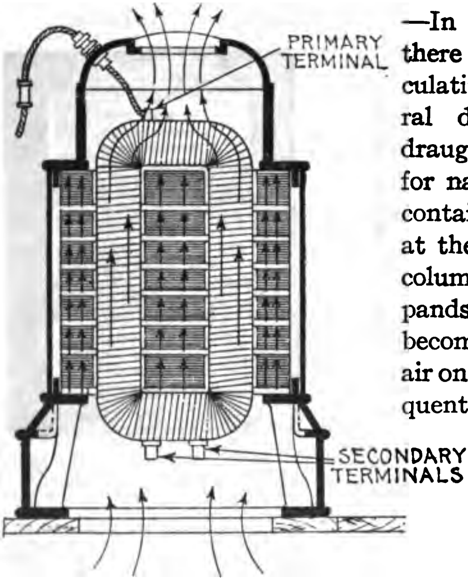


FIG. 6,508.—Forced draught or "air blast" transformer. *As is indicated* by the classification, this type of transformer is cooled by forcing a current of air through ducts, provided between the coils and between sectionalized portions of the core. The cold air is forced through the interior of the core containing the coils the air passing vertically by a blower, through the coils and out through the top. The amount of air going through the coils may be controlled independently by providing dampers in the passages. About 100 cu. ft. of air per minute per total *kw.* loss is ordinarily used for transformers which are not designed to operate above their rated capacity.

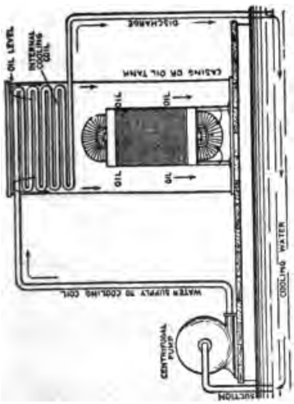


FIG. 6,509.—Water, cooled transformer with internal cooling coil, that is, with cooling coil within the transformer case. In this type, the cooling coil, through which the circulating water passes, is placed in the top of the case or tank, the latter is filled with oil so that the coil is submerged. The oil acts simply as a medium to transfer the heat generated by the transformer to the water circulating through cooling coil. *In operation* a continual circulation of the oil takes place, as indicated by the arrows, due to the alternate heating and cooling it receives as it flows past the transformer coils and cooling coil respectively.

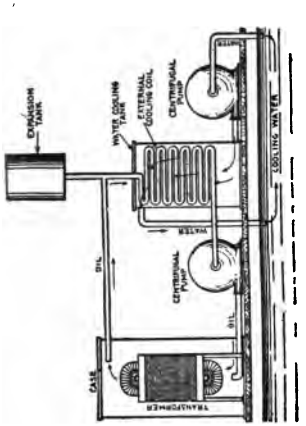


FIG. 6,510.—Water cooled transformer with external cooling coil. *In this arrangement* the cooling coil is placed in a separate tank as shown. Here forced circulation is employed for both the heat transfer medium (*oil*) and the cooling agent (*water*), two pumps being necessary. The cool oil enters the transformer case at the lowest point and absorbing heat from the transformer coils, it passes off through the top connection leading to the cooling coil and expansion tank. Since the transformer tank is closed, an expansion tank is provided to allow for expansion of the oil due to heating. The water circulation is arranged as illustrated.

In forced draught transformers the case is closed at the bottom and open at the top. A current of air is forced through from bottom to top as shown in fig. 6,508 by a fan.

For air cooling, the coils are built up high and thin and assembled with spaces between them for the circulation of the air. In forced draught transformers the air pressure required is from one-half to one ounce per sq. in. The larger transformers require greater pressure to overcome the resistance of larger air ducts. Ordinarily 150 cu. ft. of air per minute is used per *kw.* of load.

Oil Cooled Transformers.—In this type of transformer the coils and core are immersed in oil and provided with ducts to allow the oil to circulate by convection and thus serve as a medium to transmit the heat to the case, from which it passes by radiation.

Oil cooling is used especially for lighting transformers.

In such transformers, the large volume of oil absorbs considerable heat so that the rise of temperature is retarded. Hence, for moderate periods of operation, say 3 or 4 hours, the average lighting period, the maximum temperature would not be reached.

The oil, besides being a cooling agent, is a good insulator, preserves the insulation from oxidation, increasing the breakdown resistance of the insulation, and generally restores the insulation in case of puncture. A special objection to oil, however, is danger of a central station fire being augmented by the presence of the oil. Due to the high flash point of transformer oil, this affords but little extra hazard.

Good transformer oil should not contain moisture, acid, alkali, or sulphur compounds. It should have low viscosity and should not decompose or throw down sludge under operating conditions.

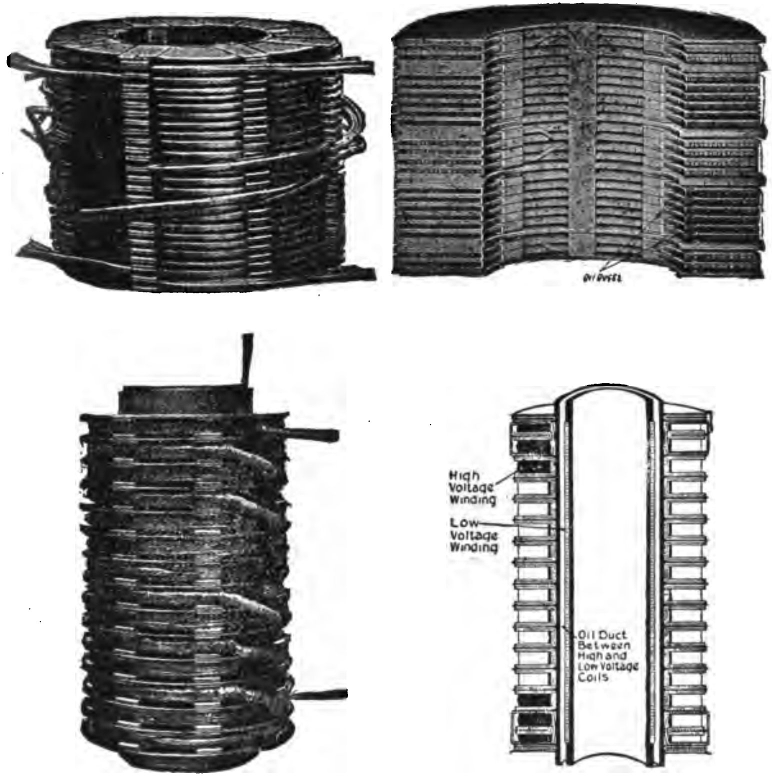
The presence of moisture can be detected by thrusting a red hot nail in the oil; if the oil "crackle," water is present. Moisture may be removed by raising the temperature slightly above the boiling point, 212° Fahr., but the time consumed (several days) is excessive.

Water Cooled Transformers.—A water cooled transformer is one in which water is the cooling agent, and, in most cases, oil is the medium by which heat is transferred from the coils to the water. In construction, pipes or a jacketed casing is provided through which the cooling water is passed by forced circulation, as shown in figs. 6,509 and 6,510.

The surface of the cooling coil should be from .5 to 1.3 sq. in. per watt of total transformer loss, depending upon the amount of heat which the external surface of the transformer case will dissipate.

For a water temperature rise of 43° Fahr., 1.32 lbs. of water per minute is required per *kw*. of load.

Transformer Insulation.—Transformers are provided with *major* and *minor* insulation. The major insulation is placed between the core and secondary (low pressure) coils, and between the primary and secondary coils.



FIGS. 6,511 to 6,514.—General Electric Coil Structures. Various coil constructions have been developed to meet the particular requirements of designs depending upon unit-size and voltage rating. In the larger sizes, circular coils of either disc or cylindrical shape are used on account of their greatly superior mechanical qualities, and the facilities they give for rigid mechanical support. In transformers using form wound coils, the insulation between the high voltage and low voltage windings, and between the high voltage winding and core, depends upon the voltage and type of winding. For transformers using disc voltage and cylindrical low voltage coils, the insulation between the high voltage and low voltage windings is composed of oil ducts and a cylinder of "573 compound" which, in addition to its high insulating properties, possesses great mechanical strength. The insulation between the high voltage winding and the core consists of specially treated fiber barriers and oil ducts. For transformers using disc high voltage and disc low voltage coils assembled interleaved, the insulation between the high voltage and the low voltage windings is composed of fiber barriers and oil ducts the number of barriers and dimensions of the ducts varying with the voltage. The insulation between the high voltage winding and the core is composed of oil ducts and a cylinder of "573 compound." As sections of the low voltage windings are placed

It consists usually of mica tubes, sometimes applied as sheets held in place by the windings, when no ventilating ducts are provided, or moulded to correct form and held between sheets of tough insulating material where ducts are provided for air or oil circulation.

The minor insulation is the insulation placed between adjacent turns of the coils.

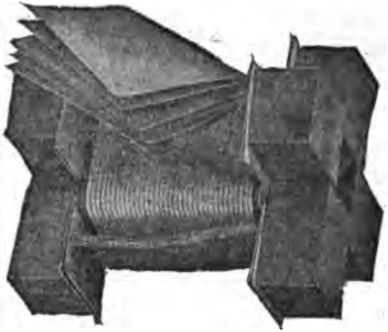


Fig. 6,515.—General Electric partly assembled transformer showing mica pad. Experience has shown the necessity of fire proof insulation in smaller sizes in order to insure protection to the lower voltage circuit. in case of burn out from abnormal operating conditions. A similar mica pad is used between ends of the high voltage coils and cores. In these transformers, therefore, the high voltage winding is practically surrounded by fireproof insulation.

Figs. 6,511 to 6,514.—*Text continued.*

at both ends of the coil attached next to the core, the ends of the high voltage winding are well insulated from the core. The insulation between the low voltage winding and the core in all core wound transformers is made up from a specially treated fiber which possesses suitable insulating properties and is not injured by the mechanical stress incident to the winding process. In the interleaved disc type of winding (fig. 6,511) both high and low voltage coils are wound in the form of discs assembled with the high voltage and low voltage coils interleaved. These coils are wound on a form and assembled over a cylinder of "573 compound" this cylinder furnishing the foundation for the winding. This is later assembled over the core and also serves as an insulation between the windings and the core. The coils are separated from each other by means of specially treated fiber spacers, furnishing generous oil ducts between coils for cooling purposes. Between high and low voltage windings and where required between coils of either winding, one or more fiber collars are inserted with oil ducts between. In the disc-cylinder type of winding (fig. 6,512) the low voltage coils are cylindrical in shape and are wound on a cylinder of "573 compound." The high voltage coils are disc coils assembled over another cylinder of the same material which is in turn assembled over the low voltage winding with an oil duct between the low voltage winding and the outer cylinder. In the cylindrical construction both high and low voltage coils are cylinders wound on forms and assembled concentrically with generous oil ducts between coils.

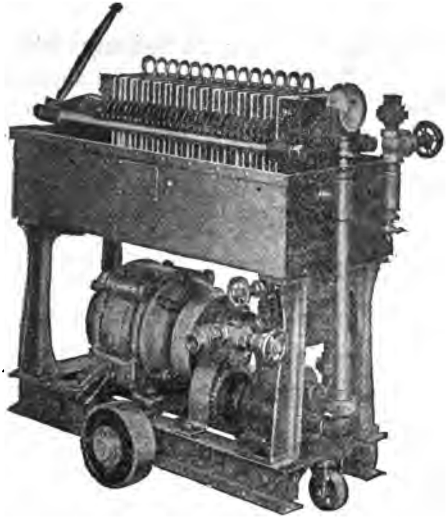


Fig. 6,516.—General Electric transformer oil dryer and filter for freeing the oil from moisture, slime and sediment. ***In operation,*** the oil is forced through several layers of dry blotting paper. The complete equipment consists of a filter press with motor driven oil pump, electric drying oven for thoroughly drying the filter paper before placing it in the press.

Since the difference of pressure is small between the adjacent turns, the insulation need not be very thick. It usually consists of a double thickness of cotton wrapped around each conductor. For round conductors, the ordinary double covered magnet wire is satisfactory.

***Mica** is the most efficient insulating material.*

It has a high dielectric strength, is fire proof, and is the most desirable insulator where there are no sharp corners.

Oil Insulated Transformers.—High voltage transformers are insulated with oil, as it is very important to maintain careful insulation not only between the coils, but also between the coils and the core. In the case of high voltage transformers, any

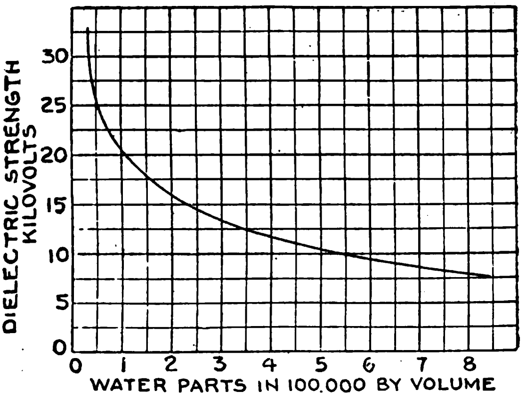


Fig. 6,517.—Curve showing the great reduction in dielectric strength produced by the presence of water in amounts up to 8 parts in 100,000.

accidental static discharge, such as that due to lighting, which might destroy one of the air insulated type, might be successfully withstood by one insulated with oil, for if the oil insulation be damaged it will mend itself at once.

By providing good circulation for the oil, the transformer can get rid of the heat produced in it readily and operate at a low temperature, which not only increases its life but cuts down the electric resistance of the copper conductors and therefore the I^2R loss.

Auto-transformers.—In this class of transformer, there is only one winding which serves for both primary and secondary. On account of its simplicity it is made cheaply.

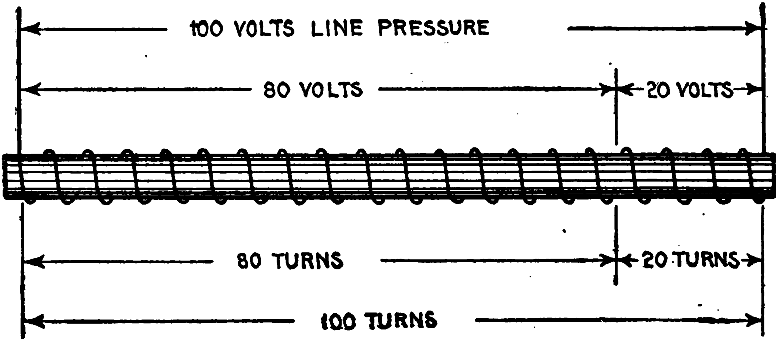


FIG. 6,518.—Diagram illustrating connections and principles of auto-transformers as explained in the accompanying text.

Auto-transformers are used where the ratio of transformation is small, as a considerable saving in copper and iron can be effected, and the whole transformer reduced in size as compared with one having separate windings.

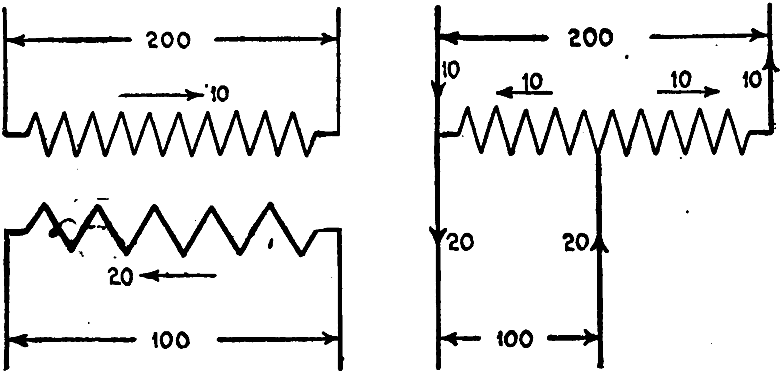
Fig. 6,518 illustrates the electrical connections and the relations between the volts and number of turns.

By using the end wire and tapping in on turn No. 20 a current at 20 volts pressure is readily obtained which may be used for starting up motors requiring a large starting current and yet not draw heavily on the line.

Constant Current Transformers for Series Lighting.—The principle of the constant current transformer as used for series lighting is readily understood by reference to the elementary diagram shown in fig. 6,521.

In this system the alternator and regulating transformer supply a constant current and variable voltage.

Constant current incandescent lighting systems for use in small towns also use this method for automatically regulating the current.



FIGS. 6,519 and 6,520.—Two winding transformer and single winding or auto-transformer. Fig. 6,519 shows a 200:100 volt transformer having a 10 amp. primary and a 20 amp. secondary, the currents being in opposing directions. If these currents be superposed by using one winding only, the auto transformer shown in fig. 6,520 is obtained where the winding carries 10 amp. only and requires only one-half the copper (assuming the same mean length of turn). If R, be the ratio of an auto-transformer, the relative size of it compared with a transformer of the same ratio and output is as $\frac{R-1}{R}$:1. ***For instance:*** a 10 *kw.* transformer of 400 volts primary and 300 volts secondary could be replaced by an auto-transformer of $10\times\frac{1.33-1}{1.33}=2.5$ *kw.*; or, in other words, the amount of material used in a 2½ *kw.* transformer could be used to wind an auto transformer of 400 :300 ratio and 10 *kw.* output.

Since the primary is connected directly to the secondary it would be dangerous to use an auto-transformer on high pressure circuits. This type of transformer has only a limited use, usually as compensator for motor starting boxes.

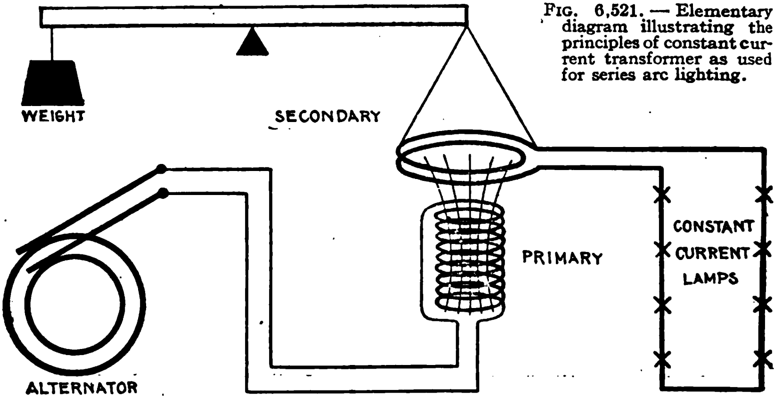


FIG. 6,521. — Elementary diagram illustrating the principles of constant current transformer as used for series arc lighting.

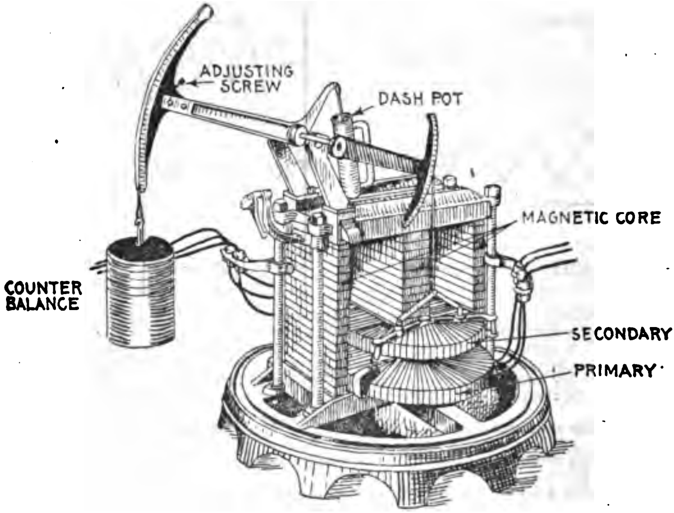


FIG. 6,522.—Mechanism of General Electric air cooled constant current transformer. *It operates* on the principle explained in the accompanying text and is built to supply 25 to 100 arc lamps at 6.6 to 7.5 amperes. The transformers are interchangeable and will operate on 60 or 125 cycles. The relative positions of the two coils may be changed in order to regulate the strength of the current more closely, by shifting the position of the arc carrying the counterbalance by means of the adjusting screw on it. A dash pot filled with special oil prevents sudden movements of the secondary coil and keeps the current through the lamps nearly constant, when they are being cut in or out of the circuit. In starting up a

Regulation.—This term applies to the means adopted either to obtain constancy of pressure or current. In the transformer, regulation is *inherent*, that is, the apparatus automatically effects its own regulation. The regulation of a transformer means, *the change of voltage due to change of load on the secondary;* it may be defined more precisely as: *the percentage increase in the secondary voltage as the load is decreased from its normal value to zero.* Thus, observation should be made of the secondary voltage, at full load and at no load, the primary pressure being held constant at the normal value.

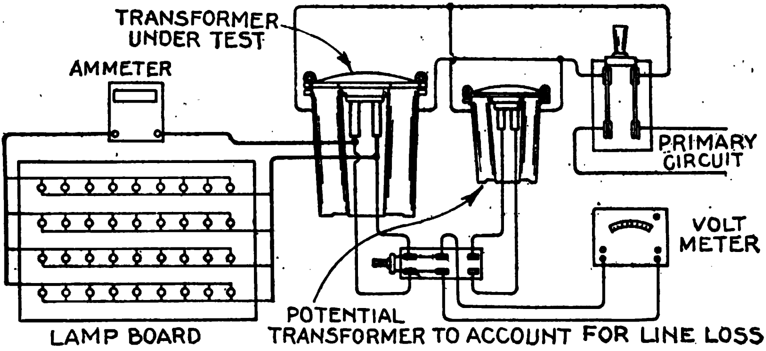


FIG. 6,523.—Diagram of connections for regulation test. *Connect* transformer under test to high tension supply circuit. A second transformer with same or other known change ratio is also to be connected up, as illustrated. By means of a double pole double throw switch, the voltmeter can be made to read the pressure on the secondary of either transformer. Supposing the same change ratio, it is evident that if both remain unloaded the voltmeter will indicate the same pressure. A gradually increasing lamp load up to the limit of the transformer capacity, will be attended by a drop in pressure at the terminals. This drop can be read as the difference of the voltmeter indications, and when expressed in per cent. of secondary voltage stands for "regulation." *Remarks:* The auxiliary transformer is necessary in order to make sure of the high tension line voltage. A large transformer under test may cause primary drop in taking power. This must be set down against it in testing regulation. The second transformer gives notice of such drop, whatever be the cause.

FIG. 6,522.—*Text Continued*

constant current transformer, it is necessary to separate the two coils as far as possible and then close the primary circuit switch and allow the two coils to come together. If the primary circuit be thrown directly on the alternator, the heavy rush of current which will follow due to the two coils being too close together might injure the lamps.

The regulation is said to be "good" or "close," when this change is small. In the design of a transformer, good regulation and low iron losses are in opposition to one another when the best results are desired in both. A well designed transformer, however, should give good results, both as to regulation and iron losses, the relative value depending upon the class of work it has to do, and size.

For 100% or unity power factor per cent regulation = % C R volts

$$= 100\left\{\frac{S_p\ R_p}{E_p} + \frac{I_s\ R_s}{E_s}\right\}$$

in which I = amperes, R, ohms, E, volts, and *p* and *s*, primary and secondary.

Transformer Losses.—The commercial transformer is not a perfect converter of energy, that is, the ***input***, or watts applied to the primary circuit is always more than the ***output*** or watts delivered from the secondary winding.

This is due to the various losses which take place, and the difference between the input and output is equal to the sum of these losses which are:

1. The *iron* or *core* loss

Due to *a*, hysteresis; *b*, eddy currents; *c*, magnetic leakage (negligibly small).

2. The *copper* losses

Due to *a*, heating the conductors (the I^2R loss); *b*, eddy currents in conductors.

Hysteresis.—In transformer operation the rapid reversal of magnetism in the core requires an expenditure of energy which is converted into heat.

This loss of energy is due to the work required to change the position of the molecules of the iron in reversing the magnetization. Extra power then must be taken from the line to make up for this loss, thus reducing the efficiency of the transformer.

The hysteresis loss depends upon the quality of the iron in the core, the magnetic density at which it is worked and the frequency.

To obtain minimum hysteresis loss the softest iron is used for the core and a low degree of magnetization is employed.

Eddy Currents.—These currents are produced in the transformer core similarly as in a generator core and are reduced to a minimum by the usual method of lamination. The thickness of the laminæ depend upon the frequency, being about from .014 to .025 in. according as the frequency is respectively high or low.

When the secondary of a transformer is open, a *no load* current passes through the primary; the energy thus supplied balances the core losses. The iron losses may be reduced to a minimum by having short magnetic paths of large area and using iron or steel of high permeability. The design and construction must keep the eddy currents as low as possible.

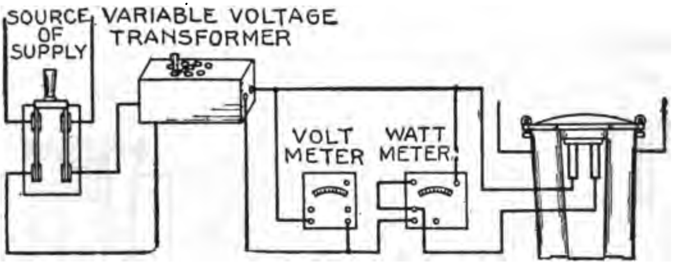


FIG. 6,524.—Method of determining core loss. *Connect* voltmeter and wattmeter as shown in the illustration to the low tension side of the transformer. By means of a variable voltage transformer bring the applied voltage to the point for which the transformer is designed. The wattmeter indicates directly the core loss, which includes a very small loss due to the current in the copper. *Cautions:* 1, Make sure of the voltage and frequency. The manufacturers' tabulated statements refer to a definite voltage and frequency and these have a decided influence upon the core loss. 2, The high tension circuit must remain open during the test.

Copper Losses.—Since the primary and secondary windings of a transformer have resistance, some of the energy supplied will be lost by heating the copper. The amount of this loss is proportional to square of the current, and is usually spoken of as the I^2R loss. The copper losses are the sum of the I^2R losses of both the primary and secondary windings, and the eddy current loss in the conductors.

The eddy current loss is very small, and may be disregarded, so that the sum of the I^2R losses of primary and secondary can be taken as the total copper loss for practical purposes.

Efficiency of Transformers.—The efficiency of transformers is *the ratio of the electric power delivered at the secondary terminals to the electric power absorbed at the primary terminals.*

Accordingly, the output must equal the input minus the losses. If the iron and copper losses at a given load be known, their values and consequently the efficiency at other loads may be readily calculated.

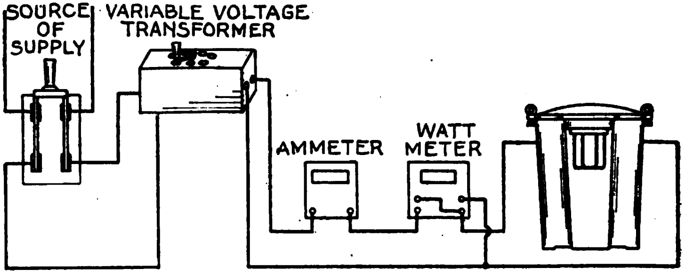


FIG. 6,525.—Method of determining copper loss. Connect ammeter and wattmeter to high tension side of transformer short circuit secondary leads, as shown in illustration, and by means of a variable voltage, adjust current to the full load value for which the transformer is intended. The wattmeter reading shows the copper loss at full load. The full load primary current of any transformer is found from the following equation

full load current = full load watts ÷ primary volts

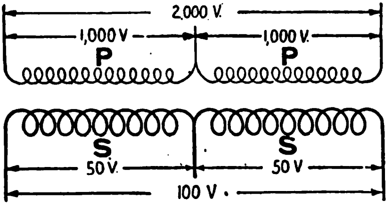
Example.—To find proper full load current on a five kw. 2,200 volt transformer, divide 5,000 watts by 2,200 volts, the full load current will then be 2.27 amperes. A slight variation in primary current greatly increases or decreases the copper loss.

Remarks.—Copper loss increases with temperature because the resistance of the metal rises. Do not overload the current coil of the wattmeter. For greater accuracy the I^2R drop of potential method should be used.

Example.—If a 10 kilowatt constant pressure transformer at full load and temperature have a copper loss of .16 kilowatt, or 1.6 per cent., and the iron loss be the same, then its

$$\text{efficiency} = \frac{\text{output}}{\text{input}} = \frac{10}{10 + .16 + .16} \times 100 = 96.9 \text{ per cent.}$$

Figs. 6,526 to 6,530.—Westinghouse low tension transformer connectors for connecting the low tension leads to the feeder wires. The transformers of the smaller capacities have knuckle joint connectors and those of the larger sizes have interleaved connectors. These connectors form a mechanically strong joint of high current carrying capacity. Since the high tension leads are connected directly to the cut out or fuse blocks, connectors are not required on these leads. The use of these connectors allows a transformer to be removed and another of the same or a different capacity substituted usually without soldering or unsoldering a joint. The connectors also facilitate changes in the low tension connections.



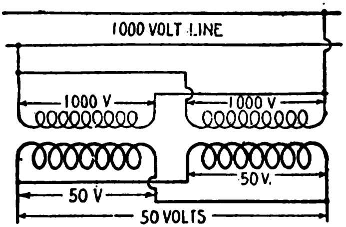
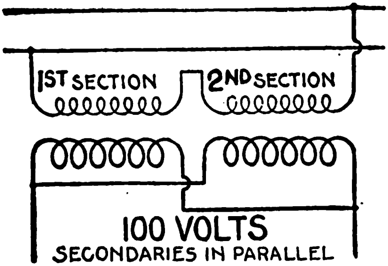
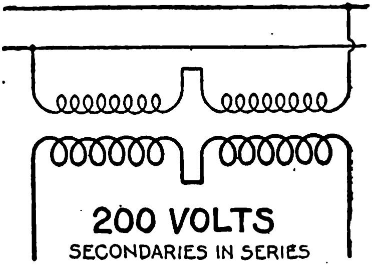


Fig. 6,531.—Diagram of single phase transformer having primary and secondary windings in two sections, showing voltages per section *with series connections.*

Fig. 6,532.—Diagram of single phase transformer with primary and secondary windings of two sections each, showing voltages per section *with parallel connection.*





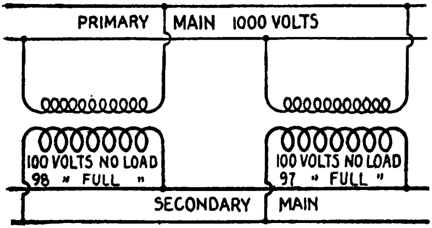
Figs. 6,533 and 6,534.—Methods of altering the secondary connections of a transformer having two sections in the secondary to obtain a different voltage. Fig. 6,533 shows the two sections *in parallel* giving say 100 volts; fig. 6,534 shows the two sections *in series* giving 200 volts.

At three-quarters load the output will be 7.5 kilowatts; and as the iron loss is practically constant at all loads and the copper loss is proportional to the square of the load, the

$$\text{efficiency} = \frac{\text{output}}{\text{input}} = \frac{7.5}{7.5 + .16 + .09} \times 100 = 96.8 \text{ per cent.}$$

The copper loss is measured by placing a wattmeter in circuit with the primary when the secondary is short circuited, and when enough pressure is applied to cause full load current to flow.

If it be desired to separate the load losses from the true I^2R loss, the resistances can be measured, and the I^2R loss calculated and subtracted from the wattmeter reading. The losses being known, the efficiency at



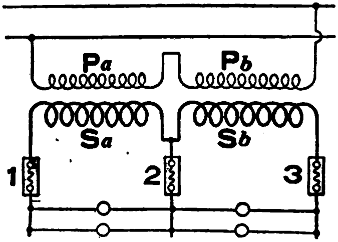


FIG. 6,535.—Diagram showing unlike single phase transformers in parallel.

FIG. 6,536.—Three wire connections for transformer having two secondary sections on different legs of the core. If the secondary terminals be connected up to a three wire distribution, as here shown diagrammatically, it is advisable to make the fuse, 2, in the middle wire, considerably smaller than necessary to pass the normal load in either side of the circuit, because, should the fuse, 1, be blown, the secondary circuit through the section, Sa, will be open, and the corresponding half of the primary winding, Pa, will nave a much higher impedance than the half of the primary winding, Pb, the inductance of which is so nearly neutralized by the load on the secondary winding, Sb. The result will be that the voltage of the primary section, Pa, will be very much greater than that of the section, Pb, and as the sections are in series the current must be the same through both halves of the winding; the drop or difference of pressure, therefore, between the terminals of Pa will be much higher than that between the terminals of Pb, consequently, the secondary voltage of Sb will be greatly lowered and the service impaired. As the primary winding, Pa, is designed to take only one-half of the total voltage, the unbalancing referred to will subject it to a considerably higher pressure than the normal value; consequently, the magnetic density in that leg of the transformer core will be much higher than normal, and the transformer will heat disastrously. If the fuse. 2, in the middle wire be made, say, one-half the capacity of each of the other fuses, this condition will be relieved by the blowing of this fuse, and as the lamps in the live circuit would not be anywhere near candle power if the circuit remained intact, the blowing of the middle fuse will not be any disadvantage to the user of the lamps. Some makers avoid the contingency just described by dividing each secondary coil into two sections and connecting a section on one leg in series with a section on the other leg of the core, so that current applied to either pair of the secondary terminals will circulate about both legs of the core any load is readily found by taking the core loss as constant and the copper loss as varying proportionally to the square of the load.

All Day Efficiency of Transformers.—This denotes the ratio

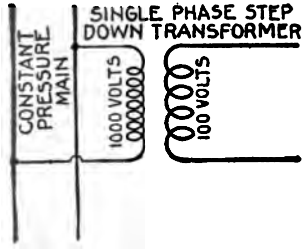


FIG. 6,537.—Single phase transformer connection with *constant* pressure main.

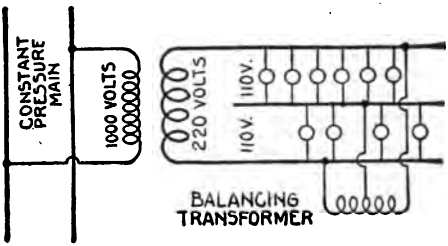
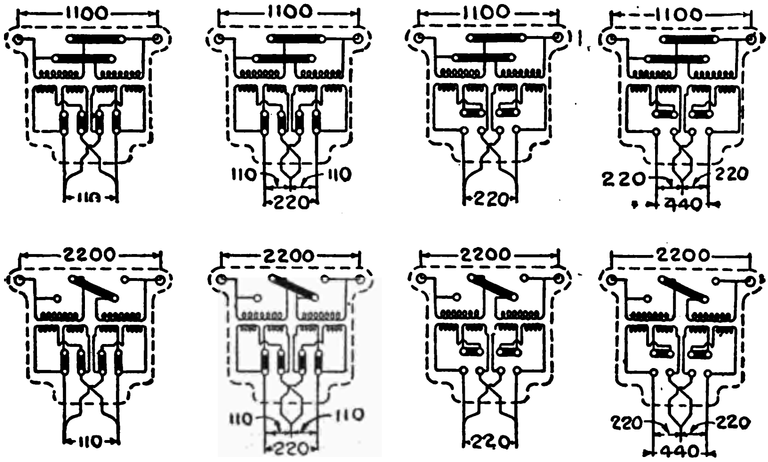
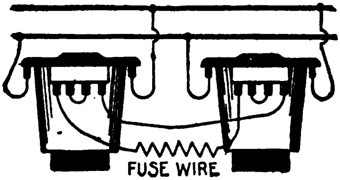


FIG. 6.538.—Usual method of single phase transformer connections for residence lighting with three wire secondaries. A balancing transformer is connected to the three wire circuit near the center of distribution as shown.



FIGS. 6,539 to 6,546.—Connections of standard transformers. All stock transformers are wound for some standard transformation ratio, such as 10 to 1, but various leads are brought out by means of which ratios of 5, 10 and 20 to 1 may be obtained for one transformer. The figures show the voltage combinations possible with a standard transformer.



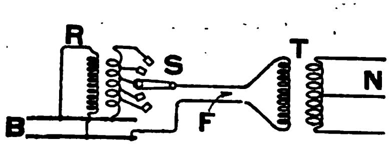
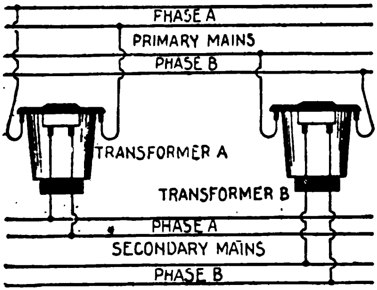


FIG. 6,547.—Method of comparing instantaneous polarities. Two of the terminals are connected as shown by a small strip of fuse wire, and then touching the other two terminals together. If the fuse blow, then the connections must be reversed; if it do not, then they may be made permanent.

FIG. 6,548.—Diagram of static booster or regulating transformer. It is used for regulating the pressure on feeders. In the figure, B, are the station bus bars, R, the regulable transformer, F, the two wire feeders, and T, a distant transformer feeding into the low pressure three wire distributing network N. The two ends of the primary, and one end of the secondary of R, are connected to the bus bars as shown. The other end of the secondary, as well as a number of intermediate points, are joined up to a multiple way switch S, to which one of the feeder conductors is attached, the other feeder main being connected to the opposite bus bar. As will be evident from the figure, by manipulating S extra volts may be added to the bus bar pressure at will, and the drop along F, conpensated for. R, is a step transformer for the total secondary difference of pressure being comparatively small. The above device possesses rather serious drawbacks, in that the switch S, has to carry the main current, and that the supply would be stopped if the switch got out of order. Kapp improved on the arrangement by putting the switch in the primary circuit.



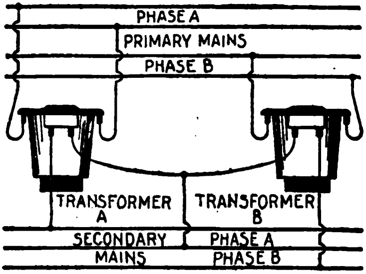
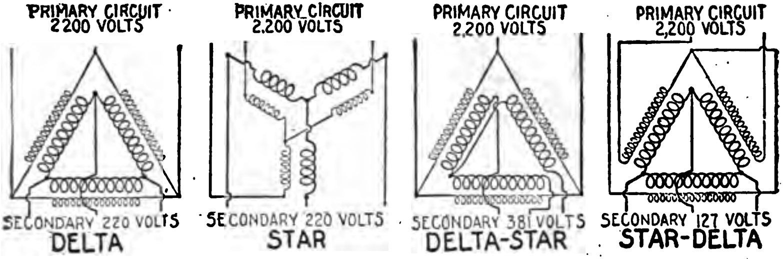
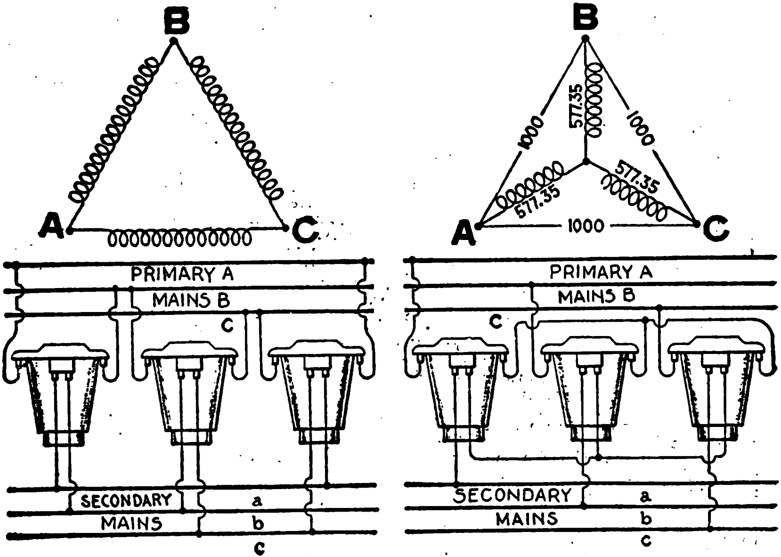


FIG. 6,549.—**Two phase transformer connections. Two single phase transformers are used and connections made just as though each phase were an ordinary single phase system.**

FIG. 6,550.—Two phase transformer connections, with secondaries arranged for three wire distribution, the primaries being independently connected to the two phases. In the three wire circuit, the middle or neutral wire is made about one-half larger than each of the two outer wires. In fig. 6,549 it makes no difference which secondary terminal of a transformer is connected to a given secondary wire, so long as no transformers are used in parallel. For example, referring to the diagram, the left hand secondary terminal of transformer A, could just as well be connected to the lower wire of the secondary phase A, and its right hand terminal connected to the upper wire, the only requirement being that the two pairs of mains shall not be "mixed." In the case shown by fig. 6,550, there is not quite so much freedom in making connections. One secondary terminal of each transformer must be connected to one of the outer wires and the other two terminals must be both connected to the larger middle wire of the secondary system. It makes no difference, however, which two secondary terminals be joined and connected to the middle wire so long as the other terminal of each transformer is connected to an outer wire of the secondary system.



Figs. 6,551 to 6,554.—Three phase transformer connections. Fig. 6,551 ***delta*** connection; fig. 6,552, ***star*** connection; fig. 6,553, ***delta-star*** connection; fig. 6,554 ***star-delta*** connection.



Figs. 6,555 to 6,558.—Three phase delta, and star connections using three transformers. There are two ways of connecting up the primaries and secondaries, one known as the "delta" connection, and illustrated diagrammatically by fig. 6,555, and the other known as the "star" connection, and illustrated by fig. 6,557. In both diagrams the line wires are lettered, A, B and C. Fig. 6,556 shows the primaries and secondaries connected up delta fashion, corresponding to fig. 6,555, and fig. 6,558 shows them connected up star fashion, corresponding to fig. 6,557. In both of the latter sketches the secondary wires are lettered to correspond with the respective primary wires. When the primaries are connected up delta of the total watt hour output of a transformer to the total watt hour input taken over a working day. To compute this efficiency it is necessary to know the load curve of the transformer for a day.

Suppose that this is equivalent to 5 hours at full load, and 19 hours at no load. Then, if W_1 be the core loss in watts, W_2 the copper loss at rated load, and W the rated output,

$$\begin{aligned} \text{output} &= 5 \times W, \\ \text{losses} &= 5\,(W_1 + W_2) + 19\,W_1, \\ \text{input} &= 5\,(W + W_1 + W_2) \\ &\quad + 19\,W_2, \end{aligned}$$

and the all day efficiency is equal to

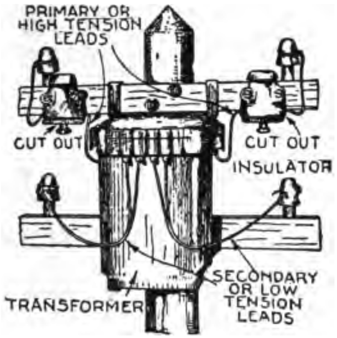


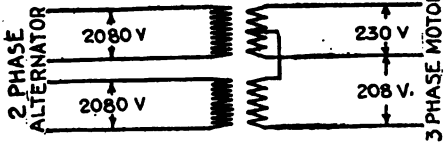
Fig. 6,559.—Installation of a transformer on pole; view showing method of attachment and disposition of the primary and secondary leads, cut outs, etc.

Figs. 6,555 to 6,558—*Text continued*
fashion, the voltage between the terminals of each primary winding is the same as the voltage between the corresponding two wires of the primary circuit, and the same is true of the secondary transformer terminals and circuit wires. The current, however, flowing through the transformer winding is less than the current in the line wire for the reason that the current from any one line wire divides between the windings of two transformers. For example, in figs. 6,555 and 6,556, part of the current from the line wire A, will flow from A, to B, through the left hand transformer, and part from A, to C, through the right hand transformer; if the current in the line wire A, be 100 amperes, the current in each transformer winding will be 57.735 amperes. When transformers are connected up star fashion, as in figs. 6,557 and 6,558, the current in each transformer winding is the same as that in the line wire to which it is connected, but the voltage between the terminals of each transformer winding is 57.735 per cent. of the voltage from wire to wire on the circuit. For example, if the primary voltage from A, to B, be 1,000 volts, the voltage at the terminals of the left hand transformer (from A to star point) will be only 577.35 volts, and the same is true of each of the other transformers if the system be balanced. These statements apply, of course, to both primary and secondary windings, from which it will become evident that if the three transformers of a three phase circuit be connected up star fashion at the primaries, and delta fashion at the secondaries, the secondary voltage will be lower than if both sides be connected up star fashion. *For example,* if the transformers be wound for a ratio of 10 to 1, and are connected up with both primaries and secondaries alike, no matter whether it be delta fashion or star fashion, the secondary voltage will be one-tenth of the primary voltage; but if the primaries be connected up star fashion on a 1,000 volt circuit, and the secondaries be connected up delta fashion, the secondary voltage will be only 57.735 volts, instead of 100 volts. The explanation of the difference between the voltage per coil in a delta system and that in a star system is that in the former each winding is connected directly across from wire to wire; whereas in the star system, two windings are in series between each pair of line wires. The voltage of each winding is not reduced to one-half, however, because the pressures are out of phase with each other, being 120°, or one-third of a cycle, apart; consequently, instead of having 500 volts at the terminals of each coil in fig. 6,557 the voltage is 577.35. The same explanation applies to the current values in a delta system. The current phase between A and B, in fig. 6,555, is 120° removed from that in the winding between A and C; consequently, the sum of the two currents, in the wire A, is 1.732 times the current in each wire; or, to state it the opposite way, the current in each winding is 57.735 per cent of the current in the wire, A. It will be well for the reader to remember that in all cases pressures differing in phase when connected in series, combine according to the well known law of the parallelogram of forces; currents differing in phase, and connected in parallel, combine according to the same law.

$$\frac{5\ W \times 100}{5\ (W + W_1 + W_2) + 19\ W_1}\ \text{per cent.}$$

Commercial or all day efficiency is a most important point in a good transformer. The principal factor in securing a high all day efficiency is to keep the core loss as low as possible.

Transformer Connections.—The alternating current has the advantage over direct current, in the ease with which the pressure and current can be changed by different connections of transformers.



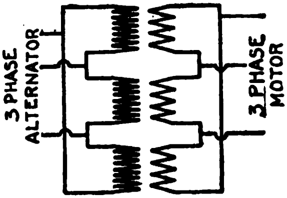


FIG. 6,560.—Diagram showing a method of operating a three phase motor on a two phase circuit, using a transformer having a tap made in the middle of the secondary winding, so as to get the necessary additional phase. While this does not give a true balanced three phase secondary, it is close enough for motor work. In the above arrangement, the main transformer supplies 54 per cent. of the current and the other with the split winding 46 per cent.

FIG. 6,561.—Three phase motor transformer connections; the [illegible]ed Delta connected transformers.

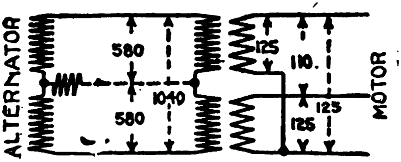
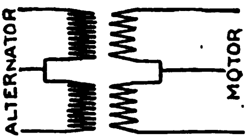


FIG. 6,562.—Diagram of transformer connections for motors on the monocyclic system.

On single phase circuits the transformer connections



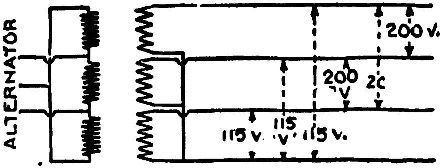
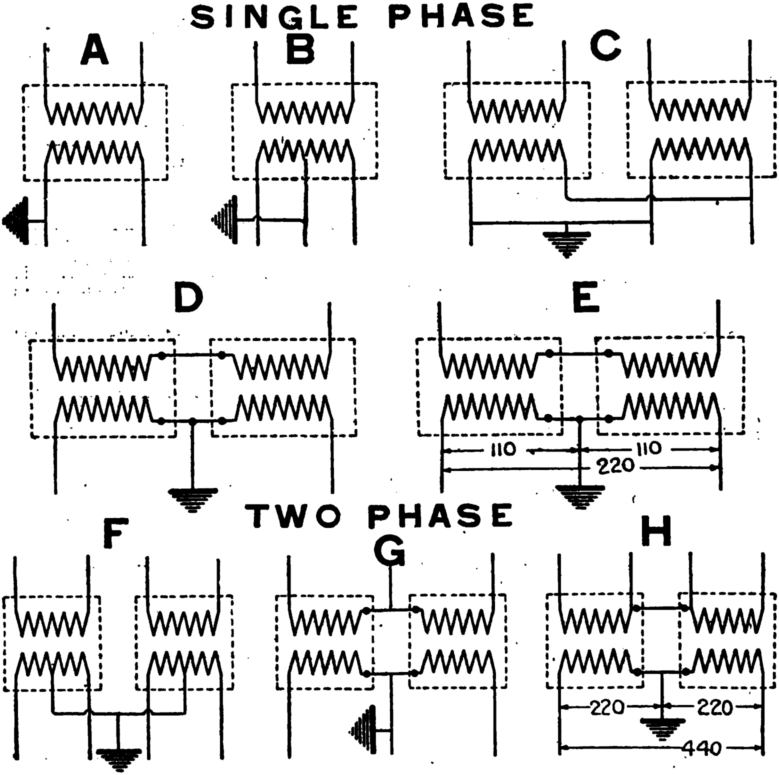


FIG. 6,563.—Three phase motor connections using two transformers.

FIG. 6,564.—Delta-star connection of three transformers for low pressure, three phase, four wire system.

can be varied to change current and pressure, and in addition on polyphase circuits the phases can also be changed to almost any form.

Fig. 6,531 shows a transformer with each winding divided into two sections. Each primary section is wound for 1,000 volts, and each secondary section for 50 volts. By connecting the entire primary winding in series,

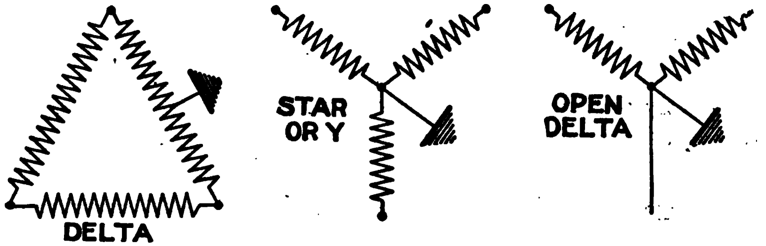


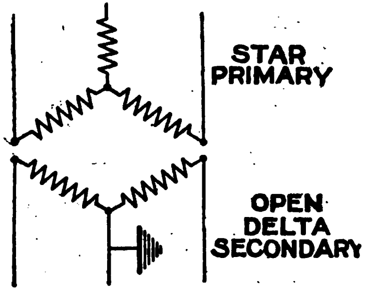
Figs. 6,565 to 6,572.—Ground connections to secondaries of ***single phase*** transformers. **A**, two wire; **B**, three wire; **C**, two separate 110 volt transformers in parallel, the secondary ground is attached to either wire; **D**, two windings, two wire; **E**, two windings, three wire; **F**, four wire; **G**, three wire; **H**, three wire with four wire primary.

the transformer may be supplied from a 2,000 volt main, as indicated, and if the secondary winding be also connected all in series, as shown, the no load voltage will be 100 between the secondary terminals.

The sections of the primary winding may be connected in parallel to a 1,000 volt main, and 100 volts obtained from the secondary, or the primary and secondary windings may be connected each with its two sections in parallel, and transformations made from 1,000 to 50 volts as represented in fig. 6,532.

This is a very common method of construction for small transformers, which are provided with convenient terminal blocks for combining the sections of each winding to suit the requirements of the case. When the two sections of either winding are connected in parallel as shown in fig. 6,532, *care must be taken to connect* **corresponding ends** *of the two sections together.*





FIGS. 6,573 to 6,576.—Ground connections to secondaries of *three phase* transformers.

Combining Transformers.—Two or more transformers built to operate at the same pressure and frequency may be connected together in a variety of ways; in fact, the primary and secondary terminals may each be considered exactly as the terminals of direct current dynamos, with certain restrictions.

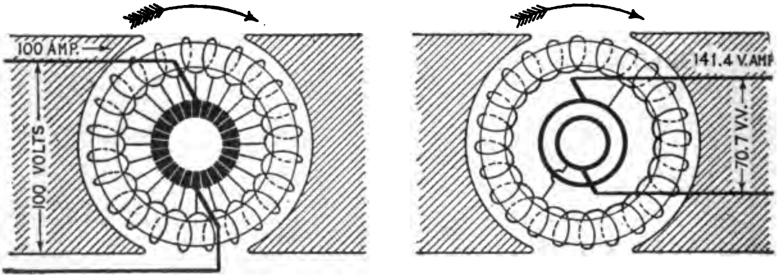
CHAPTER 103

Converters

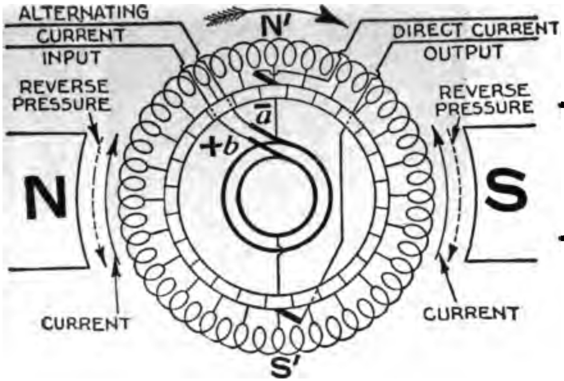
There are many instances where alternating current must be changed to direct or vice versa. Transformation from *a.c.* to *d.c.* or *d.c.* to *a.c.* may be made by means of:

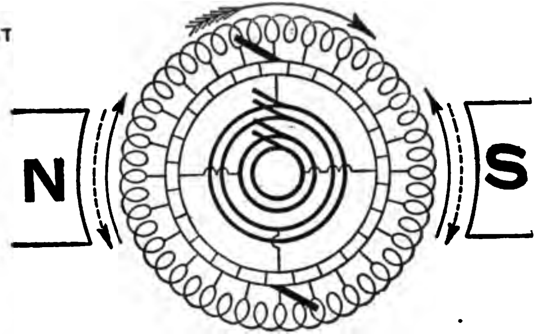
1. Rotary converters
2. Motor generator sets
3. Mercury vapor rectifiers
4. Electrolytic rectifiers.

Strictly speaking, a converter is *a revolving apparatus for converting alternating current into direct current or vice versa;* it is



FIGS. 6,577 and 6,578.—Gramme ring dynamo and alternator armatures illustrating converter operation. The current generated by the dynamo is assumed to be 100 amperes. Now, suppose, an armature similar to fig. 6,577 to be revolving in a similar field, but let its windings be connected at two diametrically opposite points to two slip rings on the axis, as in fig. 6,578. If driven by power, it will generate an alternating current. As the maximum voltage between the points that are connected to the slip rings will be 100 volts, and the virtual volts (as measured by a voltmeter) between the rings will be 70.7 (=100÷52), if the power applied in turning this armature is to be 10 kilowatts, and if the circuit be non-inductive, the output in virtual amperes will be 10,000 =70.7 =141.4. If the resistances of each of the armatures be negligibly small, and if there be no frictional or other losses, the power given out by the armature which serves as motor will just suffice to drive the armature which serves as generator. If both armatures be mounted on the same shaft and placed in equal fields, the combination is a ***motor dynamo.*** In actual machines the various losses are met by an increase of current to the motor. Since the armatures are identical, and as the similarly placed windings are passed through identical magnetic fields, one winding with proper connections to the slip rings and commutator will do for both. In this case only one field is needed; such a machine is called a ***converter.***





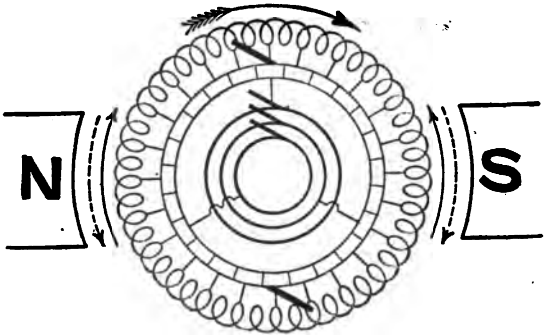


Fig. 6,579.—Diagram of ring wound single phase rotary converter. It is a combination of an asynchronous motor and a dynamo. The winding is connected to the commutators in the usual way, and divided into two halves by leads connecting segments 180° apart to collector rings. A bipolar field is shown for simplicity; in practice the field is multi-polar and energized by direct current.

Fig. 6,580.—Diagram of two phase rotary converter. This is identical with the single phase machine with the exception that another pair of collector rings are added, and connected to points on the winding at right angles to the first, giving four brushes on the alternating side for the two phase current. The pressure will be the same for each phase as in the single phase rotary. Neglecting losses the current for each phase will be equal to the direct current ×.707.

Fig. 6,581.—Diagram of three phase rotary converter. In this type, the winding is tapped at three points 120° distant from each other, and leads connected with the corresponding commutator segments.

usually called a rotary converter and is to be distinguished from the other methods mentioned above.

Broadly, however, a converter may be considered as *any species of apparatus for changing electrical energy from one form into another*. According to the standardization rules of the A.I.E.E., converters are classed and defined as follows:

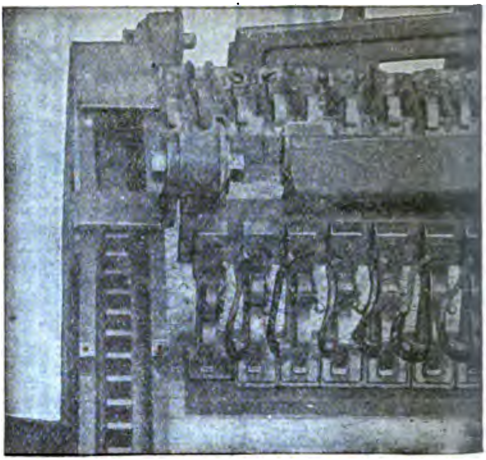


Fig. 6,582.—General Electric commutator of 1,000 kw. commutating pole synchronous converter for lighting service. Cover for the cooling vanes at end of commutator bars is removed.

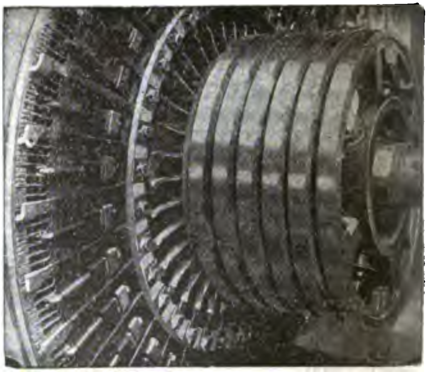
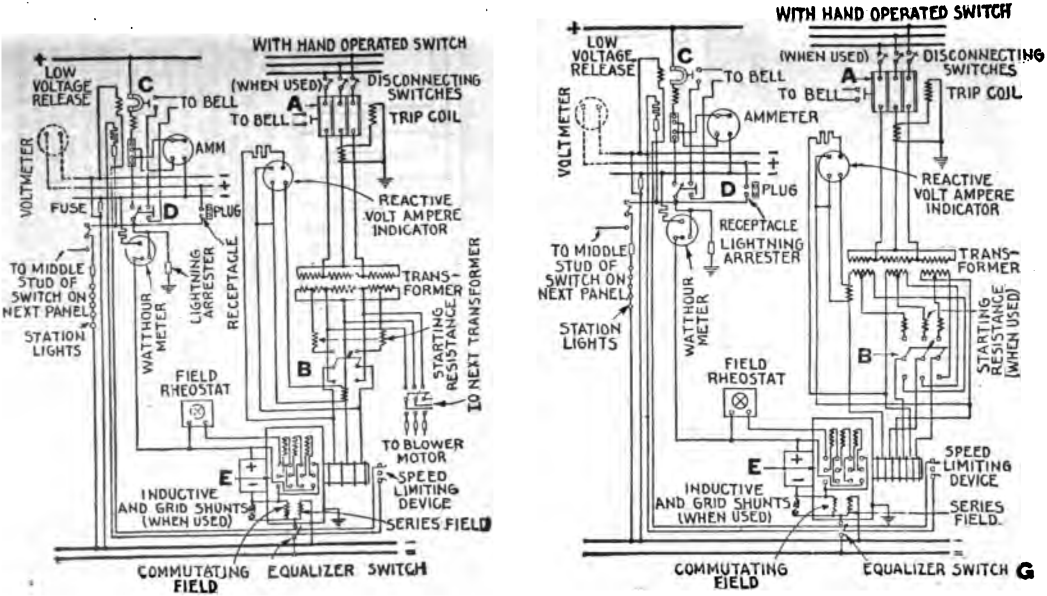
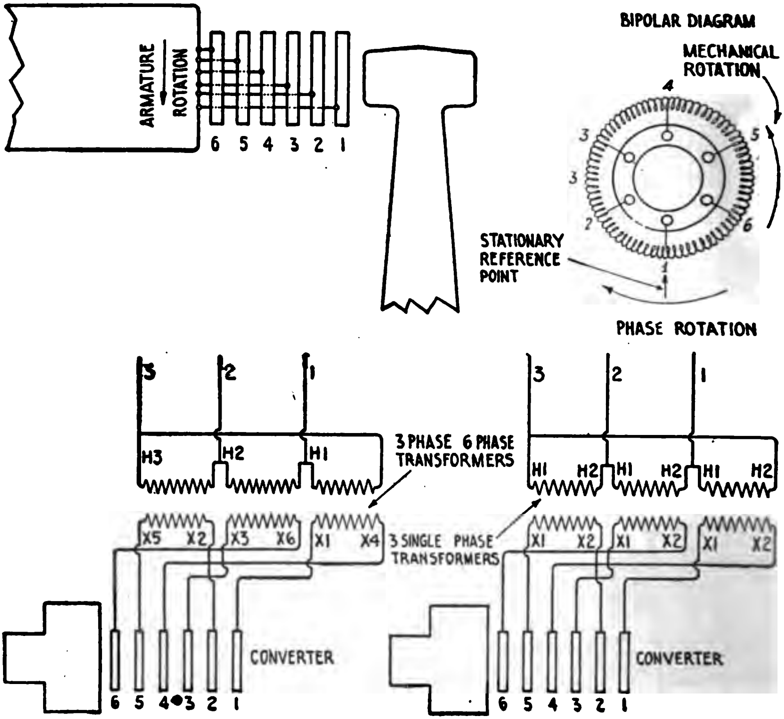


Fig. 6,583.—General Electric converter collector ring brush rigging. The brush and brush holders used on the collector rings illustrate changes in modern synchronous converter practice. The brushes are made of combined copper and graphite by a new process and have the appearance of solid copper.

Fig. 6,584.—Detail of General Electric converter armature, collector ring end.



Figs. 6,585 and 6,586.—Converter Connections. Fig. 6,585, three phase 600 volts; fig. 6,586, six phase 600 volts. It is customary to ground converter bases. The ground connection should be heavy enough to safely carry the short circuit current in case of an armature ground. Do not run single *a.c.* leads through iron pipe—two leads opposite in phase, or three leads 120° apart in phase may be run through a single pipe.



Figs. 6,587 to 6,590—Phase rotation in synchronous converters. Figs. 6,587 and 6,588 for 6 phase machine; figs. 6,589 and 6,590 primary and secondary phase rotation in 3 phase diametrical transformers for 6 phase synchronous converter. Synchronous converters are always designed to run clockwise-viewed from the commutator end, or counter-clockwise from the collector end and the phase rotation is 1-2-3-4-5-6. The collector rings are numbered from the bearing in toward the armature as in fig. 6,587. The phase rotation on the high voltage side of the transformers is 1-2-3, as shown in fig. 6,588, which shows the corresponding low voltage connections for both 3 phase and 6 phase transformers and for 3 phase and 6 phase transformers and for three single phase transformers. In the case of 3 phase, 6 phase transformers, refer to the numbering of the leads, rather than their mechanical position, as certain forms of 3 phase transformers may have a different mechanical arrangement of low voltage leads from the one shown. When the phase rotation of the high tension supply is known, this diagram may be followed in making the primary connections; if it be not known, make the connections temporarily in the most convenient manner and try them out. In either case, the connections should be tested before any attempt is made to run the converter on full voltage from the *a.c.* end.

A direct current converter converts from a direct current to a direct current.

A synchronous converter (commonly called a *rotary converter*) converts from an alternating current to a direct current.

A motor converter is a combination of an induction motor with a synchronous converter, the secondary of the former feeding the armature of the latter with current at some frequency other than the impressed frequency; that is, it is a synchronous converter in combination with an induction motor.

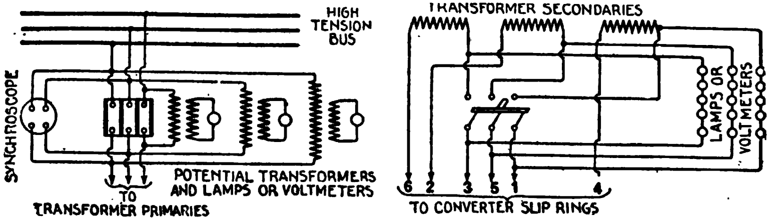
FIG. 6,591.—Equalizer connections of Westinghouse rotary converter. The armature coils are cross connected at points of equal voltage and taps are led out from the winding at suitable points to the slip rings. This construction insures a uniform armature saturation below each pole piece and eliminates one cause of sparking at the commutator.

A Frequency Converter (preferably called a *frequency changer*) converts alternating current at one frequency into alternating current of another frequency, with or without a change in the number of phases or voltages.

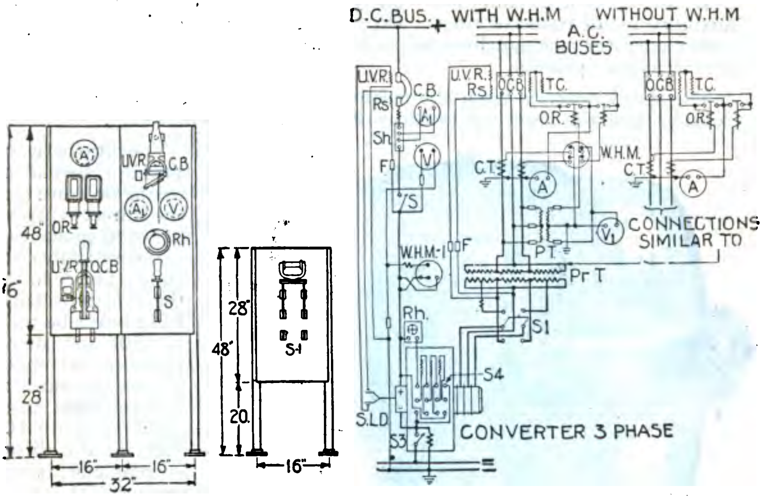
A Rotary Phase Converter changes alternating current of one or more phases into alternating current of a different number of phases, but of the same frequency.

Rotary Converters.—The synchronous or rotary converter consists of *a synchronous motor and a dynamo combined in one machine.*

FIG. 6,592.—Westinghouse pole construction for converters. The poles are built of up sheet steel laminations held together with rivets. Projections in the inner ends of the poles form seats for the field coils and hold them in position. Copper dampers set in slots in the pole faces insure stable operation. Rotary converters for railway service are almost invariably compound wound. The series windings are formed of bare copper strap. The shunt windings are of insulated copper strap or wire. Spaces between coil turns and sections are provided for ventilation.



FIGS. 6,593 and 6,594—"Phasing out" a synchronous converter. Fig. 6,593 on high tension side of the transformers. Raise the *a.c.* brushes and slip a sheet of varnished cambric or other insulating material between the brush holders and the rings. Close the oil circuit breakers and close the low tension starting switch on the down or running position. Make certain that the full secondary voltage appears at the brushes which bear on the diametrical rings 1-4, 2-5, and 3-6. Then open the starting switch and put the *a.c.* brushes down on the rings. The transformer secondaries will then be connected in Y, the stationary converter armature forming a low resistance neutral, compared to the resistance of the voltmeter, and the following voltage relations should exist at the switch: The voltages between blades and upper, or starting clips, should be the starting voltage, approximately ½ of the secondary voltage. The voltage between blades and lower, or running clips, should be full secondary voltage. Any deviation from these requirements indicated an interchange of starting and running leads. The voltage between each upper clip and the corresponding lower clip should be the difference between the starting voltage and full voltage, or approximately ½ secondary voltage. Any deviation from this requirement indicates an interchange of two starting or two running leads. The voltage between any two upper clips should be about 87 per cent of full secondary voltage and the voltage between any two lower clips should be twice this amount, or about 1¾ times full secondary voltage. Any deviation from this requirement indicates a reversed transformer secondary, or that the switch is connected in consecutive phases instead of alternate phases, as shown. If the voltages at the switch be properly symmetrical according to the above tests, the phase rotation must then be checked. The method of phasing out will depend upon the character of the equipment, and the available auxiliary apparatus. When the converter is arranged to start from the *a.c.* end, and a separate high tension bus fed by a single generator can be used to start the converter, a convenient method is to start the converter first on the starting taps, and then on the running taps by reducing the primary voltage. If a separate bus and generator be not available, start the machine on ½ voltage in the ordinary manner, but before throwing it to full voltage, check the voltages at the starting switch as follows: The voltage between each blade and the corresponding lower clip should be approximately ½ voltage and the voltage between any two lower clips should be about 130 per cent of full secondary voltage. When the converter is designed to start from the *d.c.* side or by an induction motor it must be phased out by means of lamps or voltmeters connected around the oil switch as in fig. 6,593 or around the low tension switches as in fig. 6,594. If possible, the synchroscope should be checked at the same time by connecting the lamps at the switch it is connected across. Any apparatus connected across the open switches should be capable of standing double line voltage. While "phasing out" converters designed to be synchronized at the oil switch, make certain that one phase is not reversed on the secondaries, since a reversed secondary phase with delta primary is equivalent to a short circuit. Such a reversal will make itself apparent by excessive current when starting with the transformers connected to the converter, so that the converter will not come to speed from the direct current end, or in the case of induction motor starting preventing the building up of the voltage. When the machine has reached approximately normal speed and voltage, correct phase rotation will be indicated by all the lamps across the oil switch growing bright at the same instant, followed by a period when they will all be dim at once. Reversed phase rotation will be indicated by the lamps growing bright in succession. In "phasing out" at the secondary switches, the indications of correct and reversed phase rotation are the same, respectively, as when "phasing out" on the high side and, in addition, the following indications are possible: If the lamps on two phases fluctuate together, and the third in a different manner, one phase is reversed but the phase rotation of the other two is correct. If the three lamp circuits become bright in a rapid succession and then pass through an interval when all are dim, a combination of reversed phase rotation, and reversed phase rotation, and reversed connections on one phase, is indicated. Usually the easiest method of correcting reversed phase rotation is to interchange two lines at the high voltage terminals of the transformers.



FIGS. 6,595 to 6,597.—General Electric three phase synchronous converter switch board and diagram of connections. ***Symbols:*** A, ammeter (*a.c.*); A, ammeter (*d.c.*); C.B., air circuit breaking; C.T., current transformer; F., fuse; O.C.B., oil circuit breaker; O.R., inverse time limit overload release; P.T., pressure transformer; Pr.T., power transformer; Rh., rheostat; Rs., resistance; S., switch; S_2, starting switch; S_3, equalizing switch; Sh., shunt; S. L.D., speed limit device; U.V.R., under-voltage release; T.C., trip coil; V., volt meter; V_1, volt meter (*d.c.*) (optional); W.H.M., watt hour meter (*a.c.*); W.H.M.-1, watt hour meter (*d.c.*).

NOTE.—***Operation.*** In figs. 6,595 to 6,597 the machine will be started as follows: it being assumed that all switches are opened before starting and the brushes are raised from the commutator: 1. Close high tension oil circuit breaker OCB. 2. Close the starting switch SI, and let the machine come up to synchronous speed. 3. Note the *d.c.* polarity. If the polarity be right, close the field break up switch S4 in the upper position. If the polarity be wrong, throw the field switch in the lower position and hold it there until the volt meter begins to read slightly in the right direction, then close the switch in the upper positions. Hold the starting switch S1 or S2 on the one half tap until the voltage of the *d.c.* side rises to about one half normal and becomes steady. Then throw it down with a rapid movement to the running position. Let the brushes down on the commutator. Close the equalizer switch S3 (omit for a station containing only one machine). Adjust the field rheostat to give proper bus voltage. If the transformers be connected on the right high tension tap, this will draw about 20 per cent. lagging current at no load, and will give unity power factor at about three quarter load. Close the main circuit breaker CB. Try the speed limit device by hand and reclose the circuit breaker. Make certain that the *d.c.* brushes are down on the commutator. Then close the main positive switch S. Checking the position of the brushes is as much a part of

It resembles a dynamo with an unusually large commutator and an auxiliary set of collector rings. On the collector ring side, a rotary converter operates as a synchronous motor, while on the commutator side, it operates as a dynamo.

The speed depends upon the frequency of the *a.c.* and the number of poles because the input side consists of a synchronous motor.

FIG. 6,598.—General Electric 1,200-250 volt shunt wound synchronous converter for industrial service.

The ratio between the impressed alternating pressure and the direct current pressure given out is theoretically constant, therefore, the direct pressure will always be as 1 to .707 for single phase converters or if the pressure of the machine used above indicate 100 volts at the direct current end, it will indicate 70.7 volts at the alternating current side of the circuit.

NOTE.—*Continued.*

the routine of starting as closing the switch, and is of even greater importance since considerable damage may result from connecting the machine to the *d.c.* bus before the brushes are lowered. Unfortunately, the pilot brushes do not act as a fuse in the circuit, but cause an arc to form between the brushes and commutator which holds until the machine is disconnected or flashes over and opens the *d.c.* and *a.c.* switches. Adjust the divisions of load between machines if more than one be in service, by means of field rheostats. If another machine in the same station be carrying load when a compound wound converter is started, the correct *d.c.* polarity may be insured by closing the equalizer switch S3 before the machine reaches synchronism. The series field will be supplied with current by the other machine sufficient to magnetize the poles in the right direction and cause the converter to drop into step with the proper polarity. It is also possible to insure correct polarity on machines which do not synchronize too rapidly by watching the swings of the *d.c.* voltmeter and closing the field switch S4 in the up position just as the volt meter begins its last swing in the right direction. The field will at once build up in the right direction and lock the converter in step with the correct polarity. The order of operation in shutting down a machine is as follows: 1. If operating in parallel with other machines drop the load off as far as possible without danger of inverting, by adjusting the field rheostats. 2. Open the air circuit breaker C.B. 3. Open the main positive switch S. 4. Open the equalizer switch S3. 5. Open the high tension oil circuit breaker O.C.B. 6. Allow the machine to come down to zero voltage, then open the field break up switch S4. Open the *a.c.* starting switch S1 or S2. Raise the brushes from the commutator.

There are two types of converter:

1. Single phase
2. Polyphase.

Usually two or three phase converters are used on account of economy of copper in the transmission line. The armature of a polyphase converter is connected similar to that of an alternator with either delta or star connections.°

In order to vary the voltage of a rotary on the *d.c.* side, pressure or voltage regulators are put in the *a.c.* circuit and may be regulated by small motors operated from the main switch board or by hand.

FIG. 6,599.—Commutating pole of Westinghouse commutating pole rotary converter. The commutating poles are similar in general construction to the main poles. The coils are of bare copper strap wound on edge. Ventilating spaces are provided between the pole and coil and between turns. The copper winding is bare except for a few turns at each end. Insulating bolts retain the turns in their proper position.

NOTE.—***Treatment of commutator and brushes.*** Converters are frequently shipped with the commutators freshly ground. This and the initial condition of the brush faces do not constitute a fit condition for carrying loads, and heavy loads must not be put upon a converter when first put in service. This point must be insisted upon, for if the converter be misused in this respect, its commutator may reach such a condition as to require turning, and a great deal of trouble may be experienced before proper condition is obtained. If, on the other hand, the following instructions be followed, good results are assured. When the armature is received with the commutator polished from factory testing, the converter may be loaded at once as heavily as the condition of the brush surfaces will permit with good commutation, but if the commutator be not polished, the mcahine should be run light for at least 24 hours with normal brush pressure, and then an additional 24 hours at approximately half load, in order to establish a polish on the commutator surface. The desired surface will show a very high polish by reflected light and will vary in color from a light straw to a dark brown or even a blue gray, the actual color being of no consequence as long as the bars are polished uniformly from edge to edge. Use no lubricant on the commutator either during the polishing period or subsequently. Both the carbon and the graphite brushes now furnished on synchronous converters are self-lubricating, and their characteristics are seriously impaired by the use of any external lubrication. Self-lubricating carbon brushes may in some instances leave a black deposit on the commutator when first put into service. This deposit should be wiped off as rapidly as it appears by means of a piece of dry canvas or other hard, non-linting material, which should be wound around a block and held against the commutator with sufficient pressure to remove the blackening. While the converter is being run to polish the commutator and fit the brushes, the end play device should be in operation so that the commutator and the collector rings will be polished uniformly.

The advantage of unity power factor is that it prevents overheating when the rotary is delivering its full load in watts. The strength of the magnetic field greatly influences the power factor on the high tension line but does not materially affect the voltage.

Since variation of the field strength does not materially affect the voltage by adjusting the resistance in series with the magnetic circuit, the strength of the field can be changed and the power factor kept 1 or nearly 1 as different loads are thrown on and off the rotary. If the field be too strong, a leading current is produced, and if too weak, the current lags, both of which reduce the power factor and are objectionable.

It is the duty of the attendant at the substation to maintain the proper power factor. The ordinary sizes of rotaries are from 3 to 3,000 *kw.*

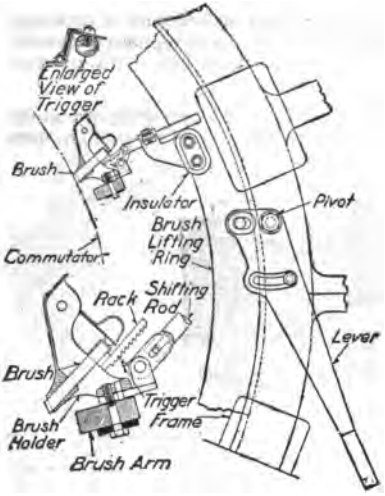


FIG. 6,600.—Westinghouse brush lifting device for cummutating pole rotary converter. A rack is attached to each brush as shown. Into this rack the spring hinged lifting hook of the raising device engages only when the lighting lever is shifted toward the raised position. Each brush is merely raised and lowered within its own holder so the brush position or commutation is not altered.

NOTE.—***Adjustment of end play device.*** After the machine has been brought up to voltage, the end play device should start automatically into operation. If the armature will not come forward, or back from the end play device it is due to an endwise pull of the field. Test the machine by running up to full speed on the *a.c.* starting tap and pull off the power without closing the field circuit. If the machine then oscillate freely in either direction and will not oscillate when up to voltage with field closed, trouble is due to pull of field. If this field pull hold the armature over against, or near to one of the bearings so that the coil delector bumps against it when the armature oscillate, the field should be removed slightly in the opposite direction to correct it. In making this movement, take care not to disturb the air gap by shifting the field to one side or the other. Make reference marks on the feet of the field frame and on the base; move one side of the field exactly the same amount as the other, and take care to give no lateral movement. Then dowel the field in the proper position for the best operation of the end play device.

NOTE.—***Adjustment of speed limit device.*** This device is adjusted at the factory (General Electric practice) to trip at 15% over speed. Check this adjustment before putting the converter into service in order to detect any change during shipment. For this overspeed test, the machine may be belted and driven by an auxiliary motor, or it may be run inverted as a *d.c.* motor and brought to the required overspeed by weakening the shunt field. In order to control the speed of compound wound converters operating as motors it will probably be found safer to disconnect or reverse the series field, or short circuit it, since the series field opposes the shunt field and tends to make the converter run away. Use an accurate speed indicator or tachometer, and check it first at the synchronous speed of the converter. Open the speed limit switch first by hand to test the circuit breaker trip coil and show that the breaker opens properly. If the speed limit device then fail to open the breaker at the required overspeed, reduce the tension on the spring by turning the nut on the adjusting screw, and conversely, if the speed limit operate at too low a speed, increase the tension on the spring. Check the final adjustment twice.

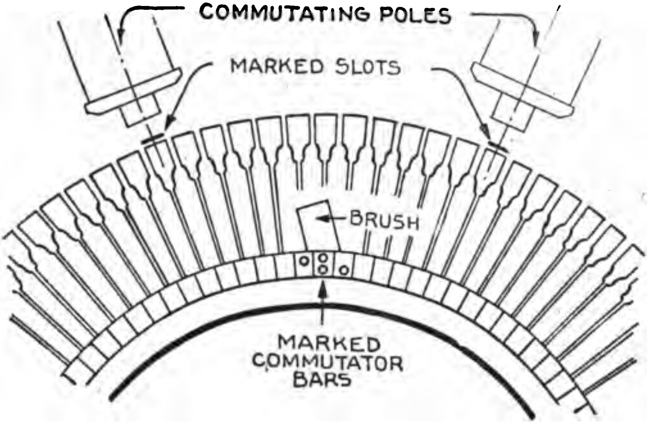


FIG. 6,601.—Detail of General Electric commutator and commutating poles. ***Commutation.*** This is affected by certain mechanical adjustments and refinements as well as by the adjustment of the commutating poles. When good commutation is not obtained after polishing the commutator, these mechanical features should be gone over thoroughly, trying the commutation after any change is made and noting the effect produced. Go over all the contacts and make certain that none are loose, particularly in the circuits. Check the *a.c.* brush pressure. It should be 3 lb. or 3¾ lb. per sq. in. per brush. Check the connections and make certain that the commutating field or any part of it is not reversed, and that one or more of the main spools are not reversed. Check the brush spacing and alignment both with paper tape, and by the commutator mica, revolving armature to two or three positions to detect errors due to variation in thickness of bars or mica. The brush spacing should always be checked with reference to the trailing side of the brush, that is, the side on which the commutator bars leave, and on which sparking usually appears. Machines of certain designs are very sensitive to brush spacing, and a variation of over 1/16 in. should be corrected. The commutator should be wrapped tightly with a long strip of paper covering its whole face and tied in place. The lapping point of this paper should then be marked, the paper should be removed, spread on a flat surface and stepped off with a large pair of dividers or similar tool into exactly equal sections, equal in number to the number of poles. The strip should then be replaced on the commutator and the studs so adjusted that the toes of the brushes on the different studs just touch these marks. ***In general,*** the more accurate the brush spacing, the more uniformly good will be the commutation. Check the mechanical neutral and try shifting the brushes each way from neutral. Very often slight shifting is advantageous. To check the neutral turn the armature over until the center lines of the two slots which are painted red are directly under the center lines of two commutating poles. The brushes of the nearest stud should be set on the center of the group of commutator bars which are stamped and painted red on the ends. Go over the brushes and see that they move freely in the holders, and that the pigtails do not interfere with any part of the rigging. Check the pressure and see that the fit is good. Look for burning or roughness of the contact surfaces. In checking the brush pressure, it will be preferable to measure the actual pressure with a spring balance, because of variation in the springs used. The correct pressure is two pounds per square inch cross section. As an example, the ¾-in. brush will have a pressure of 1⅛ lb. If a spring balance is not available, set the springs in the first notch and advance one notch for each ¼-in. wear of *d.c.* brushes, and each ½-in. wear of the *a.c.* brushes. Inspect the surface of the commutator and wipe off any blackening. If it be rough or eccentric, causing the brushes to chatter or move in the holders, it should be ground or stoned, and perhaps turned.

Compounding of Rotary Converters.—Compounding is desirable where the load is variable, such as is the case with interurban railway systems. The purpose of the compounding is to compensate automatically for the drop due to line, transformer, and converter impedance.

On account of the low power factor caused by over compounding, and the fact that sub-stations are customarily connected to the trolley at its nearest point without feeder resistance, over compounding is not recommended. An adjustable shunt to the series field is provided with each machine.

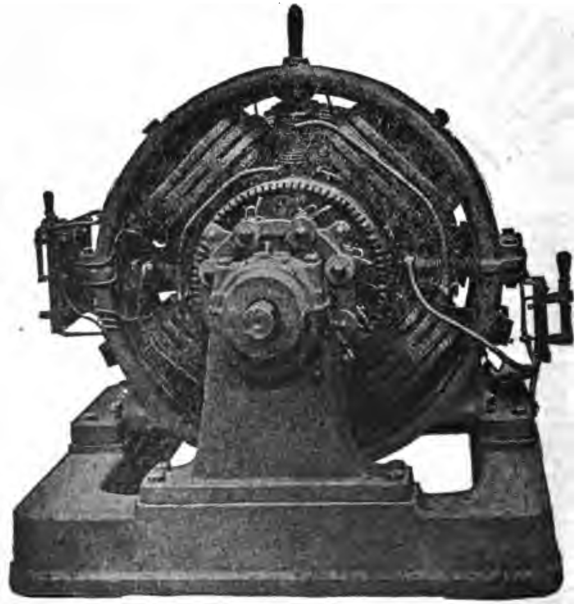
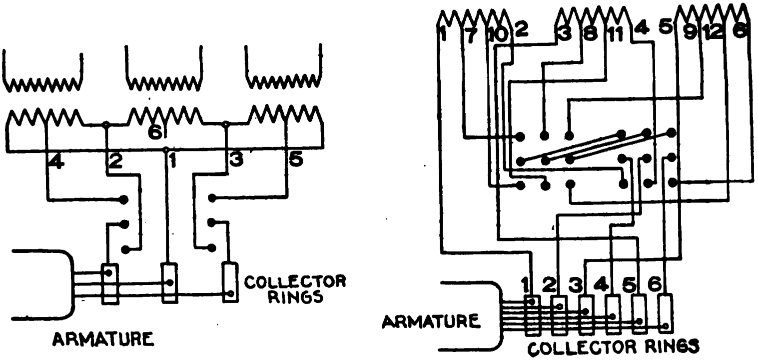


FIG. 6,602.—Westinghouse 300 *kw.*, 1,500 volt, three phase, 25 cycle, commutating pole rotary converter. The illustration shows clearly the commutating, and main poles and the relative sizes, also arrangement of the terminal connections.

NOTE.—***Adjustment of auxiliary commutating field.*** Commutating pole converters with direct connected *a.c.* boosters are provided with shunt windings on the commutating poles in addition to the customary series windings. The shunt windings are necessary in order to maintain the proper strength of commutating field under all conditions of boost and buck, since the armature reaction varies with these conditions and the series winding alone will not give the proper compensation. The auxiliary commutating field is controlled by an automatic equipment which is shipped with the converter. The installation and adjustment of this equipment is comparatively simple.

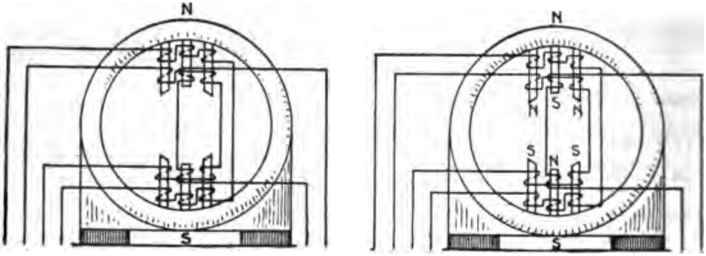
Ratio of Conversion.—The relation between the *a.c.* and *d.c.* voltages vary slightly in different machines. The ratio depends upon the number of phases and connections of the windings.

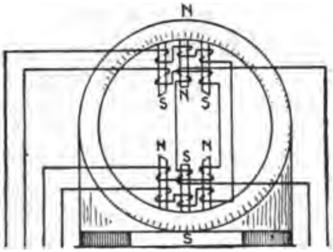


FIGS. 6,603 and 6,604.—***Alternating current starting.*** Synchronous converters are generally started from the *a.c.* side like polyphase synchronous motors. The current in the armature induces a magnetic field in the pole pieces, and as the iron has hysteresis, the induced field lags behind the current producing it, thus creating a torque. It is, however, necessary to reduce the voltage at starting in order to prevent a heavy rush of current and this is done by providing taps on the transformer secondaries. Fig. 6,603 shows the arrangement of taps for starting three phase converters, leads 1, 2 and 3 being the operating terminals, and leads 1, 4 and 5 those for starting at half voltage. Lead 6 is merely for the purpose of making the three transformers duplicates. Large converters are usually connected six phase diametrical, and when started from the *a.c.* side, it is desirable to provide taps on the transformers for one-third and two-thirds voltage as shown in fig. 6,604. Leads 1 to 6, inclusive, are the operating terminals; leads 1, 3, 5, 7, 8, and 9 are for the first step, and leads 1, 3, 5, 10, 11 and 12 are for the second step. Leads 2, 4 and 6 are for the final or full voltage step. Leads 1, 3 and 5 are connected directly to the converter and the starting is done by two triple pole double throw switches as shown. When *a.c.* is used for starting, the armature winding stands in relation to the field winding, as the primary of a stationary transformer to the secondary. A large number of turns in the field spools, compared with the turns in the armature, may produce in the field winding a high induced voltage which should be kept within safe limits. This is done by breaking up the field circuit between the spools by means of a switch provided for that purpose on the frame of the machine.

NOTE.—In the *rotary converter* no lead in either sense need be given to the brushes; for the armature reactions of the motor part being, in general, opposed by those in the dynamo part, they cancel one another to a large extent. This property is common to all those motor-generators in which there is used, whether with one winding or two, a common core in a common field. The relations between speed and field are peculiar. In the case of those grouped machines, or motor-dynamos in which each armature revolves in its own field, the conditions differ from those of the converter, where there is only one field. If in either case the continuous-current side is the primary (*i.e.* motor) side, the speed of revolution will depend on the field-magnet, the weakening of which will increase the speed. The frequency of the secondary or alternating current will in that case also vary. But the ratio of the primary and secondary voltages will be independent of speed if the fields are alike, or if only one common field is used. The secondary voltage cannot be varied, while the primary voltage is kept constant, unless separate fields and separate windings be employed. If, on the other hand, the alternating-current side be used as primary, then the machine, whether motor dynamo or converter, runs as synchronous motor with a fixed speed.

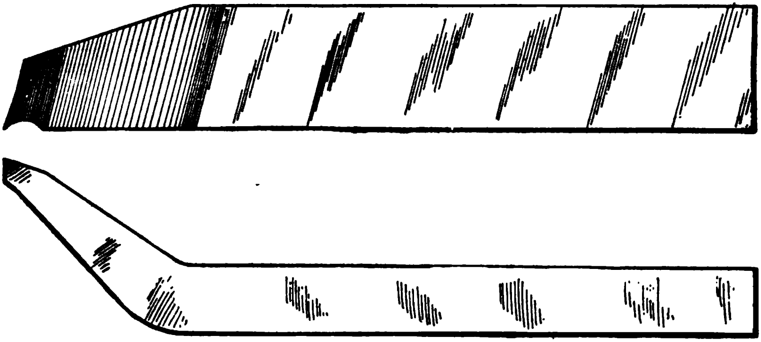
Shunt wound converters are satisfactory for sub-stations in large cities and similar installations where due to the larger number of car units demanding power, the load is more nearly constant.





FIGS. 6,605 to 6,607.—Woodbridge split pole rotary converter. Each pole is split into three sections and provided with windings as indicated in fig. 6,605. When excited as in fig. 6,606 the commutator voltage is at its highest value; when excited as in fig. 6,607, the commutator voltage is low. The change in commutator voltage for constant collector ring voltage is in virtue of the property of rotary converters that the ratio of these two voltages is a function of the width of the pole arc.

NOTE.—***The a.c. starting method*** does not require any complicated or expensive apparatus, the same switches being used for both starting and running connections. Since it is self-synchronizing, there is little possibility of confusion by the operator, as the difficulty of accurately adjusting the speed is eliminated and less time is required for the starting. After seeing that all the machine switches are open, the high tension oil switch is closed. Then the first starting switch is closed and the converter should start, running on one-half or one-third of the normal voltage as the case may be. As the speed of the machine increases, a volt meter connected across the *d.c.* side will oscillate back and forth and finally come to rest in either a positive or a reverse direction, that is, the machine may come up to synchronism with either positive or negative polarity. For this reason, it is customary to make the field switch double throw and this switch is thrown in the normal position if the volt meter indicate positive polarity. If, however, it show that the polarity of the converter is reversed, the field switch is closed in the other direction, reversing the current through the field coils. The flux set up by this reversed current in the field coils opposes and overcomes the flux induced by the *a.c.* flowing in the armature, causing the armature to drop in speed until it slips a pole, and when the pressure at the brushes is brought to zero, there is no field current and the polarity reverses. If the field switch be now opened, the converter will run in synchronism and the field switch is thrown to its original position, after which the machine is thrown successively on the two-third and the full-voltage taps. When the last switch is closed, the converter is running on full voltage and is ready for service after adjusting the shunt field rheostat to give proper voltage for the station bus bars. Three phase machines starting on one-half voltage taps with the external reactance coils in the circuit will take three-fourths to full load primary current and six phase machines starting on one third voltage taps without the reactance coils in the circuit, approximately three-fourths primary current.



FIGS. 6,608 and 6,609.—Commutator turning tool.

NOTE.—***Commutator grinding or turning.*** In many cases where a commutator is rough but is concentric, it is possible to stone it smooth with sandstone instead of turning. Whenever possible this is to be preferred, for a commutator can usually be smoothed by the removal of a few thousandths in. in this way, whereas, if it was turned, a man would probably cut away $^1/_{16}$ of an inch and possibly more before completing the work. Before stoning, all traces of oil or grease must be removed from the commutator or the stone will glaze over with copper and will not cut. A piece of grindstone or medium grade scythe stone will answer the purpose; the stone should be worked from end to end of the commutator and the surface ground down evenly. This stone should span enough of the commutator's circumference to prevent its dropping into low spots and thereby exaggerating them. While stoning, the brushes should be lifted from the commutator as the grit will cut them rapidly. After stoning, the commutator should be smoothed with fine quartz (not garnet) sand paper and then polished by using the back of the paper. Before stoning or turning the commutator the clamping bolts should be tested for tightness while the machine is warm. Extreme caution should be used in tightening the bolts; in many commutators the bolts are strong enough to distort the clamping ring. After the commutator is as true as it is possible to grind it, it is necessary to polish and smooth with the finest grade of sand paper. When using the sand paper, a very little pressure should be applied and the paper should be kept moving up and down the surface of the commutator so as to prevent it developing flats. A little oil applied with the sand paper will help to give a polished surface. Sandpapering of high speed commutators should be restricted as much as possible, and should always be done with very light pressure against the commutator.

NOTE.—***End play device and speed limiting switch.*** In order that the brushes may not wear grooves in the commutator and collector rings, the armature should have a slight reciprocating motion parallel to the shaft. To obtain this motion the larger machines are provided with an automatic, *magnetic* end play device. Current for its operation is obtained from the *d.c.* side of the converter. A condenser is connected across the make and break to facilitate the opening and closing of the circuit. Small machines having comparatively light armatures are equipped with a mechanical end play device. All synchronous converters are equipped with a device for automatically opening the direct current circuit in case the speed become too high. This safety device (or speed limiting switch, as it is generally called) consists of a switch which is operated by a centrifugal governor. The centrifugal weight is mounted on the shaft and revolves with it, while the switch is stationary and is mounted on the collector end pillow block. This weight is so designed that it operates at practically the same speed irrespective of the acceleration. The switch can be adjusted to operate at any predetermined speed. Under normal operating conditions, the circuit of the low voltage release coil on the line circuit breaker is closed, but should the speed of the converter increase to the predetermined setting, the switch, will open, thus opening the line circuit breaker. The current carrying parts are all stationary and so constructed that failure to operate is practically impossible when properly adjusted. It should be noted that the end play device and speed limiting switch are usually mounted at opposite ends of the shaft so that the operation of one does not in any way interfere with that of the other.

For example, a two phase rotary receiving alternating current at 426 volts will deliver direct current at 600 volts, while a three phase rotary receiving alternating current at 367 volts will deliver direct current at 600 volts.

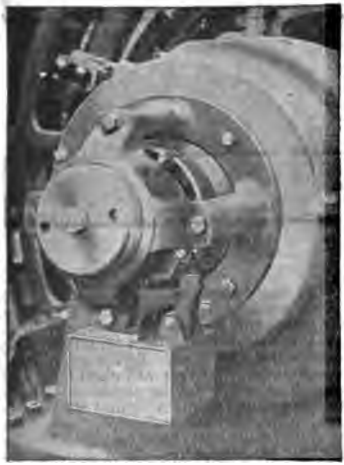


FIG. 6,610.—Oscillator and speed limit device of Westinghouse commutating pole rotary converter. It automatically prevents the armature of the converter remaining in one position and thus not allowing brushes to wear grooves in both commutator and collector rings. The oscillator is a self-contained device carried at one end of the shaft. The operating parts consist of a hardened steel ball and a steel plate with a circular ball race, backed by a spring. The machine is so installed with a slight inclination toward the end carrying the oscillator, that as the armature revolves, the ball is carried upward and owing to the convergence of the steel race and shaft face, the spring is compressed. The reaction of the spring forces the armature away from its natural position and allows the ball to drop back to the lowest point of the race.

Voltage Regulation.—Since the ratio of the *a.c.* to the *d.c.* voltage of a converter is practically constant, means must be provided to compensate for voltage variation due to changes of load in order to maintain the direct current pressure constant.

There are several methods of doing this, as by:

1. Shifting the brushes (objectionable)
2. Split pole method

NOTE.—***In starting six phase converters,*** on one-third voltage taps without the external reactance in the circuit, conditions may be found where a starting resistance must be provided to reduce the current rush. With inherent reactance transformers, however, the lower limit of starting voltage is reached and the conditions of starting will be improved. It may be found, however, in some cases of high line reactance and resistance that the voltage will drop too low for starting the machine, and if such be the case, it may be possible to start on the two-thirds voltage tap using a resistance or reactance coil to reduce the starting current. Another arrangement would also be to provide taps at 40 per cent. from one end and 30 per cent. from the other end of the transformers, so that either end could be used for starting.

NOTE.—***Two 600 volt converters*** operating in parallel on the *a.c.* and in series on the *d.c.* side, giving 1,200 volts, are generally started one at a time from the *a.c.* side. When they both have been brought up to speed and corrected for the right polarity, they are connected in series; then the field is adjusted for the proper voltage and they are ready to be thrown on the direct current system.

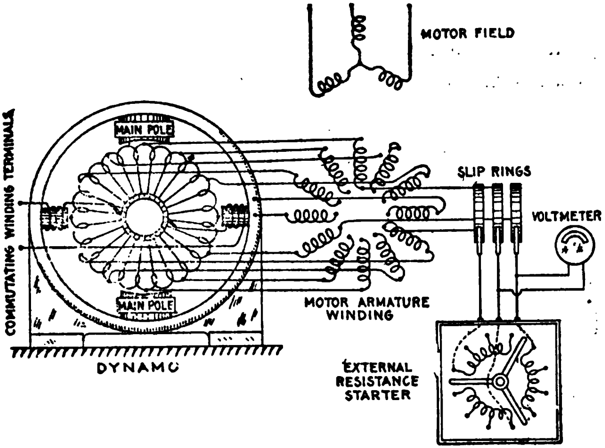


FIG. 6,611.—Diagram of "Cascade" motor generator set or motor converter, as it is called in England where it is used extensively for electric railway work. In the diagram of motor armature winding, some of the connections are omitted for simplicity. The windings are Y connected, and as they are fed by wires joined to the slip rings at the right and center, the rest of the power passes to the converter windings back to rotor winding and out to the slip rings so that part of the power enters the rotor and part through the converter.

NOTE.—***Another method of a.c. starting*** is by means of a small induction motor supported on one of the pillow blocks and with the rotor mounted on the extended synchronous converter shaft just outside the bearing. By designing the starting motor with less poles than the converter, it will enable the motor to bring the converter up to and above synchronous speed. The field switch of the converter is then closed with all the resistance cut in the field circuit. The resistance is then gradually cut out, thus increasing the iron losses of the converter and the corresponding motor torque necessary for driving it, resulting in a gradual decrease in the speed until the synchroscope indicates that the converter is in synchronism. The *a.c.* main switch is then closed and the induction motor is cut out and left to run free.

NOTE.—***D.c. starting.*** When starting from the direct current end, the collector rings of the converter are generally connected to the transformers, although this requires considerably heavier starting current than if the connections were interrupted and the *a.c.* end of the converter open circuited during starting. All the switches and breakers are assumed open on starting. Close the main *d.c.* circuit breaker. Cut the field rheostat all out. Throw in the starting switch, cutting out the resistance slowly, so that the machine is running on full voltage in one minute or less. Raise the speed to normal by means of the main field rheostat. Regulate the voltage of the *a.c.* side to the same value as the line voltage by means of the *a.c.* booster or induction regulator. Synchronize around the high tension oil switch by means of field rheostat, holding the voltage of the *a.c.* side steady. Close the high tension oil switch. Raise the *d.c.* load by means of the synchronous booster or the induction regulator, maintaining unity power factor at all loads by means of the field rheostat. The order of operations in shutting down a converter arranged to start from the *d.c.* end is as follows: Drop the load as far as possible by means of the booster or the induction regulator. Open the direct current circuit breaker. Turn the booster rheostat or the induction regulator to the maximum buck position. Open the high tension oil switch. When a converter is designed to operate on a 3-wire distribution system and the neutral for the system is obtained by connecting the middle points of the diametrical transformers, the transformer neutral must be disconnected from the main neutral bus while starting direct current, but the neutral points of the individual transformers may be left connected together. In starting this type of converter from the *a.c.* end, it is necessary not only to disconnect the transformers from the neutral bus, but to disconnect the individual transformer neutrals from each other.

3. Regulating pole method
4. Reactance method

FIG. 6,612.—Armature of Westinghouse synchronous booster converter. Heavy cast yokes form the frames. They are proportioned to rigidly support the laminated steel field poles, The poles are fastened to the frame with through bolts. A lifting hook is provided on all frames.

NOTE.—***Synchronous Converters in parallel.*** If several synchronous converters are to supply the same *d.c.* system, they can be connected in parallel in the same manner as shunt or compound wound generators, and they are even frequently operated in parallel with such generators and storage batteries. The different converters will divide the load according to their *d.c.* voltages, and these can be regulated by changing the applied alternating voltage. It is evidently necessary that all of the machines operating in parallel should have the same voltage regulation from no load to full load, and if a battery be also operated in parallel the voltage drop should be sufficiently large so as to cause the battery to take excessive loads. If no battery be used, it will, however, be more economical to have the machines designed for a less voltage drop. Synchronous converters operated in parallel should not be connected to the same transformer secondaries. Such a connection would form a closed local circuit in which heavy cross currents would flow, where any difference in the operating conditions of the machine occurs, as for example if the brushes of one of the machines were slightly displaced relative to the other. Compound wound converters for parallel operation should be provided with equalizer switches. For connecting a compound wound converter in parallel with one already running, the equalizer switch is closed first, so as to energize the series field from the running machine. Next, the shunt field circuit is closed and the field adjusted so that the voltage will correspond to that of the first machine and finally the main switch is closed. The load can then be transferred from the first to the second converter by weakening the shunt field of the former and strengthening that of the latter. If, for some reason, as for example, a short circuit the *a.c.* voltage should drop considerably the synchronous converters operating on the system would not drop out of step, as the direct voltage and load would be correspondingly reduced. If other dynamos or storage batteries, however, were operating in parallel on the same system, these would tend to maintain the direct voltage, and in such a case the *d.c.* would reverse and flow toward the converters running them as motors. Care should therefore in such cases be taken that the synchronous converters are provided with proper speed limiting devices and reverse current circuit breakers.

5. "Multi-tap" transformer method

6. Synchronous regulator.

Split Pole Method.—In this arrangement each pole is split into two or three parts. One of these parts is permanently excited and it produces near its edge the fringe of field necessary for sparkless commutation.

The effect of this is the same as shifting the brushes except that no sparking results.

The other part is arranged so that its excitation may be varied, thus shifting the resultant plane of the field with respect to the direct current brushes.

Regulating Pole Method.—These poles fulfill the same functions as commutating or interpoles on motors and dynamos.

The regulating poles are used in order to vary the ratio between the alternating current collector rings and the direct current side without the use of auxiliary apparatus such as induction regulators or dial switches which involve complicated connections and many additional wires. The regulating poles are arranged with suitable connections so that the current through them can be raised, lowered, or reversed.

Reactance Method.—This consists in inserting inductance in the supply circuit and running the load current through a few turns around the field cores. This method is sometimes called *compounding*, and as it is automatic it is generally used where there is a rapidly fluctuating load.

With less inductance, the effect of the series coils on the field of the converter is quite similar to that of the compounding of the ordinary railway dynamo.

Multi-Tap Transformer Method.—This is a non-automatic method of control and, accordingly, is not desirable except where the load is fairly constant over considerable periods of time. It requires no special explanation.

Synchronous Booster Method.—This consists in combining with the converter a revolving armature alternator having the same number of poles. The winding of the booster alternator armature is connected in series with the input circuits on the converter. The field windings are either fed with current regulated by means of a motor operated field circuit rheostat, or joined in series with the commutator leads of the converter.

Converter Troubles

Commutator Heating.—Generally due to improper brush pressure, poor commutation, bearing prolonged overload, faulty condition of commutator surface. Allowable temperature is higher than can be endured by hand.

Armature Heating.—Short circuits, or improper connections, of the armature winding cause heating in a particular spot on the armature. Go over the end clips on both ends of the armature and see that they are not bent together and short circuited. Make certain that the collector taps come out at equally spaced points, and that the equalizers are symmetrically connected. In some machines the relation of the equalizers to the collector taps varies, repeating itself at regular intervals around the armature. Continued operation at heavy loads and low power factor produces excessive heating of the tap coils, and will be apparent at equally spaced points on the armature. Change the primary tap connections on the transformer so that better power factor will be obtained at the required voltage, or if possible change the primary voltage at the generating station. General heating of the whole armature is caused by unequal air gap, a grounded shunt field spool, one or more reversed spools, or a break in the field circuit. These troubles cause large circulating currents in the armature winding, and through the equalizers. The air gaps should not vary over 12 per cent. either way from the average value. Check the connections with the connection diagram, and check the polarity by separately exciting the field and holding two iron rods against adjacent pole tips all the way around. The free ends of the rods should attract each other. With a steady current flowing through the field, take the drop on each spool separately with a voltmeter. A variation of over 9 per cent. in the drop indicates a faulty spool.

Shunt Field Heating.—Faulty spools or improper connections which cause armature heating may also cause heating of the shunt field. The trouble should be located by the above outlined procedure.

Heating of Contacts.—Bolted contacts may heat if the contact surfaces be not clean, smooth and bolted together with sufficient pressure. Particular care must be taken with the contacts of connecting strips for pole piece bridges on machines which start from the alternating current end in order to prevent excessive heating during starting.

Poor Commutation.—When the *d.c.* brushes spark, the mechanical condition of the converter should first be gone over carefully. If the brushes chatter, the commutator should be stoned or ground, and if they move up and down in the holders perceptibly, it must be turned before grinding. A rough commutator may cause vibration, in the entire brush rigging, but vibration may also result from loose assembly of the rigging or poor set up of the machine, with insufficient support under the points where the weight rests on the base.

Flash Overs.—Arcing or "flashing over" at the *d.c.* brushes may be caused by excessive overloads or short circuits on the *d.c.* system, or by disturbances on the *a.c.* supply system due to lighting, switching, or accidents to other apparatus. Protection against short circuits on the *d.c.* system can be obtained by increasing the resistance of the feeder to the distribution point where the trouble is most frequent. Short feeders should be avoided, particularly in railway work. Set the main circuit breakers at about three times full load and the feeder breakers as low as possible for continuous operation. *A.c.* disturbances should be located, and reduced to a minimum. The oil switch should be adjusted to trip instantaneously so that in case of a flash over the machine will clear itself quickly, and the damage to it will be reduced as much as possible.

Sparking of A.C. Brushes.—The *a.c.* brushes should not be allowed to spark, as they wear away rapidly when sparking. Make certain that the brushes move freely in the holders, and that the pig tails are not caught on the springs or on the sides of the brush holders. See that each brush is running at the proper pressure. If the collector rings be very rough they must be ground or turned.

The synchronous booster method is particularly desirable for serving incandescent lighting systems where considerable voltage variation is required for the compensation of drop in long feeders for operation in parallel with storage batteries and for electrolytic work where extreme variations in voltage are required by changes in the resistance of the electrolytic cells.

Motor Generator Sets.—These are employed in preferance to rotary converters when it is desirable that the generating element be independent of the *a.c.* line voltage so that any degree of voltage regulation can be obtained. The following combination of motor generators are made and used to suit local conditions:

Synchronous motor	dynamo
Induction motor	dynamo
Direct current motor	dynamo
Direct current motor	alternator
Synchronous motor	alternator
Induction motor	alternator

An advantage of motor generator sets over converters on high frequency circuits, is that the generator can be designed with a few poles and brushes set far apart, which greatly reduces the chance of flashing over in hunting.

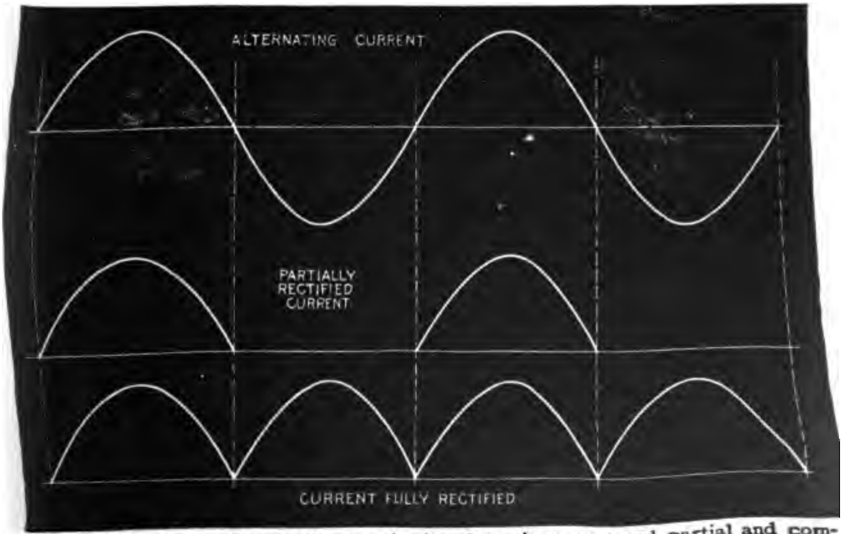
Frequency Changing Sets.—Sometimes it is necessary to change from, say 25 cycles on a power circuit to 60 cycles frequency for lighting. The combination for effecting such change consists of a synchronous motor and an alternator. If these machines be constructed with the proper difference in the number of pole, the desired frequency change will be obtained.

CHAPTER 104

Rectifiers

By definition a rectifier is a device used *to change alternating current into a uni-directional or pulsating current.* The various kinds of rectifiers may be classed as:

1. Mechanical
2. Electrolytic
3. Mercury vapor, or mercury arc
4. Electro-magnetic.



Figs. 6,613 to 6,615.—Current diagrams showing alternating current and partial and complete rectification of same.

Mechanical Rectifiers.—This type of rectifier consists of a *form of commutator operating in synchronism with the alternator and commutating or rectifying the negative waves of the alternating current.* Mechanical rectifiers are used on compositely excited alternators.

Electrolytic Rectifiers.—If two metals be placed in an electrolyte and then subjected to a definite difference of pressure, *they will* (under certain conditions) *offer greater resistance to the passage of a current in one direction, than in the other direction.* On account of this so-called valve effect, electrolytic rectifiers are sometimes called "valves."

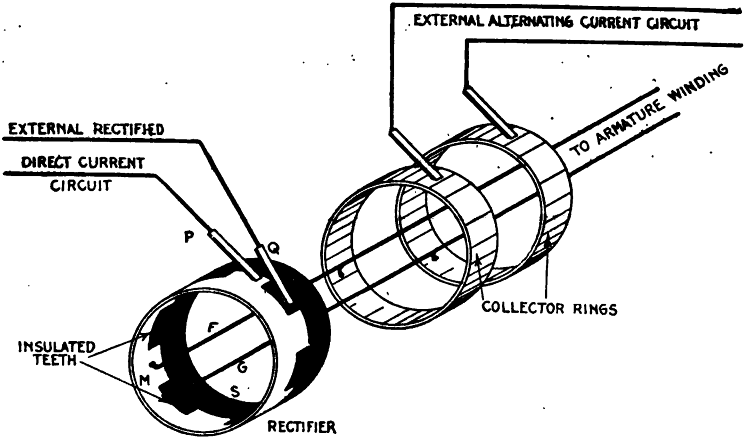
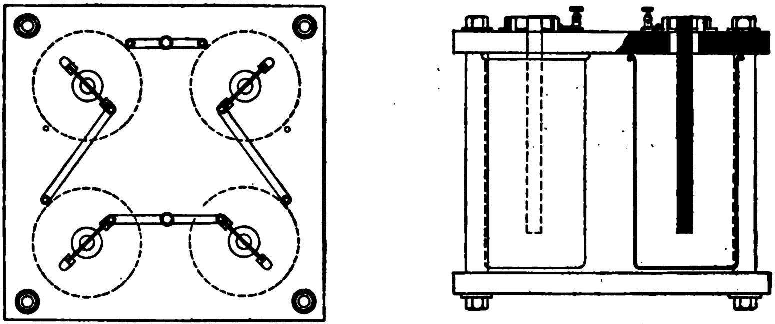


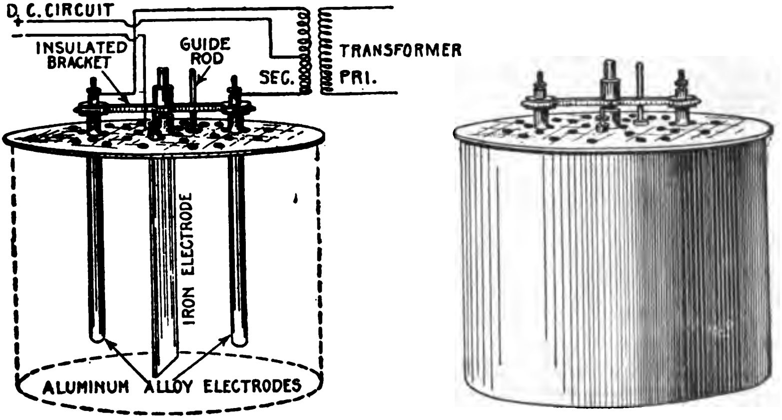
FIG. 6,616.—Mechanical rectifier. The rectifier consists of two castings M and S, with teeth which fit together as shown, being insulated so they do not come in contact with each other. Every alternate tooth, being of the same casting, is connected together, the same as though joined by a conducting wire. There are as many teeth as there are poles. The part M, of the rectifier is connected to one of the collector rings by F, and the part S, to the other ring by G.

When an electrolytic rectifier is not in use for some time the electrodes will lose the film; in such case they must be reformed. The loss of film may be prevented by removing the electrodes from the electrolyte and



PLAN ELEVATION

FIGS. 6,617 and 6,618.—Nodon "valve" or electrolyte rectifier. The cathode is a rod of aluminum alloy held centrally in a leaden vessel which forms the anode and contains the electrolyte, a concentrated solution of ammonium phosphate. Only a short portion at the lower end of the cathode is utilized, the rest, which is rather smaller in diameter, being protected from action by an enclosing glass sleeve. ***In operation,*** a film of normal hydroxide of aluminum forms over the surface of the aluminum electrode. This film presents a very high resistance to the current when flowing in one direction but very little resistance when flowing in the reverse direction. When the cell is supplied with *a.c.*, half of the *a.c.* wave will be suppressed and an intermittently pulsating current will be obtained. Both halves of the *a.c.* waves may be utilized by coupling a series of cells in opposed pairs. The current density at the cathode ranges from 5 to 10 amp. per sq. dm. In the larger sizes, the cells are made double, and a current of air is kept circulating between the walls by means of a motor driven fan. Maximum efficiency at 140 volts is between 65 and 75% and is practically independent of the frequency between the limits of 25 and 200 cycles.



FIGS. 6,619 and 6,620.—Mohawk electrolytic rectifier. ***To put in commission***, clean out the jar. Fill with distilled or rain water. Add six pounds of electro salts, stir and after all salts drying them. To preserve proper density of the electrolyte, **water must be added from time to time to make up for evaporation. Only pure water should be used.**

If a rectifier heat, it is an indication that it is passing alternating current, and when this condition obtains, if the electrolyte be very weak it will cause a buzzing sound. Operating a rectifier with weak electrolyte will destroy the electrodes. Excessive heating of the electrolyte indicates that the rectifier needs recharging.

Mercury Vapor (or Arc) Rectifiers.—The terms *vapor* or *arc* as applied to rectifiers, do not indicate a different principle; the Westinghouse Co. employ the former term and the General

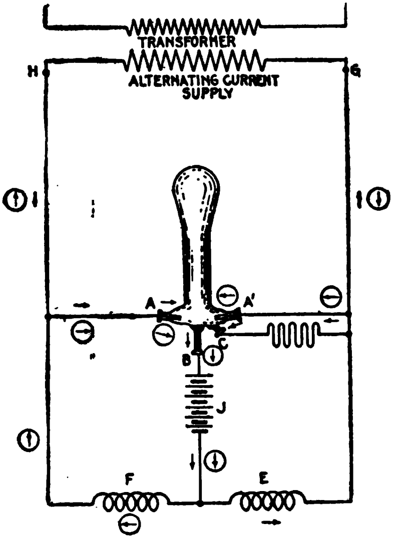


FIG. 6,621.—Elementary diagram of mercury arc rectifier connections. A.A., graphite anodes; B, mercury cathode; C, small starting electrode; D, battery connection; E and F, reactance coils; G and H, transformer terminals; J, battery. The small starting electrode C, is connected to one side of the *a.c.* circuit, through resistance; and by rocking the tube, a slight arc is formed, which starts the operation of the rectifier tube. At the instant the terminal H, of the supply transformer is positive, the anode A, is then positive, and the arc is free to flow between A and B. Following the direction of the arrow still further, the current passes through the battery J, through one-half of the main reactance coil E, and back to the negative terminal G, of the transformer. When the impressed voltage falls below a value sufficient to maintain the arc against the reverse pressure of the arc and load, the reactance E, which heretofore has been charging, now discharges, the discharge current being in the same direction as formerly. This serves to maintain the arc in the rectifier tube until the pressure of the supply has passed through zero, reversed, and built up such a value as to cause the anode A, to have a sufficiently positive value to start the arc between it and the cathode B. The discharge circuit of the reactance coil E, is now through the arc A'B, instead of through its former circuit. Consequently the arc A'B, is now supplied with current, partly from the transformer, and partly from the reactance coil E. The new circuit from the transformer is indicated by the arrows enclosed in circles.

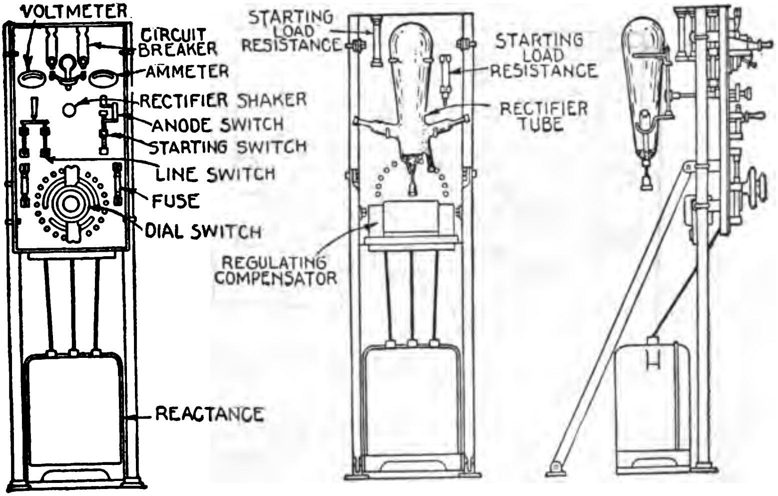
FIGS. 6,619 and 6,620.—*Text continued.*

are dissolved place the cover in position. The specific gravity of the solution should be 1.125. The middle iron electrode must hang straight down in the solution and not touch either of the other aluminum alloy electrodes. The aluminum alloy electrodes are mounted on an insulated bracket that slides up and down on a ¼" rod. This rod screws in the hole taped in the middle of the cover. The electrodes give the best results only when perfectly smooth. Should they get rough, covered with a deposit or a white coating remove from the solution, and clean with fine sand paper. Finish with fine sand paper. Form the film again and the electrodes will be as good as new. Clean iron electrode occasionally.

Electric Co., the latter as a distinguishing title or trade mark.

Fig. 6,621 is an elementary diagram of a mercury arc rectifier and its operation is explained fully under the illustration.

In the manufacture of rectifiers, other metals than mercury could be used, but they are not because, on account of the arc produced, they would gradually wear away and could not be conveniently replaced. In operation the heat generated in the bulb is dissipated through the tube to the air, large tubes being submerged in a tank of oil.



Figs. 6,622 to 6,624.—General Electric mercury arc rectifier outfit, or charging set. The cut shows front, rear, and side views of the rectifier, illustrating the arrangement on a panel of the rectifier tube with its connection and operating devices. ***To start the rectifier,*** close in order named line switch and circuit breaker; hold the starting switch in opposite position from normal; rock the tube gently by rectifier shaker. When the tube starts, as shown by greenish blue light, release starting switch and see that it goes back to normal position. Adjust the charging current by means of fine regulation switch on the left; or, if not sufficient, by one button of coarse regulation switch on the right. The regulating switch may have to be adjusted occasionally during charge, if it be desired to maintain charging amperes approximately constant.

An inherent defect of mercury rectifiers is the reverse pressure of about 14 volts produced by the arc and which remains nearly constant for all loads, resulting in decrease in commercial efficiency on light loads.

The advantage of a rectifier over a motor generator set for small units is higher efficiency and lower first cost. A small one to two horse power motor generator outfit has an efficiency of only 40 to 50 per cent., while mercury vapor rectifiers will have from 75 to 80 per cent. The capacity of a rectifier tube is from 40 to 50 amperes. Rectifiers are specially desirable for charging storage batteries from local *a.c.* lighting circuits.

Electro-Magnetic Rectifiers.—This type of rectifier consists essentially of *a double contact rocker which rocks on pivot (midway between the contacts), in synchronism with the frequency of the alternating current, so changing the connections at the instants of reversals of the alternating current that a direct current is obtained.*

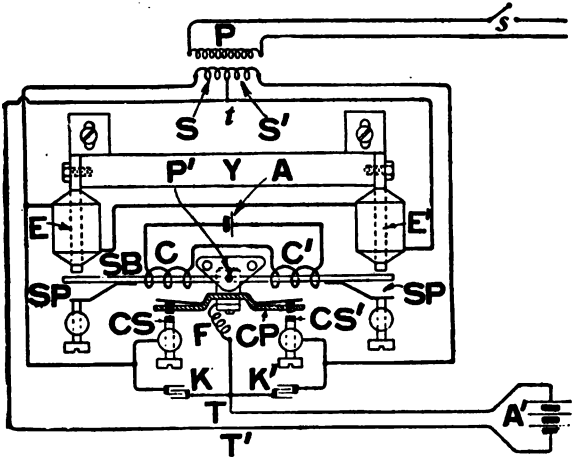


FIG. 6,625.—Diagram of Premier Ampero electro-magnetic rectifier. Owing to the direct current in the magnetizing coils C and C′, one end of SB, will be permanently of north and the other of south polarity; and since the polarities of the poles E and E′, will alternate with the alternations of the transformer secondary current, SB, will rock rapidly on its pivot, and contact will be made by turns with CS and CS′. The purpose of the condensers K and K′, is to reduce the sparking at these points. When contact is made at CS, the direct current terminals T and T′, are connected to the S, half of the secondary winding; and when contact is made at CS′, they are connected to the S′, half. Thus a rectified undirectional current will flow from T and T′, and it may be used to charge the battery A′, work a small motor or for various other purposes requiring direct current. When the rectifier is used for charging storage batteries, the separate cell A, may sometimes be dispensed with, the winding C,C′, being connected to one of the cells under charge. The rectifier is adjusted to suit the frequency of the supply circuit by altering the distance of the poles of E and E′, from the ends of the polarized armature SB; and also by changing the tension of SP,SP, by means of the screw studs against which they bear.

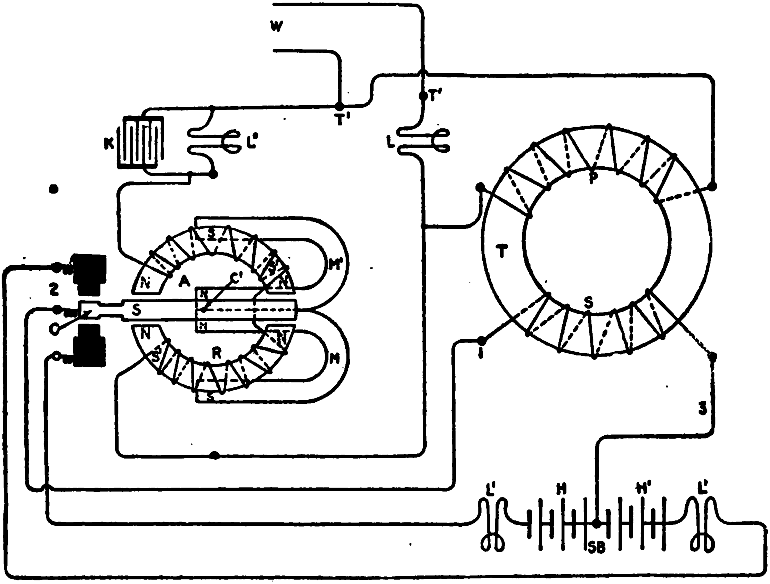
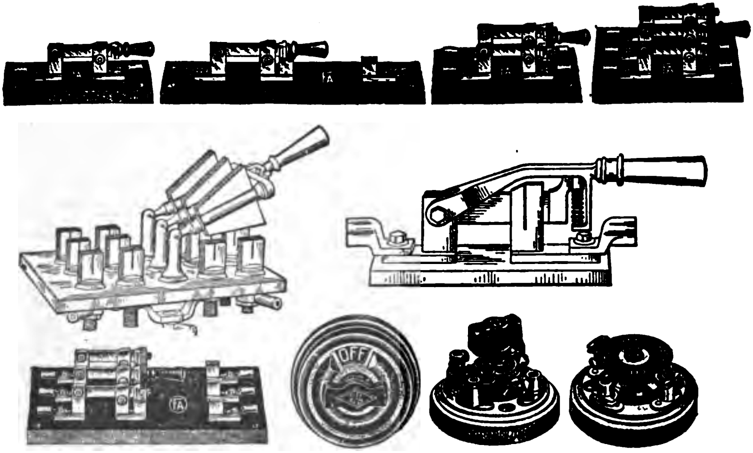


FIG. 6,626.—Diagram of General Electric (Batten) electro-magnetic rectifier. It is desirable for light and occasional service, where direct current is required but only an alternating supply is available, being used for charging storage batteries, exciting spark coils, performing electrolytic work, etc. The rectifier consists of a step down static transformer T, by means of which the circuit pressure is reduced to about 50 volts; also, a polarized relay R, the contact tongue C of which moves to one side or the other in sympathy with the alternations of the current in the primary winding P, the secondary current induced in the winding S being thereby rendered direct in the outer circuit. T', T' are the main terminals which are connected to the alternating current supply through the wires W. Lamps inserted at L are used as resistances in the primary circuit, the reduction of the voltage already alluded to being effected by this means. In charging storage batteries where a low pressure is required, a lamp (or lamps) should be connected in the secondary circuit as shown, S B being the storage battery, and L' L' the lamp resistances in series therewith, the battery has one end of the secondary S connected to its middle. Thus the alternating current leaving the transformer by the wire 1, passes by flexible connection 2, to the vibrating contact tongue C of the relay, the latter causing the currents in either direction to flow through the two halves H, H' of the battery, whence the current re-enters the secondary of the transformer by the wire 3. The soft iron core of the relay is in two halves S' S' and the armature A, carrying C, vibrates between their polar extremities. M, M' are two permanent magnets with their like poles together at the center C' where A is pivoted. Supposing these poles are north as indicated, the extremities of A will be south. The south ends of M, M being in juxtaposition with the centers of the soft iron cores S', S' will render their extremities facing the ends of A of north polarity. The windings on S', S' are connected in series with each other, and in shunt with P across the main terminals T', T'. Then because of the polarization of A and S', S', the former will vibrate rapidly in sympathy with the alternations of the current. K is a condenser shunted by a lamp resistance L", this being found to improve the working of R.

CHAPTER 105

D.C. Control and Indicating Apparatus

For the proper control and safe operation of dynamos, motors, and other *d. c.* apparatus, numerous control and indicating devices are necessary, such as



Figs. 6,627 to 6,636.—Various switches. Fig. 6,627 to 6,630, one two and three pole single throw knife switches; fig. 6,631, triple pole, double break, double throw knife switch for heavy current; fig. 6,632, quick break, single pole, single throw knife switch for heavy current; fig. 6,633, three pole single throw knife switch with fuse connections; figs. 6,734 and 6,635, snap switch with and without cover showing construction—the indicating dial registers "on" or "off"; fig. 6,636, gas engine snap switch.

Control Devices
- Switches
- Fuses
- Circuit Breakers
- Rheostats
- Arresters

Indicating Devices
- Galvanometers
- Ammeters
- Voltmeters
- Wattmeters

1. Control Devices

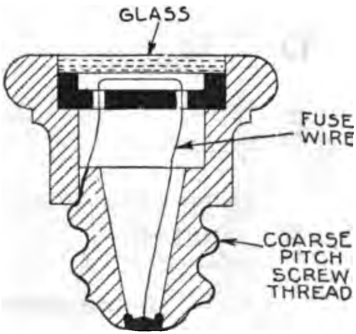
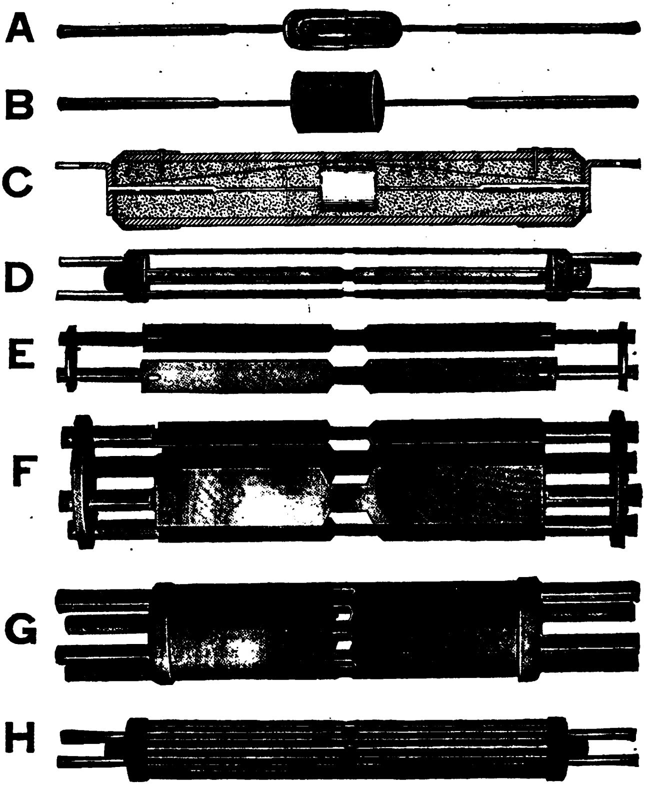


Fig. 6,637.—Spool of fuse wire usually made of an alloy of tin and lead, such as half and half solder. Bismuth is frequently added to the alloy to lower the melting point. For half and half solder the melting point is 370° Fahr. The current required to "blow" a fuse increases somewhat with the age of the fuse owing to oxidation and molecular changes. Fuses are sometimes rated according to the number of amperes to be taken normally by the circuit they are to protect. Open fuses are so unreliable that circuit breakers are preferable for large currents; when fuses are used, the enclosed type as shown in figs. 6,639 and 6,640 is usually the more desirable.

Fig. 6,638.—Cross section through plug fuse. With this type of fuse it is impossible to place any except the correct size of plug in the socket.

Figs. 6,639 and 6,640.—D and W enclosed or cartridge fuse showing blow indication. When the fuse blows, it is indicated by the appearance of a black spot within the circle on the lable as in fig. 6,640. Fuses should be placed wherever the size of wire changes or wherever there is a branch of smaller size wire connected, unless the next fuse on the main or larger wire is small enough to protect the branch or small wire, but more lights may be added on the large wire, making it necessary to put in a larger one. Experiments have shown that for large fuses, a multiple fuse is more sensitive than a single one. A one hundred ampere fuse may be made by taking four wires of twenty-five amperes capacity.



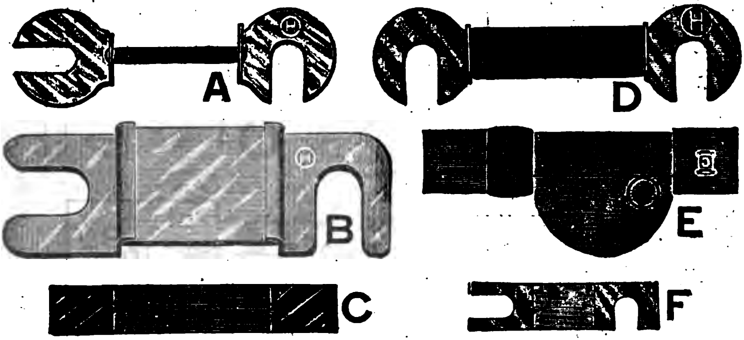
FIGS. 6,641 to 6,648.—Interior construction of D. & W. fuses. ***In the manufacture*** of these fuses, four types of fuse link are used according to capacity of fuse, and classified as: 1, air drum link; 2, flat link; 3, multiple link; 4, cylinder link In the air drum link, figs. **A** and **B**, a capsule provides an air space about the center of the link, the rate of heat conduction through the confined air being very slow, the temperature of that portion of the link rises rapidly with increasing current, rendering the blowing point practically constant; fig. **C**, shows a section through the complete fuse. In the flat link, fig. **D**, the section is reduced in the center, cutting down as far as possible the volume of metal to be fused. Figs. **E** to **G**, show various forms of multiple link construction. By subdividing the metal, increased radiating surface is obtained which permits a reduction in the volume of fusible metal necessary, and the metal vapor formed when the fuse blows on heavy over load is more readily dissipated. Figs. **F** and **G**, show two forms of the cylinder link, the plain cylinder fig. **F**, being used for low voltage and large current, and fig. **G**, for certain high tension service. The corrugated cylinder presents more surface to the fuse filling than the plain type and secures a maximum radiating surface with resulting minimum volume of metal for a given current.

Switches.—A switch is *a device by means of which an electric circuit may be opened or closed,* turning on and off the current. There are numerous kinds of switches.

A ***single pole switch*** controls only one of the two wires of a circuit; a ***double pole switch*** controls both.

A ***two pole switch*** breaks the circuit with less *arcing* than a single pole switch. Switches are said to be *single* or *double* **break,** according as each pole or blade is constructed to give one or two breaks, thus a two pole double break switch breaks the circuit in four places simultaneously, rendering it capable of stopping a heavy current without undue arcing.

In the quick break switch the contact pieces are snapped apart by a spring to reduce the duration of the arc as much as possible.

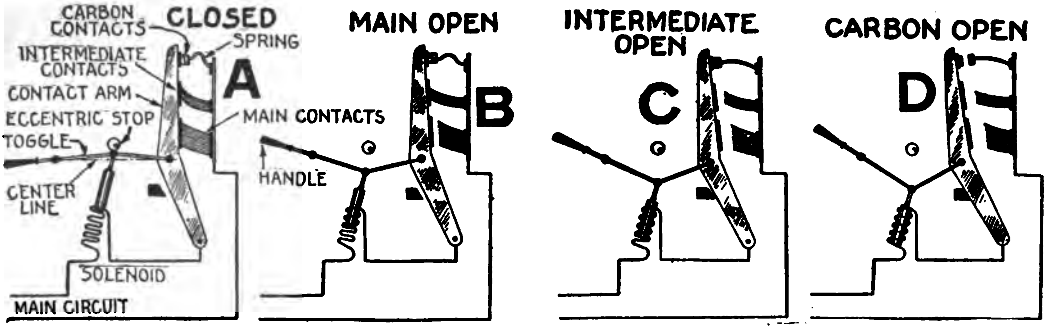


Figs. 6,649 to 6,654.—Various open fuses. Fig. 6,649, fuse for main and branch blocks; fig. 6,650, standard railway fuse; fig. 6,651, Edison main style; fig. 6,652, sneak current fuse; fig. 6,653, W. U. pattern; fig. 6,654, Bell telephone style; When an open fuse "blows as a result of overloading, the rupture is accompanied by a flash, and by spattering of the fused material. With large currents this phenomenon is a source of danger, and the use of enclosed fuses is accordingly recommended whenever the rating of the fuse exceeds 25 amperes.

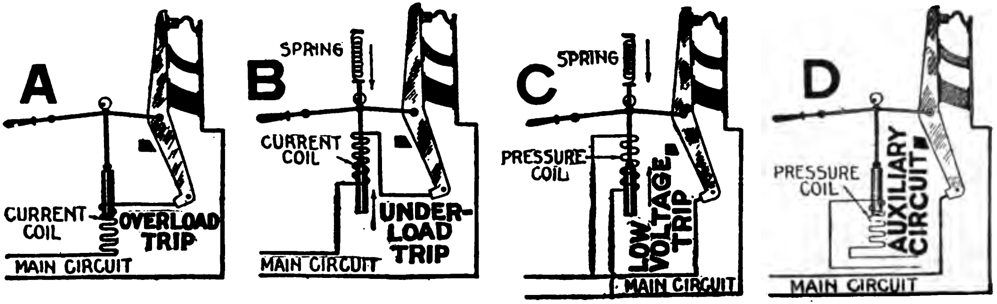
A switch whose contact pieces consist of a pivoted blade and fixed jaws is called a ***knife switch,*** and *it should be placed so that gravity tends to open it.*

A ***double throw switch*** controls two circuits and is used when it is desired to open one circuit and quickly close another, for instance, in ignition, the engine is started on the battery circuit and then the double throw switch is thrown over to the magneto side. Evidently both circuits cannot be closed at the same time which is a desirable feature.

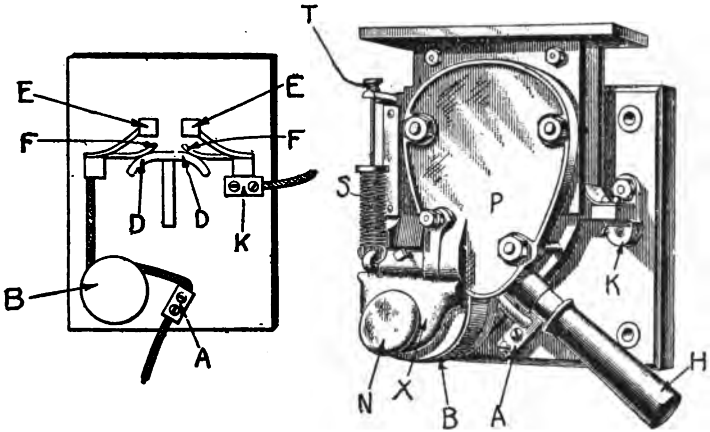
Fuses.—By definition, a fuse is simply a strip of fusible metal



Figs. 6,655 to 6,658.—Elementary diagrams illustrating the operation of a carbon circuit breaker of the overload type, showing the progressive opening of such device. Fig. 6,655, closed position; fig. 6,656, main contacts open; fig. 6,657, intermediate contacts open; fig. 6,658, carbon contacts open, circuit broken.



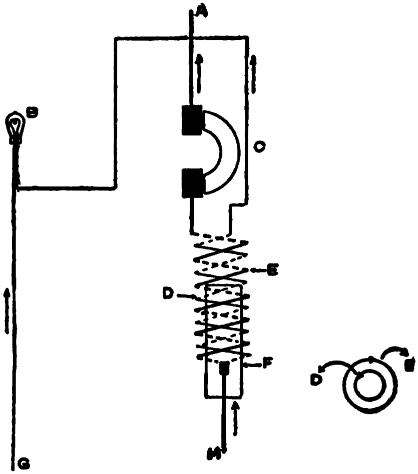
Figs. 6,659 to 6,662.—Elementary diagrams illustrating the various methods of electromagnetic control for circuit breakers. Fig. 6,659, overload trip; fig. 6,660, underload trip; fig. 6,661, low voltage trip; fig. 6,662, control from auxiliary circuit by means of a "relay."



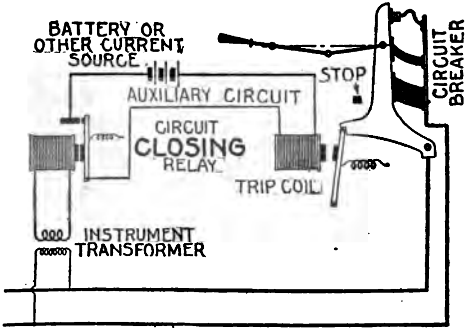
FIGS. 6,663 and 6,664.—*Magnetic* ***blow out*** *circuit breaker.* Its operation is based on theprinciple that a *conductor carrying a current in a magnetic field will tend to move in a direction at right angles to the field.* ***In operation,*** A and K, are the terminals, D,D, is a contact that is forced up against F,F, when the breaker is set. The current then takes the path A–B–F–D,D–F–K. ***When the breaker trips,*** the contact piece D,D, flies down and the tendency is for an arc to form between F,F; the magnetic field blows the arc upwards, and whatever burning takes place is on the contacts E,E, which are so constructed that they may be readily renewed. ***To trip the breaker by hand,*** the knob N, is pressed.

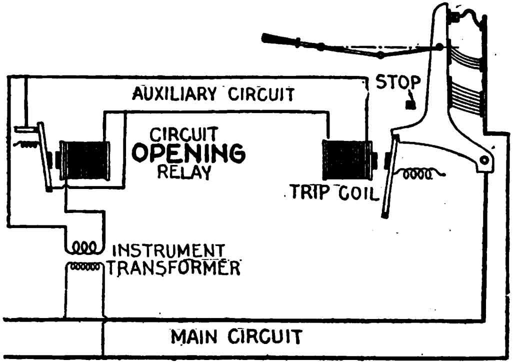
often consisting of lead with a small percentage of tin connected in series in the circuit.

If the temperature exceed a predetermined limit by an abnormal increase of current, the fuse will melt or "blow," thus opening and protecting the current. All circuits



FIGS. 6,665 and 6,666—Reverse current circuit breaker: fig. 6,666, view looking at end of coils of cut out, showing direction of current. A, to + bus bar; B, resistance lamp; C, brush of cut out D, shunt coil; E, series coil; F, core that trips cut out; G, to – bus bar; H, to + pole of dynamo.





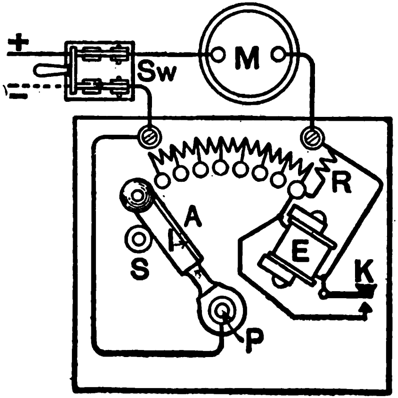
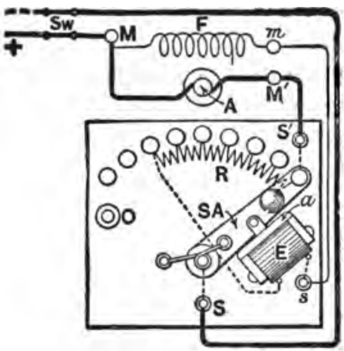


FIG. 6,667.—Diagram illustrating the operation of a ***circuit closing relay.*** When the predetermined abnormal condition is reached in the main circuit, the relay closes the auxiliary circuit, thus energizing the trip coil and opening the breaker.

FIG. 6,668.—Diagram illustrating the operation of a ***circuit opening relay.*** When the relay contacts are in the normal closed position, as shown, the coil is short circuited. When the predetermined abnormal condition is reached in the main circuit, the relay contacts are opened with a quick break, sending the current through the trip coil momentarily, and opening the breaker.

FIG. 6,669.—**Starter** with no voltage release for a series motor. A helical spring coiled around the lever pivot P, and acting on the lever A, tends to keep it in the off position against the stop S. This lever carries a soft iron armature I, which is held by the poles of the electro-magnet E, when, in starting the motor, the arm has been gradually forced over as far as it will go. Should anything happen to interrupt the current while the motor M, is running, E, will lose its magnetism and A, will be released, and will fly over to the off position. E, is usually shunted by a small resistance R, so **that only a portion of the main current flows through it.** This device **constitutes the *no voltage release*, and ensures that all the resistance is in circuit every time the motor is started.**



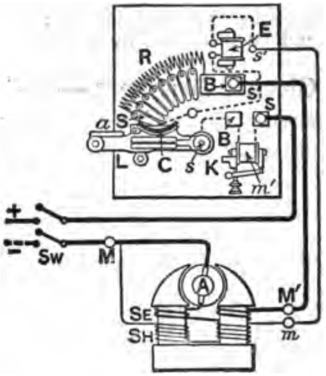


Fig. 6,670.—Starter with no voltage release for a shunt motor. The terminals of the motor are at M, M′, *m*, and those of the starter at S, S′, *s*. The lever SA, is shown in the "on" position. The current enters the motor at the terminal M, and there divides, part going through the field coil F, and the main current through the motor armature A. The armature current enters the starter at the terminal S′, and traversing the lever SA, leaves by the terminal S. The field current enters the starter at the terminal *s*, traverses the coil of the magnet E, (which holds up the armature *a*, linked to the lever) and thence completes its journey through the whole of the resistance R, and through the lever SA, to the terminal S. When the supply is cut off by opening Sw, or should the field circuit be accidentally broken, the magnet E, will release *a*, and the lever, which will thereupon fly to the "off" stop O. It should be noticed that when SA, is off, A and F, form a closed circuit with the resistance R and magnet E. The inductance of F, has consequently no chance of causing destructive sparking when the current is shut off. ***In starting*** the motor, Sw is first closed, and then, as the lever is slowly moved, the resistance R, which at first is all in circuit with A, is gradually transferred from A to F. The resistance of R, is too small to affect appreciably the current in F, which necessarily consists of a comparatively large number of turns of fine wire. The arrangement is adopted to render the breaking of the shunt circuit unnecessary.

Fig. 6,671.—Starter with no voltage release and overload release connected to a compound motor. With a shunt motor, the only difference in the diagram would be that the series winding SE, would be absent, and the armature A, would then be connected straight across between the main terminals M and M′. When switch Sw, is closed, the current will enter the starter at its terminal S, and pass through the magnet coil *m*′, of the overload release to the switch lever L, which is shown in the off position. As soon as L, is moved up to make contact with the first contact S, the current divides; part going through the resistance R, and the terminals S′ and M′, to the series coil SE (if a compound motor), and armature A; and part through the no voltage magnet E, to the shunt winding SH. As the lever L, is moved up toward E, the effect is to take R, out of the armature circuit and put it into the shunt circuit. When the iron armature *a*, fixed on the switch lever, comes against the poles of E, the laminated copper brush C, bears against the blocks B, B, and so affords a better path for the current than through the spindle *s*. Should the supply voltage fail, either temporarily or permanently, E, will release *a*, and L, will fly off under the tension of a helical spring coiled round *s*. If there should be an overload on the motor, tending to pull it up and cause an excess of current to flow through the armature; this excess current, passing through *m*′, will make it attract its armature, so bringing two contacts together at K, which will short circuit E, and allow the switch to fly off. The connections between E and *m*′, are not shown in the figure. When only the normal current is flowing, the attraction between *m*′, and its armature is not sufficient to pull the latter up. The actual forms and arrangement of parts on the starters are well shown in some of the figures.

subject to abnormal increase of current which might overheat the system should be protected by fuses.

Circuit Breakers.—A circuit breaker is a switch which is opened automatically when the current or the pressure exceeds or falls below a certain limit, or which can be tripped by hand.

The automatic operation depends on properly arranged electromagnets. Circuit breakers are made to operate on overload or underload, and a reverse current, the latter type being sometimes called a discriminating cut out.

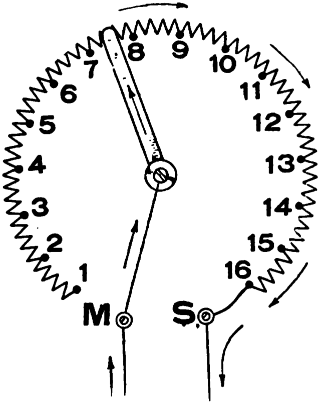


FIG. 6,672.—Diagram of plain rheostat. The rheostat is connected in series in the circuit that it is to control. ***In operation,*** when the lever is on contact 1, the current is opposed by all the resistance of the rheostat so that the flow is very small. As the lever is moved over contacts 1, 2, 3, etc., the coils are successively cut out, thus diminishing the resistance, and when contact 16 is reached all the resistance is short circuited allowing the full current to flow. M and S are the terminals.

FIGS. 6,673 to 6,675.—General Electric ***magnetic blow out arrester*** for use on railways. ***It consists of an adjustable spark gap in series with a resistance. Part of the resistance*** is in shunt with a blow out coil, between the poles of which is the spark gap. ***In operation.*** when the lightning pressure comes on the line, it causes the spark gap to break down and a discharge occurs through the gap and the resistance rod to ground. Part of the current shunts through the blow out coil producing a strong magnetic field across the spark gap. The magnetic field blows out the discharge arc and restores normal conditions.

Rheostats.—By definition, a rheostat is *a variable resistance box*.

It contains a number of resistance elements joined in series so arranged that they may be progressively cut out of the circuit by the movement of a lever over a number of contacts connecting different forms of the resistance.

A rheostat is connected in series in a circuit, and when designed to be used in starting motors it is frequently called a starting box or "starter."

For motor control a rheostat should be provided with an overload release and a no-voltage release.

Lightning Arresters.—These devices *provide paths by which lightning disturbances or other static discharges may pass to the earth.*

In general, their construction comprises an assembly of air gaps, resistances, inductances and arc suppression devices. A lightening arrester must prevent excessive pressure differences between line and ground, and between conductor turns in the electrical apparatus.

An *air gap* is frequently used to form the necessary high resistance which must

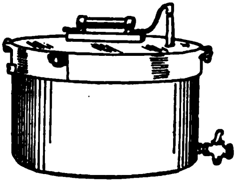


FIG. 6,676.—Westinghouse ***electrolytic station lightning arrester*** for direct current up to 1,500 volts consists of a tank of oil in which are placed, on properly insulated supports, a nest of cup shaped aluminum trays. The spaces between the trays are filled with electrolyte, a sufficient quantity for one charge being furnished with each arrester. The top tray is connected with the line through a 60 ampere fuse, and the bottom tray is connected to the tank which is thoroughly grounded by means of a lug. The fuse is of the enclosed type and mounted on the cover of the arrester. A ***small charging current*** flows through the trays continuously and keeps the films on the trays built up, so that no charging is required. This charging current is not, however of sufficient value to raise the temperature appreciably. The immersed area of each tray is 100 square inches. The shape and the arrangement of the trays is such that any gases generated by the discharge can pass out readily without disturbing the electrolyte between the trays.

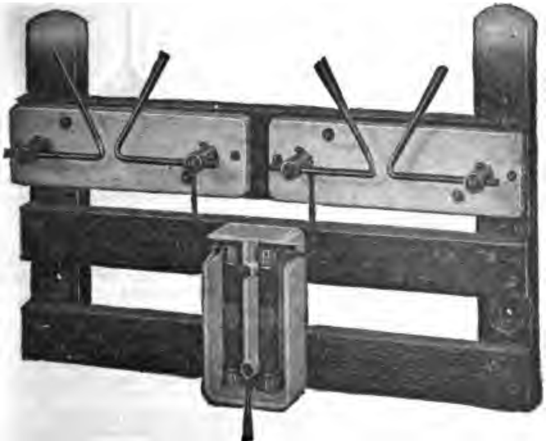
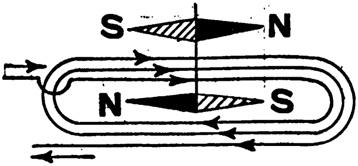


FIG. 6,677.—General Electric horn type ***air gap*** arrester, mounted for 15 light series arc circuit. The horn type arrester consists of a horn gap wit h series resistance between each line and ground.

which must be interposed between the ground and the conductor. The resistance is such that any voltage very much in excess of the maximum normal will cause a discharge to ground, whereas at other times the conductor is ungrounded because of the air gap. This forms the principle of air gap arresters. There may be one gap or many in series, and the gap may be in air or in vacuum. Other methods are: electrolytic, magnetic blow out, choke coils, static interruptors, etc.



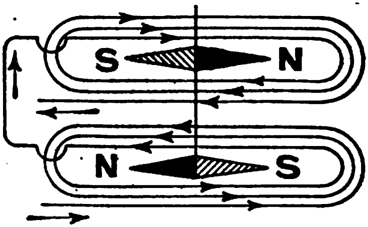
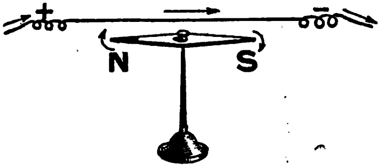
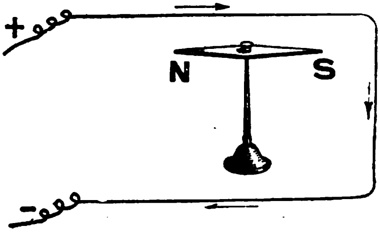


FIG. 6,678.—Connections of single coil astatic needles. The coil surrounds the lower needle and the direction of the current between the two needles tends to turn them the same way.

FIG. 6,679.—Connections of double coil astatic needles. ***With this arrangement,*** the direction of current in both coils will tend to turn the system in the same direction, making the needles more sensitive than with a single coil in fig. 6,678.





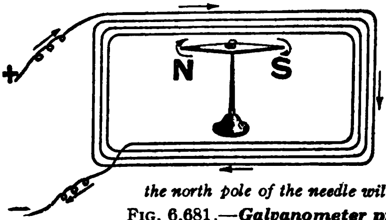


FIG. 6.680.—***Galvanometer principles I.*** Effect of neighboring current upon a magnetic needle: The north pole of the needle will turn toward the east, for by Ampere's rule, ***if a man could swim in the conductor with the current, and turn to face the needle, then the north pole of the needle will be deflected toward his left hand.***

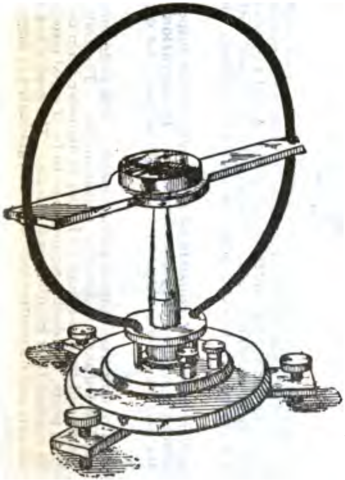
FIG. 6,681.—***Galvanometer principles II.*** Effect of neighboring current in a loop. In accordance with Ampere's rule, the ***upper*** wire causes the N pole of the needle to turn to the left, while if a man imagine himself swimming in the lower wire in the direction of the current, and facing the needle (that is, swimming on his back), the N pole of the needle will turn to his left—that is to the east. The effect of the loop then has double the effect of the single wire in fig. 6,680.

FIG. 6,682.—***Galvanometer principles III.*** Effect of neighboring current in a coil. The coil, as shown, is equivalent to several loops, that is, the force tending to deflect the needle is equal to that of a single loop multiplied by the number of turns. Hence, by using a coil with a large number of turns, a galvanometer may be made very sensitive so that the needle will be perceptibly deflected by very feeble currents.

Fig. 6,683.—Breguet upright galvanometer with glass shade.

Fig. 6,684.—Bunnell horizontal galvanometer. It has two coils, one of which is of zero resistance and one of fifty ohms resistance adapting it to a variety of test.

Fig. 6,685.—Bunnell galvanometer for measurements of instruments, lines, batteries, wires and any object from $^1/_{100}$ to 10,000 ohms or more.



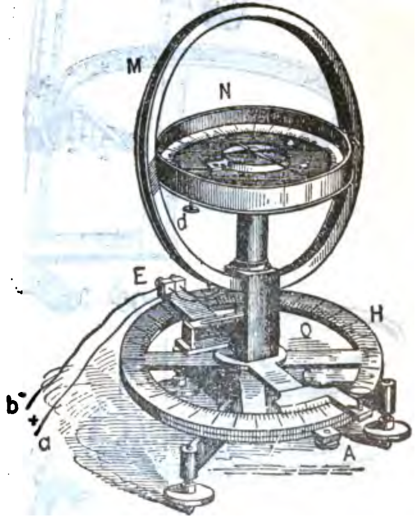
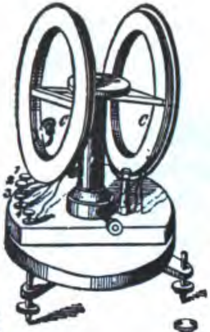


Fig. 6,686.—***Tangent*** galvanometer. ***It consists of*** a short magnetic needle suspended at the center of a coil of large diameter and small cross section. If the instrument be so placed that, when there is no current in the coil, the suspended magnet lies in the plane of the coil, that is, if the plane of the coil be set in the magnetic meridian, then *the current passing through the coil is proportional to the tangent of the angle by which the magnet is deflected from the plane of the coil*, or zero position—hence the name: "tangent galvanometer."

Fig. 6,687.—***Sine*** galvanometer. ***The parts are:*** M, coil; N, graduated dial of magnetic needle H, graduated dial by which the amount of rotation necessary to bring the needle to zero is; measured; E, terminals of the coil; O upright standard carrying coil and graduated dial of magnetic needle; C, base with levelling screws. ***In operation,*** the coil is moved so as to follow the needle until it is parallel with the coil. Under these circumstances, the strength ***of the deflecting current*** *is proportional to sine of angle of deflection.*



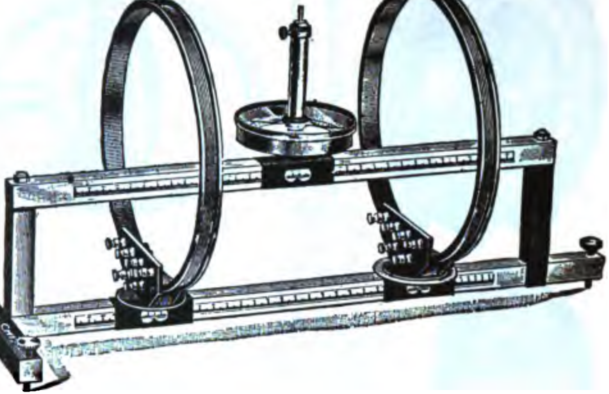
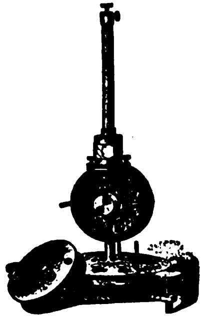


FIG. 6,688.—Queen reflecting static galvanometer. It is mounted on a mahogany base with levelling screws. A plain mirror is attached above the upper needle. The entire combination of mirror and needles is suspended by unspun silk from the interior of a brass tube, which also carries a weak controlling magnet. A dial 4 inches in diameter and graduated in degrees, enables the deflections of the needle to be accurately read. The mirror can be used with a reading telescope and scale, or by means of a lantern, the image of a slit may be reflected from the mirror to a screen. Resistance, .5 to 1,000 ohms.

FIG. 6,689.—***Differential*** galvanometer. ***It consists of*** a magnetic needle suspended between two coils of equal resistance so wound as to tend to deflect the needle in opposite directions. ***In operation,*** the needle *shows no deflection when two equal currents are sent through the coils in opposite directions.* Its special use is for comparing two currents.

FIG. 6,690.—Central Scientific Co. universal tangent galvanometer. This instrument may be used as a tangent, Gaugain, Helmholtz-Gaugain, sine, cosine, Wiedemann or detector galvanometer. The coils, which slide on a beam parallel to the one carrying the needle box, are wound on brass rings 12 inches in diameter. On each ring are wound two coils of 48 turns each, connected to separate binding posts, and double wound so as to be of equal resistance. The coils and needle box are each provided with an indicator for reading their position on the scale. The needle box is swivelled and removable and one coil may be rotated about its vertical axis and its position read on a disc graduated in degrees. Currents may be measured ranging from .000002 ampere to 100 amperes.



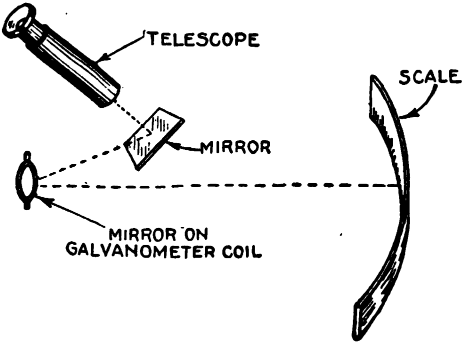
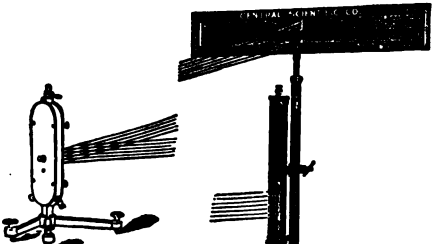


FIG. 6,691.—Queen ***dead beat*** and ***ballistic*** galvanometer. ***In construction,*** the magnetic system is given considerable weight, so arranged as to give the reading without useless swings of the needle. This is obtained by hanging a bell magnet with its mirror by a long cocoon fibre, the eddy currents induced in the copper bringing the system quickly to rest. ***Used for*** measuring momentary currents, for instance, the discharge of a condenser.

FIG. 6,692.—Telescope method of reading galvanometer deflections by reflections of scale reading in mirror.



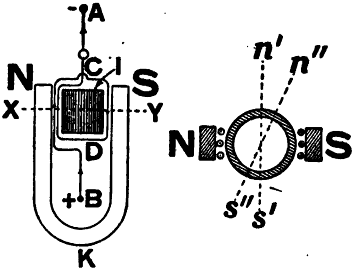
FIGS. 6,693 and 6,694.—Galvanometer lamp and scale for individual use. ***The scale*** is etched on a ground glass strip 6 centimeters wide by 60 centimeters long with long centimeter divisions and short millimeter divisions the entire length, reading both ways from zero in the center. It is mounted in an adjustable wooden frame. A straight filament lamp (110 volts) is enclosed in a metal hood japanned black to cut out all reflected light.

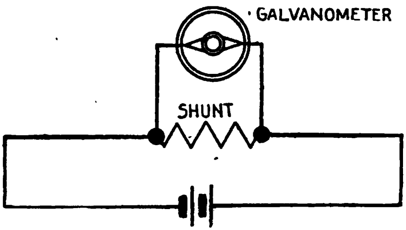
FIG. 6,695.—Queen reading telescope. This arrangement is utilized to measure the deflections of a galvanometer having suspended mirror moving system. ***It consists of*** a reading telescope mounted as illustrated with a millimeter scale, having a length of 50 centimeters. In use, the image of the scale is seen in the galvanometer mirror through the telescope. The eye piece of the telescope has a cross hair which acts as a reference line so that by noting the particular division on the scale when the galvanometer is at rest, the amount of deflection can be readily observed when the galvanometer is deflected.

2. *Indicating Devices*

Galvanometers.—These instruments are for indicating the presence of an electric current in a circuit, and determining its direction, strength and pressure, by measuring the electromagnetic effect of the current.

Its principle is that a magnetic needle is deflected when influenced by an electromagnetic field, and a simple galvanometer consists essentially of a magnetic needle suspended within a coil of wire and free to swing over the face of a graduated dial. The action of the current was discovered by *Oersted.* Galvanometers may be divided into two general classes, as those having: 1, a movable magnet and stationary coil, and 2, stationary magnet and movable coil; either type may have a short or long coil. The principle forms of galvanometer are: 1, astatic; 2, tangent; 3, sine; 4, differential; 5, ballistic; 6, D'Arsonval.





FIGS. 6,696 and 6,697.—Diagrams of *D'Arsonval* galvanometer. ***In construction,*** the coil is wound upon a copper form, and suspended between a permanent magnet by fine wires to the points A and B. The magnet has its poles at N and S. There is a soft iron cylinder fixed between the poles in order to intensify the magnetic field across the air gaps in which the coil moves. $n's'$, position of coil when no current is flowing; $n''s''$, position when current is flowing. This galvanometer is adapted to general use.

FIG. 6,698.—Diagram showing method of connecting galvanometer shunt. ***The shunt greatly increases the range of measurement.***

Ammeters and Voltmeters.—An ammeter or ampere meter is simply a commercial form of galvanometer so constructed that the deflection of the needle indicates directly the strength of current *in amperes*.

A good ammeter should have a very low resistance so that very little of the energy of the current will be absorbed; the needle should be dead beat, and sufficiently sensitive to respond to minute variations of current.

According to the principle of operation, ammeters and volt-meters are classified as:

1. Moving iron;
2. Moving coil;
3. Solenoid or plunger;
4. Magnetic vane;
5. Hot wire;
6. Electrostatic;
7. Astatic;
8. Inclined coil;
9. Fixed and movable coil.

Ammeters are connected ***in series*** *in the circuit, or* ***in shunt;*** according as they are designed to receive all or only a fraction of the current.

A voltmeter has a high resistance coil instead of one of low resistance, so that very little current will pass through it.

If a high resistance be connected in series with a sensitive ammeter that will measure very small currents, then the current

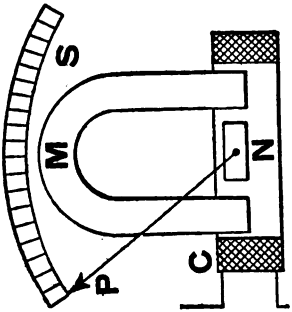


FIG. 6,699.—*Moving iron type instrument.* The essential parts are: N, soft iron needle; C, coil; M, permanent magnet; P, pointer; S, scale. *Current passing through the coil acts on the needle, causing it to turn against the restraining force due to the influence of the permanent magnet.*

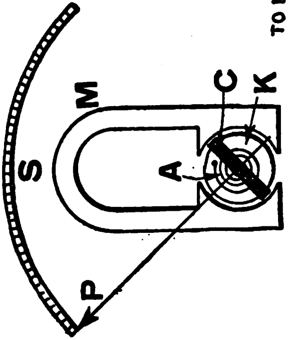


FIG. 6,700.—*Moving coil type instrument.* The essential parts are: A, spiral spring; C, coil; K, soft iron core; M, permanent magnet; P, pointer; S, scale. *Current passing through the coil causes the moving system to turn against the restraining force due to the influence of the permanent magnet.*

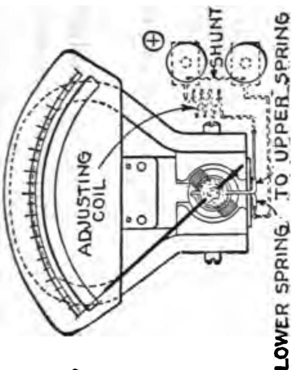
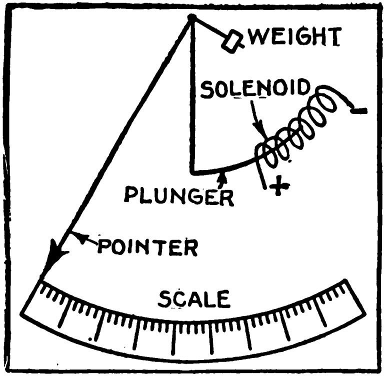
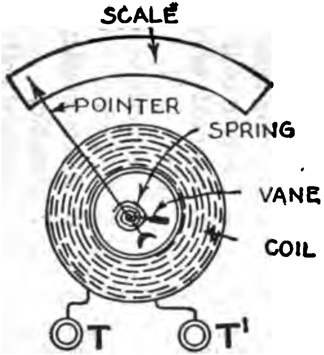


FIG. 6,701.—Western Ammeter showing shunt enclosed within the instrument. The reading is *dead beat* which means *without useless vibrations of the needle.*





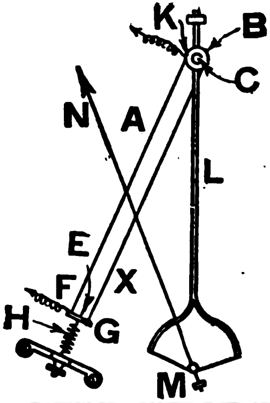


FIG. 6,702.—Plunger type instrument. ***In principle,*** *the current to be measured passes through the solenoid, producing a magnetic effect on the soft iron plunger which tends to draw it into the coil, and thus cause the pointer to move over the graduated scale.* The instrument, because of the residual magnetism of the air is less reliable than the usual types. ***Adapted*** to large currents.

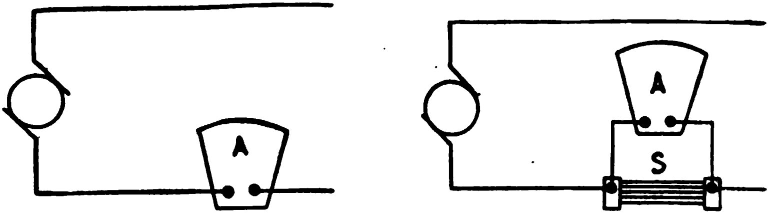
FIG. 6,703.—Magnetic vane instrument. ***In principle,*** a soft iron vane, *eccentrically pivoted within a coil carrying the current to be measured, is attracted toward the position where it will conduct the greatest number of magnetic lines of force against the restraining force of a spring or equivalent.* T and T' are the terminals.

FIG. 6,704.—Diagram showing principle and construction of the Whitney ***hot wire*** instruments. The action of instruments of this type *depends on the heating of a wire by the passage of a current causing the wire to lengthen.* This elongation is magnified by suitable mechanism and transmitted to the pointer of the instrument. AX, wire; B, pulley; C, shaft; E, plate; F and G, ends of wire; H, spring; M, pulley; N, pointer.

passing through the circuit is directly proportional to the pressure or voltage at its terminals and the instrument may be calibrated to read volts. A voltmeter is connected ***in parallel*** in the circuit.

Wattmeters.—These instruments are designed to measure directly the products of the amperes and volts in a circuit and give its readings in watts. In the *dynamometer* type there are two coils, or sets of coils, one of which is fixed and the other movable.

The movable coil is connected in the current circuit, and the fixed coil in the pressure circuit, or the reverse. The *induction* type is used on alternating current circuits. In this type, electromagnets are arranged near a vane in which eddy currents

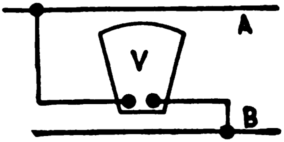


Figs. 6,705 and 6,706.—Connections for series and shunt ammeters. When the construction is such that all the current passes through the instrument, it is connected as in fig. 6,705 but where the instrument is designed to take only a fraction of the current, it is connected across a shunt, as in fig. 6,706, a definite proportion of the current passing through the instrument and the remainder through the shunt.

1,000 Ampere Type B Shunt

400 Ampere Type D Shunt

Figs. 6,707 and 6,708.—Westinghouse ammeter shunts. These shunts are used where heavy currents are to be measured. The shunt is connected in series with the bus bar or circuit to be measured, and its terminals are connected by means of small leads to the ammeter or other instrument.



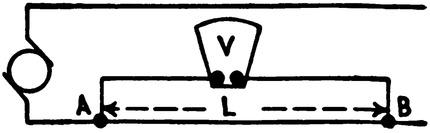


Fig. 6,709.—Voltmeter connection for measuring the pressure in an electric circuit. The voltmeter is connected *in parallel* in the circuit at the point where the voltage is to be measured.

Fig. 6,710.—Voltmeter connection for measuring the "drop" or fall in voltage in a certain length of wire, as for instance, the length between the points A and B. The voltmeter is *shunted* between the two points whose pressure difference is to be measured.

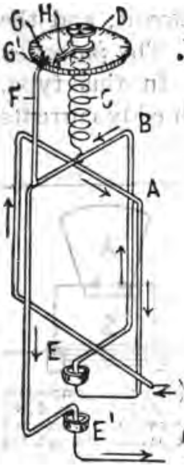


Fig. 6,711.—Diagram of Siemens' electro-dynamometer. *It consists of* two coils on a common axis, but set in planes at right angles to each other in such a way that a torque is produced between the two coils which measures the product of their currents. This torque is balanced by twisting a spiral spring through a measured angle of such degree that the coils shall resume their original relative positions. If used for measuring *current*, the coils are connected in series, and the reading is then proportional to the square of the current. If used as a *wattmeter*, one coil carries the main current and the other a small current, which is proportional to the pressure. The reading is then proportional to the power in the circuit.

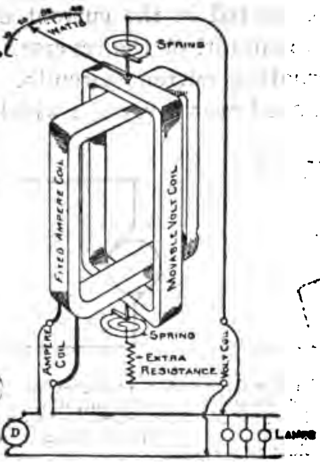


Fig. 6,712.—Diagram showing connections of Siemens' electro-dynamometer as arranged to read watts.

are caused to flow which react on the magnetic field, and the record made is proportional to the force of the reaction. A *recording* wattmeter is one that will register the watt-hours expended during an interval of time.

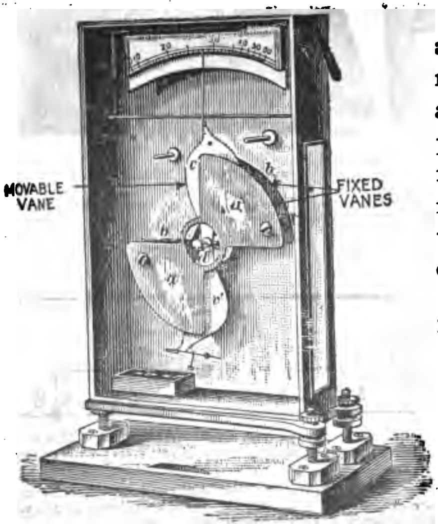


Fig. 6,713—Kelvin ***electrostatic*** voltmeter for high pressures up to 200,000 volts. ***In principle,*** *the vanes which act as condensers take charges proportional to the pressure difference between them, resulting in a certain attraction which tends to rotate the movable disc against the restraining force of gravity.* In the figure *aa* and *b* are two fixed vanes and *c* a movable vane, carrying a pointer and having a proper weight at its lower end.

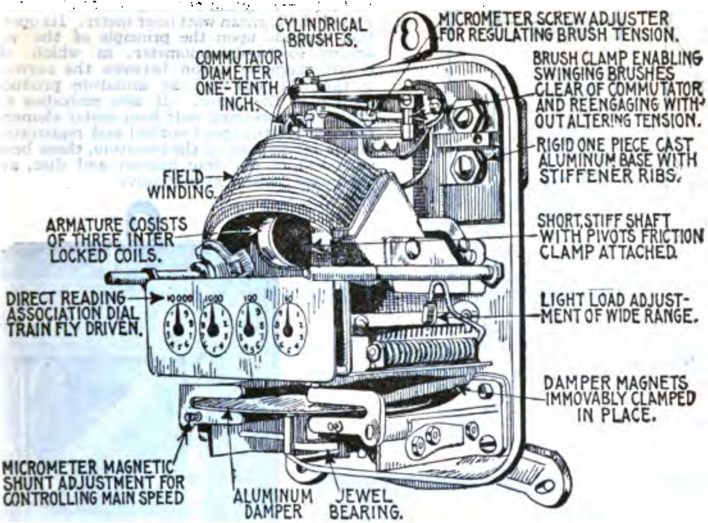


Fig. 6,714.—Interior view of Columbia watt hour meter showing construction, principal parts, and connections. The armature winding consists of three coils approximately circular in shape. The coils are form wound, interlocked with one another and with the light impregnated fibre disc which serves as a spacer for them. The aluminum damper disc has the conventional anti-creep provision in the shape of the three small soft iron plugs, mounted close to the central staff. The commutator has three segments and is made of chemically pure silver. Each brush is formed of a length of phosphor bronze wire bent like a hair pin and secured at its "U" end to a brass sleeve, which in turn is secured to an insulated stud by a set screw. An extension on the sleeve carries a micrometer screw brush adjustment.

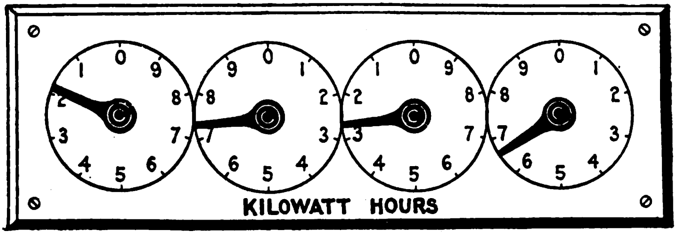


Fig. 6,715.—Watt hour meter recording dials. ***To read the meter:*** Begin at the left and set down for each dial the *lower* figure next to each hand, not necessarily the figure nearer the hand. In the above example the statement is 1,726 kilowatt hours or 1,726,000 watt hours. Subtract the previous statement to arrive at registration for a given period. Some meters are subject to a multiplying constant so stated on their face, and the registration of such meters must be multiplied by the constant as shown, to determine the actual consumption of electrical energy.

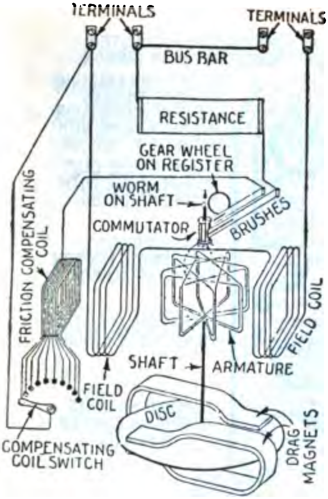


Fig. 6,716.—Diagram showing internal connections of the Duncan watt hour meter. Its operation depends upon the principle of the well known electro-dynamometer, in which the electro-magnetic action between the currents in the field coils and an armature produces motion in the latter. It also embodies the other two necessary watt hour meter elements required for the speed control and registration of the revolutions of the armature, these being embodied in the drag magnet and disc, and the meter register respectively.

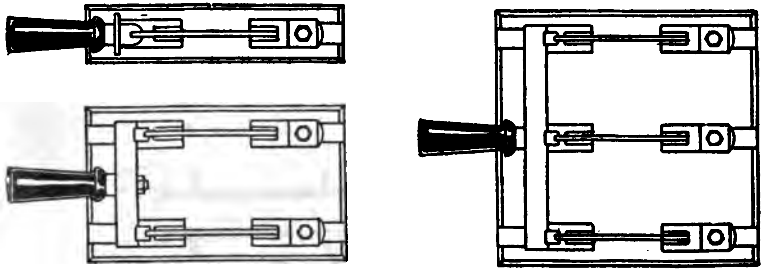
Fig. 654.—Interior view of Thompson watt hour meter (type C-6). Capacity: 5 to 600 amperes, two wire, and 5 to 300 amperes, three wire; 100 to 250 volts. The meter is supported by three lugs, the upper one of which is keyholed, and the lower right hand one slotted. This permits rapid and accurate levelling as the top screw can be inserted and the meter hung thereon approximately level.

Fig. 656.—Interior of Thompson watt hour meter (type C-6) showing armature, small commutator and gravity brushes. A spherical armature moving within circular field coils is the construction adopted in this meter. The armature is wound on a very thin paper shell, stiff enough to withstand the strain due to winding and subsequent handling. The wire composing the armature is of the smallest gauge consistent with mechanical strength. Ribbon wire is employed for the field coils, thus economizing space and further carrying out the idea of concentration.

CHAPTER 106

A.C. Control and Indicating Apparatus

Various devices are required for the proper control of the alternating current, such as,



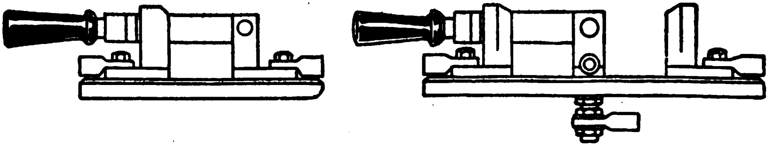
Figs. 6,718 to 6,720.—Various single throw switches. Fig. 6,718, single pole; fig. 6,719, double pole; fig. 6,720, three pole. *A single pole switch should only be used for very light duty.*

1. Switching devices;
   a. Ordinary switches; *b.* Oil break switches;
   c. Remote control switches.

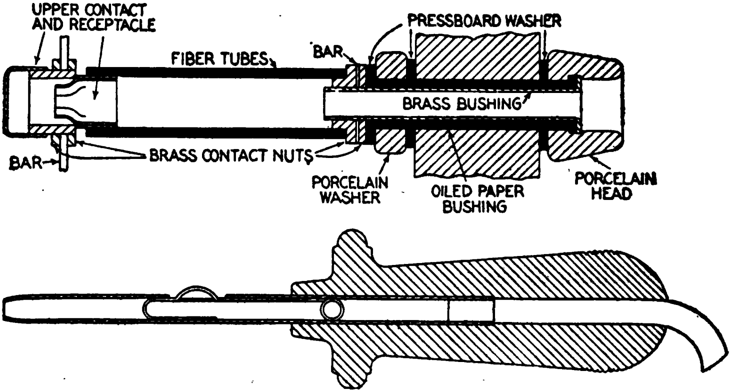
2. Current or pressure limiting devices;
   a. Fuses; *b.* Reactances; *c.* Circuit breakers; *d.* Relays.

3. Lightning protection devices;
    - *a.* Air gap arresters;
    - *b.* Multi-gap arresters;
    - *c.* Horn gap arresters;
    - *d.* Electrolytic arresters;
    - *e.* Vacuum tube arresters;
    - *f.* Choke coils;
    - *g.* "Static" interrupters.

4. Regulating devices;
    - *a.* Induction voltage regulators;
    - *b.* Variable ratio transformer regulators {drum type; dial type;
    - *c.* Compensation shunts;
    - *d.* Pole type regulators;
    - *e.* Small feeder voltage regulators;
    - *f.* Automatic voltage regulators;
    - *g.* Line drop compensators;
    - *h.* Starting compensators;
    - *i.* Star delta switches;
    - *h.* Synchronous condensers.



Figs. 6,721 and 6,722.—Various single pole switches. Fig. 6,721, single throw; fig. 6,722 double throw.



Figs. 6,723 and 6,724.—Enclosed arc bus transfer plug switch. The current is supplied in a tube enclosed at one end, thereby confining the arc and limiting the supply of air.

5. Indicating devices;

- *a.* Moving iron instruments
  - plunger type;
  - inclined coil type;
  - magnetic vane type;
- *b.* Hot wire instruments;
- *c.* Induction instruments
  - shielded pole type;
  - repulsion type;
- *d.* Dynamometers;
- *e.* Instrument transformers;
- *f.* Watthour meters
  - commutator type;
  - induction type;
  - Faraday disc type;
- *g.* Frequency indicators
  - synchronous motor type;
  - resonance type;
  - induction type;
- *h.* Synchronism indicators
  - lamp type;
  - voltmeter type;
  - resonance type;
  - rotating field type;
- *i.* Power factor indicators
  - wattmeter type;
  - rotating field type;
- *j.* Ground detectors;
- *k.* Earth leakage cut outs;
- *l.* Oscillographs.

1. Switching Devices

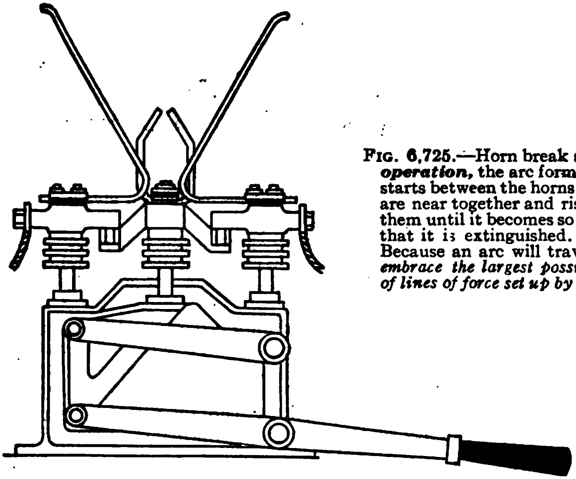
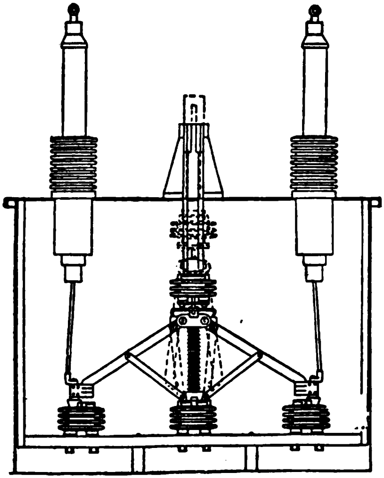


FIG. 6,725.—Horn break switch. ***In operation,*** the arc formed ~~at break~~ starts between the horns where they are near together and rises between them until it becomes so attenuated that it is extinguished. ***Reason:*** Because an arc will travel so as *to embrace the largest possible number of lines of force set up by the current*

A switch is *a piece of apparatus for making, breaking, or changing the connections in an electric circuit.*

Since the electric current cannot be stopped instantly when the circuit in which it is flowing, is broken, an arc is formed as the switch contacts separate; this tends to burn the contacts, and to short circuit, the severity of such action depending on the voltage and the proximity of the switch terminals. Accordingly, in switch design, provision must be made to counteract these tendencies. Thus,

1. The contacts should separate along their entire length, rather than at a point;



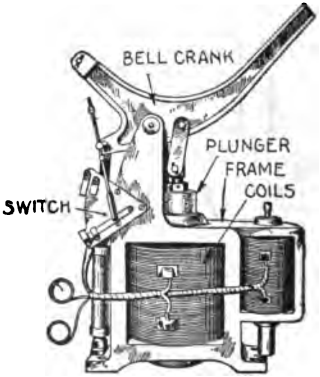


Fig. 6,726.—Kelman oil break switch with pantograph mechanism giving double horizontal break.

Fig. 6,727.—Kelman electric control for oil switch. A small switch on the frame automatically opens the coil circuit at the end of the stroke in either direction and operates signal lamps to indicate the open or closed position.

2. The terminals should be far enough apart and properly protected to prevent short circuiting of the arcs;

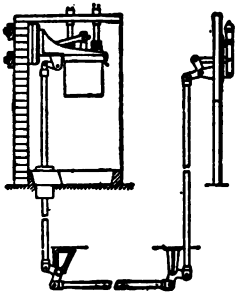
3. The break should be quick;

4. The gap should be surrounded by the proper medium (air or oil) to meet the requirements of the electrical conditions.

A great variety of switches have been introduced to suit the different requirements. Knife switches are used for low pressure service, the multiple break form being used where it is desired to reduce the arcing distance. Knife switches should open downward so gravity will keep them open.

Forms of Break.—On high pressure circuits there are several types of switch; they are classified *with respect to the break*, that is to say, according as the break takes place.

1. In open air;
2. In an enclosed air space;
3. Aided by a metal fuse;
4. Aided by a horn;
5. In oil.



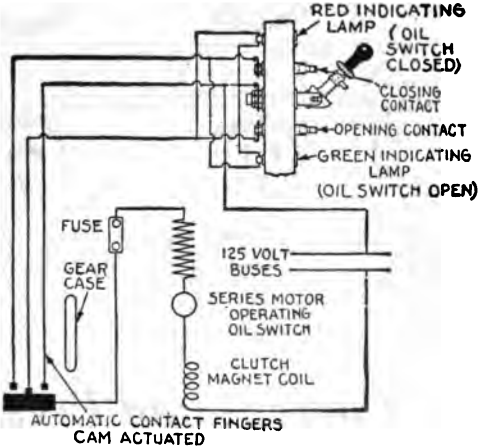


FIG. 6,728.—Remote control hand operated oil switch.

FIG. 6,729.—Remote control (electric) power operated oil switch connection diagram. Standard motor control pressure, 125 volts.

If the break take place in open air, a relatively long gap is required to extinguish the arc. The enclosed air break switch is more compact. The opening arm of a metal fuse break switch draws the fuse through a tube thus opening the circuit without much disturbance. In a horn gap switch, the arc formed on breaking the circuit, as it travels toward the extremities of the horns, becomes attenuated and is finally ruptured.

An oil switch is one in which the break occurs under oil; it is used almost universally on high pressure *a.c.* circuits.

Remote Control.—It is desirable in the case of switches on high pressure circuits (1100 volts and over) to locate the parts which carry the high pressure current *at some distance from the switchboard in order that they may be operated with safety.*

They may be operated either by hand or by power. Electricity or compressed being used for power control.

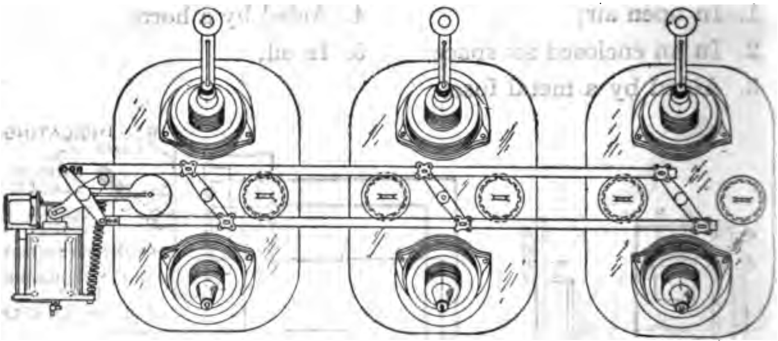


Fig. 6,730.—Pacific ***oil switch with solenoid control,*** designed for 60,000 and 70,000 volt installations; it is capable of handling a 25,000 kw. generating station. The break is horizontal, made by the rotation of a flat member edgewise through the oil. The solenoid, at its extreme outer position, has a free start before commencing to move the control parts of the switch. As it approaches the extreme inner position, where the opening spring and the contacts begin to offer the greatest resistance, the magnetic action is, of course, most powerful, and the leverage by which it is applied moves to an increasing radius, by means of rollers working in the curved slots of the control shaft levers.

2. *Current and Pressure Limiting Devices*

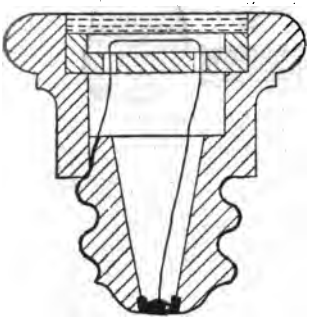
The importance of current and pressure limiting devices is to *protect circuits from overheating due to abnormal current.*

Fuses.—A fuse is "an electrical safety valve," or ***wire or strip of metal in a cut out, which may be fused by an excessive current.***

NOTE.—Oil switches are often used on systems with generator capacity of many thousand kilowatts. It is therefore essential that the switches shall be able to break not only their normal current, but also greatly increased current that would flow if a short circuit or partial short circuit occur.

For large currents, circuit breakers should be used in place of fuses.

Current Limiting Inductances.—These are sometimes called *reactances*, and are used *to protect alternators from high*



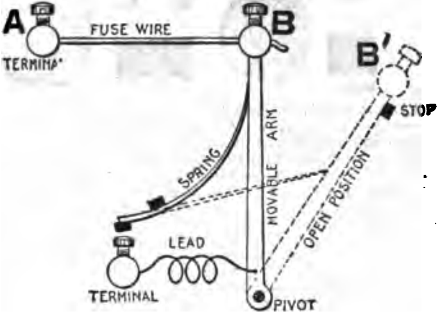


Fig. 6,731.—Plug fuse. It is placed in circuit by screwing it into a socket.

Fig. 6,732.—Quick break fuse. The fuse wire is connected between the fixed terminal A and the movable arm B, and is held under tension by the spring which exerts pressure on the movable arm in a direction tending to separate A and B. ***In operation,*** when the fuse blows, the movable arm quickly moves to the position B′, thus attenuating the arc and accelerating its extinguishment.

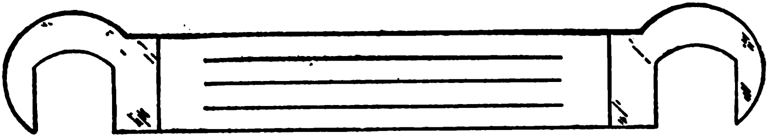


Fig. 6,733.—Notched end fuse. ***It consists of a strip of metal (or wire) fixed between two end pieces to fit around the terminals.*** This type is often proportioned so that it is only possible to place the correct size of fuse in the terminals.

Fig. 6,734.—Noark enclosed fuse ferrule. Two prongs O and V, which are a part of the knife blade K, pass through the square holes in the ends of the ferrule R, and are riveted to the anchor plate T. A vent screen prevents the escape of the granular material through vent holes A, but permits vapor to pass.

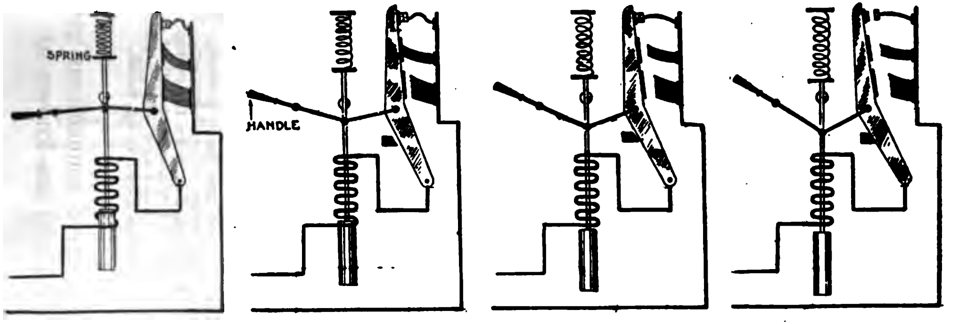
FIGS. 6,735 to 6,744.—General Electric instantaneous overload *circuit opening* relays, covers removed. Circuit opening relays are used chiefly in those cases where direct current for the tripping circuit is not available. Alternating current trip coils have relatively high impedance and impose a heavy volt ampere load on the current transformers. To reduce this load during normal operation the circuit opening relay is frequently used and is usually necessary where instruments and meters are to be operated on the same current transformers as the trip coils if the greatest accuracy be required. The relay contacts in the normal, closed position, short circuits the trip coil. When the relay operates on overload or other abnormal condition the contacts are opened with a quick break, sending the current through the trip coil circuit momentarily and tripping the switch. With circuit opening relays, the trip coils of the oil switch must be set to trip somewhat lower than the setting of the relay. *In construction* the relay consists of a solenoid with iron frame forming the support for the relay; a central plunger or armature of special construction which is picked up or released by the magnetic action of the solenoid; a plunger rod which actuates the relay contacts, which are mounted on an insulated base usually above the solenoid; a tube or plate for the calibration marking and adjustment; covers of glass or metal to keep out dust.

frequency surges coming in from the outside, and *to limit the current from other machines*.

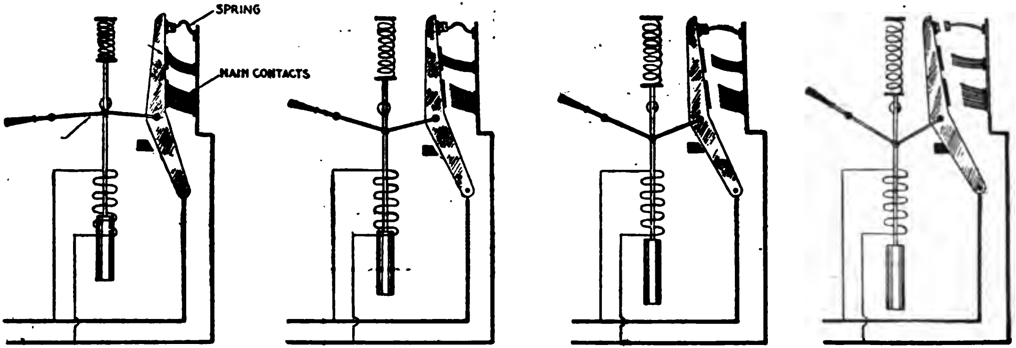
As usually constructed, a reactance consists of bare stranded cable wound around a concrete core and held in place by wooden supports.

Circuit Breakers.—By definition, a circuit breaker is *a device, which*

FIG. 6,745.—General Electric current limiting reactance.



FIGS. 6,746 to 6,749.—Elementary diagrams illustrating the operation of a carbon circuit breaker of the ***underload type,*** showing the progressive opening of such device. Fig. 2,250, closed position; fig. 2,251, main contacts open; fig. 2,252, intermediate contacts open; fig. 2,253, carbon contacts open, circuit broken.

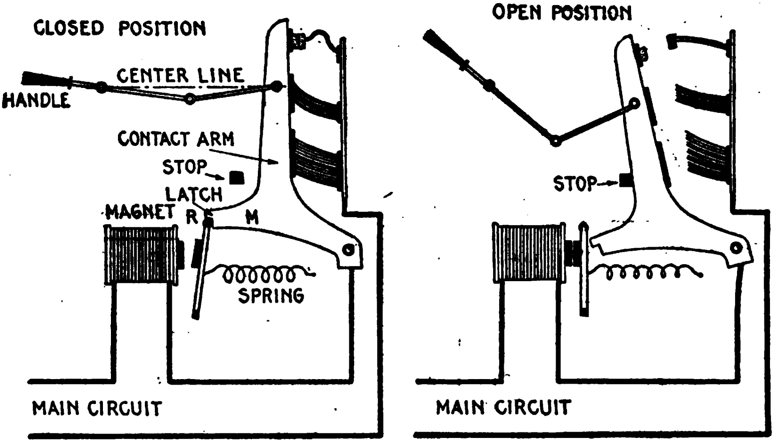


FIGS. 6,750 to 6,753.—Elementary diagrams illustrating the operation of a carbon circuit breaker of the ***low voltage type,*** showing the progressive opening of such device. Fig. 6,750, closed position; fig. 6,751, main contacts open; fig. 6,752, intermediate contacts open; fig. 6,753, carbon contacts open—circuit broken.

***automatically** opens the circuit in event of abnormal conditions, in the circuit.*

The arc may be broken: 1, by magnetic blow out, 2, by thermal break, or 3, by carbon break. In the carbon break the arc is progressively broken through: 1, main contacts, 2, intermediate contacts, and 3, carbon contacts.

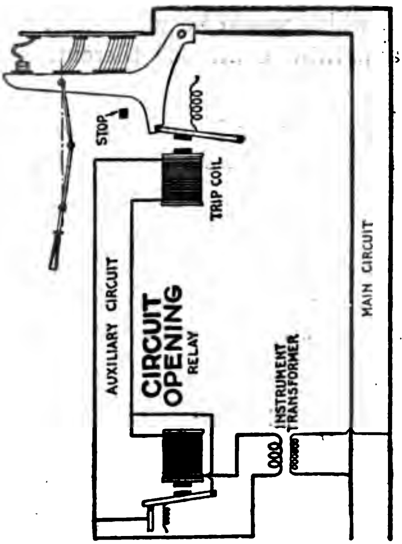
Automatic Control of Circuit Breakers.—This is secured *by the use of solenoids or trip coils*. These coils may be wound in series or in shunt with the main circuit, or in shunt with an auxiliary circuit.



Figs. 6,754 and 6,755.—Elementary circuit breaker with magnet and latch control. The toggle gives sufficient leverage to easily close switch against pressure of brush contact. The roller R, engages latch arm M, and reduces friction. ***In operation,*** when the current exceeds a pre-determined limit, the magnet attracts the latch and releases the contact arm. The brush contacts which are exerting pressure against the contact arm, rapidly push it away, and assisted by gravity, the arm flies open to the position shown in fig. 6,755.

The automatic controls arising from these connections give various kinds of protection to the circuit and are known as

1. Overload trip;
2. Underload trip;
3. Low voltage trip;
4. Auxiliary circuit trip.



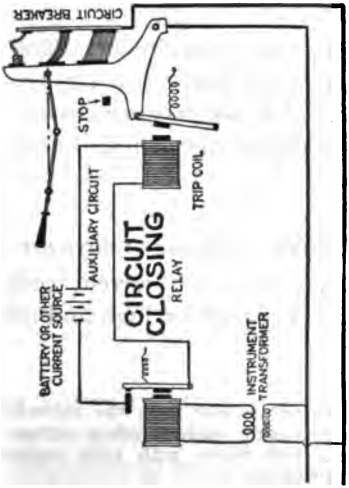


Fig. 6,756.—Elementary *circuit closing* relay. When the predetermined abnormal condition is reached in the main circuit, the relay closes the auxiliary circuit, thus energizing the trip coil and opening the breaker.

Fig. 6,757.—Elementary *circuit opening* relay. With relay contact closed, as shown, the coil is short circuited. *In operation,* when the predetermined abnormal condition is reached in the main circuit, the relay contacts are opened with a quick break, sending the current through the trip coil momentarily, and opening the breaker.

Relays.—By definition a relay is *a device which* **opens** *or* **closes** *an* **auxiliary circuit** *under pre-determined electrical conditions in the main circuit.*

The object of a relay is generally to act as a sort of electrical multiplier, that is to say, *it enables a comparatively weak current to bring into operation a much stronger current.*

There are numerous types of relay the features of which are here briefly given.

Protective Relays.—These are used ***to protect*** *circuits from abnormal*

NOTE.—Oil break switches and carbon break circuit breakers are commonly used to open electrical circuits at some given overload and on short circuit. To secure additional protection under a variety of abnormal condition or to provide for a certain pre-determined operation or sequence of operations, relays may be employed.

conditions of voltage, or current, which would be undesirable or dangerous to the circuit and apparatus contained therein.

Regulative Relays.—This class of relay is used ***to control** the condition of a main circuit through control devices operated by a secondary circuit.*

Communicative Relays.—These are used *for signalling in a great variety of ways* ***to indicate*** *the position of switching apparatus or* ***pre-determining*** *the condition of electric circuits.*

Circuit Opening Relays.—The duty of a circuit opening relay is *to open the* ***auxiliary circuit,*** *usually alternating current is used, and thereby cause the oil switch or circuit breaker to be opened by the use of a trip coil in the secondary of a current transformer, or* by *low voltage release coil.*

Circuit Closing Relays.—The duty of a circuit closing relay is ***to close*** *the auxiliary circuit at the time when the pre-determined abnormal condition is reached in the primary circuit.* The closing of the auxiliary circuit energizes the trip coil and opens the breaker.

Primary and Secondary Relays.—Primary relays are sometimes called series, relays as they have the current coils connected directly in series with the line, both on high and low tension circuits.

Secondary relays receive their current supply from the secondary circuits of current transformers. Alternating current relays connected to secondary of pressure transformers and relays with both current and pressure windings are included in this class.

Overload Relays.—Series relays are connected directly in series with the line and are chiefly used with high pressure oil break switches *for overload protection*.

If current transformers are to be used on the same circuits for other purposes, and have sufficient capacity to admit of adding a relay coil, secondary relays would be more economical; otherwise, the series relays are less expensive.

By means of a specially treated wooden rod, the relay operates a tripping switch, closing a separate tripping circuit, usually 125 or 250 volts direct current. Series relays are essentially the same as secondary relays except in the coil winding and insulation.

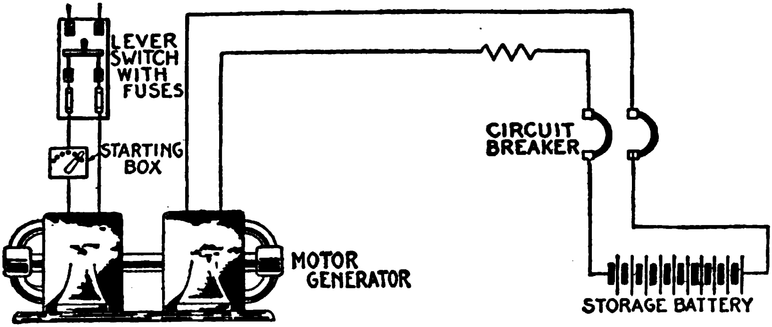


FIG. 6,758.—Diagram showing *storage battery and charging dynamo protected by* **double pole single coil underload circuit breaker.** ***In operation,*** the *circuit breaker disconnects the battery when fully charged, and protects the dynamo from reverse current.*

Underload Relays.—These are similar in construction to low voltage relays but have current instead of pressure windings.

Over Voltage Relays.—These are usually of the circuit closing type and are similar to secondary overload relays, but have pressure instead of current windings.

Low Voltage Relays.—Relays of this class are in most cases used for *the* **protection** *of motors in the event of a temporary weakening or failure of the pressure.*

They are also used in connection with a low voltage release or shunt trip coil on an oil switch or a circuit breaker.

Reverse Energy Relays.—The chief object of this species of relay is *to* ***protect*** *the generator.*

When so used, the overload adjustment is set at the maximum value to give overload protection only at the maximum carrying capacity of the generator and a sensitive reverse protection to prevent a return of energy from the line.

Reverse Phase Relays.—This type of relay is used chiefly *to* ***prevent*** *damage in case of reversal of leads in re-connecting wiring to two or three phase motors.*

Differential Relays.—In this type there are two electromagnets. In normal working these oppose and neutralize each other. Should, however, either winding become stronger or weaker than the other, the balance is upset, the magnet energized, and the relay comes into operation.

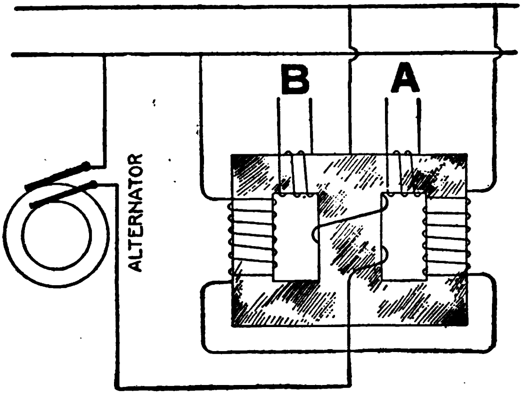


FIG. 6,759.— Elementary differential relay transformer for reverse current circuit breaker or discriminating cut out. The windings oppose each other, should either winding become stronger or weaker than the other, the balance is upset, the magnet is energized, and the relay comes into operation. A modification of such a relay for alternating current is here shown.

Instantaneous Relays.—The so-called instantaneous relays operate almost instantly on the occurrence of the abnormal condition that they are to control.

Time Limit Relays.—Under this classification there are two sub-divisions: 1, definite time limit, 2, inverse time limit.

The definite time limit mechanism consists of an air dash pot, and an air diaphragm or equivalent retarding device connected to the contact mechanism.

The inverse time limit mechanism is attached directly to an air bellows and in operation tends to compress the bellows against the action of a specially constructed escape valve in the latter. Sometimes a damping magnet which acts on a disc or drum is used.

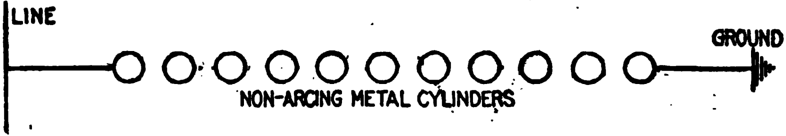


FIG. 6,760.—Non-arcing multigap arrester. Based on the principle of *employing for the terminals across which the arc is formed, such metals as are least capable of maintaining an alternating arc between them.* The action is such that the "line current" which follows the lightning discharge follows as an arc, but is stopped at the end of one alternation because of the property of the non-arcing metals to carry an arc in one direction, but requiring an extremely high voltage to start a reverse arc.

3. *Lightning Protection Devices*

The devices are ordinarily called *lightning arresters*. In operation *they provide a* **path** *by which the lightning disturbances or other static discharges may pass to the earth.*

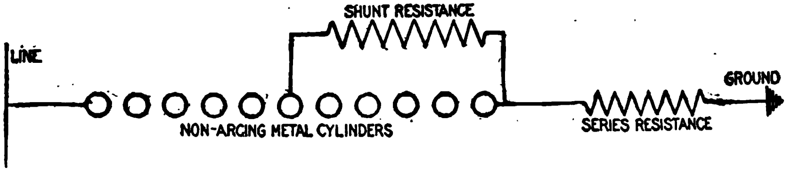


FIG. 6,761.—Low equivalent multigap arrester. About half of the total number of gaps are shunted by a resistance, and another resistance inserted between the cylinders and the earth. With this arrangement the middle point is at ground pressure, and there are between line and ground only one half of the total number of gaps. The introduction of synchronous motors made it necessary that the arc should be extinguished immediately, otherwise the synchronous motors and converters would drop out of step, and the system would in this way be shut down. To insure the breaking of the arc, the resistance was added as shown.

In general, the construction of lightning arresters comprises: 1, air gaps, 2, resistances, 3, inductances, 4, arc suppressing devices.

Air Gap Arresters.—A method of relieving any abnormal pressure condition is ***to connect*** *a discharge air gap* ***between*** *some point on an electric conductor and the ground.*

The resistance thus interposed between the ground and the conductor is such that any voltage very much in excess of the maximum normal will cause a discharge to ground, whereas at other times the conductor is ungrounded because of the air gap.

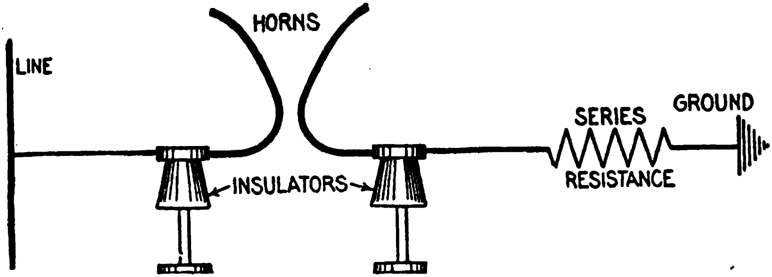


FIG. 6,762.—Horn gap arrester, diagram showing arrester and connections between line and ground. The horn type arrester was invented by Oelschlaeger for the Allgemeine Electricitaets Gesellschaft, and like the Thomson arc circuit arrester, ***its operation*** is based on the fact that *a short circuit once started at the base, the heat generated by the arc will cause it to travel upward until it becomes so attenuated that it is ruptured.* On circuits of high voltage this rupture sometimes takes a second or two, but seems to act with little disturbance of the line. ***Sometimes*** a *water resistance* is used, a *choke coil being* inserted in the circuit in series.

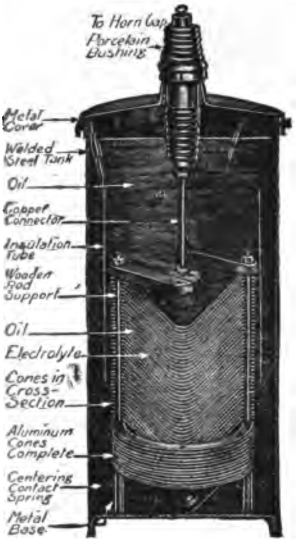
Multi-Gap Arresters.—These consist of *a number of cylinders spaced with a small air gap between them and placed between the line to be protected and the ground, or between line and line.*

In operation, the multi-gap arrester discharges at a much lower voltage than would a single gap having a length equal to the sum of the small gaps.

Horn Gap Arresters.—A horn gap arrester consists essentially of *two horn shaped terminals forming an air gap of variable length, one horn being connected to the line to be protected and the other to the ground usually through a series resistance.*

In operation, the arc, due to the line current which follows a discharge, rises between the diverging horns and becoming more and more attenuated is finally extinguished.

It is used as an emergency arrester on some overhead lines, to operate only when a shut down is unavoidable.



Electrolytic Arresters.—The action of these arresters *depends on the phenomenon that a non-conducting film is formed on the surface of aluminum when immersed in certain electrolytes*.

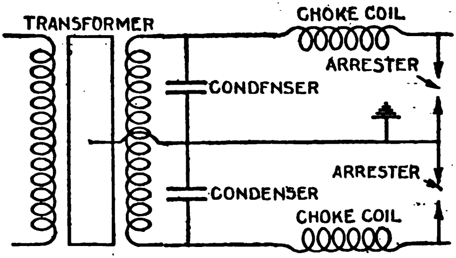
FIG. 6,763.—Cross section of General Electric aluminum ***electrolytic*** arrester. ***In principle,*** its operation depends on the phenomenon that *a non-conducting film is formed on the surface of aluminum when immersed in certain electrolytes*.

FIG. 6,764.—General Electric magnetic blow out arrester for line use. ***It consists*** **essentially of a small spark gap which is in series with a resistance and between the poles of a magnet. The spark gap and the magnet are mounted within procelain blocks in such a way that the discharge arc is blown by the magnet through an arc chute and a cooling grid which is also held by the porcelain.**

NOTE.—*Ground Connections.*—In all arrester installations good grounnd connetions are important. Instead of the customary ground plate, a better ground connection is made by driving a number of one inch iron pipes six or eight feet into the earth surrounding the station, connecting all these pipes together by means of a copper wire or, preferably, by a thin copper strip. A quantity of salt should be placed around each pipe at the surface of the ground and the ground thoroughly moistened with water.

If the film be exposed to a higher pressure, it may be punctured by many minute holes, thus so reducing its resistance that a large current may pass. When the pressure is again reduced, the holes become resealed and the film again effective.

Choke Coils.—Because of its property of self-induction, a choke coil will offer *a relatively high resistance to the passage of lightning and at the same time allow free passage to all ordinary electric currents.*



FIGS. 6,765 and 6,766.—General Electric choke coils. Fig. 6,765, low pressure coil, 6,600 volts; fig. 6,766, low voltage choke coil, 4,600 volts.

FIG. 6,767.—Diagram showing connections of static interrupter for protecting a transformer.

"Static" Interrupters.—A static interrupter is a *combination of a choke coil and a condenser*, the two being mounted together and placed in a tank and oil insulated.

It is used on high pressure circuits and its function is to so delay the erroneously called "static" wave in its entry into the transformer coil, that a considerable portion of the latter will become charged before the terminal will have reached full pressure.

4. Regulating Devices

Regulation of Alternators.—Practically all the methods employed for regulating the voltage of dynamos and *d.c.* circuits, are applicable to alternators and *a.c.* circuits.

For example, in order that they shall automatically maintain a constant or rising voltage with increase of load, alternators are provided with composite winding similar to the compound winding of dynamos, but since the *a.c.* cannot be used directly for exciting the field magnets, an accessory apparatus is required to rectify it or change it into *d.c.* before it is used for that purpose.

It is a fact, however, that composite wound alternators do not regulate properly for inductive as well as non-inductive loads.

In order to overcome this defect compensated field alternators have been designed which automatically adjust the voltage for all variations of load and lag.

A. C. Feeder Regulation.—With slight modification, the various methods of feeder regulation employed with *d.c.*, may be applied to *a.c.* distribution circuits.

For instance, if a non-inductive resistance be introduced in any electric circuit, the consequent drop in voltage will be equal to the current multiplied by the resistance. Therefore, feeder

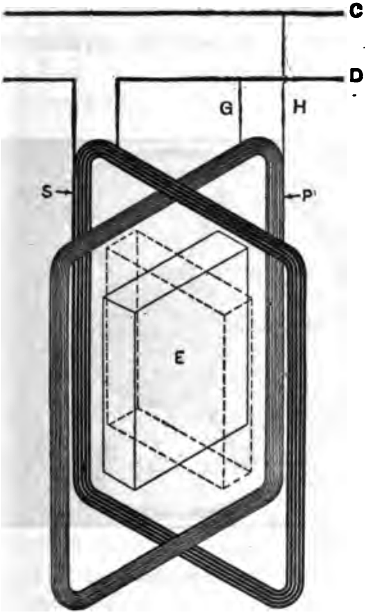


Fig. 6,768.—Diagram *illustrating the principle of induction voltage regulators. The primary coil* P, *consisting of many turns of fine wire*, is connected across the main conductors C and D, coming from the alternator. *The secondary coil* S, *consisting of a few turns of heavy wire*, is connected in series with the conductor D. The laminated iron core E, mounted within the coils, is capable of being turned into the position shown by the dotted lines. When the core is in plane of P, the magnetic lines of force produced in it by the primary coil, induces a pressure in the secondary coil which aids the voltage; when turned to the position indicated by the dotted lines, the direction of the magnetic lines of force are reversed with respect to the secondary coil and an opposing pressure will be produced therein. Thus, by turning the core, the pressure difference between the line wires G and H, can be varied so as to be higher or lower than that of the main conductors C and D. Regulators operating on this principle may be used for *theatre dimmers*, as controllers for series lighting, and also to adjust the voltage or the branches of unbalanced three wire single phase and polyphase systems.

regulation by means of rheostats is practically the same in the case of *a.c.* as in that of *d.c.* In the case of the former, however, the effect of self-induction may also be utilized to produce a drop in voltage. In practice, this is accomplished by the use of self-induction coils which are commonly known as reactance coils.

Application of Induction Type Regulators.—In supplying lighting systems, where the load and consequently the pressure drop in the line increases or decreases, *it becomes necessary to raise or lower the voltage of an a.c., in order to regulate the voltage delivered at the distant ends of the system.*

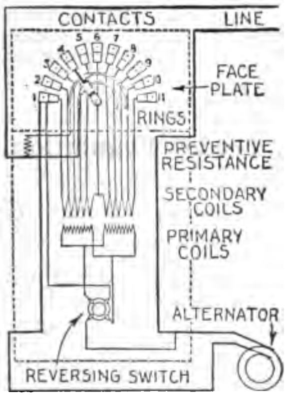


Fig. 6,769.—Diagram showing connections of Stillwell regulator.

Fig. 6,770.—Dial of Westinghouse dial type variable ratio voltage regulator.

This is usually accomplished by means of *a.c. regulators or induction regulators.* A devise of this kind is essentially a transformer, the primary of which is excited by being connected directly across the circuit, while the secondary is in series with the circuit as shown in fig. 6,768. By this method the circuit receives the voltage generated in the secondary.

There are two kinds of pressure regulator: 1, induction regulator, and 2, variable ratio transformer.

Induction Voltage Regulator.—It consists of a *primary*

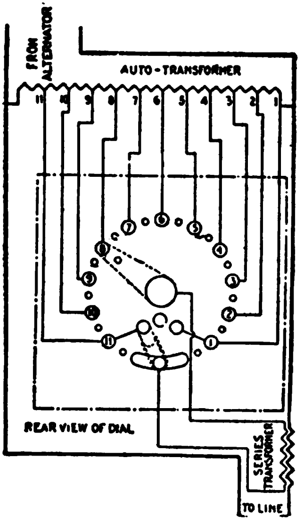


FIG. 6,771.—Diagram of connections for Westinghouse ***11 point dial, series transformer and auto-transformer.*** The auto-transformer has a number of taps connected across the line, the series transformer is placed in series with one side of the line, and connected to a dial, as shown.

winding or exciting coil, and a secondary winding which carries the entire load current.

The primary is wound for the full transmission voltage, and is connected across the line, while the secondary is connected in series with the line.

In operation, when the primary coil is turned to various positions, the magnetic flux sent through the secondary coil varies in value, thereby causing corresponding variation in the secondary voltage, the character of which depends upon the value and direction of the flux.

Induction regulators are operated by hand or automatically by means of a small motor controlled by voltage regulating relays. Two relays are used because a primary relay of sufficient accuracy could not be made powerful enough to carry the relatively large current required for operating the motor.

Variable Ratio Transformer Voltage Regulators.—The principle of operation of this class of regulator is virtually the same as that of the induction type regulator; that is, both consist of regulating transformers, but ***in the variable ratio method*** *the primary or series coil is divided into a number of sections which may be successively cut in or out of the circuit to be regulated*, instead of varying the flux through the entire coil, as in the induction type.

There are two mechanical forms of variable ratio regulator: 1, drum type, and 2, dial type.

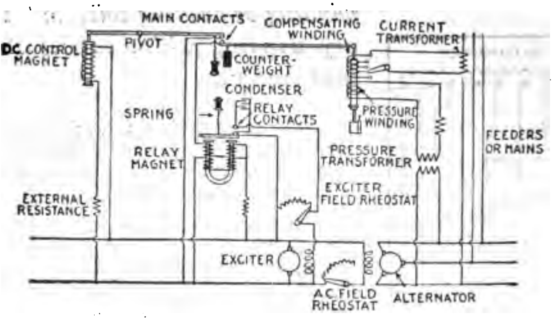
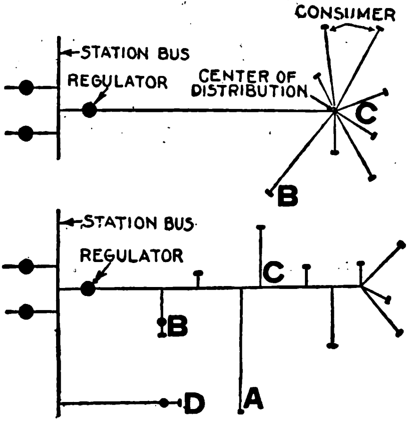
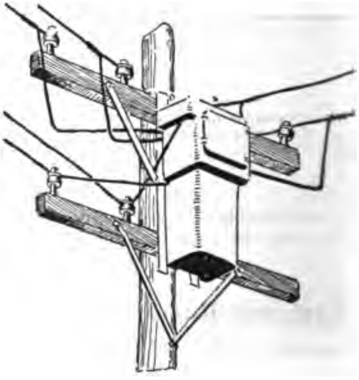


Fig. 6,772.—Diagram of General Electric automatic voltage regulator connections with alternator and exciter.





Figs. 6,773 and 6,774.—Systems of distribution illustrating use of ***small feeder*** or ***pole type voltage regulators.*** The drop is generally negligible except on long lines as, consumer B, fig. 6,773. In order to obtain perfect regulation at B, it would be necessary to install a separate regulator in that line, this regulator to be installed either at the center C, or preferably at B. In a great many cases the power distribution is not as ideal as indicated in fig. 6,773, but rather as shown in fig. 6,774, that is, the consumers are connected all along the feeder. In this case there is no definite center of distribution, and the automatic regulator installed in the station can be adjusted to give only approximately constant voltage at an imaginary center of distribution C; that is, the voltage cannot be held constant at any definite point during changes of load distribution. The majority of the consumers may, however, obtain sufficiently good voltage, while a few may have reason for criticism. To overcome this difficulty it is necessary either to increase the copper in the feeder or else to install small automatic regulators.

Fig. 6,775.—General Electric pole type regulator in service as installed on top of pole.

Small Feeder Voltage Regulators.—In some generating stations the voltage is maintained constant at the bus bars and the line drop compensated by automatically operated regulators connected in the main feeders.

It is possible in this way to obtain constant voltage at all loads at the various distribution centers; that is, at those points on the feeders where the lines of the majority of consumers are connected as shown in fig. 6,774.

It is evident, however, that, while the voltage at the center of distribution can be maintained constant, no account can be taken of the drop in the lines between this center and the consumers. This drop is, however, generally negligible.

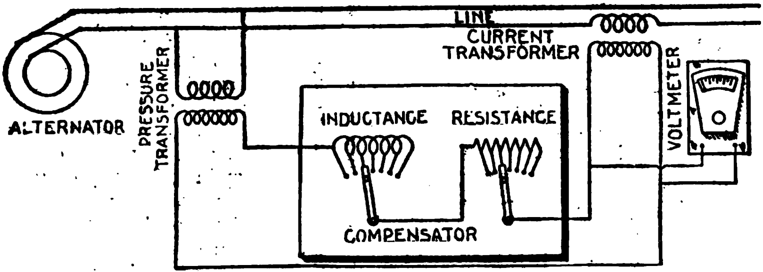
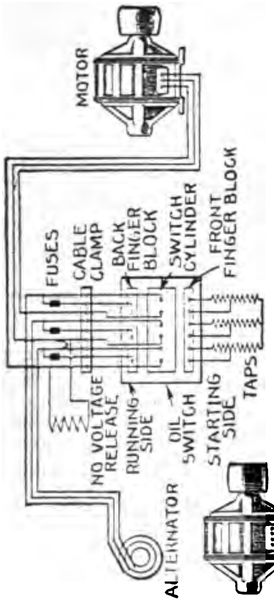


FIG. 6,775.—Diagram showing ***essential parts and connections for a line drop compensator. The compensator corrects the voltmeter indication at the supply end of a feeder for the ohmic and inductive drop in pressure between that point and the point of consumption,*** so that the reading of the station voltmeter corresponds with the actual voltage at the point of consumption, independent of the power factor and current. ***It is especially useful*** for adjusting pressure regulators.

Automatic Voltage Regulators for Alternators.—The accurate regulation of voltage on any *a.c.* system is of importance. The desired voltage may be maintained constant at the alternator terminals by rapidly opening and closing a shunt circuit across the exciter field rheostat.

Line Drop Compensators.—In order that the actual voltage at a distant point on a distribution system may be read at the station *some provision must be made to* **compensate** *for the line drop*, that is, for the difference in voltage between the alternator and the center of distribution.



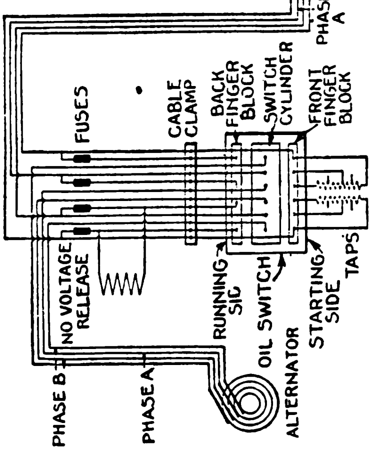


FIG. 6,776.—Diagram of connections of General Electric two phase starting compensator with no voltage release and fuses.

FIG. 6,777.—Diagram of connections of General Electric three phase starting compensator with low voltage release and fuses.

In order to do this a device known as a "line drop compensator" is placed in the volt meter circuit as shown in fig. 6,775.

The elements of the compensator are a variable resistance and a variable inductance. In manipulation, if the amount of inductance and resistance be properly adjusted, there will be produced a local circuit corresponding exactly in all its characteristics to the main circuit. Hence, any change in the main circuit produces a corresponding change in the local circuit, and causes the volt meter to always indicate the pressure at the end of the line or center of distribution or at any point for which the adjustment is made.

Starting Compensators.—These are used for starting induction motors and consist of *inductive windings* (*one for each phase*) *with a number of taps connecting with switch contacts* as shown in figs. 6,776 and 6,777.

A starting compensator is similar to a rheostat except that inductive windings are used in place of the resistance grids. Starting compensators are not necessary for small motors up to, say, 7 horse power.

Star Delta Switches.—These are starting switches, designed for use *with small three phase squirrel cage motors having their windings so arranged that they may be connected in star for starting and in delta for running.*

In starting the motor, the drum lever is thrown in the starting direction which connects the field windings of the motor **in star.** When the motor has accelerated and has come partially up to speed, the starting lever is quickly thrown to the running position in which position the field windings are connected **in delta.** The effect of connecting the field winding in star at starting is to reduce the voltage applied to each phase winding, while in the running position each phase of the field winding has full line voltage impressed upon it.

Synchronous Condensers.—A synchronous motor when sufficiently excited will produce a leading current, that is, when over excited it acts like a great condenser, and *when thus operated on circuits containing induction motors and similar apparatus for the purpose of improving the power factor it is called a synchronous condenser.*

The relation of power factor to the size and efficiency of prime movers, generators, conductors, etc., and the value of synchronous condensers for improving the power factor is generally recognized.

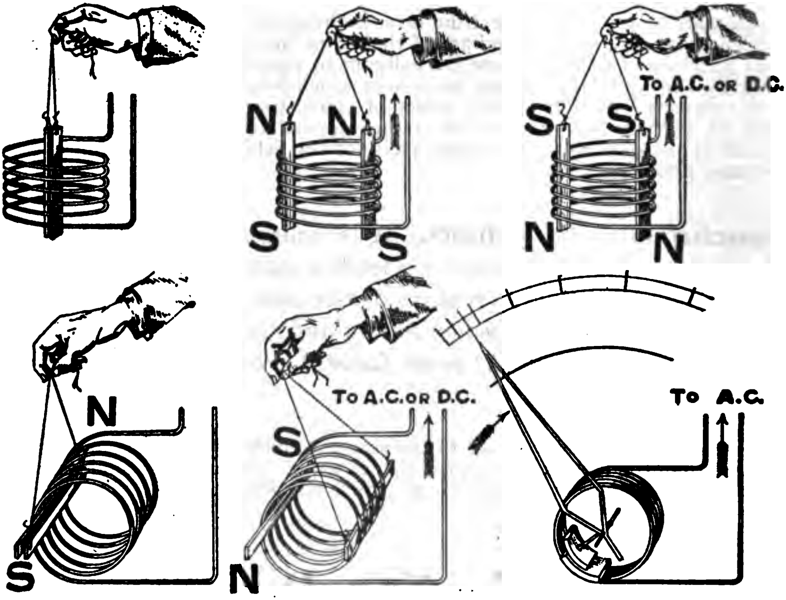
5. *Indicating Devices*

In the measurement of *a.c.*, it is not the average, or maximum value of the current wave that defines the current commercially, but the *square root of the mean square value*, because this gives the equivalent heating effect referred to direct current and it is the value that *a.c.* ammeters and voltmeters indicate.

There are several types of instrument for measuring *a.c.*, and they may be classified as

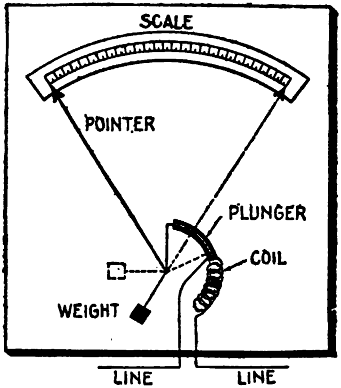
1. Electromagnetic (moving iron)
    - *a.* Plunger;
    - *b.* Inclined coil;
    - *c.* Magnetic vane.
2. Moving coil
3. Hot wire
    - *a.* Shielded pole;
    - *b.* Rotary field.
4. Induction

Electromagnetic or Moving Iron Instruments.—This



Figs. 6,778 to 6,783.—Principle of moving iron repulsion instruments. If direct current be sent through the two small pieces of iron suspended vertically within a solenoid by thread as in fig. 6,778, they will become magnetized and since they are in the same magnetic field both will be affected the same, and will repel each other as in fig. 6,779. If the current be sent through the solenoid in the opposite direction the result will be the same. Next if the coil be laid on its side and the two pieces of iron be placed within it horizontally as in fig. 6,781, one fixed and the other free to move and a current be passed through the solenoids the two pieces of iron will repel each other. If an *a. c.* be used instead of *d. c.* and it reverses with sufficient frequency, the polarity of the two pieces of iron will reverse in step with the current and they will repel each other as before. Hence on employing this principle in instrument construction two curved pieces of iron are used, one fixed and the other pivoted so that it will rotate when electrically repelled from the fixed iron as in fig. 6,783. A pointer attached to the movable iron moves over a graduated scale.

type of instrument depends for its action upon *the pull of flux in endeavoring to reduce the reluctance of its path.*



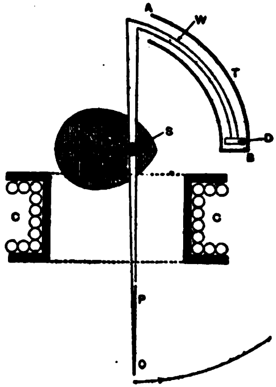
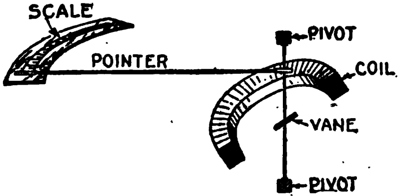


Fig. 6,784.—Plunger form of electromagnetic or moving iron type of ammeter. The plunger is so suspended that the magnetic pull due to the current flowing through the coil is balanced by gravity. For *a.c.* the plunger is laminated.

Fig. 6,785.—One form of ***plunger instrument*** as made by Siemens. *It has gravity control, is dead beat, and is shielded from external magnetic influence.* ***The moving system consists of*** a thin soft iron pear shaped plate pivoted on a horizontal spindle S, running in jewelled centers. To this spindle S, is also attached a light pointer P, and a light wire W, bent as shown, and carrying a light piston D, which works in a curved air tube T. This tube T, is closed at the end B, but is fully open at the other end A, and constitutes the air damping device for making the instrument dead beat.



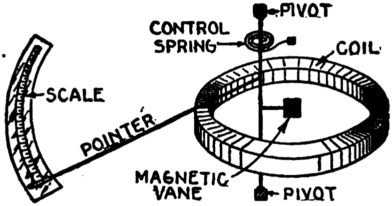


Fig. 6,786.—Inclined coil form of electromagnetic or moving iron instrument. ***In operation,*** when a current is passed through the coil, the iron tends to take up a position with its longest sides parallel to the lines of force, which results in the shaft being rotated and the pointer moved on the dial, the amount of movement depending upon the strength of the current in the coil.

Fig. 6,787.—Magnetic vane form of electromagnetic or moving iron instrument. ***In principle, a piece of soft iron placed in a magnetic field and free to move, will move into such position as to conduct the maximum number of lines of force.*** ***In operation,*** the vane will move against the restraining force of a spring so that the distance between it and the inner edge of the coil will be as small as possible.

This pull is proportional to the product of the flux and the current, and so long as no part of the magnetic circuit becomes saturated, the flux is proportional to the current, hence the pull is proportional to the square of the current to be measured.

Hot Wire Instruments.—In principle, these depend for their operation on *the expansion and contraction of a fine wire carrying either the current to be measured or a definite proportion of that current.*

The expansion or contraction of the wire is caused by temperature changes, which in turn are due to the heating effect of the current flowing

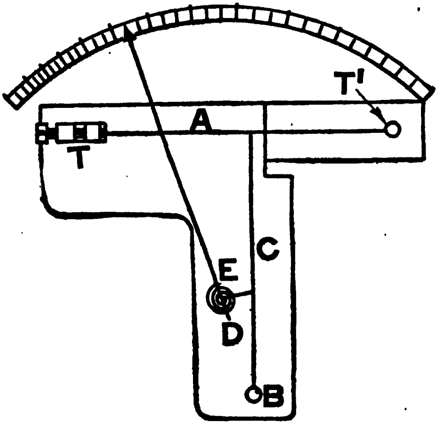
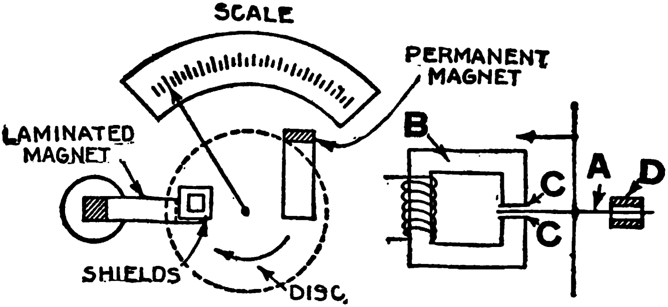


FIG. 6,788.—Hot wire instrument. A, is the active wire carrying the current to be measured and stretched between the terminals T and T'. It is pulled taut at its middle point by another wire C (fastened at B), which carries no current, and is, in its turn, kept tight by a thread passing round the pulley D, attached to the pointer spindle, the whole system being kept in tension by the spring E.

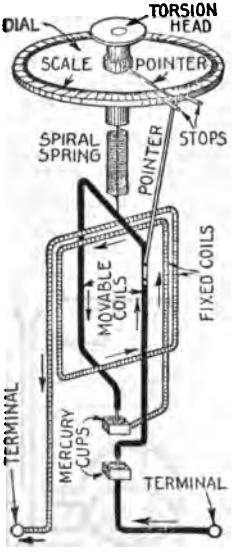


FIGS. 6,789 and 6,790.—Plan and elevation of shielded pole type of induction instrument. *It consists of* a disc A, or sometimes a drum and a laminated magnet B. Covering some two-thirds of the pole faces are two copper plates or shields C, and a permanent magnet D. *In operation,* eddy currents are induced in the two copper plates or shields C, which attract those in the disc, producing in consequence a torque in the direction shown by the arrow, against the opposing action of a spring. Magnet D, damps the oscillations.

through the wire. These variations are magnified by suitable multiplying gear.

Induction Instruments.—These were invented by Ferraris, and are sometimes called after him.

They are for alternating current only. The shielded pole type is shown in figs 6,789 and 6,790. In the rotary field type, the parts are arranged similar to those of wattmeters, the necessary split phase being produced



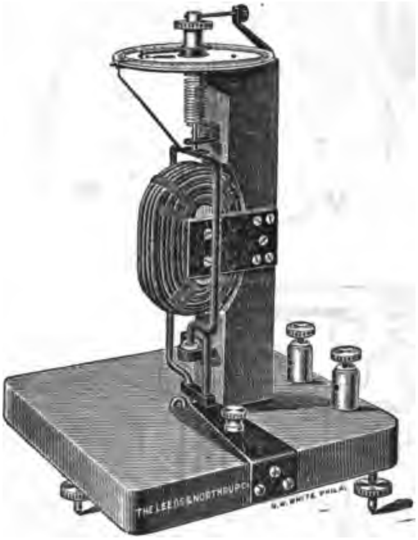


Fig. 6,791.—Diagram of Siemens' dynamometer. ***It consists of*** two coils on a common axis but set in planes at right angles to each other in such a way that a torque is produced between the two coils which measures the product of their currents. This torque is measured by twisting a spiral spring through a measured angle of such degree that the coils shall resume their original relative positions. ***When constructed as a voltmeter,*** both coils are wound with a large number of turns of fine wire, making the instrument sensitive to small currents. Then by connecting a high resistance in series with the instrument, it can be connected across the terminals of a circuit whose voltage is to be measured. ***When Constructed as a wattmeter,*** one coil is wound so as to carry the main current and the other made with many turns of fine wire of high resistance suitable for connecting across the circuit.

Fig. 6,792.—Leeds and Northrup ***electro-dynamometer.*** *It is a reliable instrument for the measurement of alternating currents of commercial frequencies.*

by dividing the current into two circuits, one inductive and the other non-inductive.

Dynamometers.—These are used to measure volts, amperes, or watts, and their operation depends on *the reaction between two coils when the current to be measured is passed through them.*

One of the coils is fixed and the other movable. The ends of the movable coil dip into

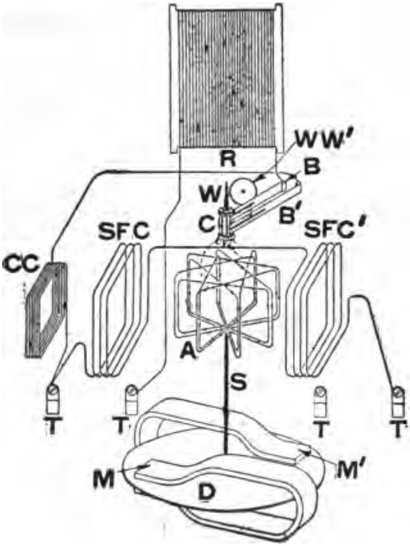


FIG. 6,793.—Internal connections of Thompson recording commutator type watt hour meter. ***The parts are:*** A, armature; BB', brushes; C, commutator; CC, friction compensation coil; D, disc; MM', drag magnets; R, resistance; S, shaft; SFC, SFC', series field coils; T, terminals; W, worm; WW', worm wheel.

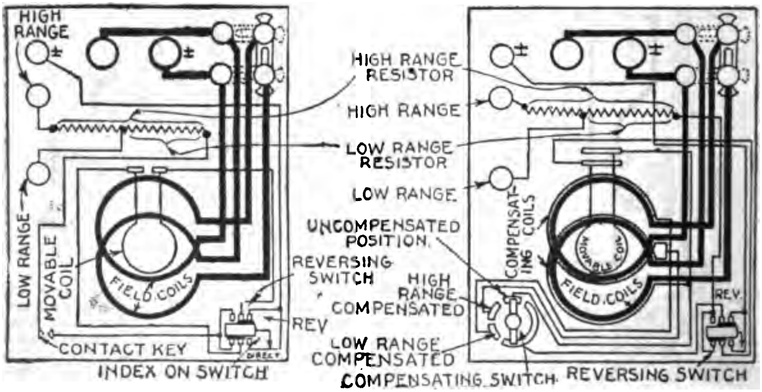


FIG. 6,794.—Internal connections of Weston 30 watt meter. When the links are in the position indicated by full lines the sections of the field are connected in series and the instrument is ready for use on the low current range. When the links are in the position indicated by dotted lines the sections of the field are connected in multiple and the instrument is ready for use on the high current range.

FIG. 6,795.—Internal connections of Weston low power factor watt meter.

mercury cups, which act as pivots and electrical contacts, making connection with one end of the fixed coil and one terminal of the instrument.

Watt Hour Meters.—A watt hour meter is a watt meter that will register the watt hours expended during an interval of time. *Watt hour meters are often erroneously called* ***recording*** *or* ***integrating*** *watt meters.*

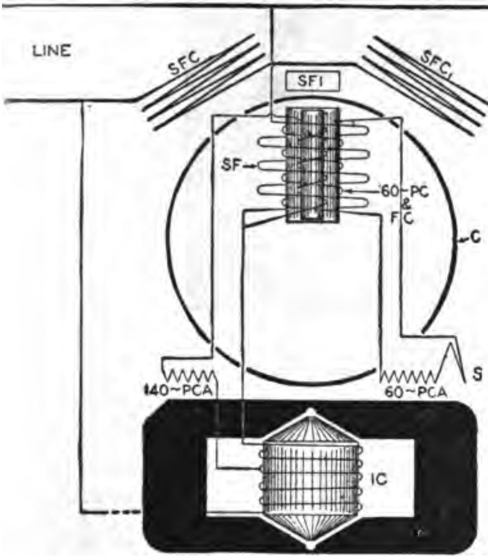
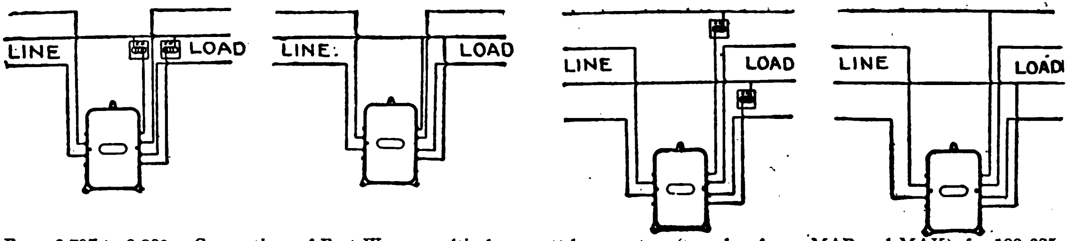


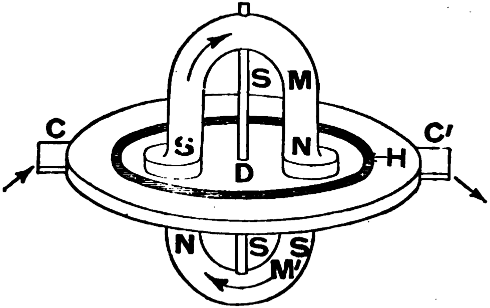
FIG. 6,796 —Diagram of Fort Wayne, induction watt hour meter. ***It is designed*** to register the energy of alternating current circuits regardless of the power factor, ***and embodies the usual induction motor, eddy current generator and registering mechanism.*** The electrical arrangement of the meter consists of ***a current circuit*** composed of two coils connected in series with each other and in series with the line to be measured, and ***a pressure circuit*** consisting of a reactance coil and a pressure coil connected in series with each other and across the line to be measured. In addition, the pressure circuit contains a light load coil wound over a laminated sheet steel member, adjustably arranged in the core of the pressure coil and connected across a small number of turns of the reactance coil so as to give a field substantially in phase with the impressed pressure. The light load winding is further provided with a series adjustable resistance furnished for the purpose of regulating the current flowing in the light load winding, thereby providing a means of lagging the meter on high frequencies, such as 125 or 140 cycle circuits. The pressure circuit also comprises a lag coil wound over the upper limb of the core of the pressure circuit and provided with an adjustable resistance for obtaining a field component in quadrature with the shunt field.

There are several types of the electromoter form of watt hour meter, which may be classified as: 1, commutator type; 2, induction type; 3, Faraday disc type. The essential parts of a watt hour meter are a motor, generator, and counting mechanism.

In operation, the motor runs at a speed proportional to the energy passing through the circuit, it drives the counting mechanism at the proper speed to indicate the amount of energy consumed. The generator furnishes the load for the motor. The meter is compensated, to correct the



Figs. 6,797 to 6,800.—Connections of Fort Wayne multi-phase watt hour meters (type k₃—forms MAB and MAK), for 100-625 volt circuits, 5-150 amperes. Fig. 6,797 two and three phase, three wire circuit, 25-36 cycles; fig. 6,798 two and three phase, 3 wire circuit, 36 cycles and above; fig. 6,799 two phase 4 wire circuit, 25-36 cycles; fig. 6,800 two phase, 4 wire circuit, 36 cycles and above.



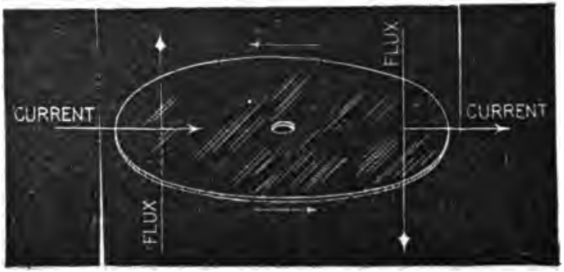
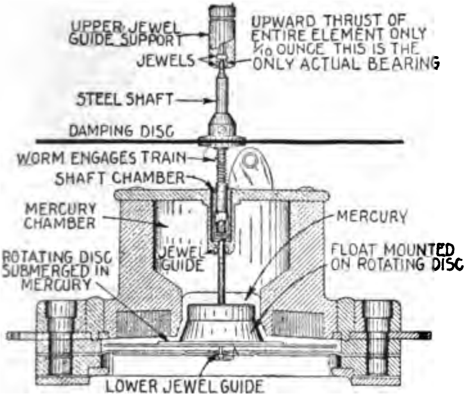


Fig. 6,801.—Faraday disc, or mercury motor ampere hour meter; view showing electric and magnetic circuits. The electric current enters the contact C, passes through the comparatively high resistance mercury H, to the edge of the low resistance copper disc D, across the disc to the mercury H, and out of contact C′. The magnetic flux cuts across the disc on each side from N, to S, making a complete circuit through M and M′. When connected to an eddy current damper or generator which requires a driving force directly proportional to the speed of rotation, the mercury motor generator becomes a meter.

Fig. 6,802.—Diagram showing relative direction of current, magnetic flux, and motion of disc in Faraday disc, or mercury motor ampere hour meter. According to the laws of electromagnetic induction, *if a current carrying conductor cut a magnetic field of flux at right angles, a force is exerted upon the conductor, tending to push it at right angles to both the current and the flux.*

error due to friction, by exacting an adjustable auxiliary field from the shunt or pressure circuit. The induction type of watt hour meter is the equivalent of a squirrel cage induction motor.

The moving element is a rotating disc which acts like the squirrel cage armature of an induction motor, developing the motive torque for the meter; it revolves through an air gap in which a rotating field is produced.



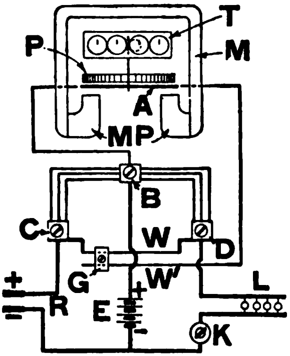
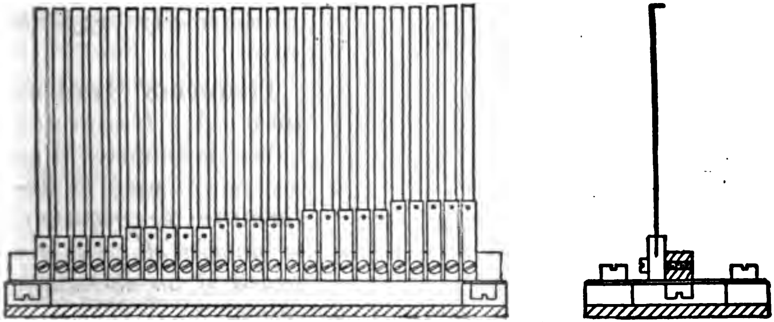


Fig. 6,803.—Sectional view of Faraday disc or mercury motor ampere hour meter as made by Sangamo Electric Co. The illustration does not show the magnets and indicating mechanism.

Fig. 6,804.—Circuit diagram of Sangamo *differential shunt type ampere hour meter for use in battery charging.*



Figs. 6,805 and 6,806.—Frahm resonance type frequency meter reeds. Owing to the principle employed in the meter it is evident that the indications are independent of the voltage, change of wave form, and external magnetic fields.

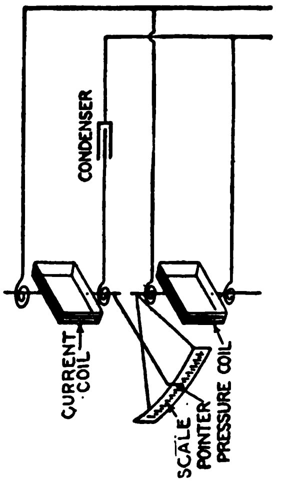


FIG. 6,807.—Langsdorf and Gegole induction type frequency meter. *Its operation* is based on the fact that if an alternating pressure of E, volts be impressed on a condenser of capacity C, in farads, the current in amperes will be equal to $2\pi\sim EC$, provided the pressure be constant. For a discussion of this meter, see *Electrical Review*, vol. LVIII, page 114.

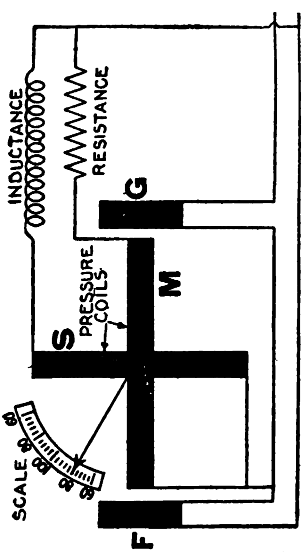


FIG. 6,808.—Single phase, disc or rotating field type power factor meter. *In construction*, the coils are placed about a common axis, along which is pivoted an iron disc or vane. The magnetizing coils FG, are in series with the load. *In operation*, if the load be very inductive, the coil M, experiences very little torque and the system will set itself as shown in the figure. As the load becomes less inductive, the torque on S, decreases and on M, increases so that the system takes up a particular position for every angle of lag or lead.

There is also a retarding disc in which eddy currents are induced in rotating through a constant field produced by permanent magnets.

The retarding disc may be the same disc used for the moving element, in which case the meter field acts on one edge while the permanent magnet field acts on the edge diametrically opposite. This arrangement simplifies the number of parts and saves space and weight of moving element.

The Faraday disc type, or mercury motor ampere horn meter consists essentially *of a copper disc floated in mercury between the poles of a magnet and provided with leads to and from the mercury at diametrically opposite points.*

Frequency Indicators.—A frequency indicator or meter is an instrument used ***to determine*** *the frequency, or number of cycles per second of an alternating current.*

There are several forms of frequency indicator, whose principle of operation differs, and according to which, they may be classed as: 1, synchronous type; 2, resonance type; and 3, induction type.

In the synchronous type *a small synchronous motor is connected in the circuit of the current whose frequency is to be measured.*

After determining the revolutions per minute by using a revolution counter, the frequency is easily calculated as follows:

frequency = (revolutions per second × number of pole) ÷ 2.

Fig. 6,809.—Westinghouse induction type frequency meter. The normal frequency is usually at the top of the scale to facilitate reading. The damping disc moves in a magnetic field, thus damping by the method of eddy currents. The standard meters are designed for circuits of 100 volts nominal and can be used for voltages up to 125 volts. For higher voltages, transformers with nominal 100 volt secondary should be used.

The resonance type consists of *a pendulum, or reed, of given length, which responds to periodic forces having the same natural period as itself.*

The instrument comprises a number of reeds of different lengths, mounted in a row, and all simultaneously subjected to the oscillatory attraction of an electromagnet excited by the supply current that is being measured. The reed, which has the same natural time period as the current will vibrate, while the others will remain practically at rest.

Fig. 6,810.—Westinghouse rotary type of synchroscope or synchronism indicator. The indication is by means of a pointer which assumes at every instant a position corresponding to the phase angle between the pressures of the bus bars and the incoming machine, and therefore rotates when the incoming machine is not in synchronism. The direction of rotation indicates whether the machine be fast or slow, and the speed of rotation depends on the difference in frequency. The pointer is continuously visible, during both the dark and light periods of the synchronizing lamps.

This type is desirable for laboratory use.

The induction type consists of *two voltmeter electro-magnets acting in opposition on a disc attached to the pointer shaft.*

One of the magnets is in series with an inductance, and the other with a resistance, so that any change in the frequency will unbalance the forces acting on the shaft and cause the pointer to assume a new position, when the forces are again balanced. The aluminum disc is so arranged that when the shaft turns in one direction, the torque of the magnet tending to rotate it decreases, while the torque of the other magnet increases. The pointer therefore comes to rest where the torques of the two magnets are equal, the pointer indicating the frequency on the scale.

Synchronism Indicators.—These devices, sometimes called synchroscopes, or synchronizers *indicate the exact difference in phase angle at every instant,* and the difference in frequency, between an incoming machine and the system to which it is to be connected, so that the coupling switch can be closed at the proper instant. There are several types of synchronizer, such as: 1, lamp or volt meter type; 2, resonance or vibrating reed type, and 3, rotating field type.

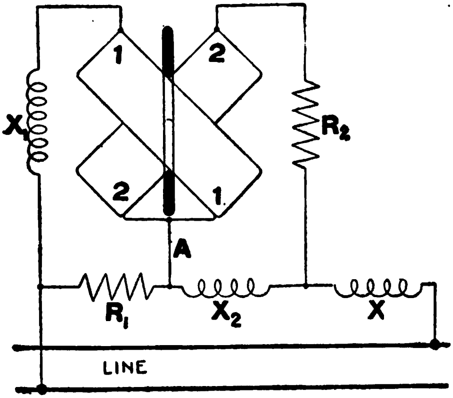


FIG. 6,811.—Diagram of Weston induction type frequency meter connections. The coils are connected in series across the line, with a reactor in series with one and a resistor in series with the other. A resistor is connected in parallel with one coil and the reactor, and a reactor is connected in parallel with the other coil and the resistor; then the whole combination is connected in series with a reactor, the purpose of which is to damp out the higher harmonics. The circuits, as shown, form a Wheatstone bridge, which is balanced at normal frequency. An increase in frequency will increase the reactance of the reactors and thus upset the balance of the bridge, allowing more current through one coil and less through the other.

The simplest arrangement consists of *a lamp or preferably* *a voltmeter connected across one pole of a two pole switch connecting the incoming machine to the bus bars, the other pole of the switch being already closed.*

If the machines be out of step, the lamps will fluctuate in brightness, or the voltmeter pointer will oscillate, the pulsation becoming less and less as the incoming machine approaches synchronous speed. Synchronism is shown by the lamp remaining out, or the voltmeter at zero.

The resonance type works on the same principle *as the resonance type of frequency meter already described.*

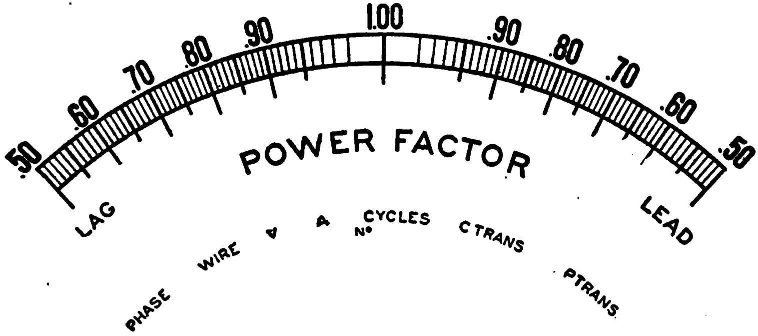
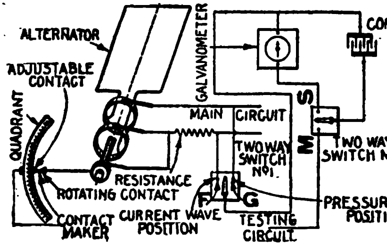


FIG. 6,812.—Weston power factor instrument scale. Range from .50 lagging to .5 leading. The scale divisions are open and very nearly uniform, except near unity power factor, where the instrument is extremely sensitive. A change in time phase angle of 5 degrees at unity power factor will produce a deflection of the pointer of .35 in.

The operation of the rotating field type depends on the production of a rotating field by the currents of the metered circuits in angularly placed coils, one for each phase in the case of a polyphase indicator. In this field is provided a movable iron vane or armature, magnetized by a stationary coil whose current is in phase with the voltage of one phase of the circuit. As the iron vane is attracted or repelled by the rotating field, it takes up a position where the zero of the rotating field occurs at the same instant as the zero of its own field.

In the single phase meter the positions of voltage and current coils are interchanged and the rotating field is produced by means of a split phase winding, connected to the voltage circuit.

Power Factor Indicators.—Meters of this class indicate the



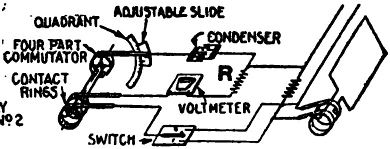
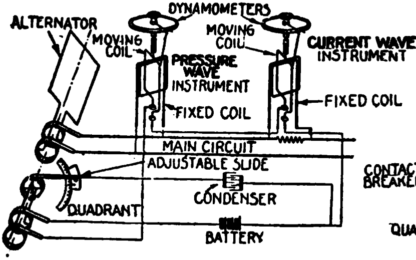


FIG. 6,813.- Joubert's *step by step method* of wave form measurement. For current wave measurement switch No. 1 is placed on contact F, and for pressure wave measurement on contact G, switch No. 2 is now turned to M, and the drop across the resistance (assuming switch No. 1 to be turned to contact F) measured by charging the condenser, and then discharging it through the galvanometer by turning the switch to S. This is repeated for a number of positions of the contact maker, noting each time the galvanometer reading and position of the contact maker. By plotting the positions of contact maker as abscissæ, and the galvanometer readings as ordinates, the curve through them will represent the wave form. The apparatus is calibrated by passing a known constant current through the resistance.

FIG. 6,814.—*Four part commutator method* of wave form measurement. The contact device consists of two slip rings and a four part commutator. One slip ring is connected to one terminal of the source, the other to the volt meter, and the commutator to the condenser. By adjusting R, when a known direct current pressure is impressed across the terminals, the volt meter can be rendered direct reading.



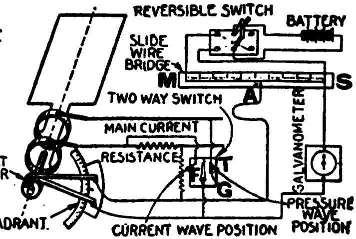


FIG. 6,815.—*Modified four part commutator method* of wave form measurement (Duncan's modification). By this method one contact maker can be used for any number of waves having the same frequency. Electro-dynamometers are used and the connections are made as here shown. The moving coils are connected in series to the contact maker, and the fixed coils are connected to the various sources to be investigated, then the deflection will be steady and by calibration with direct current can be made to read directly in volts.

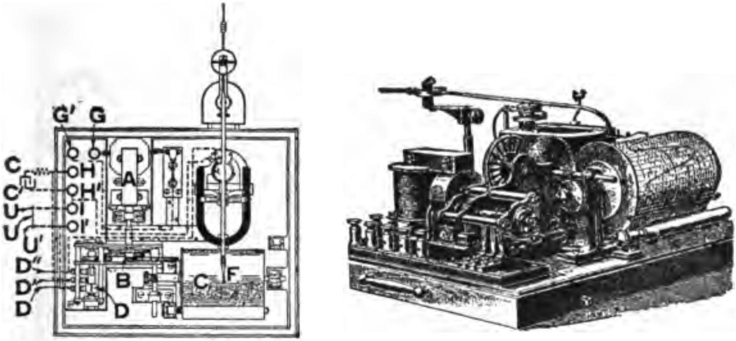
FIG. 6,816.—*Ballistic galvanometer method* of wave form measurement. *The test may be made* by placing the contact breaker in successive positions and taking galvanometer readings, the switch being turned to F in measuring the current wave, and to G in measuring the pressure wave. M S is the slide wire bridge and A the contact slider. If belt drive be used, and pulleys be of same size, paste a thin strip of paper around the face of one of the pulleys thus altering the velocity ratio of the drive slightly from unity.

phase relationship between pressure and current, and are therefore sometimes called *phase indicators*.

There are two types: 1, watt meter type; and 2, disc, or rotating field type.

In the wattmeter type, the phase relation between the pressure and the current fluxes is such that on a non-inductive load the torque is zero.

For instance, in a dynamometer wattmeter, the pressure circuit is made highly inductive and the instrument then indicates *volts* × *amperes* × *sin* ϕ instead of *volts* × *amperes* × *cos* ϕ, that is to say, it will indicate the wattless component of the power. A dynamometer of this type is sometimes called an idle current wattmeter.



Figs. 6,817 and 6,818.—Hospitalier ondograph. Fig. 6,817, mechanism and connections; fig. 6,818 exterior view. The instrument represents a development of Joubert's step by step method of wave form measurement. ***The principle*** on which its action is based consists in *automatically charging a condenser from each 100th wave, and discharging it through a recording galvanometer, each successive charge of the condenser being automatically taken from a point a little farther along the wave.* ***In construction,*** a synchronous motor A, is so connected by gears B, to a commutator D, that for *n* revolutions of the motor, the commutator makes *n*−1 revolutions. The commutator automatically charges condenser *cc*; from the line and discharges it through a galvanometer E, which indicates instantaneous current valves. HH' are meter terminal connected to condenser *cc'*, through a resistance; II', are connections to service to be measured. ***In operation,*** a long pivoted pointer carrying a pen and actuated by electro-magnets, records on a revolving drum a wave form representing the alternating current, pressure or current wave.

The disc, or rotating field type, consists of two pressure coils placed at right angles to each other, one being connected through a resistance, and the other through an inductance so as to "split" the phase and get the equivalent of a rotating magnetic field.

Ground Detectors.—Instruments of this name are used for detecting (and sometimes measuring) the leakage to earth through the insulation of a line or network and are sometimes called *ground or earth indicators*, *or leakage detectors*.

For low tension systems ***moving coil*** (*for alternating current*) or ***moving iron*** instruments (*for direct current*) are the most used, while for high tension systems electrostatic voltmeters are to be preferred.

Wave Form Indicators.—The various methods of wave form measurement may be classed as: 1, step by step; and 2, constantly recording, the latter being the more convenient method.

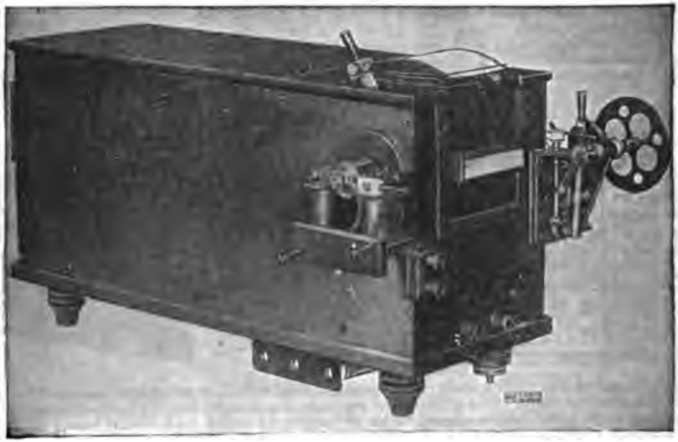
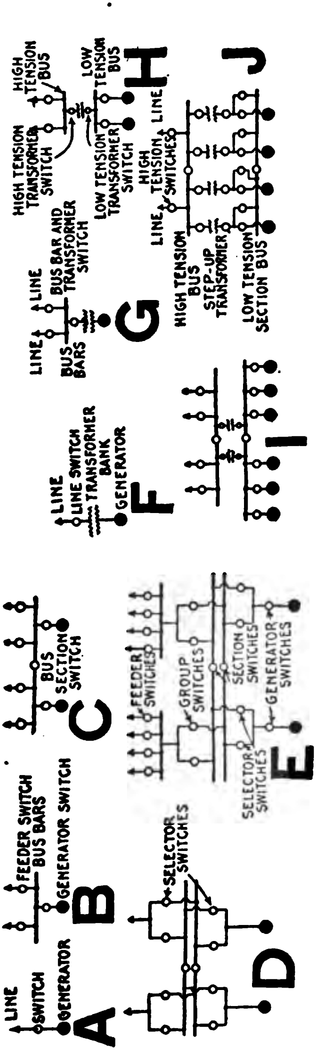


FIG. 6,819.—General Electric moving coil osallograph, ***the moving element consists of single loops of flat wire carrying a small mirror and held in tension by small spiral springs.*** The current passing down one side and up the other, forces one side forward and the other backward, thus causing the mirror to vibrate on a vertical axis. The vibrator elements fit into chambers between the poles of electro-magnets, and are adjustable, so as to move the beam from the mirror, both vertically and horizontally. A sensitized photographic film is wrapped around a drum and held by spring clamps. The drum, with film, is placed in a case and a cap then placed over the end, making the case light, when the index is either up or down. The loading is done in a dark room. A driving dog is screwed into the drum shaft and which, when the drum and case are in place revolves the film past a slot.

Switchboard Connection Principles.—The interconnection of generators, transformers, lines, bus bars, and switches with their relays, in modern switchboard practice is shown by the diagrams, figs. 6,820 to 6,829.



FIGS. 6,820 to 6,829.—Diagrams illustrating principles of switchboard connections. Diagram **A**, simplest form generator feeding directly into line. **B**, generator supplying two or more feeders through single set of bus bars requiring switch for each feeder and single generator switch. **C**, two generators and addition of bus section switch **D**, several generators supplying two independent circuits. **E**, standard connection for city street railway. **F**, simplest system with transformers. **G**, system with several lines. **H**, several generators connected to low tension bus bars through generator switches. **I**, system with many feeders supplied by several small generators. **J**, system with generator transformer unit.

The figures being lettered A, to J, for simplicity, the generators are indicated by black discs, and the switches by open circles, while each heavy line represents a set of bus bars consisting of two or more bus bars according to the system of distribution. It will be understood, also, in this connection, that the number of pole of the switches and the type of switch will depend upon the particular system of distribution employed.

Switchboard Panels.—The term "panel" means *the slab of marble or slate upon which is mounted the switches, and the indicating and controlling devices*.

There are usually several panels comprising switchboards of moderate or large size, these panels being classified according to the division of the system that they control, as for instance: 1, generator panel; 2, feeder panel; 3, regulator panel; etc.

In the care of a dynamo, the generator panel would have mounted upon it a reverse current circuit breaker, an ammeter, a double pole main switch (or perhaps a single pole switch, since the circuit breaker could also be used as a switch) a double pole socket into which a plug could be inserted to make connection with a voltmeter mounted on a swinging bracket at the end of the board; a rheostat handle, the spindle of which operates the shunt rheostat of the machine, the rheostat being placed either directly behind the spindle, if of small size, or lower down with chain drive from the hand wheel spindle, if of larger size, a field discharge switch and resistance, a lamp near the top of the panel for illuminating purposes, a fuse for the voltmeter socket, and, if desired, a watthour meter.

The indicating and control apparatus for a feeder circuit is assembled on a panel called the feeder panel.

The most common equipment in the case of a direct current feeder panel comprises an ammeter, a double pole switch, and double pole fuses or instead of the fuses, a circuit breaker on one or both poles; in the case of a traction feeder a choke coil and a lightning arrester are often added.

CHAPTER 107

Tests

Most tests are made with a galvanometer and other devices such as switches, resistance sets, etc.

Pressure Measurement.—*The* **total** *pressure of a circuit is independent of resistance or current*, hence in measuring pressure with an ordinary voltmeter, since the measurement is made on *closed circuit*, the reading gives **less** *than the total pressure*.

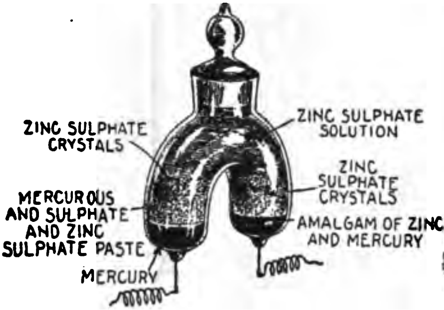
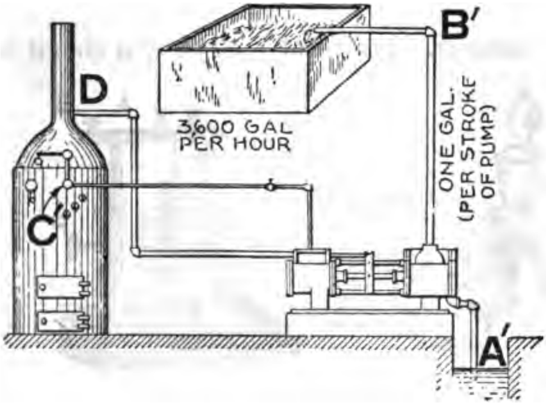


FIG. 6,830.—Clark cell, or standard for the *International volt.* The pressure is 1.434 volts at 15° C., decreasing .00115 volt for each increase of 1° C.

FIG. 6,831.—Queen weight voltameter for determining the strength of current by the weight of metal deposited in a given time. ***To calculate,*** the strength of an unknown current which has passed through a weight voltameter, *divide the gain in weight by the number of seconds the current flows through the instrument and by the weight deposited by one ampere in one second*. That is, current strength in amperes = gain in weight ÷ (time in seconds × .0003286).

The error is very slight because the resistance of the voltmeter is very high and the current so small that the loss of pressure in the battery can be neglected.

FIG. 6,832.—Standard resistance box: 100,000 ohms, in four units of 10,000, 20,000, 30,000, and 40,000 ohms. An "infinity" plug separates each coil from the ones adjacent. Segments are elevated from the hard rubber top by special washers in order to increase insulation. Binding posts are so arranged as not to be in the way when plugs are used.



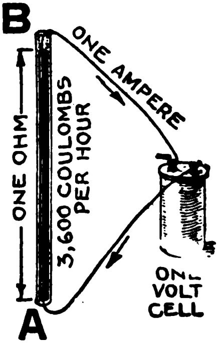
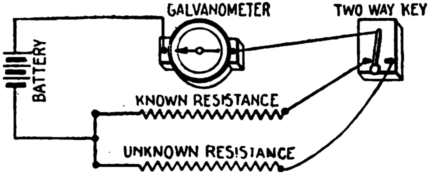


FIG. 6,833.—Diagram of steam pump showing hydraulic analogy illustrating the difference between amperes and coulombs. If the current strength in fig. 6,834 be one ampere, the quantity of electricity passing any point in the circuit per hour is 1 × 60 × 60 = 3,600 coulombs. The *rate* of current flow of one ampere here illustrated may be compared to the rate of discharge of a pump as in fig. 6,833. Assuming the pump to be of such size that it discharges a gallon per stroke and is making 60 strokes per minute, the quantity of water discharged per hour (coulombs in fig. 6,834) is 1 × 60 × 60 = 3,600 gallons. Following the analogy further (in fig. 6,834), the pressure of one volt is required to force the electricity through the resistance of one ohm between the terminals A and B. In fig. 6,833, the boiler must furnish steam pressure on the pump piston to overcome the friction (resistance) offered by the pipe and raise the water from the lower level A' to the higher level B'. The difference of pressure between A and B in the electric circuit corresponds to the difference of pressure between A' and B'. The cell furnishes the energy to move the current by maintaining a difference of pressure at its terminals C and D; similarly, the boiler furnishes energy to raise the water by maintaining a difference of pressure between the steam pipe C and exhaust pipe D'.

FIG. 6,834—The ***International ohm.*** By definition, ***the resistance of 14.452 grammes of mercury in the form of a column of uniform cross section 106.3 centimeters in length, at a temperature of 0° C.*** This is approximately equivalent to a column 106.3 *cm.* long, having a uniform cross section of 1 sq. mm. In the figure the resistance of the external circuit and the standard one volt cell is assumed to be zero.



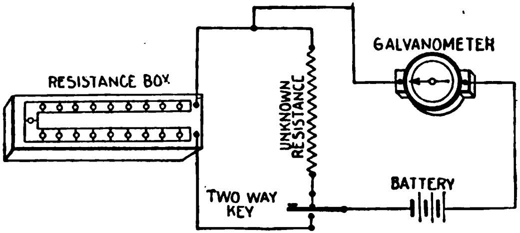
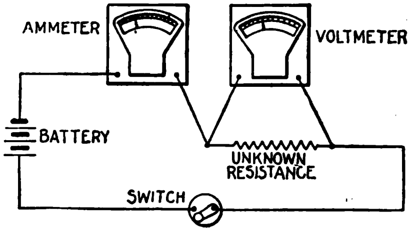


FIG. 6,835.—***Direct deflection method*** of testing resistances; a useful and simple method which may be used in numerous tests. Galvanometer readings are taken through the known, and unknown resistances, and the current being proportional to the deflections, the value of the unknown resistance is easily calculated.

FIG. 6,836.—***Substitution method*** of testing resistances. ***In testing,*** first note deflection with unknown resistance in circuit, then press key so that the current will pass through the resistance box, and adjust the resistance in the box so that the deflection of the galvanometer is about the same as with the unknown. Now switch from one circuit to the other, changing the resistance in the box until equal deflections are obtained. When this obtains, the resistance in the box is the same as the resistance being tested.



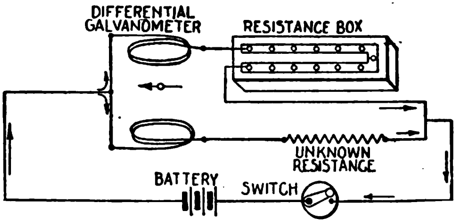
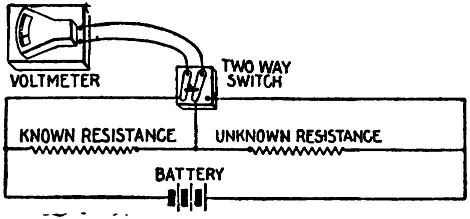


FIG. 6,837.—***Fall of potential method*** of testing resistances; a convenient method for testing at stations, requiring only the usual instruments to be found at a station. The resistance of the voltmeter must be very high.

FIG. 6,838.—***Differential galvanometer method*** of testing resistances. ***In making the test,*** the resistance box is adjusted till the galvanometer needle shows no deflection. When this condition obtains, the resistance in circuit in the resistance box is equal to the unknown resistance, hence, a reading of the box gives the value of the unknown resistance.



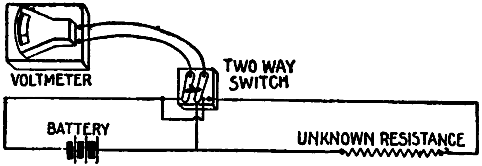
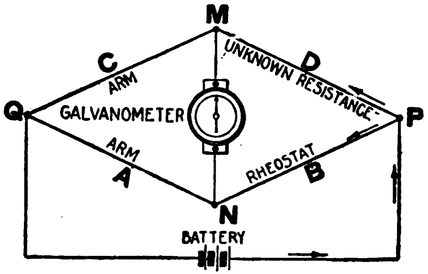


Fig. 6,839.—***Drop method*** **of testing resistances. The apparatus is connected as shown and readings taken with voltmeter across known and unknown resistance. The unknown resistance is then easily calculated.**

Fig. 6,840.—***Voltmeter method*** **of testing resistances.** Knowing the resistance of the voltmeter, turn switch to the left and from reading calculate resistance corresponding to one division of the scale. Turn switch to right and multiply reading by resistance required for deflection of one division. This gives resistance of voltmeter and unknown resistance; subtracting from this the resistance of voltmeter gives value of the unknown resistance.



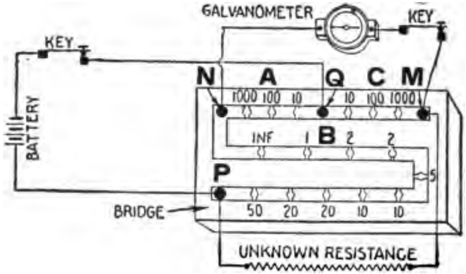
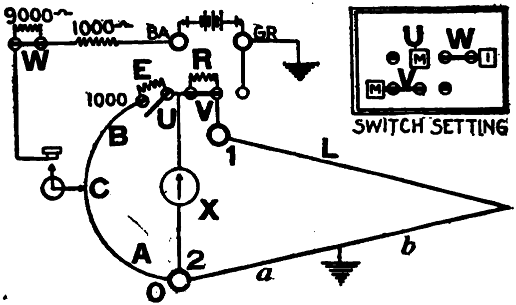


Fig. 6,841.—Diagram showing principle of ***Christie*** or ***so-called*** Wheatstone's bridge. A,B,C, and D, are the four members which constitute the bridge. The current from the battery divides at P, part traversing DC, and part transversing BA. The galvanometer, connected to M and N, will indicate when the currents are equal in the two branches by giving *no* deflection. This is then a *zero* or *nil method* of testing. The resistances and keys required in testing are arranged in fig. 6,842. In the actual instrument, the members A,B,C, and D are known by the names given in the figure.

Fig. 6,842.—Diagram showing usual arrangement of resistances in arms of Wheatstone's bridge. ***In practice,*** the bridge is seldom or never made in the lozenge shape of the diagram, fig. 6,841, this diagram being given merely for clearness. The resistance box of fig. 6,842 is, in itself, a complete "bridge," the appropriate connections being made by screws at various points. The letters in the above diagram correspond with those in fig. 6,841 and the three figures should be carefully compared.

Current Measurement.—The unit of current, called the *ampere*, is defined as *the unvarying current which, when passed through a solution of nitrate of silver in water* (15 *per cent. by weight of the nitrate) deposits silver at the rate of* .001118 *gramme per second.*

This chemical decomposition is measured by an electrolytic cell called a *voltameter*.



FIGS. 6,843 and 6,844—Murray loop method of fault location with leeds and Northrup fault finder, *Case 1*.—When there are two wires having equal resistance, in one of which there is a fault. Connect and set switches as shown; join the good wire to post 1 and the faulty wire to post 2. The resistance of E, is equal to that of AB. From the symmetry of the arrangement, it is evident that, if the fault were exactly at the junction between the good and bad wires, the contact point C, would rest for a balance at 1,000 on the scale, or at 500 if the fault were half-way along the bad wire; hence, at whatever point it comes to rest, the reading divided by 1,000 and multiplied by the length of the bad wire is the distance from the instrument to the fault.

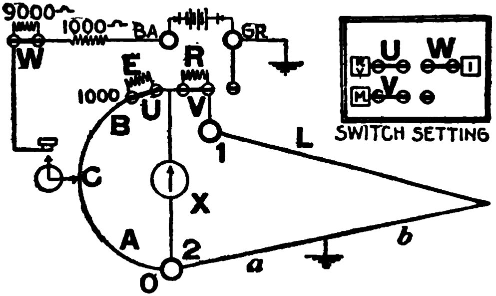
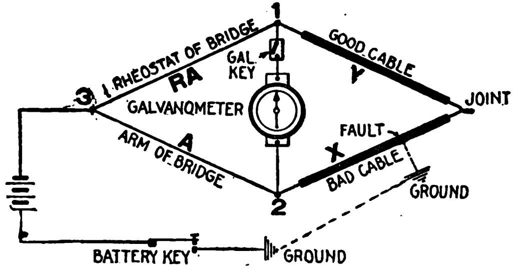


FIG. 6,845 and 6,846.—Murray loop method of fault location with Leeds and Northrup fault finder: *Case 2*.—Where the good and bad wires are unequal. The figure shows the connections. It is the ordinary Murray loop and it is evident that the resistance v, to the fault will be obtained from the formula $a-(A+1{,}000)$ X r, where r, is the resistance of the loop, and A, is the reading of the contact C, on its scale. The distance d, to the fault is obtained from the formula d^2Ar + (1,000 X M) where M is the resistance per mile of the faulty wire.



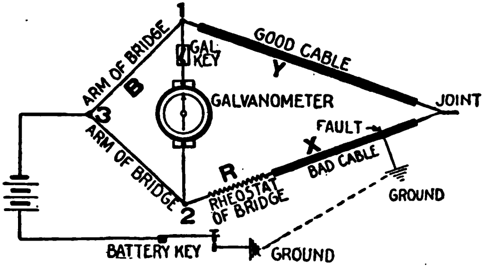
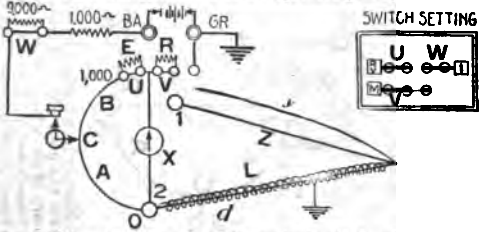
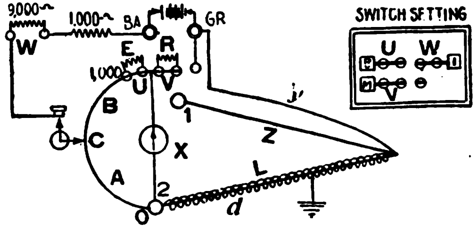


Fig. 6,847.—The Murray loop test. The apparatus is connected as in the figure. The rheostat of the bridge is used in place of the second arm to permit large adjustment. X and Y, are the resistances of the cable between the fault and the points 1 and 2 respectively.

Fig. 6,848.—The Varley loop test. The diagram shows the various connections. X and Y, are the resistances of the cable between the fault and the points 1 and 2 respectively. L, is the resistance of the good and bad cable or X+Y.





Figs. 6,849 and 6,850.—Special loop test with Leeds and Northrup fault finder. For the first measurement connect the faulty wire to 2, either of the good wires, as Z, to 1, the post Gr, to ground, and short circuit the coils R and E, by closing switches U and V, as in the figures. Balance in the usual way and call the dial reading A. For the second measurement, connect the post Gr, (disconnected from ground), to the other good wire y as shown in figs. 6,851 and 6,852, and get another balance; call this reading A′. The distance *d*, to the fault is determined from the simple formula $d = AL \div A'$ where L, is the length of the cable or faulty wire.

Figs. 6,851 and 6,852.—Special loop test as made with the Leeds and Northrup fault finder. Diagram showing connections for the second measurement. The special loop test may be used to advantage where the length of the cable or faulty wire only is known, and where there are two other wires which may be used to complete the loop. To use an outside battery, connect one pole to Ba, and ground the other. The pressure of this battery must never exceed 110 volts; if it be over 25 volts, see that switch W, is open.

Resistance Measurement.—Ohm's law shows that the strength of the current falls off in proportion as the resistance in the circuit increases.

This gives a basis for measuring resistance. There are various methods by which an unknown resistance may be measured, as by the: 1, direct deflection method; 2, method of substitution; 3, fall of potential method; 4, differential galvanometer method; 5, drop method; 6, voltmeter method; 7, wheatstone bridge method.

Christie Bridge.—For accurate measurements of resistance this method is almost universally used.

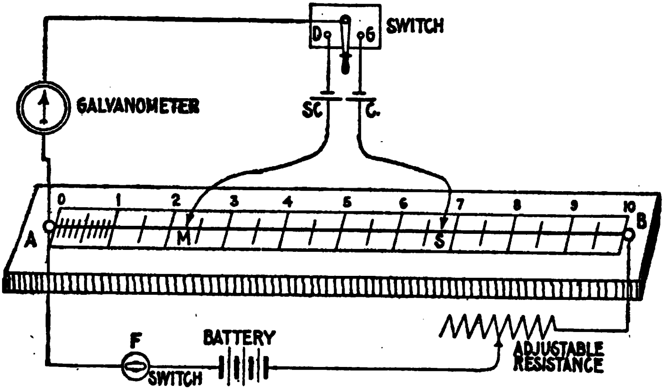


FIG. 6,853.—Diagram of potentiometer showing method of measuring the voltage of a cell. The potentiometer is simply a high resistance wire of uniform diameter stretched between two binding posts, A and B, in such a way that contact can be made at its ends and along its length. Necessary circuits are plainly shown in the figure; Sc, is a *standard cell* and C, the cell to be tested. M, and S are sliding contacts, connecting with the "slide wire."

The so-called "Wheatstone" bridge was invented by Christie, and improperly credited to Wheatstone, who simply applied Christie's invention to the measurement of resistances.

Loop Test.—This is a method of *locating a fault in a telegraph or telephone circuit when there is a good wire running parallel with the defective one.*

In the process, the good and bad wires are joined at their distant ends and one terminal of the battery is connected to a Wheatstone bridge, while the other terminal is grounded. There are different ways of making loop tests as by: 1, Murray loop; 2, Varley loop; 3, Special loop.

Commercial Testing

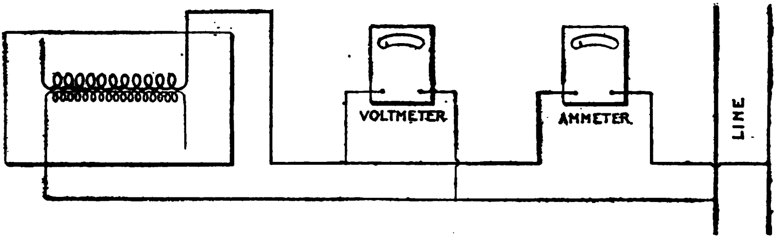


FIG. 6,854.—Transformer insulation resistance test. The insulation, besides being able to resist puncture, due to increased voltage, must also have sufficient resistance to prevent any appreciable amount of current flowing between primary and secondary coils. It is, therefore, sometimes important that the insulation resistance between primary and secondary be measured. This can be done, as here shown. Great care should be taken to have all wires thoroughly insulated from the ground, and to have an ammeter placed as near as possible to the terminals of the transformer under test, in order that current leaking from one side of the line to the other, external to the transformer, may not be measured. Great care is required in making this measurement, in order to obtain consistent results.

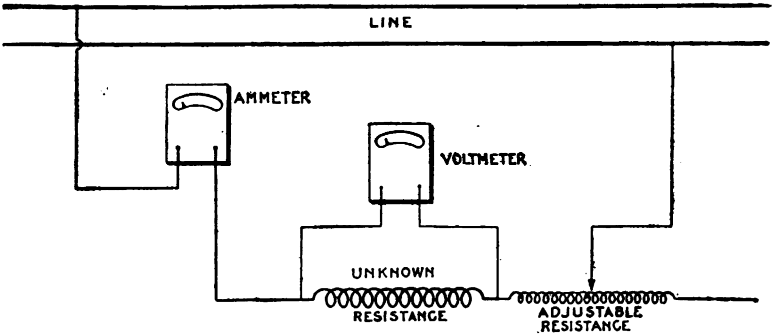


FIG. 6,855.—Resistance measurement by "drop" method. The circuit whose resistance is to be measured, is connected in series with an ammeter and an adjustable resistance to vary the flow of current. A voltmeter is connected directly across the terminals of the resistance to be measured, as shown in the figure. According to Ohm's law $I=E \div R$, from which, $R=E \div I$. If then the current flowing in the circuit through the unknown resistance be measured, and also the drop or difference of pressure, the resistance can be calculated by above formula. In order to secure accurate determination of the resistance such value of current must be used as will give large deflections of the needle on the instruments employed. A number of independent readings should be taken with some variation of the current and necessarily a corresponding variation in voltage. The resistance should then be figured from each set of readings and the average of all readings taken for the correct resistance.

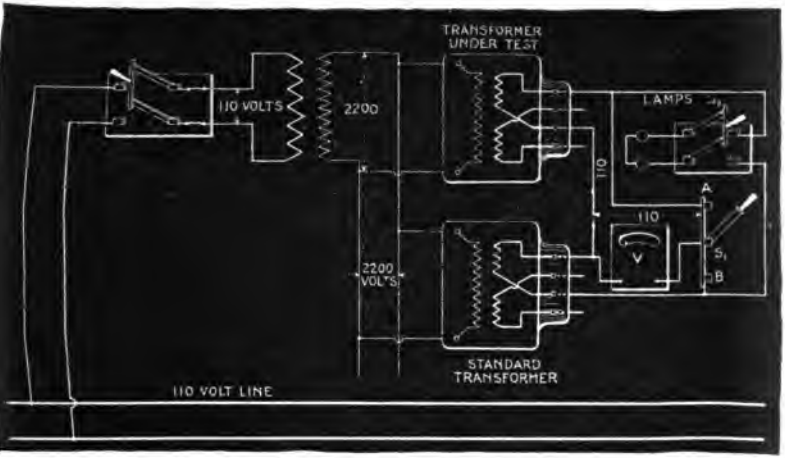


FIG. 6,856.—Transformer winding or ratio test. The object of this test is to check the ratio between the primary and the secondary windings. For this purpose a transformer of known ratio is used as a standard. Connect the transformer under test with a standard transformer as shown. Leave switch S_2, open. With the single pole double throw switch in position, S_1B, the voltmeter is thrown across the terminals of the standard transformer. With the switch in position S_1A, the voltmeter is thrown across the terminals of the transformer under test. The voltmeter should be read with the switch in each position. If the winding ratio be the same as that of the standard transformer, the two voltmeter readings will be identical.

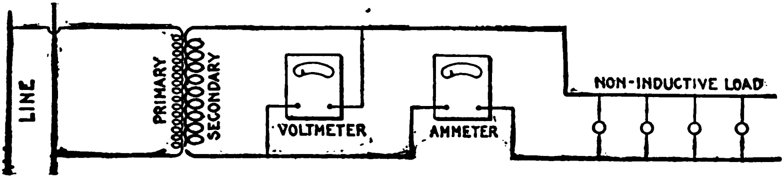


FIG. 6,857.—Temperature test of transformer with non-inductive load. The figure shows the simplest way of making the test. Connect the primary of the transformer to the line as shown, and carry normal secondary load by means of a bank of lamps or other suitable resistance, until full load secondary current is shown by the ammeter in the secondary circuit. The transformer should then be allowed to run at its rated load for the desired interval of time, temperature readings being made of the oil in its hottest part, and also of the surrounding air. Where temperatures of the coil rather than temperatures of the oil are desired, it is necessary to use the resistance method. This is obtained by first carefully measuring the resistance of both primary and secondary coils at the temperature of the room, and then, after the transformer has been under heat test for the desired time, disconnect it from the circuit and again measure the resistance of primary and secondary. For proper method of calculating the temperature rise from resistance measurements, the reader is referred to the standardization rules of the A. I. E. E. In making resistance measurements of large transformers by the drop method care should be taken to allow both ammeter and voltmeter indications to settle down to steady values before readings are taken. This may require several minutes. Each time the current is changed it is necessary in order to obtain check values on resistance measurements, to wait until the current is again settled to its permanent value before taking readings.

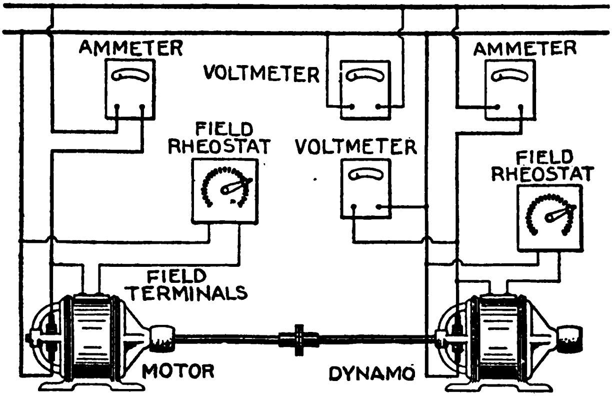


FIG. 6,858.—Temperature test of direct current motor or dynamo; loading back method. The motor is started in the usual way, with the dynamo belted to it, the circuit of the dynamo being open. The field of the dynamo is then adjusted so that the dynamo voltage is equal to that of the line. The dynamo is then connected to the circuit and its field resistance varied until it carries normal full load current. Under these conditions, if the motor and dynamo be of the same size and type, the motor will carry slightly in excess of full load, the difference being approximately twice the losses of the machines. Under these conditions the total power drawn from the line is equal to twice the loss of either machine. Temperature readings are taken as in other temperature tests.

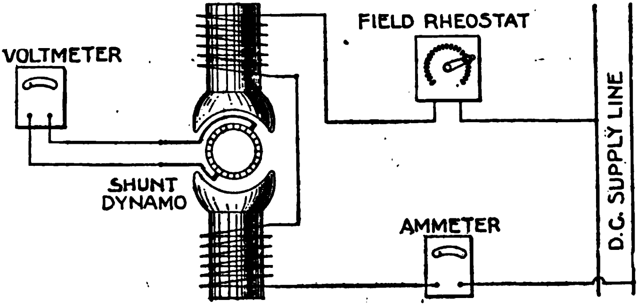


FIG. 6,859.—Direct motor or dynamo magnetization test. The object of this test is to determine the variation of armature voltage without load, with the current flowing through the field circuit. The armature should be driven at normal speed. The adjustment resistance in the field circuit is varied and the voltage across the armature measured. The curve obtained by plotting these two figures is usually called magnetization curve of the dynamo. It is usual to start with the higher resistance in the field circuit so that very small current flows, gradually increasing this current by cutting out the field resistance. When the highest no load voltage required is reached, the field current is then diminished, and what is called the descending (as opposed to the ascending) magnetization curves are obtained. The difference in the two curves is due to the lag of the magnetization behind the magnetizing current, and is caused by the hysteresis of the iron of the armature core.

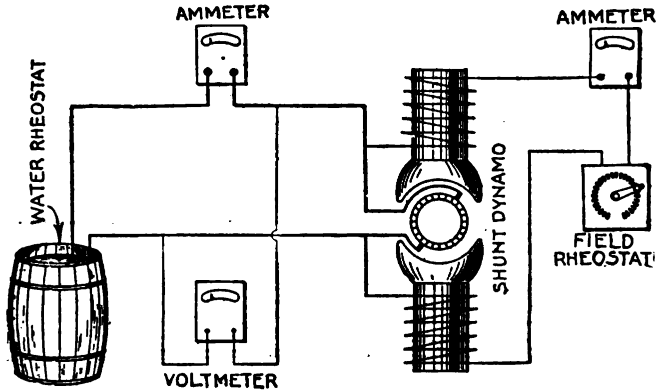


FIG. 6,860.—Shunt dynamo, external characteristic test. The shunt field is so adjusted that the machine gives normal voltage when the external circuit is open. The field current is then maintained constant and the external current varied by varying the resistance in the circuit. By plotting voltage along the vertical, against the corresponding amperes represented along the horizontal, the external characteristic is obtained.

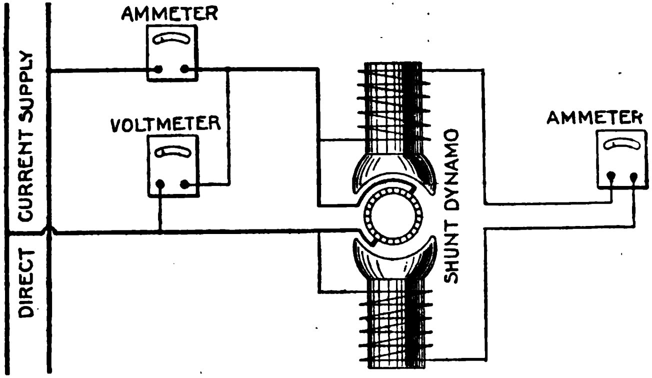


FIG. 6,861.—Load and speed test of direct current shunt motor. ***The object*** of this test is to maintain the voltage applied to the motor constant, and to vary the load by means of a brake and find the corresponding variation in speed of the machine and the current drawn from the circuit. If the motor be a constant speed motor, the field resistance is maintained constant. The above indicates the method of connecting instruments for the test alone; for starting the machine the ordinary starting box should, of course, be inserted.

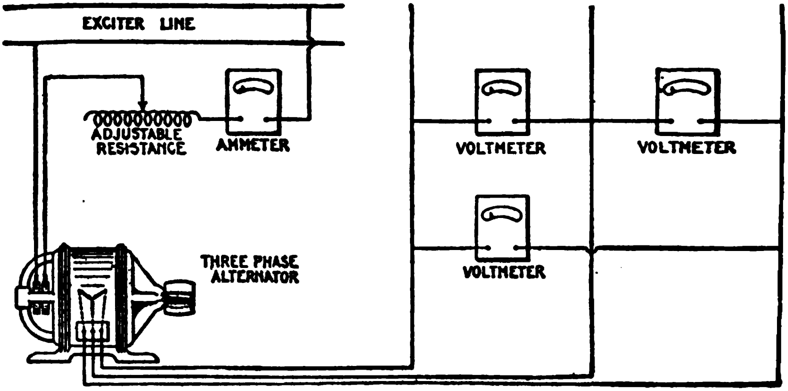


FIG. 6,862.—Alternator excitation or magnetization curve test. The object of this test is to determine the change of the armature voltage due to the variation of the field current when the external circuit is kept open. As here shown, the field circuit is connected with an ammeter and an adjustable resistance in series with a direct current source of supply. The adjustable resistance is varied, and readings of the voltmeter across the armature, and of the ammeter, are recorded. The speed of the generator must be kept constant, preferably at the speed which is given on the name plate. The excitation or magnetization curve of the machine is obtained by plotting the current and the voltage.

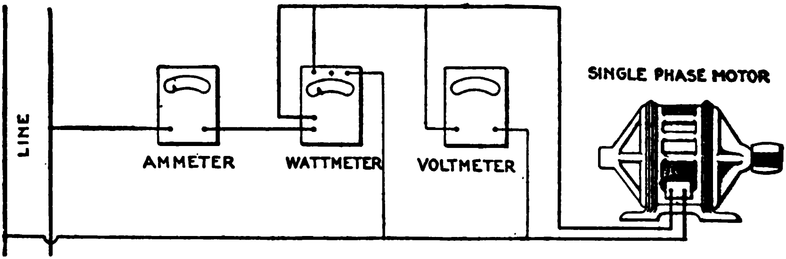


FIG. 6,863.—Single phase motor test. In this method of measuring the input of a single phase motor of any type, the ammeter, voltmeter and wattmeter are connected as shown in the illustration. The ammeter measures the current flowing through the motor, the voltmeter, the pressure across the terminals of the motor, and the wattmeter the total power which flows through the motor circuit. With the connections as shown, the wattmeter would also measure the slight losses in the voltmeter and the pressure of coil of the wattmeter, but for motors of ¼ H.P. and larger, this loss is so small that it may be neglected. The power factor may be calculated by dividing the true watts as indicated by the wattmeter, by the product of the volts and amperes.

NOTE.—In motor testing, by the methods illustrated in the accompanying cuts, it is assumed that the motor is loaded in the ordinary way by belting or direct connecting the motor to some form of load, and that the object is to determine whether the motor is over or under loaded, and approximately what per cent. of full load it is carrying. All commercial motors have name plates, giving the rating of the motor and the full load current in amperes. Hence the per cent. of load carried can be determined approximately by measuring the current input and the voltage.

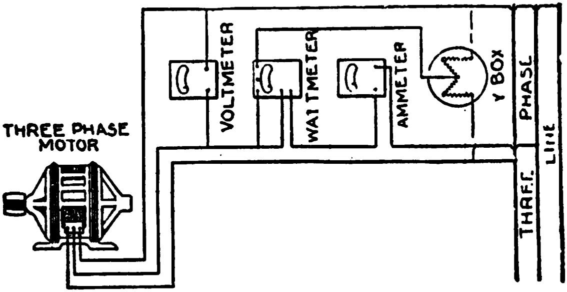


Fig. 6,864.—Three phase motor, one watt meter and Y box method. This method is of service, only, provided the voltages of the three phases are the same. A slight variation of the voltage of the different phases may cause a very large error in the readings of the wattmeter, and inasmuch as the voltage of all commercial three phase circuits is more or less unbalanced, this method is not to be recommended for motor testing. With balanced voltage in all three phases, the power is that indicated by the wattmeter, multiplied by three. Power factor may be calculated as before.

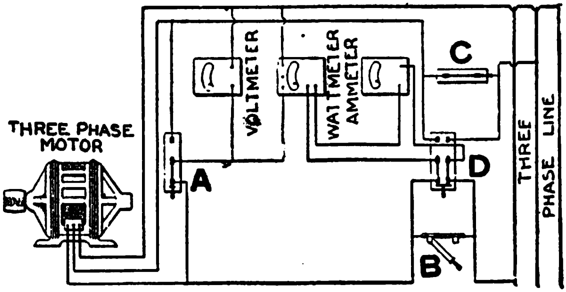


Fig. 6,865.—Three phase motor test; one watt meter method .This method is equivalent to the two watt meter method with the following difference. A single volt meter (as shown above) with a switch, A, can be used to connect the volt meter across either one of the two phases. Three switches, B, C, and D, are employed for changing the connection of the ammeter and watt meter in either one of the two lines. With the switches B and D, in the position shown, the ammeter and watt meter series coils are connected in the left hand line. The switch C, must be closed under these conditions in order to have the middle line closed. Another reading should then be taken before any change of load has occurred, with switch A, thrown to the right, switch B, closed, switch D, thrown to the right and switch C, opened. The ammeter and the current coil of the watt meter will then be connected to the middle line of the motor. In order to prevent any interruption of the circuit, the switches B, D and C, should be operated in the order given above. With very light load on the motor the watt meter will probably give a negative deflection in one phase or the other, and it will be necessary to reverse its connections before taking the readings. For this purpose a double pole, double throw switch is sometimes inserted in the circuit of the pressure coil of the watt meter so that the indications can be reversed without disturbing any of the connections. It is suggested, before undertaking this test, that the instructions for test by two watt meter and by the polyphase watt meter methods be read.

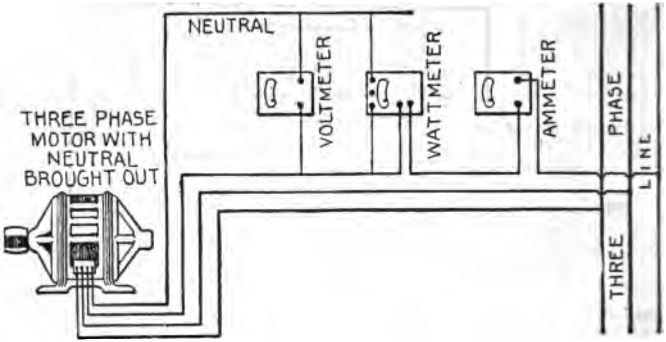


FIG. 6,866.—Test of three phase motor with neutral brought out; single watt meter method. Some star connected motors have the connection brought out from the neutral of the winding. In this case the circuit may be connected, as here shown. The volt meter now measures voltage between the neutral and one of the lines, and the watt meter the power in one of the three phases of the motor. Therefore, the total power taken by the motor will be three times the watt meter readings. By this method, just as accurate results can be obtained as with the two watt meter method. The power factor will be the indicated watts divided by the product of the indicated amperes and volts.

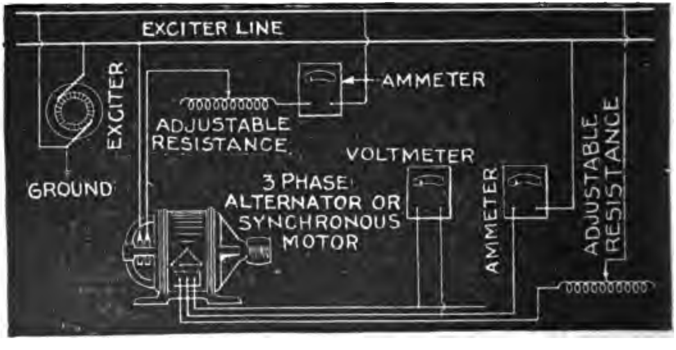


FIG. 6,867.—Three phase alternator or synchronous motor temperature test. Supply the field with normal field current. The armature is connected in open delta as illustrated, and full load current sent through it from an external source of direct current, care being taken to ground one terminal of the dynamo so as to avoid danger of shock due to the voltage on the armature winding. The field is then driven at synchronous speed. If the armature be designed to be connected star for 2,300 volts, the voltage generated in each leg of the delta will be 1,330 volts, and unless one leg of the dynamo were grounded, the tester might receive a severe shock by coming in contact with the direct current circuit. The insulation of the dynamo would also be subjected to abnormal strain unless one terminal were grounded. By the above method the field is subjected to its full copper loss and the armature to full copper loss and core loss. Temperature readings are taken as per standardization rules of the A. I. E. E. This method may also be used with satisfactory results on large three phase motors of the wound rotor type. If the alternator pressure be above 600 volts, a pressure transformer should be used in connection with the voltmeter.

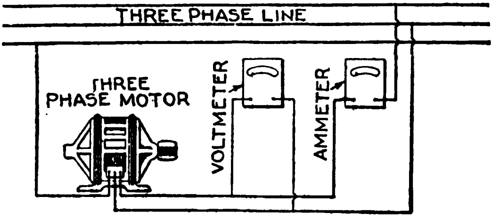


Fig. 6,868.—Three phase motor test; voltmeter and ammeter method. If it be desired to determine the approximate load on a three phase motor, this may be done by means of the connections as shown in the figure, and the current through one of the three lines and the voltage across the phase measured. If the voltage be approximately the rated voltage of the motor and the amperes the rated current of the motor (as noted on the name plate) it may be assumed that the motor is carrying approximately full load. If, on the other hand, the amperes show much in excess of full load rating, the motor is carrying an overload. The heat generated in the copper varies as the square of the current. That generated in the iron varies anywhere from the 1.6 power, to the square. This method is very convenient if a wattmeter be not available, although, it is, of course, of no value for the determination of the efficiency or power factor of the apparatus. This method gives fairly accurate results, providing the load on the three phases of the motor be fairly well balanced. If there be much difference, however, in the voltage of the three phases, the ammeter should be switched from one circuit to another, and the current measured in each phase. If the motor be very lightly loaded and the voltage of the different phases vary by 2 or 3 per cent., the current in the three legs of the circuit will vary 20 to 30 per cent.

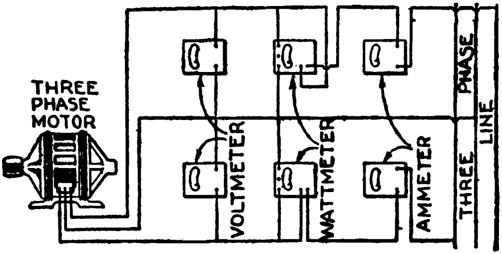
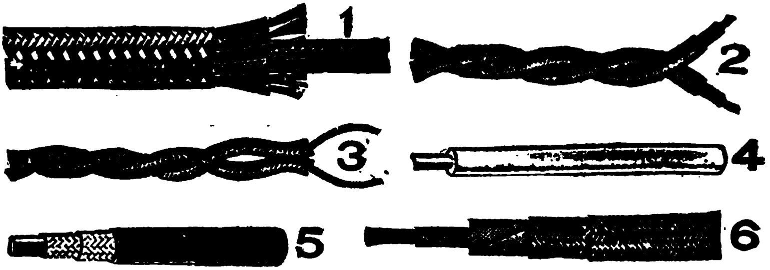


Fig. 6,869.—Three phase motor test by the two wattmeter method. If an accurate test of a three phase motor be required, it is necessary to use the method here indicated. Assume the motor to be loaded with a brake so that its output can be determined. This method gives correct results even with considerable unbalancing in the voltages of the three phases. With the connections as shown, the sum of the two wattmeter readings gives the total power in the circuit. Neither meter by itself measures the power in any one of the three phases. In fact, with light load one of the meters will probably give a negative reading, and it will then be necessary to either reverse its current or pressure leads in order that the deflection may be noted. In such cases the algebraic sums of the two readings must be taken. In other words, if one read plus 500 watts and the other minus 300 watts, the total power in the circuit will be 500 minus 300, or 200 watts. As the load comes on, the readings of the instrument which gave the negative deflection will decrease until the reading drops to zero, and it will then be necessary to again reverse the pressure leads on this wattmeter. Thereafter the readings of both instruments will be positive, and the numerical sum of the two should be taken as the measurement of the load. If one set of the instruments be removed from the circuit, the reading of the remaining wattmeter will have no meaning. As stated above, it will not indicate the power under these conditions in any one phase of the circuit. The power factor is obtained by dividing the actual watts input by the product of the average of the voltmeter readings × the average of the ampere readings × 1.73.

CHAPTER 108

Wires and Wire Calculations

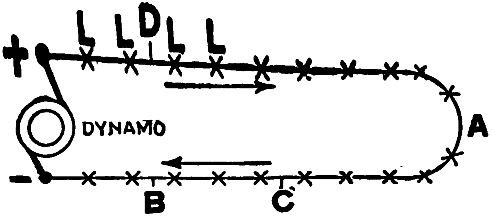
Wires.—Copper is used in nearly all cases of wiring because it combines high electrical conductivity with good mechanical qualities and reasonable price.



FIGS. 6,870 to 6,875.—Various wires. Fig. 6,870, elevator cable for annunciators; fig. 6,871, rubber insulated wires for telephone and telegraph; fig. 6,872, twisted weather proof wires; fig. 6,873, slow burning wire; fig. 6,874, slow burning weather proof wire; fig. 6,875, gas engine ignition cable.

Electric light and power wires are usually of copper. They vary in size from No. 8 to No. 0000 B. & S. gauge, or from ⅛ in. to nearly ½ in. in diameter. Iron wire is largely used for telegraph and telephone lines, although it is rapidly being replaced by copper in long lines.

Where conductors are very large (as for instance dynamo leads), and where it is essential that they should be as flexible as possible, strands as small as No. 20 or 22 B. & S. gauge may be used.



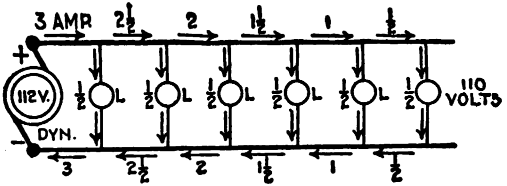
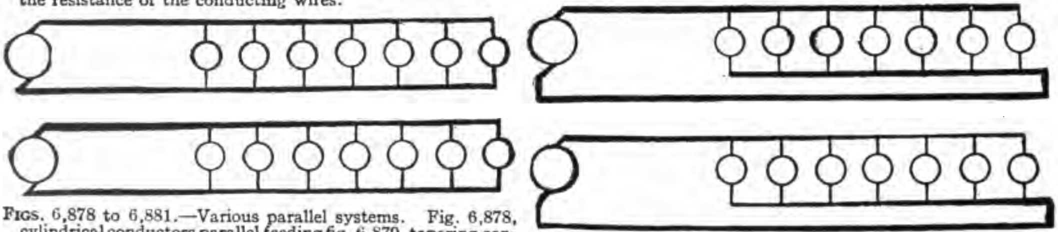


Fig. 6,876.—Series system of distribution. **This is a constant current system, so called because the current remains practically constant.** It was formerly used chiefly for arc lighting. The difference of pressure between any two points in the circuit is equal to the lamp voltage (about 50 volts) multiplied by the number of lamps between the points, ***Danger;*** if the line be grounded at **B** owing to defective insulation, the pressure of the circuit at **B**, will be zero, and therefore, a man standing on the ground could touch that point without receiving a shock, but if he should touch the line at the point **C**, he will receive a slight shock of 150 volts, as there are three lamps between the point **C**, and the ground connection **B**. Therefore, the danger of touching the circuit increases directly with the resistance between the point touched and the ground connection, so that if a man touch the circuit at the point **D**, he will receive a dangerous shock of 16×50=800 volts. In practice, sixty lamps are often placed on a single arc lighting circuit, so that its total pressure is about 3,000 volts, thus greatly increasing the danger of the system.

Fig. 6,877.—Parallel system of distribution. This is a constant voltage system and is used principally for incandescent lighting and electric motor circuits. With six lamps on the circuit, each requiring one-half ampere of current, at 110 volts, the dynamo will have to supply a current of 3 amperes at a pressure of 112 volts, and this current will flow through the circuit and distribute itself as shown on account of the lesser resistance of the wire relatively to that of the lamps. At the first lamp, the 3 amperes will divide, ½ ampere flowing through the lamp and the remaining 2½ amperes passing on to the next lamp and so on through the entire circuit. The reduction of pressure from 112 volts across the brushes to 110 volts at the last lamp is due to the resistance of the conducting wires.



Figs. 6,878 to 6,881.—Various parallel systems. Fig. 6,878, cylindrical conductors parallel feeding fig. 6,879, tapering conductors parallel feeding; fig. 6,880, cylindrical conductors anti-parallel feeding; fig. 6,881, tapering conductors anti-parallel feeding. The term "tapering" is here used to denote a conductor made up of lengths of wire, each length smaller than the preceding length, the object of such arrangement being to avoid a waste of copper by progressively diminishing the size of wire so that the relation between circular mils and amperes is kept approximately constant. In an anti-parallel system, the current is fed to the lamp from the opposite ends of the system, For most conditions of service, wires are protected with an insulating covering. Wires used in interior circuits should have a covering which shall act both as an electrical insulator and as a mechanical protection.

Resistance of Wires.—For quick calculation the following method of obtaining the resistance (approximately) of wires will be found convenient:

1,000 feet No. 10 B. & S. wire, which is about .1 inch in diameter (.1019), has a resistance of one ohm, at a temperature of 68° F. and weighs 31.4 pounds. A wire three sizes larger, that is No. 7, has twice the cross section and therefore one-half the resistance. A wire three sizes smaller than No. 10, that is No. 13, has one-half the cross section and therefore twice the resistance. Thus, starting with No. 10, any number three sizes larger will double the cross sectional area and any wire three sizes smaller will halve the cross sectional area of the preceding wire.

TABLE OF THE PROPERTIES OF COPPER WIRE

Giving weights, length and resistances of wires of Matthiessen's Standard Conductivity for both B. & S. G. (Brown & Sharpe Gauge) and B. W. G. (Birmingham Wire Gauge) from Transactions October 1903, of the American Institute of Electrical Engineers.

Gauges. To the nearest fourth significant digit.				Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils			@ 68° F.
0000		0.460	211,600	640.5	1.561	.04893
	0000	0.454	206,100	623.9	1.603	.05023
	000	0.425	180,600	546.8	1.829	.05732
000		0.4096	167,800	508.0	1.969	.06170
	00	0.380	144,400	437.1	2.288	.07170
00		0.3648	133,100	402.8	2.482	.07780
	0	0.340	115,600	349.9	2.858	.08957
0		0.3249	105,500	319.5	3.130	.09811
	1	0.3000	90,000	272.4	3.671	.1150
1		0.2893	83,690	253.3	3.947	.1237
	2	0.2840	80,660	244.1	4.096	.1284
	3	0.2590	67,080	203.1	4.925	.1543
2		0.2576	66,370	200.9	4.977	.1560
	4	0.2380	56,640	171.5	5,832	.1828
3		0.2294	52,630	159.3	6.276	.1967
	5	0.2200	48,400	146 5	6.826	.2139
4		0.2043	41,740	126.4	7.914	.2480
	6	0 2030	41,210	124.7	8.017	.2513

TABLE OF THE PROPERTIES OF COPPER WIRE

(*Continued*)

Gauges.	To the nearest fourth significant digit.			Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils			@ 68° F.
5		0.1819	33,100	100.2	9.980	.3128
	7	0.1800	32,400	98.08	10.20	.3196
	8	0.1650	27,230	82.41	12.13	.3803
6		0.1620	26,250	79.46	12.58	.3944
	9	0.1480	21,900	66.30	15.08	.4727
7		0.1443	20,820	63.02	15.87	.4973
	10	0.1340	17,960	54.35	18.40	.5766
8		0.1285	16,510	49.98	20.01	.6271
	11	0.1200	14,400	43.59	22.94	.7190
9		0.1144	13,090	39.63	25.23	.7908
	12	0.1090	11,880	35.96	27.81	.8715
10		0.1019	10,380	31.43	31.82	.9972
	13	0.0950	9,025	27.32	36.60	1.147
11		0.09074	8,234	24.93	40.12	1.257
	14	0.08300	6,889	20.85	47.95	1.503
12		0.08081	6,530	19.77	50.59	1.586
	15	0.07200	5,184	15.69	63.73	1.997
13		0.07196	5,178	15.68	63.79	1.999
	16	0.06500	4,225	12.79	78.19	2.451
14		0.06408	4,107	12.43	80.44	2.521
	17	0.0580	3,364	10.18	98.23	3.078
15		0.05707	3,257	9.858	101.4	3.179
16		0.05082	2,583	7.818	127.9	4.009
	18	0.04900	2,401	7.268	137.6	4.312
17		0.045260	2,048	6.200	161.3	5.055
	19	0.042000	1,764	5.340	187.3	5.870
18		0.040300	1,624	4.917	203.4	6.374
19		0.035890	1,288	3.899	256.5	8.038
	20	0.035000	1,225	3.708	269.7	8.452
	21	0.032000	1,024	3.100	322.6	10.11
20		0.031960	1,022	3.092	323.4	10.14
21		0.028460	810.1	2.452	407.8	12.78
	22	0.028000	784.0	2.373	421.4	13.21
22		0.025350	642.4	1.945	514.2	16.12
	23	0.025000	625.0	1.892	528.6	16.57

TABLE OF THE PROPERTIES OF COPPER WIRE

(*Concluded*)

Gauges. To the nearest fourth significant digit.				Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils.			@ 68° F.
23		0.022570	509.5	1.542	648.4	20.32
	24	0.022000	484.0	1.465	682.6	21.39
24		0.020100	404.0	1.223	817.6	25.63
	25	0.020000	400.0	1.211	825.9	25.88
	26	0.018000	324.0	.9808	1,020	31.96
25		0.017900	320.4	.9699	1,031	32.31
	27	0.016000	256.0	.7749	1,290	40.45
26		0.015940	254.1	.7692	1,300	40.75
27		0.014200	201.5	.6100	1,639	51.38
	28	0.014000	196.0	.5933	1,685	52.83
	29	0.013000	169.0	.5116	1,955	61.27
28		0.012640	159.8	.4837	2,067	64.79
	30	0.012000	144.0	.4359	2,294	71.90
29		0.011260	126.7	.3836	2,607	81.70
30		0.010030	100.5	.3042	3,287	103.0
	31	0.010000	100.0	.3027	3,304	103.5
	32	0.009000	81.0	.2452	4,078	127.8
31		0.008928	79.70	.2413	4,145	129.9
	33	0.008000	64.0	.1937	5,162	161.8
32		0.007950	63.21	.1913	5,227	163.8
33		0.007080	50.13	.1517	6,591	206.6
	34	0.007000	49.0	.1483	6,742	211.3
34		0.006305	39.75	.1203	8,311	260.5
35		0.005615	31.52	.09543	10,480	328.4
36	35	0.005000	25.0	.07568	13,210	414.2
37		0.004453	19.83	.06001	16,660	522.2
	36	0.004000	16.	.04843	20,650	647.1
38		0.003965	15.72	.04759	21,010	658.5
39		0.003531	12.47	.03774	26,500	830.4
40		0.003145	9.888	.02993	33,410	1047.

Safe Carrying Capacity of Wire.—All wires will heat when a current of electricity passes through them.

The greater the current or the smaller the wire, the greater will be the heating effect.

The following table gives safe carrying capacity of wires for temperature increase of 30° over that of the surrounding air:

SAFE CARRYING CAPACITIES OF WIRES

(Maximum amperes allowed by the Underwriters.)

Brown and Sharpe Gauge	Circular mils	Rubber insulation — Amperes	Other insulations — Amperes	Circular mils	Rubber insulation — Amperes	Other insulations — Amperes
18	1,624	3	5	400,000	325	500
16	2,583	6	10	500,000	400	600
14	4,107	15	20	600,000	450	680
12	6,530	20	25	700,000	500	760
10	10,380	25	30	800,000	550	840
8	16,510	35	50	900,000	600	920
6	26,250	50	70	1,000,000	650	1,000
5	33,100	55	80	1,100,000	690	1,080
4	41,740	70	90	1,200,000	730	1,150
3	52,630	80	100	1,300,000	770	1,220
2	66,370	90	125	1,400,000	810	1,290
1	83,690	100	150	1,500,000	850	1,360
0	105,500	125	200	1,600,000	890	1,430
00	133,100	150	225	1,700,000	930	1,490
000	167,800	175	275	1,800,000	970	1,550
0000	211,600	200	300	1,900,000	1,010	1,610
	200,000	225	325	2,000,000	1,050	1,670
	300,000	275	400			

TABLE OF WIRE EQUIVALENTS

(Brown and Sharpe gauge)

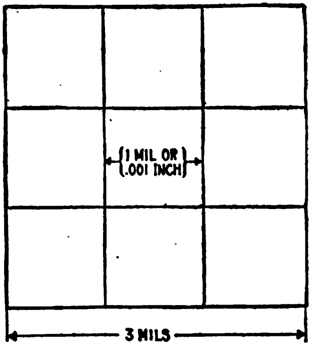
0000	2 No. 0	4 No. 3	8 No. 6	16 No. 9	32 No. 12	64 No. 15
000	2 " 1	4 " 4	8 " 7	16 " 10	32 " 13	64 " 16
00	2 " 2	4 " 5	8 " 8	16 " 11	32 " 14	64 " 17
0	2 " 3	4 " 6	8 " 9	16 " 12	32 " 15	64 " 18
1	2 " 4	4 " 7	8 " 10	16 " 13	32 " 16	64 " 19
2	2 " 5	4 " 8	8 " 11	16 " 14	32 " 17	64 " 20
3	2 " 6	4 " 9	8 " 12	16 " 15	32 " 18	64 " 21
4	2 " 7	4 " 10	8 " 13	16 " 16	32 " 19	64 " 22
5	2 " 8	4 " 11	8 " 14	16 " 17	32 " 20	64 " 23
6	2 " 9	4 " 12	8 " 15	16 " 18	32 " 21	64 " 24
7	2 " 10	4 " 13	8 " 16	16 " 19	32 " 22	64 " 25
8	2 " 11	4 " 14	8 " 17	16 " 20	32 " 23	64 " 26
9	2 " 12	4 " 15	8 " 18	16 " 21	32 " 24	64 " 27
10	2 " 13	4 " 16	8 " 19	16 " 22	32 " 25	64 " 28
11	2 " 14	4 " 17	8 " 20	16 " 23	21 " 26	64 " 29
12	2 " 15	4 " 18	8 " 21	16 " 24	32 " 27	64 " 30
13	2 " 16	4 " 19	8 " 22	16 " 25	32 " 28	....
14	2 " 17	4 " 20	8 " 23	16 " 26	32 " 29	....
15	2 " 18	4 " 21	8 " 24	16 " 27	32 " 30	....
16	2 " 19	4 " 22	8 " 25	16 " 28	....	....
17	2 " 20	4 " 23	8 " 26	16 " 29	....	....
18	2 " 21	4 " 24	8 " 27	16 " 30	....	....
19	2 " 22	4 " 25	8 " 28	....	....	....
20	2 " 23	4 " 26	8 " 29	....	....	....
21	2 " 24	4 " 27	8 " 30	....	....	....

1. Direct Current Wiring

Wiring Calculations.—In determining the size of wire, there are four known factors:

1. Length of circuit in feet;
2. Maximum current in amperes;
3. Drop or volts lost in the circuit, *in % of the impressed voltage*;
4. Heating effect of the current.

The calculation is based on the *mil foot*, which is a *foot of copper wire one mil in diameter and whose resistance is equal to 10.79 ohms at 75° Fahr.*



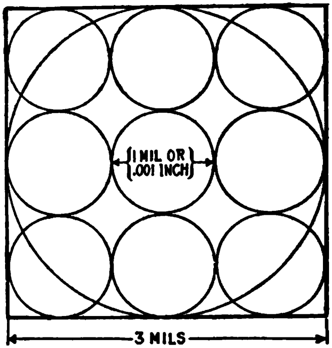


FIG. 6,882.—Diagram illustrating square mils. A square mil is a unit of area employed in measuring the areas of cross sections of square or rectangular conductors. It is equal to .000001 square inch. One square mil equals 1,2732 circular mils. The figure shows an area of nine square mils; this is equal to 9 × 1.2732 = 11.4588 circular mils.

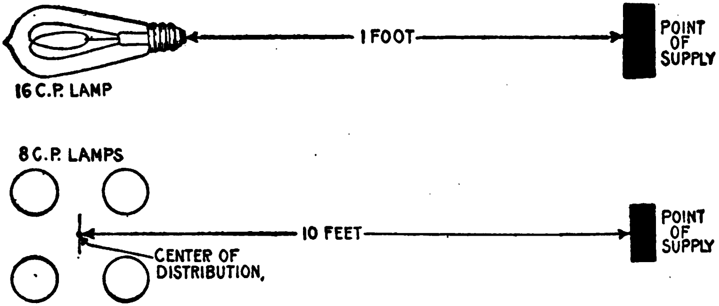
FIG. 6,883.—Diagram illustrating circular mils. The circular mil is used as a unit of cross sectional area in measuring wires. *It is equal to the area of a circle* .001 *in. diameter;* its value is .0000007854 square inch. In the figure the sum of the areas of the nine small circles equals the area of the large circle. This is evident from the following: Take the diameter of the small circles as unity, then the diameter of the large circle is three. Hence, the sum of the area of the small circles $\times (\frac{1}{4}\pi \times 1^2) \times 9 = .7854 \times 9 = 7.0686$; area of the large circle $= \frac{1}{4}\pi \times 3^2 = .7854 \times 9 = 7.0686$. Therefore since the area of the large circle equals the sum of the areas of the small circles, the area of a wire in circular mils is equal to *the square of its diameter expressed in mils.*

The first step is to find an expression for the resistance of the wire which may be later substituted in Ohm's law formula. Accordingly, the resistance of any conductor is equal to *its length in feet multiplied by its resistance per mil foot and the product divided by its area in circular mils*, thus:

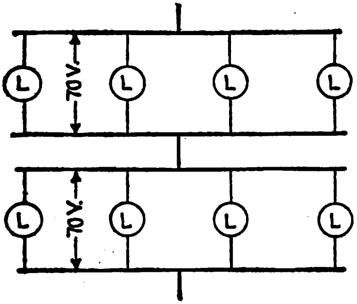
$$\text{resistance in ohms} = \frac{\text{length in feet} \times \text{resistance per mil foot}}{\text{circular mils}}$$

or

$$\text{ohms} = \frac{\text{feet} \times 10.8}{\text{circular mils}} \dots\dots\dots\dots\dots\dots (1)$$



Figs. 6,884 and 6,885.—Diagrams illustrating the meaning of the term lamp foot, and how tc apply it in calculating a circuit. ***As defined,*** *one 16 candle power lamp at a distance of one foot from the fuse block or point of supply is called a lamp foot;* this is equivalent to one 8 candle power lamp at a distance of 2 feet, or one 32 candle power lamp one-half foot from the fuse block. In fig. 6,885, there are four 8 candle power lamps, and the distance to center of distribution is 10 feet. The circuit then contains $4 \div 2 \times 10 = 20$ lamp feet.



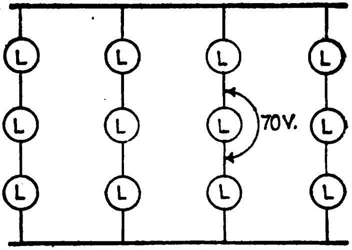
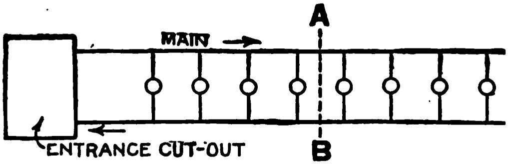


Fig. 6,886.—Series-parallel system of distribution. ***It consists of*** groups of parallel connected receptive devices, the groups being arranged in the circuit in series.

Fig. 6,887.—Parallel-series system of distribution. ***It consists of*** groups of series connected receptive devices the groups being arranged in the circuit in parallel.



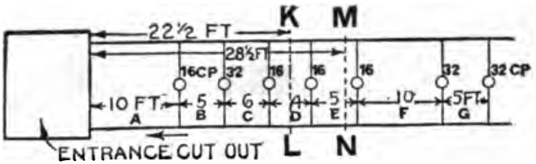
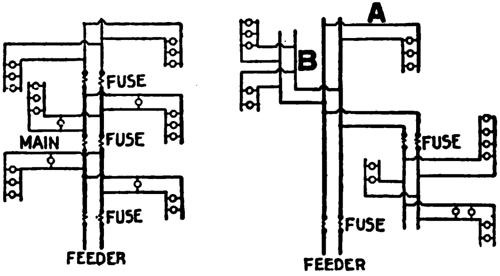
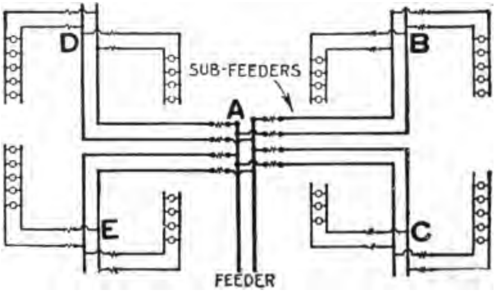


Fig. 6,888.—The center of distribution of a circuit coincides with the geometrical center of the group of lamps when the lamps are of uniform size and spaced equal distances apart. The center of distribution is here indicated by the dotted line A B.

Fig. 6,889.—Diagram of an irregular circuit illustrating method of finding the center of distribution. Rule: *Divide the sum of the lamp feet for each section by the number of* 16 *candle power lamps or equivalent in the circuit;* the quotient gives the distance in feet from the fuse block to the center of distribution.





Figs. 6,890 and 6,891.—The "tree" and "modified tree" systems of wiring. The tree system consists of a feeder reducing in size and supplying mains for each floor, the general arrangement resembling the trunk and branches of a tree. A better arrangement is the modified tree (fig. 6,891) in which the size of the feeder *is not reduced*. With this arrangement the losses are considerably reduced owing to the much smaller losses on the feeder between those centers farthest away from the point of supply.

Fig. 6,892.—Distribution with sub-feeders (multi-center distribution). The feeder connects at a central point, A, with several sub-feeders which run to distributing centers, as at B, C, D, and E. With this arrangement, compound wound dynamos with a proper amount of over compounding will give nearly uniform pressure at A for all loads.

(calling the resistance per mil foot 10.8 instead of 10.79 to facilitate calculation).

Now, according to Ohm's law,

$$\text{volts} = \text{amperes} \times \text{ohms} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

hence, substituting in (2) the value for the resistance in ohms, as obtained in (1):

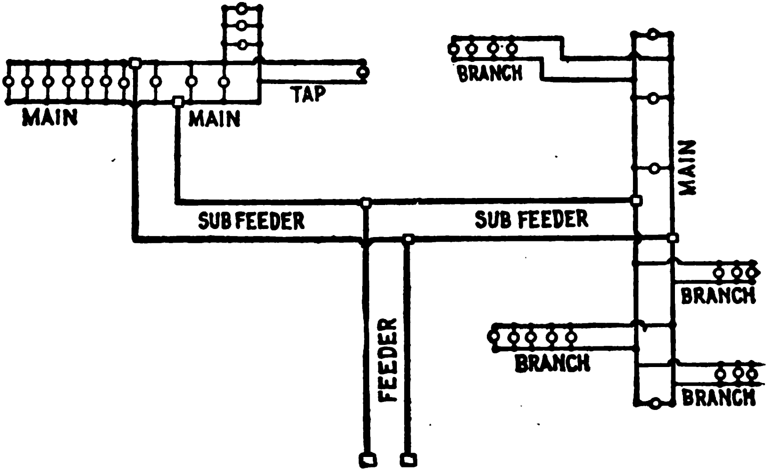
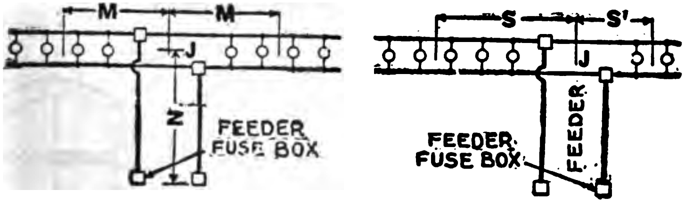


Fig. 6,893.—Various parts of a circuit: 1, feeder; 2, sub-feeders; 3, mains; 4, branches; 5 taps.



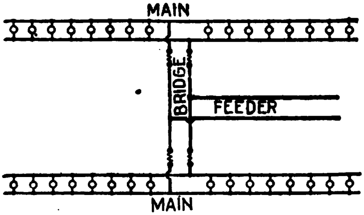
Figs. 6,894 and 6,895.—Symmetrical and unsymmetrical distribution. When a main is supplied by a feeder, the junction of the two, if practicable, is located at the electrical center of the main, as indicated in fig. 6,894, so that the distribution is symmetrical, that is, the ampere feet each way from the junction are the same. In fig. 6,895 there are four lamps on each side of the junction, **J**; the center of each group is at a distance, **M**, so that the lamp feet in each half of the main are 5 × **M**. The lamp feet of the feeder would be 10 × **N**, **N** being the distance from the feeder fuse block to the junction, **J**. In fig. 6,895, if the distance **S** be 14 feet, and the lamps, 16 *c.p.*, the lamp feet in the left hand main equals 5 × 14 = 70, while in the main to the right, taking **S'** at 10 feet, there are only 2 × 10 = 20 lamp feet. Hence what appears to be one continuous main in this case would have to be treated as two mains, and each part figured separately.

$$\text{volts} = \text{amperes} \times \frac{\text{feet} \times 10.8}{\text{circular mils}}$$

or using the usual symbols

TABLE FOR TAPS, BRIDGES OR OTHER WIRES AT NEGLIGIBLE DROP

Wire Nos.	0	1	2	3	4	5	6	7	8	10	12	14	16	18
Lamp Feet 52 v.	300	260	200	160	130	100	80	65	50	38	24	15	9	6
Lamp Feet 110 v.	1,280	1,085	860	680	560	435	345	280	220	160	100	60	40	25



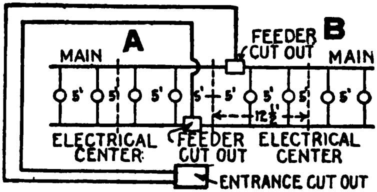
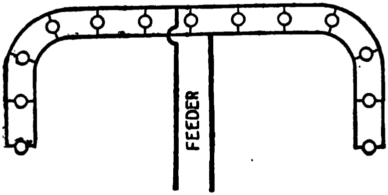
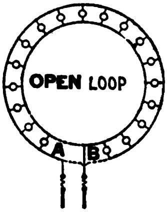


FIG. 6,896.—Diagram of bridge wiring.

FIG. 6,897.—Wiring diagram for lights requiring unusually long feeders.





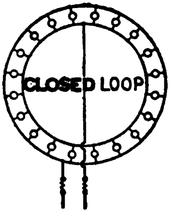


FIG. 6,898.—Arrangement of feeder and mains in parallel system. By locating the feeder at the electrical center, less copper is required for the mains. The cut does not show the fuses which in practice are placed at the junction of feeder and main.

FIGS. 6,899 and 6,900.—Wrong and right methods of loop wiring.

$$E = I \times \frac{\text{feet} \times 10.8}{\text{circular mils}} \quad \ldots\ldots\ldots (3)$$

or expressed as a formula, (3) means that the volts lost, or *drop* between the beginning and end of a circuit is equal to the current flowing through the circuit multiplied by the product of the conductors' length in feet

LAMP TABLE FOR RUBBER COVERED WIRES

Showing the maximum number of 16 candle power 110 to 240 volt lamps in parallel that may be carried by the various sizes of wire without violating the underwriters' rules.

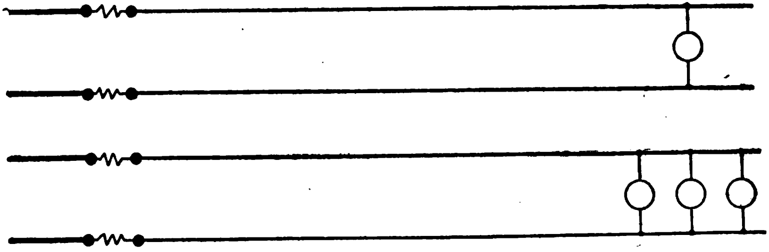
Wire size B. & S. gauge.	Amperes.	3.1-watt lamps		3.5-watt lamps.		4-watt lamps.		
		At 110 volts.	220 V.	At 110 volts.	220 V.	220 V.	230 V.	240 V.
0000	210	462	924	412	825	722	754	787
000	177	389	778	347	695	608	636	663
00	150	330	660	294	589	515	539	562
0	137	279	558	249	499	436	456	476
1	107	235	470	210	420	367	384	401
2	90	197	396	176	353	309	323	337
3	76	167	334	149	298	261	273	285
4	65	143	286	127	255	223	233	243
5	54	118	237	106	212	185	194	202
6	46	101	202	90	180	158	165	172
8	33	72	145	64	129	113	118	123
10	24	52	105	47	94	82	86	90
12	17	37	74	33	66	58	61	63
14	12	26	52	23½	47	41	43	45
16*	6	13	..	11	..	20	21	22

*This size can be used only in the shape of flexible cord.

LAMP TABLE FOR WEATHER PROOF WIRES

Showing the maximum number of 16 candle power 120 to 240 volt lamps in parallel that may be carried by various sizes of weather proof wire without violating the underwriters' rules.

Wire size B. & S. gauge.	Amperes.	3.1-watt lamps.		3.5-watt lamps.		4-watt lamps.		
		110 V.	220 V.	110 V.	220 V.	220 V.	230 V.	240 V.
0000	312	686	1372	612	1225	1072	1121	1170
000	262	576	1152	514	1029	900	941	982
00	220	484	968	432	864	756	790	825
0	185	407	814	363	726	636	665	693
1	156	343	686	306	612	536	560	585
2	131	288	576	257	514	450	470	491
3	110	242	484	216	432	378	395	412
4	92	202	404	180	361	316	330	345
5	77	169	338	151	302	264	276	288
6	65	143	286	127	255	223	233	243
8	46	101	202	90	180	158	165	172
10	32	70	140	62	125	110	115	120
12	23	50	101	45	90	79	82	86
14	16	35	70	31	63	55	57	60



FIGS. 6,901 and 6,902.—Simplest forms of circuit, consisting of a main with one or more lamps at the end. The smallest size wire allowed (No. 14 B. & S. gauge) will generally be found amply large for such circuits. Note carefully the difference between a main and a branch by comparison with fig. 6,893. A main begins from a fuse block, while a branch is an offset from a main without any fuse block.

multiplied by the resistance of one mil foot of wire, divided by the area of the conductor in circular mils, since the length of the circuit is given as the "run" or distance one way, that is, one half the total length of wire in the circuit, formula (3) must be multiplied by 2 to get the total drop, that is:

$$E = I \times \frac{\text{feet} \times 10.8 \times 2}{\text{circular mils}} = \frac{I \times \text{feet} \times 21.6}{\text{circular mils}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Solving the last equation for the unknown quantity, the following equation is obtained for size of wire:

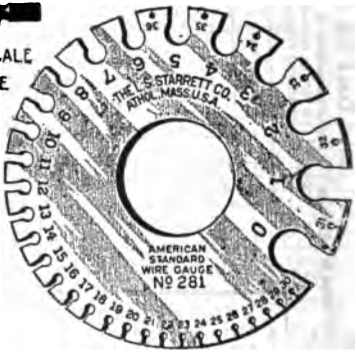
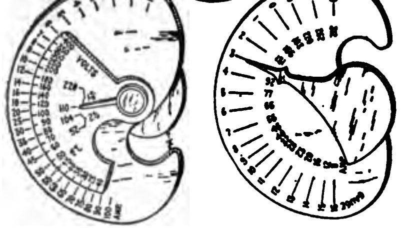


Fig. 6,903.—Brown and Sharpe (B. & S.), or American Standard wire gauge.



Figs. 6,904 and 6,905.—U. S. wireman's calculating gauge; views showing both sides. On the side shown in fig. 6,904, set the required number of feet on the small circle opposite the required number of amperes on the large circle, then set the small pointer at the required voltage and loss. Then on the other side (fig. 6,905) the large pointer will indicate the required size of wire in B. & S. gauge, and will also indicate the safe carrying capacity, while the wire may be gauged by slot A (fig. 6,904.)

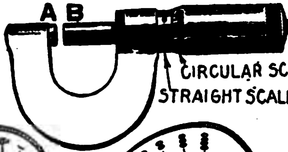


Fig. 6,906.—Micrometer screw gauge. It consists essentially of a screw whose thread is accurately turned to a pitch of some convenient fraction of an inch or centimeter. When the screw is screwed home, the surfaces of A and B meet, and the instrument should then read zero on both the straight and the circular scale. If this be not so, there is a zero error which must be either allowed for, or corrected by means of the screw provided for that purpose. If the pitch of the screw in the gauge be $1/20$th of an inch, and the circular scale consist of 50 divisions, then for each revolution of the screw, the surface B will travel a distance equal to the pitch, that is $1/20$th of an inch. The graduations on an instrument of this kind are generally $1/10$th of an inch on the straight scale, with shorter lines to mark the half divisions. The thickness of a wire on the straight scale can therefore be read to the nearest $1/20$th inch. Each division of the circular scale represents $1/50$th of a revolution of the screw, which corresponds to a change in distance between A and B, of $\frac{1}{50}$ of $\frac{1}{20} = \frac{1}{1,000}$ If then the reading on the straight scale be 1 and on the circular scale 35, the distance between A and B is $.1 + .035 = .135$ inch.

TABLE OF VARIOUS WIRE GAUGES

In decimal parts of an inch

Number of Wire Gauge	American, or Brown & Sharpe (B. & S.)	Birmingham, or Stubs (B. W. G.)	Washburn & Moen Mfg. Co., Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke, Mass.	Old English, From Brass Mfrs' List	British Standard (S. W. G.)	Number of Wire Gauge
0000000							.500	0000000
000000			.460				.464	000000
00000			.430	.450			.432	00000
0000	.46000	.454	.393	.400			.400	0000
000	.40964	.425	.362	.360	.3586		.372	000
00	.36480	.380	.331	.330	.3282		.348	00
0	.32486	.340	.307	.305	.2994		.324	0
1	.28930	.300	.283	.285	.2777		.300	1
2	.25763	.284	.263	.265	.2591		.276	2
3	.22942	.259	.244	.245	.2401		.252	3
4	.20431	.238	.225	.225	.2230		.232	4
5	.18194	.220	.207	.205	.2047		.212	5
6	.16202	.203	.192	.190	.1885		.192	6
7	.14428	.180	.177	.175	.1758		.176	7
8	.12849	.165	.162	.160	.1605		.160	8
9	.11443	.148	.148	.145	.1471		.144	9
10	.10189	.134	.135	.130	.1351		.128	10
11	.090742	.120	.120	.1175	.1205		.116	11
12	.080808	.109	.105	.1050	.1065		.104	12
13	.071961	.095	.0920	.0925	.0928		.0920	13
14	.064084	.083	.0800	.0800	.0816	.08300	.0800	14
15	.057068	.072	.0720	.0700	.0726	.07200	.0720	15
16	.050820	.065	.0630	.0610	.0627	.06500	.0640	16
17	.045257	.058	.0540	.0525	.0546	.05800	.0560	17
18	.040303	.049	.0470	.0450	.0478	.04900	.0480	18
19	.035890	.042	.0410	.0400	.0411	.04000	.0400	19
20	.031961	.035	.0350	.0350	.0351	.03500	.0360	20
21	.028462	.032	.0320	.0310	.0321	.03150	.0320	21
22	.025347	.028	.0280	.0280	.0290	.02950	.0280	22
23	.022571	.025	.0250	.0250	.0261	.02700	.0240	23
24	.020100	.022	.0230	.0225	.0231	.02500	.0220	24
25	.017900	.020	.0200	.0200	.0212	.02300	.0200	25
26	.015940	.018	.0180	.0180	.0194	.02050	.0180	26
27	.014195	.016	.0170	.0170	.0182	.01875	.0164	27
28	.012641	.014	.0160	.0160	.0170	.01650	.0148	28
29	.011257	.013	.0150	.0150	.0163	.01550	.0136	29
30	.010025	.012	.0140	.0140	.0156	.01375	.0124	30
31	.008928	.010	.0130	.0130	.0146	.01225	.0116	31
32	.007950	.009	.0120	.0120	.0136	.01125	.0108	32
33	.007080	.008	.0110	.0110	.0130	.01025	.0100	33
34	.006305	.007	.0100	.0100	.0118	.00950	.0092	34
35	.005615	.005	.0095	.0095	.0109	.00900	.0084	35
36	.005000	.004	.0090	.0090	.0100	.00750	.0076	36
37	.004453		.0085	.0085	.0095	.00650	.0068	37
38	.003965		.0080	.0080	.0090	.00575	.0066	38
39	.003531		.0075	.0075	.0083	.00500	.0052	39
40	.003145		.0070	.0070	.0078	.00450	.0048	40
41							.0044	41
42							.0040	42

NOTE.—The sizes of wire are ordinarily expressed by an arbitrary series of numbers. Unfortunately there are several independent numbering methods, so that it is always necessary to specify the method or wire gauge used. The above table gives the numbers and diameters in decimal parts of an inch for the various wire gauges in general use.

$$\text{circular mils} = \frac{\text{amperes} \times \text{ft.} \times 21.6}{\text{“drop”}} \quad (5)$$

Example.—What size wire should be used on a 250 volt circuit to transmit a current of 200 amperes a distance of 350 feet to a center of distribution with a loss of three per cent. under full load?

The volts lost or drop is equal to $250 \times .03 = 7.5$ volts.

Substituting the given value in formula (5)

$$\text{circular mils} = \frac{350 \times 200 \times 21.6}{7.5} = 201{,}600$$

$$\text{Diameter} = \sqrt{201{,}600} = 449 \text{ mils or } .449 \text{ in.}$$

From the table 3,634 - **274** the nearest **(larger) size** of wire is 0000 B. & S. gauge.*

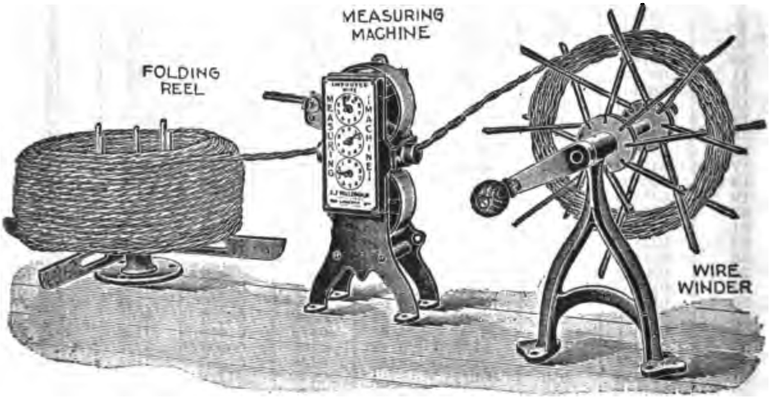


FIG. 6,907—Wire measuring outfit. It will quickly and accurately measure all wires from No. 0 to No. 40 inclusive, and can also be used for measuring lamp cord, rope, tape, etc. It is made so that it may be fastened to either the center or side wall and is compact, the winder and reel being so arranged that they may be closed when not in use.

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*NOTE.—***Caution.***—The size thus obtained should be compared with the table of carrying capacity of wires as given on page 277 - 3,637 to see if the wires would have to carry more than the allowable current.

NOTE.—In using the table for taps it is only necessary to calculate the lamp feet of the tap and take the size of wire corresponding to the nearest greater number of lamp feet in the table. The lamp feet specified by this table should not be exceeded by more than 10 per cent. Thus, if a tap measure 108 lamp feet, in 110 volt lamps, No. 12 wire would be used. But if it measure 115 lamp feet, it would be advisable to use No. 10 wire.

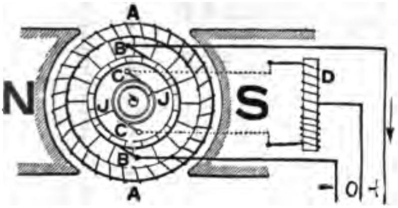
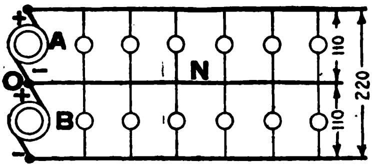


FIG. 6,908.—Dobrowolsky three wire system with self induction coil. ***In construction*** the coil D, may be carried by and revolve with the dynamo armature. The pressure at terminals of the coil is alternating, and the inductances of the two halves of the coil D, being equal, the pressure of the neutral wire O, is kept midway between the pressures of the outside wires + and −. ***In operation,*** when the two sides of the system are unbalanced in load, the difference in current carried in one direction or the other by the neutral wire passes freely through the coil D, since the current is steady, or varies slowly, and is therefore unimpeded by the self-induction.



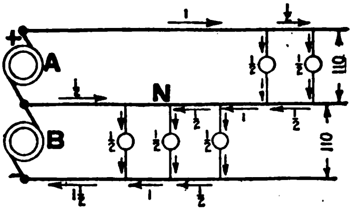
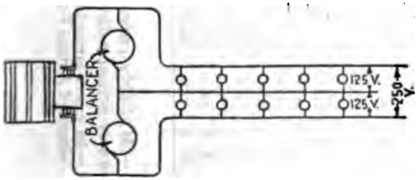


FIG. 6,909.—Three wire system with balanced load. ***The middle wire*** known as the ***neutral wire***; it keeps the system balanced in case of unequal loading, that is, a current will flow through it, to or from the dynamos, according to the preponderance of lamps on the one side or the other.

FIG. 6,910.—Three wire system with unbalanced load. ***As shown,*** there are five lamps in circuit, requiring 2½ amperes of current at a pressure of 110 volts. The two lamps in the upper set will require 1 ampere, and the three lamps in the lower set, 1½ amperes. Since a pressure of 110 volts can force only a current of one ampere through resistance of the two lamps in the upper set, it is evident, that the additional ½ ampere required by the three lamps in the lower set will have to be supplied through the neutral wire, as shown.



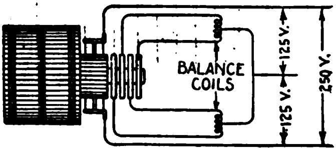


FIG. 6,911.—Diagram showing connections of balancing set in three wire one dynamo system ***The set*** consists of a motor and dynamo connected, and its operation is practically the same as a dynamotor.

FIG. 6,912.—Diagram showing connections of balancing coil system. ***The dynamo*** used in this system is provided with both commutator and collector rings.

WIRING TABLE FOR LIGHT AND POWER CIRCUITS

VOLTS	PERCENTAGE OF LOSS																
2000	1.7	1.5	1.4	1.2	1.1	1.0	0.75	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
1000	3.4	2.9	2.7	2.4	2.2	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
500	6.5	5.7	5.2	4.8	4.3	3.9	2.9	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2
220	13.7	12.0	11.0	10.3	9.3	8.3	6.5	4.4	3.9	3.5	3.1	2.7	2.2	1.8	1.4	0.9	0.45
110	—	—	20.0	18.5	17.0	15.4	12.0	8.4	7.6	6.8	6.0	5.2	4.4	3.5	2.7	1.8	0.9
52	—	—	—	—	—	—	22.4	16.1	14.7	13.3	11.8	10.3	8.8	7.1	5.5	3.7	1.9

*Carrying Capacity Amperes.	Size B. & S.	ACTUAL VOLTS LOST																
		35	30	27.5	25	22.5	20	15	10	9	8	7	6	5	4	3	2	1
300	0000	345800	296400	271700	247000	222300	197600	148200	98800	88920	79040	69160	59280	49400	39520	29640	19760	9880
245	000	274400	235200	215600	196000	176400	156800	117600	78400	70560	62720	54880	47040	39200	31360	28520	15680	7840
215	00	217525	186450	170912	155375	139837	124300	93225	62150	55935	49720	43505	37290	31075	24860	18645	12430	6215
190	0	172550	147900	135575	123250	110925	98600	73950	49300	44370	39440	34510	29580	24650	19720	14790	9860	4930
160	1	136850	117300	107525	97750	87975	78200	58650	39100	35190	31280	27370	23460	19550	15640	11730	7820	3910
135	2	108500	93000	85250	77500	69750	62000	46500	31000	27900	24800	21700	18600	15500	12400	9300	6200	3100
115	3	86100	73800	67650	61500	55350	49200	36900	24600	22140	19680	17220	14760	12300	9840	7380	4920	2460
100	4	68250	58500	53625	48750	43875	39000	29250	19500	17550	15600	13650	11700	9750	7800	5850	3900	1950
90	5	54250	46500	42625	38750	34875	31000	23250	15500	13950	12400	10850	9300	7750	6200	4650	3100	1550
80	6	43050	36900	33825	30750	27675	24600	18450	12300	11070	9840	8610	7380	6150	4920	3690	2460	1230
60	8	26985	23130	21202	19275	17347	15420	11565	7710	6939	6168	5397	4626	3855	3084	2313	1542	771
40	10	16975	14550	13337	12125	10912	9700	7275	4850	4365	3880	3395	2910	2425	1940	1455	970	485
30	12	10675	9150	8388	7625	6862	6100	4575	3050	2745	2440	2135	1830	1525	1220	915	610	305
22	14	6720	5760	5280	4800	4320	3840	2880	1920	1728	1536	1344	1152	960	768	576	384	192
15	16	4235	3630	3328	3025	2723	2420	1815	1210	1089	968	847	726	605	484	363	242	121

RULE.—*Multiply current in amperes by single distance and refer to the nearest corresponding number under column of actual volts lost, to find size of wire.*

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*NOTE.—In case a larger loss than any given in the table is required, proceed as follows:—Divide the ampere feet by 10 and then refer to column of Actual Volts Lost divided by 10, from which the size of wire is found as before.

Calculations for Three Wire Circuit.—In all cases of interior conduit work, and in most cases of inside open work, the main feeders from a three wire source of supply are installed on the three wire plan, and the sub-feeders and distributing mains, on the two wire plan, except where the application of the method necessitates the use of unwieldy sizes.

In laying out sub-feeders and mains, the total load, under normal operating conditions, should be divided as nearly as possible into two equal parts, and one part connected on each side of the neutral part of the entrance cut out, or the neutral bus bar of the switch board or panel board in an isolated plant, thus making the load on each side of the neutral wire of the feeder as near equal as possible.

Fig. 6,913 shows a three wire panel board with connections for 12 mains, those shown in solid lines as A, B, C, etc., being connected between the neutral wire and the negative wire of the feeder, and those shown by dotted lines as G, H, I, etc., being connected between the neutral wire

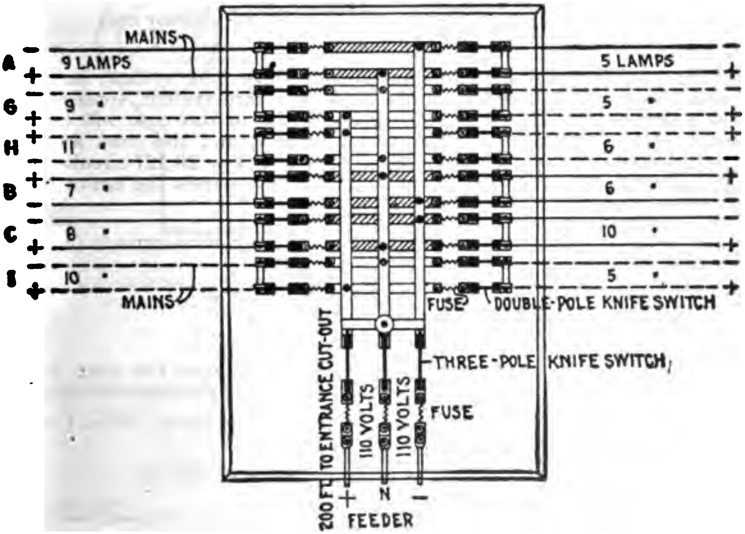

Fig. 6,913.—Three wire circuit panel board with connections for 12 mains. The wires shown in solid lines as A, B, C, etc., are connected between the neutral wire and the negative wire of the feeder, and those shown by dotted lines, as G, H, I, etc., are connected between the neutral wire and the positive wire of the feeder.

and the positive wire of the feeder. The total load consists of ninety-one 16 candle power lamps, which are so distributed that the positive wire of the feeder carries the current for 46 lamps, and the negative wire, 45 lamps, the neutral wire carrying the difference or current for 1 lamp.

The proper size of wire for the mains may be calculated as already explained, but in calculating the outer wires of the three wire feeder, the neutral wire should be disregarded and the outer wires connected as a *two wire circuit carrying the total load of 91 lamps at the over all pressure of 220 volts.*

Example.—Ninety-one 16 candle power lamps consuming 3.1 watts per candle power at a pressure of 110 volts, will require a current of

$$\frac{16 \times 3.1 \times 91}{110} = 41 \text{ amperes}$$

The distance from the entrance cut out to the main or feeder switch is 200 feet, then for a 2 per cent. drop, or a loss of 110 × .02 = 2.2 volts, the cross sectional area of the wire will be,

$$\frac{41 \text{ amperes} \times 200 \text{ feet} \times 21.6}{2.2 \text{ volts}} = 80{,}509 \text{ circular mils}$$

The joint resistance of the lamps on a three wire system, however, would be four times greater than on a two wire system; consequently the resistance of the outer wires of the feeder in this case will be four times greater for the same percentage of loss, and the cross sectional area of each of the outer wires will be, 80,509 ÷ 4 = 20,127 circular mils. According to the underwriters' rules, this value compels the use of No. 6 B. & S. gauge wire.

If the *lamp* voltage, 110 volts, be used, the two wire formula (5) must be modified to,

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\text{drop} \times 4}$$

but if an *over all* voltage (that is, the voltage between the outer wires), of 220 volts be used, the two wire formula does not require any modification.

The proper size of wire may also be calculated by means of the formula

$$\frac{\text{drop}}{2 \times \text{distance} \times \text{amperes}} = \text{resistance per foot} \ldots\ldots\ldots\ldots (1)$$

Example.—If in calculating a three wire feeder, the over all voltage be 220 volts, the drop = 4.4 volts, twice the distance = 400 feet, and the current = 20.5 amperes, then,

$$\frac{4.4 \text{ volts}}{400 \text{ feet} \times 20.5 \text{ amperes}} = .0005365 \text{ ohms per foot}$$

In the table of the properties of copper wire which gives the resistance of various sizes of wire, it will be noted that at all of the given temperatures No. 8 wire has a resistance greater than the value just calculated, therefore, No. 6 B. & S. gauge wire should be used for the outer wires of the feeder. In the table the resistance is given per 1,000 feet, hence it is only necessary to move the decimal point to obtain the resistance per foot.

If the calculation be based on the lamp voltage, 110 volts, the formula (1) must be modified to

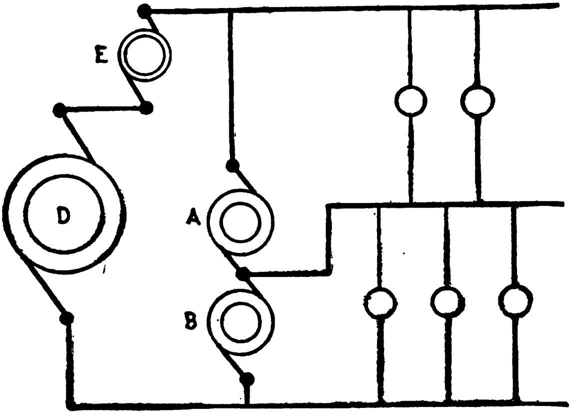

FIG. 6,914.—Three wire compensator system. A and B are the compensators or equalizers. They consist of auxiliary dynamos coupled together and connected to the system as shown. D, is the main dynamo, and E, a booster.

$$\frac{\text{drop} \times 4}{2 \times \text{distance} \times \text{amperes}} = \text{resistance} \ldots\ldots\ldots\ldots\ldots (2)$$

In this case, drop = 2.2 volts, 2 × distance = 400 feet, and current = 41 amperes, then,

$$\frac{2.2 \text{ volts} \times 4}{400 \text{ feet} \times 41 \text{ amp.}} = \frac{8.8}{16{,}400} = .005364 \text{ ohms}$$

NOTE.—***Size of the neutral wire.***—In three wire circuits, the size of the neutral wire will depend to a great extent upon operating conditions. In the case of installations which occasionally have to be worked as two wire systems, the cross section of the neutral wire should be equal to the combined cross section of the two outer wires. For interior wiring which must pass inspection, the neutral wire must always be twice the size of one of the outside wires.

660 Watt Circuits.—In laying out interior wiring to conform to the requirements of the Code, all circuits should be so balanced, and distributed so that the total wattage of all the lamps in each circuit will not exceed 660 watts.

Electric irons, heaters, washers, and other appliances should have special base or wall recepticles which should be run as a special circuit and calculated as 660 watts where the load is less than 660 watts, the size should be calculated according to the amount of current the appliance consumes (amperes).

Figuring in Watts Instead of Amperes.—*The power required to operate most electrical appliances is marked in* **watts.**

For instance, the standard incandescent lamp is rated as equivalent to the light given by 16 candles, and may consume, according to type and make, from 50 to 56 watts, or from 3.1 to 3.5 watts per candle power. Therefore, a 660 watt circuit will carry thirteen 16 candle power 49.6 watt lamps, or eleven 56 watt lamps.

The proper size wire for a 660 watt circuit will depend upon the voltage for which the lamps are made. For example: a 16 candle power lamp which consumes 56 watts on 110 volt circuit will take, $56 \div 110 = .5$ or ½ ampere of current, while the same lamp, if made for 220 volts, will take only $55 \div 220 = .25$ or ¼ ampere. Therefore, eleven 16 candle power 56 watt lamps will require a current of 5½ amperes at 110 volts, or 2¾ amperes at 220 volts.

According to the laws of resistance, the resistance of a round wire is inversely proportional to the square of the diameter, and if the circuit be taken at 100 feet, and the allowable percentage of drop at 1 volt, then according to formula (5), on page 748, the wire required for a circuit carrying eleven 16 candle power 56 watt 110 volt lamps, will have a cross sectional area of,

$$\frac{5.5 \times 100 \times 21.6}{1} = 11{,}880 \text{ circular mils}$$

while the same number of lamps on a 220 volt circuit will require wire having a cross sectional area of,

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NOTE.—***National Electrical Code.***—No wire smaller than No. 14 may be used for electric light wiring except No. 18 which may be used in fixtures and in flexible cords. For branch circuits in 110 volt or 220 volt light wiring No. 14 wire is the smallest size permitted. But for main service wires the size of wire is rarely under No. 12 or No. 10 and in most cases the local lighting company should be consulted as to minimum size.

$$\frac{2.75 \times 100 \times 21.6}{1} = 5{,}940 \text{ circular mils}$$

In order to conform to the underwriters' requirements, No. 8, B. & S. gauge, wire must be used for the circuit carrying the 110 volt lamps, while No. 12, B. & S. wire, would be sufficient for the 220 volt circuit.

Figuring in Watt Feet.—Dy definition a *watt foot* is *the product of one watt multiplied by one foot;* it is a convenient unit for quick calculation with the aid of tables.

30 Volts

Rule.—To find the size of wire to carry a given number of watts a given distance, on 30 volt circuits, *multiply the distance in feet by the total number of watts to be carried (thus obtaining the watt feet), and use the size of wire in the table specified for the nearest number of watt feet.*

TABLE OF WATT FEET FOR 30 VOLTS

Between	0	and	18,870	watt	ft.	use	No.	12	wire
"	18,871	"	29,000	"	"	"	"	10	"
"	29,000	"	46,545	"	"	"	"	8	"
"	46,545	"	73,018	"	"	"	"	6	"
"	73,018	"	116,363	"	"	"	"	4	"
"	116,363	"	186,180	"	"	"	"	2	"
"	186,180	"	232,727	"	"	"	"	1	"
"	232,727	"	290,000	"	"	"	"	0	"
"	290,000	"	372,362	"	"	"	"	00	"

Example.—Ten 20 watt lamps are to be installed in a barn 200 ft. distant. What size wire is required for 30 volt circuit?

Load = 10 × 20 × 200 = 40,000 watt ft. Nearest size wire from table is No. 8.

110 Volts

Rule.—*In using the table just given for 110 volts multiply either the watts or the distance by* $3\frac{2}{3}$—because for a given load the current is reduced 110 ÷ 30 = $3\frac{2}{3}$ times as compared with 30 volts.

Example.—Ten 20 watt lamps are to be installed in a barn 200 ft. distant. What size wire is required for 110 volt circuit?

Load = 10 × 20 × 200 × 40,000 watt feet, and for 110 volts, 40,000 ÷ $3\frac{2}{3}$ = 1,090 watt feet. Nearest size wire from table is No. 12.

The following table gives minimum size wire for *d.c.* motor wiring when wires are concealed or partly concealed, also good practice for open wires.

MINIMUM WIRE SIZES FOR MOTORS

(Western Electric Co.)

	Size wire B. & S. Gauge				Size Wire B. & S. Gauge		
H.P.	30 volts	110 volts	220 volts	H.P.	30 volts	110 volts	220 volts
1/16	14	..	..	3	..	10	14
¼	14	..	..	4	..	8	12
½	10	14	14	5	..	6	10
1	8	14	14	7½	..	4	8
2	..	12	14	10	..	3	6

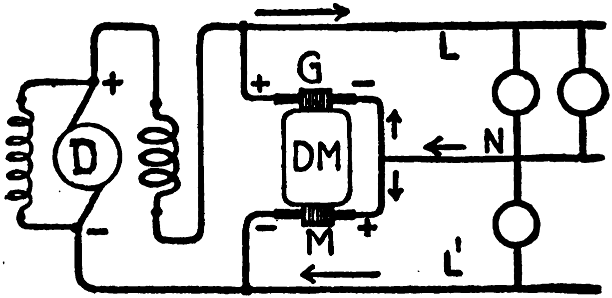


Fig. 6,915.—Diagram showing dynamotor connections when used as an equalizer in the three wire system. DM, dynamotor; G, generator side; M, motor side.

This table only shows safe size of wire to avoid overheating. If motor be over 30 ft. from dynamo, larger wire must be used. Find amperes in the table which follows and select size of wire by using the table of watt ft., dividing the watt ft., by the proper factor for voltages other than 30.

Approximate Amperes Taken at 30 Volts

Motors		Mazda Lamps	
Horsepower	Amperes	Watts	Amperes
1/16	2½	10	.3
⅛	5	20	.7
¼	9	40	1.3
½	16	75	2.5
1	30	..	...

	Amperes
6 in. 4 blade, fan motors	.80
12 in., 6 blade fan motors	1.00
Flatiron	16.4
Toaster	15.0
Disc heater	15.0
Water heater	9.4
Coffee percolator	14.0
Water heater	15.6
Soldering iron	10.0
Cleaner	4.0
Washing machine	8.0
Sewing machine	.66

A motor is rated by the power it delivers, not by the power it takes. The figures given are the approximate amperes when the motor is working at full load.

Example.—What size wire is required for a ***h.p.*** motor, 220 volt motor located 200 feet from the dynamo?

From the table of approximate amperes at 30 volts, a 1 ***h.p.*** motor would require 30 amperes. Load at 30 volts = 30 × 30 × 200 = 180,000 watt feet, and for 220 = 180,000 × 30 ÷ 220 = 24,545 watt feet. Size wire for table of watt feet for 30 volts is No. 10.

Ratings in Watts.—A motor is rated by the power it delivers, not by the power it takes. The figures given are the approximate watts at full load.

APPROXIMATE WATTS

(Western Electric Co.)

1/16 H.P. motor	75
1/8 H.P. motor	150
1/6 H.P. motor	210
¼ H.P. motor	270
Sewing machine	20
For sewing machine	20
Vacuum cleaner, 1/12 H.P.	120
Vacuum cleaner, 1/12 H.P.	120
Vacuum cleaner, 1/6 H.P.	230
Washing machine, 1/6 H.P.	230
Washing machine, 1/6 H.P.	230
Dish washer, 1/7 H.P.	200
6 in. fan	23
9 in. fan, non-oscillating	25
Electric iron	500
Toaster	440
Disc heater (various sizes)	450 to 600

Wire Calculations for Motors.—The proper size of wire for a motor may be readily determined by means of the following formula:

$$\text{circular mils} = \frac{\text{H.P.} \times 746 \times D \times 21.6}{E \times L \times K} \qquad (6)$$

in which

H. P. = horse power of motor;
746 = watts per H. P.;
D = length of motor circuit from fuse block to motor;
21.6 = ohms per foot run in circuit where wires are one mil in diameter;
E = voltage at the motor;
L = drop in percentage of the voltage at the motor;
K = efficiency of the motor expressed as a decimal.

The average values for K, are about as follows: 1 H.P., .75; 3 H.P., .80; 5 H.P., .80; 10 H.P. and over, 90 per cent.

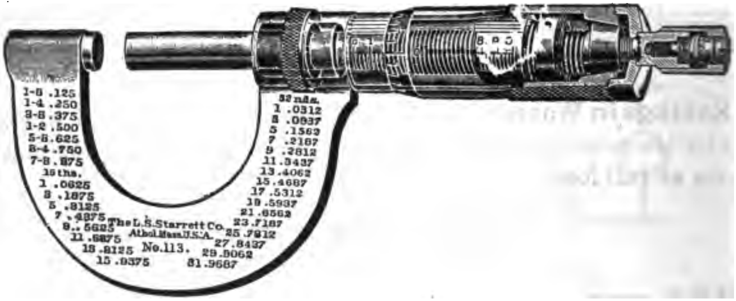


FIG. 6,916—Phantom view of Starrett micrometer calipers showing construction. Over the barrel is placed a thin graduated sleeve, which causes the base or zero line, instead of having this line marked on the barrel itself. This sleeve may be turned by means of a small spanner wrench to bring the zero line correct to compensate for wear. The thin sleeve also keeps dirt from the screw. A knurled locking nut contracting a split bushing around the spindle tightens and keeps the spindle central and true, or by a slight turn locks it firm, making a solid gauge when desired. The anvil and spindle are hardened, ground and lapped.

Example.—What is the proper size of wire for a 10 *h.p.* 220 volt motor, with 2% drop on 200 ft. circuit.

Substituting the given values in the formula on page 758:

$$\text{circular mils} = \frac{10 \times 746 \times 200 \times 21.6}{220 \times 4.4 \times .9} = 36{,}991$$

The nearest larger value to this result, in the table of carrying capacities of copper wire (page 3,634 - 274), is 41,740, corresponding to No. 4 wire, B. & S. gauge.

In all cases the size of the wire thus formed should be compared with that allowed by the underwriters for full load current of motor, plus 25 per cent. of that current, and if the size calculated happen to be smaller than the allowable size, it should be increased to the latter, otherwise it will not pass inspection.

TABLE OF AMPERES PER MOTOR

H. P.	Per Cent. Eff.	Watts Input.	50 Volts.	100 Volts.	220 Volts.	500 Volts.
¾	70	800	16	7	4	2
1½	70	1600	32	15	7	3
3	75	2980	60	27	14	6
5	80	4660	93	42	21	9
7½	85	6580	132	60	30	13
10	85	8780	176	80	40	18
15	85	13200	264	120	60	26
20	85	17600	352	160	80	35
25	85	21900	438	199	100	44
30	90	24900	498	226	113	50
40	90	33200	664	301	151	66
50	90	41400	828	376	188	83
60	90	49700	994	452	226	99
70	90	58000	1160	527	264	116
80	90	66300	1330	603	302	133
90	90	74600	1490	678	339	149
100	90	82900	1660	755	377	166
120	90	99500	1990	905	453	199
150	90	124000	2480	1130	564	248

TABLE OF AMPERES PER DYNAMO

K. W.	125 Vs.	250 Vs.	500 Vs.	Appx. H. P.	K. W.	125 Vs.	250 Vs.	500 Vs.	Appx. H. P.
1.	8	4	2	1.3	30.	240	120	60	40.
2.	16	8	4	2.7	37.5	300	150	75	50.
3.	24	12	6	4.0	40.	320	160	80	53.
5.	40	20	10	6.7	50.	400	200	100	67.
7.5	60	30	15	10.	60.	480	240	120	80.
10.	80	40	20	13.	75.	600	300	150	100.
12.5	100	50	25	17.	100.	800	400	200	134.
15.	120	60	30	20.	125.	1000	500	250	167.
20.	160	80	40	27.	150.	1200	600	300	201.
25.	200	100	50	34.	200.	1600	800	400	268.

To determine the current required for a motor, as for instance, the 10 H. P. motor under consideration, *multiply the horsepower by 746, and divide the product by the voltage of the motor multiplied by its efficiency as follows:* (10 × 746) ÷ (220 × .90) = 37.6 amperes.

This value increased by 25 per cent. of itself (37.6 × .25 = 9.4 amp.) is equal to 37.6 plus 9.4 = 47 amperes. In the table of carrying capacities of copper wire (page **277-3,637**), 50 amperes is given as the allowable carrying capacity of No. 6, B. & S. gauge, rubber covered wire, hence this wire is amply large.

MISCELLANEOUS FORMULAE FOR COPPER WIRES

Diameter squared = circular mils
Circular mils × .7854 = square mils
.000003027 × circular mils = lbs. per ft.
.003027 × circular mils = lbs. per 1,000 ft.
.0159847 × circular mils = lbs. per mile
.003879 × square mils = lbs. per 1,000 ft.
.33033 ÷ circular mils = ft. per lb.
.0000002924 × circular mils = lbs. per ohm
.342 ÷ circular mils = ohms per lb.
.096585 × circular mils = ft. per ohm
10.353568 ÷ circular mils = ohms per ft.

Breaking weight of wire ÷ area = breaking weight per square inch.

Breaking weight per square inch × area = breaking weight of wire.

The weight of copper wire is 1 1/7 times the weight of iron wire of same diameter.

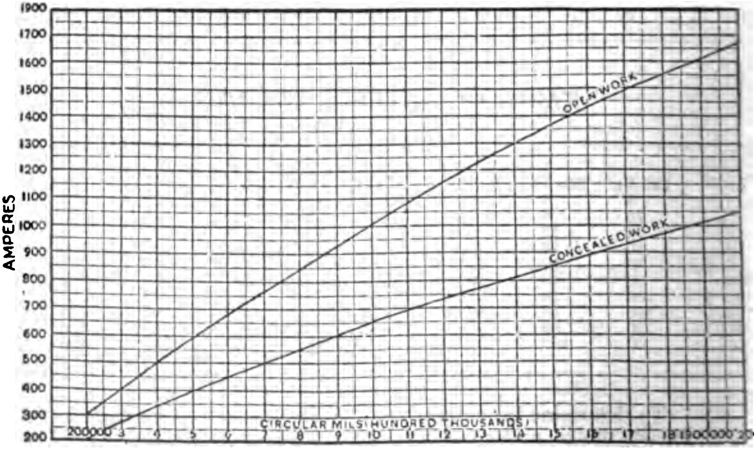
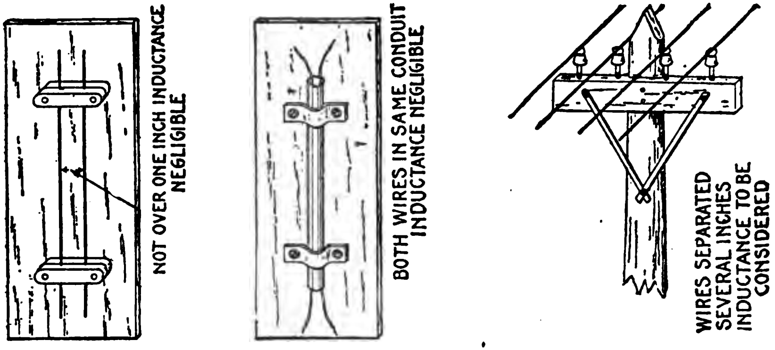


Fig. 6,917.—Diagram showing capacities of cables for both open and concealed work as allowed by the underwriters.

2. Alternating Current Wiring

Because of the peculiar behaviour of *a.c.* current, there are several effects which must be considered in making *a.c.* wiring calculations, which do not enter into *d.c.* calculations. They are:

1. Self-induction;
2. Mutual-induction;
3. Power factor;
4. Skin effect;
5. Corona effect;
6. Frequency;
7. Resistance.

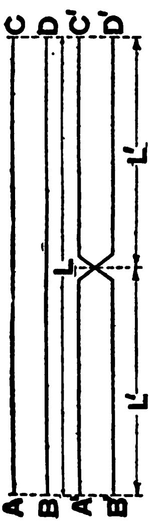


FIGS. 6,918 to 6,920.—Example of wiring showing where inductance is negligible, and where it must be considered in wire calculations.

Induction.—The effect of induction, whether self-induction or mutual induction, is to set up a back pressure of *spurious resistance*, which must be considered, as it sometimes materially affects the calculation of circuits even in interior wiring.

Besides variations of current strength self-induction depends upon the shape of the circuit, and the character of the surrounding medium

If the circuit be straight, there will be little self-induction, but if coiled, the effect will become pronounced. If the surrounding medium be air, the self-induction is small, but if it be iron, the self-induction is considerable.



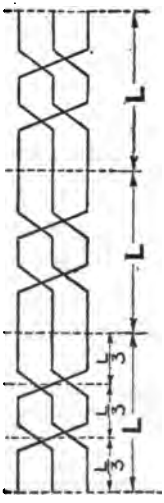


FIG. 6,921.—Transposition diagram for two parallel lines consisting of two wires each.

FIG. 6,922.—Transposition diagram for three phase, three wire line, transposing at the vertices of an equilateral triangle. The line is originally balanced and becomes unbalanced on transposing, a procedure which should be resorted to only to prevent *mutual induction*.

FIG. 6,923.—Transposition diagram of three phase, three wire line, with center arranged in a straight line.

FIGS. 6,924 and 6,925.—Capacity effect in single phase and three phase transmission lines.

When iron conduits are used, the wires of each circuit should not be installed in separate conduits, because such arrangement will cause excessive self-induction.

Mutual induction is *the effect of one alternating current circuit upon another*. Its effect as a rule in ordinary installations is negligible.

The effect of mutual induction is to induce surges in the line where a difference of frequency exists between the two currents, and to induce high electrostatic charges in lines carrying little or no current, such as telephone lines. The effect may be nullified by *transpositions;* that is, by transposing the wires of one of the lines so that the effect produced in one section is opposed by that in another.

Capacity.—In any given system of electrical conductors a pressure difference between two of them corresponds to the presence of a quantity of electricity in each.

The constant connecting the charge and the resulting pressure is called the capacity of the system. All circuits have a certain capacity, because each conductor acts like the plate of a condenser, and the insulating medium, acts as the dielectric. The capacity depends upon the insulation.

INDUCTANCE PER MILE OF THREE PHASE CIRCUIT

Size B. & S.	Diam. in inch.	Distance d in inches.	Self inductance L henrys.	Size B. & S.	Diam. in inch.	Distance d in inches.	Self inductance L henrys.
0000	.46	12	.00234	4	.201	12	.00280
		18	.00256			18	.00300
		24	.00270			24	.00315
		48	.00312			48	.00358
000	.41	12	.00241	5	.182	12	.00286
		18	.00262			18	.00307
		24	.00277			24	.00323
		48	.00318			48	.00356
00	.365	12	.00248	6	.162	12	.00291
		18	.00260			18	.00313
		24	.00285			24	.00329
		48	.00330			48	.00369
0	.325	12	.00254	7	.144	12	.00298
		18	.00276			18	.00310
		24	.00293			24	.00336
		48	.00331			48	.00377
1	.289	12	.00260	8	.128	12	.00303
		18	.00281			18	.00325
		24	.00308			24	.00341
		48	.00338			48	.00384
2	.258	12	.00267	9	.114	12	.00310
		18	.00288			18	.00332
		24	.00304			24	.00348
		48	.00314			48	.00389
3	.229	12	.00274	10	.102	12	.00318
		18	.00294			18	.00340
		24	.00310			24	.00355
		48	.00351			48	.00396

CAPACITY IN MICRO-FARADS PER MILE OF CIRCUIT FOR THREE PHASE SYSTEM

Size B. & S.	Diam. in inch.	Distance A in inches.	Capacity C in micro-farads	Size B. & S.	Diam. in inch.	Distance A in inches.	Capacity C in micro-farads
0000	.46	12	.0226	4	.204	12	.01874
		18	.0204			18	.01726
		24	.01922			24	.01636
		48	.01474			48	.01452
000	.41	12	.0218	5	.182	12	.01830
		18	.01992			18	.01690
		24	.01876			24	.01602
		48	.01638			48	.01426
00	.365	12	.0124	6	.162	12	.01788
		18	.01946			18	.01654
		24	.01832			24	.01560
		48	.01604			48	.0140
0	.325	12	.02078	7	.144	12	.01746
		18	.01898			18	.01618
		24	.01642			24	.01538
		48	.01570			48	.01374
1	.289	12	.02022	8	.128	12	.01708
		18	.01952			18	.01586
		24	.01748			24	.01508
		48	.0154			48	.01350
2	.258	12	.01972	9	.114	12	.01660
		18	.01813			18	.01552
		24	.01710			24	.01478
		48	.01510			48	.01326
3	.229	12	.01938	10	.102	12	.01636
		18	.01766			18	.01522
		24	.01672			24	.01452
		48	.01480			48	.01304

For a given grade of insulation, the capacity is proportional to the surface of the conductors, and inversely to the distance between them.

A three phase three wire transmission line spaced at the corners of an equilateral triangle as regards capacity acts precisely as though the neutral line were situated at the center of the triangle.

The capacity of circuits is readily calculated by applying the following formulæ:

$$C = \frac{38.83\ sc\ 10^{-8}}{\log\ (D + d)}$$ per mile, insulated cable with lead sheath;

$$C = \frac{38.83 \times 10^{-8}}{\log\ (4h \div d)}$$ per mile, single conductor with earth return;

$$C = \frac{19.42 \times 10^{-8}}{\log\ (2A + d)}$$ per mile of parallel conductors forming metallic circuit;

in which

C = Capacity in micro-farads; for a metallic circuit, C = capacity between wires;

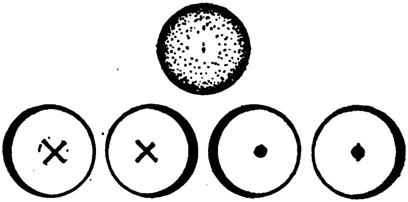
sc = Specific inductive capacity of insulating material; = 1 for arc, and 2.25 to 3.7 for rubber;

D = Inside diameter of lead sheath;

d = Diameter of conductor;

h = Distance of conductors above ground;

A = Distance between wires.



FIGS. 6,926 to 6,930.—Skin effect and shield effect. Fig. 6,926, section of conductor illustrating skin effect or tendency of the alternating current to distribute itself unequally through the cross section of a conductor as shown by the varied shading, which represents the current flowing most strongly in the outer portions of the conductor. For this reason it has been proposed to use hollow or flat instead of solid round conductors; however, with frequency not exceeding 100, the skin effect is negligibly small in copper conductors of the sizes usually employed. In figs. 6,927 and 6,928, or 6,929 and 6,930, if two adjacent conductors be carrying current in the same direction, concentration will occur on those parts of the two conductors remote from one another, and the nearer parts will have less current, that is to say, they will be *shielded*. In this case, the induction due to one conductor will exert its opposing effect to the greatest extent on those parts of the other conductor nearest to it; this effect decreasing the deeper the latter is penetrated.

Frequency.—The number of cycles per second has a direct effect upon the inductance.

In the case of a transmission line alone; the lower frequencies are the more desirable, in that they tend to reduce the inductance drop and charging current. The inductance drop is proportional to the frequency.

Skin Effect.—The tendency of *a.c.* current to confine itself to the *outer* portions of the conductor has the effect of increasing the ohmic resistance.

If the conductor be large, or the frequency high, the central portion of the conductor carries little if any current, hence the resistance is therefore greater for alternating current than for direct current.

For frequencies of 60 or less, with conductors having a diameter not greater than 0000 B. & S. gauge, skin effect may be neglected.

To calculate skin effect for a given wire, its area in circular mils is multiplied by the frequency, which gives the ratio of the wire's ohmic resistance to its combined resistance.

The following table gives these ratio factors for large wires.

RATIO FACTOR FOR COMBINED RESISTANCE

Cir. mils. × frequency	Ratio factor	Cir. mils. × frequency	Ratio factor
10,000,000	1.00	70,000,000	1.13
20,000,000	1.01	80,000,000	1.17
30,000,000	1.03	90,000,000	1.20
40,000,000	1.05	100,000,000	1.25
50,000,000	1.08	125,000,000	1.34
60,000,000	1.10	150,000,000	1.43

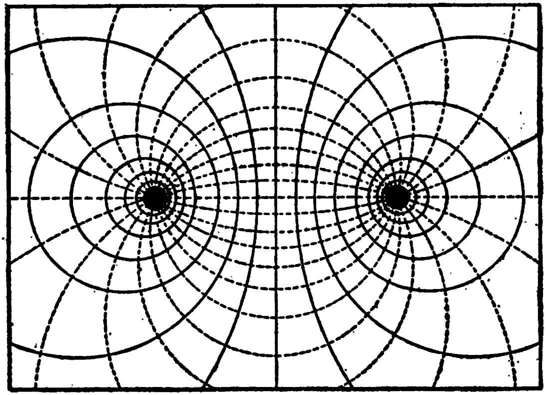


FIG. 6,931.—Electromagnetic and electrostatic fields surrounding the conductors of a transmission line. The electromagnetic field is represented by lines of magnetic force that surround the conductors in circles, (the solid lines) and the electrostatic field by (dotted) circles passing from conductor to conductor across at right angles to the magnetic circles. For any given size of wire and distance apart of wires, there is a certain voltage at which the critical density or critical gradient is reached, where the air breaks down and luminosity begins—the critical voltage where corona manifests itself. At still higher voltages, corona spreads to further distances from the conductor and a greater volume of air becomes luminous. Incidentally, it produces noise. Now to produce light requires power and to produce noise requires power. Air is broken down and is heated in breaking down, and to heat also requires power; therefore, as soon as corona forms, power is consumed or dissipated in its formation. When this phenomenon occurs on the conductors of an alternating current circuit, a change takes place in relation to current and voltage. On the wires of an alternating current transmission line, at a voltage below that where corona forms—at a voltage where wires are not luminous—considerable current, more or less depending on voltage and length of wire, flows into the circuit as capacity current or charging current.

Corona Effect.—When two wires, having a great difference of pressure are placed near each other, a certain phenomenon occurs, which is called *corona effect.*

When the spacing or distance between the wires is small and the difference of pressure in the wires very great, a continuous passage of energy takes place through the dielectric or atmosphere, the amount of this energy may be an appreciable percentage of the power transmitted. Therefore in laying out high pressure transmission lines, this effect must be considered in the spacing of the wires.

They should be so spaced as to lessen the tendency to leakage and to prevent the wires swinging together or against towers. The spacing should be only sufficient for safety, since increased spacing increases the self-induction of the line, and while it lessens the capacity, it does so only in a slight degree.

The following spacing is in accordance with average practice:

SPACING FOR VARIOUS VOLTAGES

Volts	Spacing	Volts	Spacing	Volts	Spacing
5,000	28 ins.	45,000	60 ins.	90,000	96 ins.
15,000	40 ins.	60,000	60 ins.	105,000	108 ins.
30,000	48 ins.	75,000	84 ins	120,000	120 ins.

Wire Calculations.—In the calculation of *a.c.* circuits, the two chief factors which make the computation different from that for direct current circuits, is *induction* and *power factor*. The first depends on the frequency, and physical condition of the circuit, and the second upon the character of the load.

Induction may be neglected in cases where the wires of a circuit are not spaced over an inch apart, or in conduit work, where both wires are in the same conduit. Induction must be considered on exposed circuits with wires separated several inches, especially with large wires.

The size of wire for any alternating circuit may be determined by slightly modifying the formula used in direct current work, which as derived on page 3,646-286, is:

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\text{drop}} \dots\dots\dots\dots (1)$$

It is sometimes however convenient to make the calculation in terms of watts. Formula (1) may be modified for such calculation.

In modifying the formula, the "drop" should be expressed in percentage instead of actual volts lost, that is, instead of the difference in pressure between the beginning and the end of the circuit.

In any circuit the loss in percentage, or

$$\%\ \text{loss} = \frac{\text{drop}}{\text{impressed pressure}} \times 100$$

from which

$$\text{drop} = \frac{\%\ \text{loss} \times \text{impressed pressure}}{100} \dots\dots (2)$$

Substituting equation (2) in equation (1)

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\frac{\%\ \text{loss} \times \text{imp. pressure}}{100}}$$

$$= \frac{\text{amperes} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{imp. pressure}} \dots\dots\dots\dots (3)$$

Equation (3) is modified for calculation in terms of watts as follows: The power in watts is equal to the *applied voltage* multiplied by the current, that is to say, the power is equal to the *volts at the consumer's end of the circuit* multiplied by the current, or simply

$$\text{watts} = \text{volts} \times \text{amperes}$$

from which

$$\text{amperes} = \frac{\text{watts}}{\text{volts}} \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

$$\text{circular mils} = \frac{\frac{\text{watts}}{\text{volts}} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}}$$

$$= \frac{\text{watts} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}^2} \quad \ldots\ldots\ldots\ldots (5)$$

This formula (5) applies to a direct current two wire circuit, and to adapt it to any alternating current circuit it is only necessay to use the letter M instead of the number 2,160. thus

$$\text{circular mills} = \frac{\text{watts} \times \text{feet} \times M}{\%\ \text{loss} \times \text{volts}^2} \quad \ldots (6)$$

in which M is a coefficient which has various values according to the kind of circuit and value of the power factor. These values are given in the following table:

VALUES OF M

SYSTEM	POWER FACTOR									
	1.00	.98	.95	90	.85	.80	.75	.70	.65	.60
Single phase	2,160	2,249	2,400	2,660	8,000	3,380	3,840	4,400	5,112	6,000
Two phase (4 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000
Three phase (3 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000

NOTE.—The above table is calculated as follows: For ***single phase*** $M = 2{,}160 \div \text{power factor}^2 \times 100$; for ***two phase*** four wire, or three phase three wire, $M = \frac{1}{2}\,(2{,}160 \div \text{power factor}^2)\ 100$. Thus the value of M for a single phase line with power factor $.95 = 2{,}160 \div .95^2 \times 100 = 2{,}400$.

It must be evident that when 2,160 is taken as the value of M, formula (6) applies to a two wire direct current circuit and also to a single phase *a.c.* circuit when the power factor is unity.

In the table, the value of M, for any particular power factor is found by dividing 2,160 by the square of that power factor for single phase and twice the square of the power factor for two phase and three phase.

Figuring With Watts.—The table which follows is for finding the value of the current in the line using the formula.

$$I = W \div (E \times T)$$

in which I = current in line; E, voltage between main conductors at receiving or consumers' end; W = watts.

VALUES OF T

System	Power Factor				
	1.00	.98	90	.80	.70
Single phase..........	1.00	.98	.90	.80	.70
Two phase, 4 wire.....	2.00	1.96	1.80	1.60	1.40
Three phase, 3 wires...	1.73	1.70	1.55	1.38	1.21

Example.—What is the current in a two phase line transmitting 1,000 watts at 550 volts, power factor .8? Substituting 1 = 1,000 ÷ (550 × 1.6) = 1.13 amperes.

There is no saving in copper using two phases, but it is desirable on power circuit because two phase motors are self-starting. For equal working conditions, each wire of the three phase system is half the size of one of the wires of the single phase system, hence the weight of copper required for the three phase system is 75% of that required for the single phase system. Since in the two phase system half of the load is carried by each phase, each wire of the three phase system is the same size as one of the wires of the two phase system, hence, the copper required by the three phase system is 75% of that required by the two phase system.

Example.—What size wires must be used on a single phase circuit 2,000 feet in length to supply 30 kw. at 220 volts with loss of 4%, the power factor being .9?

The formula for circular mils is

$$\text{circular mils} = \frac{\text{watts} \times \text{feet} \times M}{\%\ \text{loss} \times \text{volts}^2} \dots\dots\dots\dots\dots\dots (1)$$

Substituting the given values and the proper value of M from the table, in (1)

$$\text{circular mils} = \frac{30{,}000 \times 2{,}000 \times 2{,}660}{4 \times 220^2} = 824{,}380$$

Referring to the accompanying table of the properties of copper wire, the nearest *larger* size wire is No. 1 B. & S. gauge having an area of 83,690 circular mils.

Drop.—In order to determine the drop or volts lost in the line, the following formula may be used

$$\text{drop} = \frac{\%\ \text{loss} \times \text{volts}}{100} \times S \dots\dots\dots (1)$$

in which the % loss is a percentage of the applied power, that is, the power delivered to the consumer and not a percentage of the power at the alternator. "volts" is the pressure at the consumer's end of the circuit.

The coefficient S, has various values as given in the accompanying tables. As will be seen from the table, the value of S, to be used depends upon the size of wire, spacing, power factor and frequency.

These values are accurate enough for all practical purposes, and may be used for distances of 20 miles or less and for voltages up to 25,000.

On longer lines the capacity effect makes this method of determining the drop somewhat inaccurate.

Example.—A circuit supplying current at 440 volts, 60 frequency, with 5% loss and .8 power factor is composed of No. 2 B. & S. gauge wires spaced one foot apart. What is the drop in the line?

VALUE OF "S" FOR 25 CYCLES

Size of wire B. & S. gauge	Area in circular mils.	.98 power factor					.90 power factor					.80 power factor					.70 power factor				
		Spacing of conductors					Spacing of conductors					Spacing of conductors					Spacing of conductors				
		1″	2″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″
500,000	500,000	1.01	1.17	1.23	1.29	1.36	1.02	1.22	1.35	1.43	1.61	1.00	1.15	1.30	1.47	1.62	1.00	1.00	1.16	1.33	1.49
300,000	300 000	1.04	1.10	1.13	1.18	1.21	1.00	1.08	1.16	1.25	1.31	1.00	1.00	1.09	1.16	1.25	1.00	1.00	1.00	1.02	1.12
0,000	211,600	1.03	1.07	1.09	1.11	1.14	1.00	1.02	1.07	1.13	1.15	1.00	1.00	1.00	1.03	1.10	1.00	1.00	1.00	1.00	1.00
000	167,800	1.00	1.05	1.06	1.09	1.10	1.00	1.00	1.02	1.07	1.11	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.00	1.00
00	133,100	1.00	1.03	1.05	1.06	1.08	1.00	1.00	1.00	1.02	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0	105,500	1.00	1.01	1.02	1.03	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	83,690	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	66,370																				
3	52,630																				
4	41,740	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	33,100																				
6	26,250																				
7	20,820	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	16,510																				
9	13,090																				
10	10,380																				

VALUE OF "S" FOR 60 CYCLES

Size of wire B. & S. gauge	Area in circular mils.	.98 power factor					.90 power factor					.80 power factor					.70 power factor				
		Spacing of conductors					Spacing of conductors					Spacing of conductors					Spacing of conductors				
		1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″
500,000	500,000	1.21	1.45	1.61	1.77	1.92	1.32	1.80	2.11	2.44	2.75	1.27	1.89	2.25	2.64	3.03	1.14	1.72	2.12	2.53	2.92
300,000	300,000	1.15	1.29	1.38	1.48	1.57	1.19	1.47	1.66	1.84	2.02	1.11	1.46	1.68	1.90	2.12	1.00	1.33	1.56	1.78	2.01
0,000	211,600	1.12	1.22	1.28	1.34	1.41	1.13	1.33	1.45	1.58	1.63	1.03	1.27	1.43	1.58	1.75	1.00	1.14	1.29	1.45	1.69
000	167,800	1.09	1.18	1.22	1.28	1.29	1.08	1.23	1.33	1.44	1.53	1.00	1.16	1.28	1.41	.153	1.00	1.02	1.15	1:28	1.50
00	133,100	1.07	1.14	1.18	1.21	1.25	1.03	1.16	1.24	1.32	1.40	1.00	1.07	1.17	1.27	1.36	1.00	1.00	1.03	1.13	1.21
0	105,500	1.05	1.10	1.14	1.17	1.20	1.00	1.09	1.16	1.22	1.28	1.00	1.00	1.07	1.15	1.22	1.00	1.00	1.00	1.01	1.09
1	83,690	1.04	1.08	1.10	1.13	1.15	1.00	1.05	1.09	1.14	1.19	1.00	1.00	1.00	1.05	1.11	1.00	1.00	1.00	1.00	1.00
2	66,370	1.02	1.05	1.08	1.10	1.12	1.00	1.00	1.04	1.08	1.12	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00	1.00
3	52,630	1.02	1.04	1.06	1.07	1.09	1.00	1.00	1.00	1.03	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	41,740	1.00	1.02	1.03	1.04	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	33,100																				
6	26,250	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	20,820																				
8	16,510	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	13,090																				
10	10,380																				

According to the formula

$$\text{drop} = \frac{\%\text{ loss} \times \text{volts}}{100} \times S$$

Substituting the given values, and the value of S, as obtained from the table for frequency 60

$$\text{drop} = \frac{5 \times 440}{100} \times 1 = 22 \text{ volts}$$

Current.—As has been stated, the effect of power factor less than unity, is to increase the current; hence, in inductive circuit calculations, the first step is to determine the current flowing in a circuit. This is done as follows:

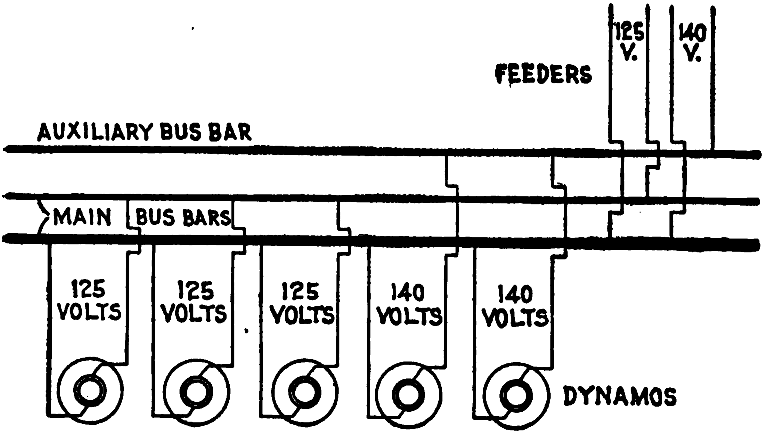


FIG. 6,932.—Diagram showing use of auxiliary bus bar. In order to avoid the necessity for boosters, some stations have an extra bus bar, which is kept at a higher pressure than the main bus, and to this are connected the feeders that have an extra large drop.

$$\text{current} = \frac{\text{apparent load}}{\text{volts}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and

$$\text{apparent load} = \frac{\text{watts}}{\text{power factor}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Substituting (2) in (1)

$$\text{current} = \frac{\frac{\text{watts}}{\text{power factor}}}{\text{volts}} = \frac{\text{watts}}{\text{power factor} \times \text{volts}} \ldots\ldots\ldots (3)$$

Example.—A 50 horse power 440 volt motor has a full load efficiency of .9 and power factor of .8 How much current is required?

Since the brake horse power of the motor is given, it is necessary to obtain the electrical horse power, thus

$$\text{E. H. P.} = \frac{\text{brake horse power}}{\text{efficiency}} = \frac{50}{.9} = 55.5$$

which in watts is

$$55.5 \times 746 = 41{,}403$$

which is the actual load, and from which

$$\text{apparent load} = \frac{\text{actual load}}{\text{power factor}} = \frac{41{,}403}{.8} = 51{,}754$$

The current therefore at 440 volts is

$$\frac{\text{apparent load}}{\text{volts}} = \frac{51{,}754}{440} = 117.6 \text{ amperes}$$

Example.—A 50 horse power single phase 440 volt motor, having a full load efficiency of .92 and power factor of .8, is to be operated at a distance of 1,000 feet from the alternator. The wires are to be spaced 6 inches apart and the frequency is 60, and % of loss 5. Determine: **A,** *electrical horse power;* **B,** *watts;* **C,** *apparent load;* **D,** *current;* **E,** *size of wires;* **F,** *drop;* **G,** *voltage at the alternator.*

A. ***Electrical horse power***

$$\text{E. H. P.} = \frac{\text{brake horse power}}{\text{efficiency}} \times \frac{50}{.92} = 54.3$$

or,

$$54.3 \times 746 = 40{,}508 \text{ watts}$$

B. ***Watts***

$$\text{watts} = \text{E. H. P.} \times 746 = 54.3 \times 746 = 40{,}508$$

C. ***Apparent load***

$$\text{apparent load or } kva = \frac{\text{actual load or watts}}{\text{power factor}} = \frac{40{,}508}{.8} = 50{,}635$$

D. *Current*

$$\text{current} = \frac{\text{apparent load or kva}}{\text{volts}} = \frac{50{,}635}{440} = 115 \text{ amperes}$$

E. *Size of wires*

$$\text{cir. mils} = \frac{\text{watts} \times \text{feet} \times \text{M}}{\% \text{ loss} \times \text{volts}^2} = \frac{40{,}508 \times 1{,}000 \times 3{,}380}{5 \times 440^2} = 141{,}443$$

From table page 1,907, nearest size *larger* wire is No. 00 B. & S. gauge.

F. *Drop*

$$\text{drop} = \frac{\% \text{ loss} \times \text{volts}}{100} \times \text{S} = \frac{5 \times 440}{100} \times 1.17 = 25.74 \text{ volts}$$

NOTE.—Values of S are given on page 1910.

G. *Voltage at alternator*

$$\text{alternator pressure} = \text{volts at motor} + \text{drop} = 440 + 25.74 = 465.7 \text{ volts}$$

CHAPTER 109

Inside Wiring

The different methods of interior wiring may be conveniently grouped into the following general classes:

1. Open or exposed wiring;
2. Wires run in mouldings;
3. Concealed knob and tube wiring;
4. Armored (B.X.) cable wiring;
5. Flexible conduit wiring;
6. Rigid conduit wiring.

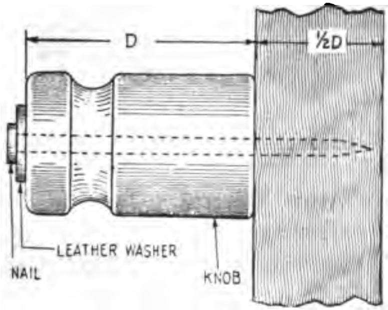


FIG. 6,933.—Correct knob fastening. Unless the member to which knob is fastened be deep enough to permit a nail penetrating to a depth of one half the height of the knob as here shown, use wood screws or nails. On stone or tile walls, special bolts should be used.

1. Open or Exposed Wiring

This method of wiring possesses the advantages of being cheap, durable and accessible.

It is used a gerat deal in factories, mills and buildings where the unsightly appearance of the wires exposed on the walls or ceilings is of no consequence.

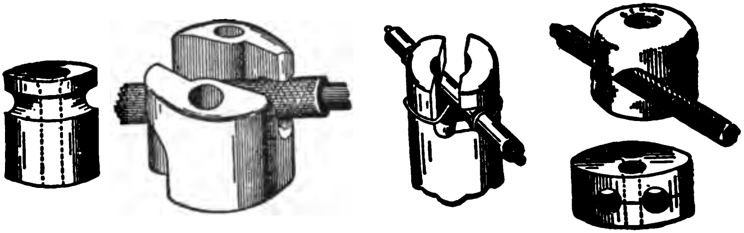
The kinds of wire used is either *rubber covered* or slow burning weather proof wire.

Rubber insulation should always be used where the wire is in a damp place, such as a cellar, and either weather proof or rubber insulation may be used to protect it against corrosive vapors.

For wiring in bakeries, mills, heat treating rooms, boiler rooms and all other warm rooms, slow burning asbestos covered wire is required.

There are two methods of open or exposed wiring; known as

1. Knob wiring; 2. Cleat wiring.



FIGS. 6,934 to 6,938.—Various porcelain knobs.

Knob Wiring.—This is the simplest and cheapest method. It is forbidden in some cities, except for temporary decorative work.

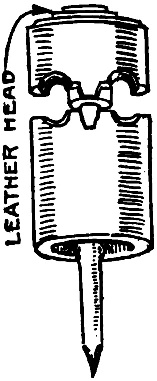
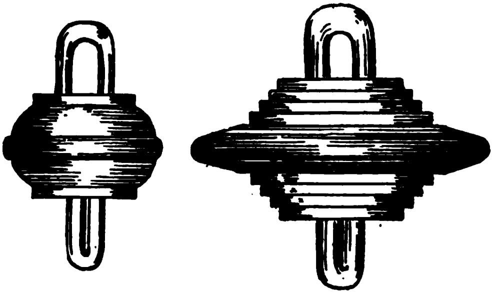


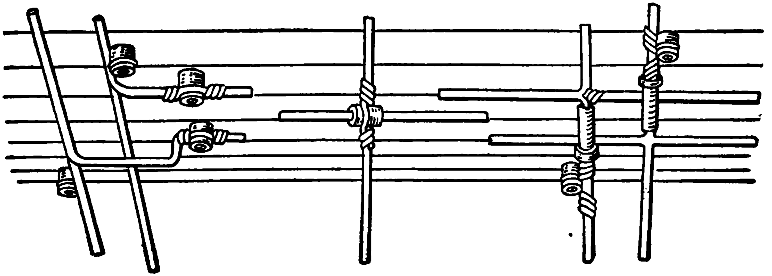
FIG. 6,939.—Knob complete with nail and leather head. The leather head is pinched over on the side so that nail cannot fall out.



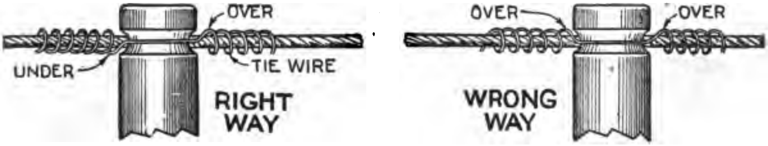
FIGS. 6,940 and 6,941.—Strain insulators as used on ends of wire when run on mill timbers.

The knobs should be placed every 4½ ft. and the wires not less than 5 inches apart.

Knobs are secured by means of wood screws or nails, when nails are used, leather washers called leather heads are slipped over the nail so that the head of the knob will not be broken when the head of the nail is hit by a hammer.



FIGS. 6,942 to 6,944.—Crossing of wires. Where wires cross each other, tubes should be used except in case of large stiff wires as in fig. 6,942; here one wire may be bent down and carried under the other; fig. 6,943, short bushing strung on the wire—this method is usually unsatisfactory, especially where a large number of wires cross each other; fig. 6,944, wires crossing each other through tubes. Flexible tubing, such as circular loom may be used in crossing wires in dry locations. Insulators should always be provided where wires cross to support the wires, thus preventing the upper wires sagging and touching those below.



FIGS. 6,945 and 6,946.—Right and wrong methods of tying wires to grooved knobs, called *tying in*. In fig. 6,945. one end of the tie wire passes over the wire, the other passes under. Pliers must be used so that the wires will be firmly secured. In tying in the wires, the first and last knob should be tied in and the intermediate knobs tied in last. Where the wires are of a large size a block and tackle should be used, care being taken not to pull too tight as this will stretch the wire. The tie wires should be of solid wire and of the same size as the wire to be secured, one wire is passed underneath the wire and the other wire is passed over so that it is secured at both ends. Pliers should be used as tie wire cannot be properly secured by hand.

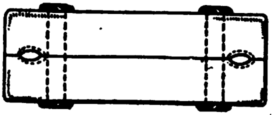
In crossing over pipes or wires, porcelain tubes should be used. When it is impossible to use porcelain tubes flexible loom can be used. Where the wires are run over, sweating, or dripping water, pipes, the loom or tubes should be placed on top of the pipe to prevent the water eating into the insulation. The ends of the tubes or loom should be taped to prevent them working loose and moving away from their original positions.

When passing through walls and partitions, the wires should be protected by tubes; where this is impossible loom can be used.

Knobs must not be run down side walls any farther than 7 ft. from the floor at this point they should be boxed in, or run in loom a continuous piece of loom into a conduit.

Knob wires can be run on rafters provided they are in blind attics or in places out of reach. Knob wires should not be run on cellar joists, unless protected from each side by guard strips.

In buildings of mill construction, where the wires are not less than number 8,



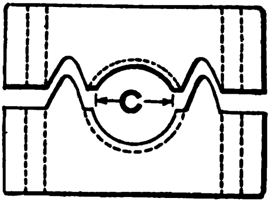
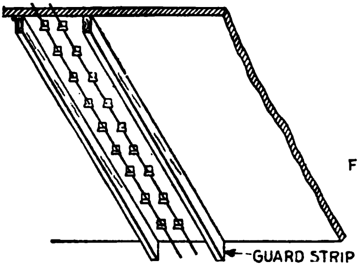


Fig. 6,947.—Common two wire cleat for wire sizes No. 14 to No. 10.

Fig. 6,948.—B. & D. one wire cleat for wires No. 8 to No. 0.



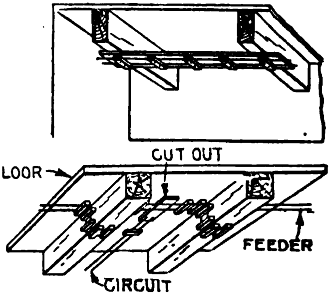
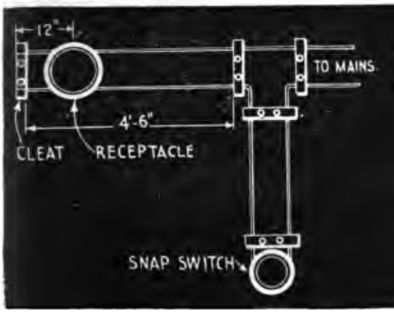


Fig. 6,949.—Method of protecting exposed wiring on low ceilings by two guard strips.

Figs. 6,950 and 6,951.—Cleat wiring methods. Fig. 6,950, cleat work across beams, the cleats are carried by boards attached to the beams; fig. 6,951, method of carrying wires on cleats around beams.

B. & S. gauge, the wires may be run from timber to timber if they be spaced six inches apart. Where wires are run in this manner, they should be dead-ended by strain insulators or by using double knobs. Heavy wires such as used in mills or for outside work can be supported ("tied in") on grooved knobs.

Cleat Wiring.—This method of wiring cannot be used in theatres, public buildings or garages that contain more than **two** cars..



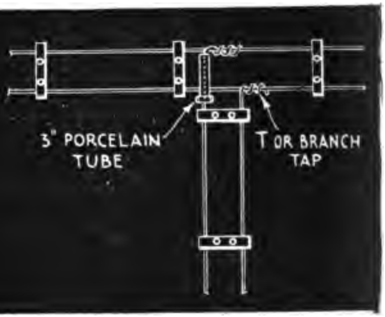
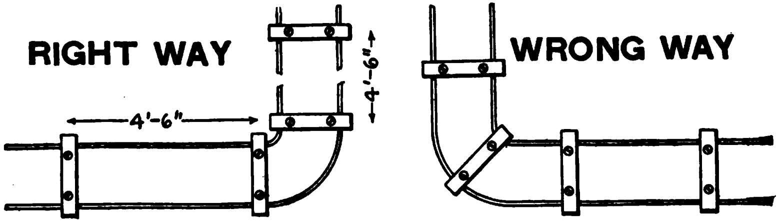


Fig. 6,952.—Cleat wiring for snap switch to operate receptacle. On long runs such as in factories, the wires should be deadened to a cleat located not less than one ft. from the last light, receptacle or drop.

Fig. 6,953.—Cleat wiring method of making a tap for branch circuit. Tubes always should be used, the tube being placed over the wire so that it rests upon the main wire, a cleat should then be installed so that the tube cannot slip away leaving the wires unprotected.



Figs. 6,954 and 6,955.—Right and wrong methods of making a turn with cleats. In fig. 6,955, an additional cleat is used adding unnecessary expense.

Before making a cleat installation, the local inspection bureau should be consulted, as cleats are fast becoming outlawed in many states.

Cleats.—They are constructed of porcelain, the tops and bottoms being alike and inter-changeable. They may be obtained with grooves for two or three wires. Cleats are best secured to wooden surfaces by wood screws, but for quick and rough work nails protected by leather washers called nail heads or leather heads may be used.

For securing cleats to wood 2 inches number 8 flat or round head screws should be used, where nails are to be used the ten penny 10D size should be used. For metal ceiling work, toggle bolts similar to those used for metal moulding should be used, except in places where the metal overlaps each other wood screws may be secured to the wooden furring strips. For plastered ceilings constructed with wooden lath 2½ in. No. 8 wood screws should be used. Where the ceiling is constructed with metal lath, the only means of securing the cleats are with commercial toggle bolts. On concrete ceilings, holes drilled and filled with wooden plugs are good cleat

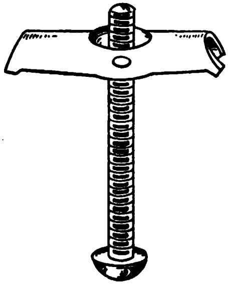


FIG. 6,956.—Toggle bolt for securing cleat to metal ceilings, or ceilings on which plaster is laid on metal lath. A hole is first punched in the ceiling with a 20 penny nail or a brad awl. the bolt is then inserted through the cleats and is shoved up into the ceiling.

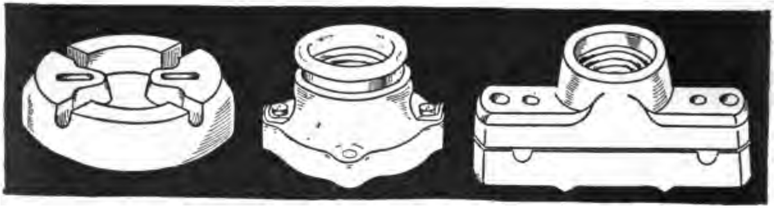


FIG. 6,957.—Snap switch sub-base as used under snap switches for cleat wiring.

FIGS. 6,958 and 6,959.—Exposed and concealed contact cleat receptacles. The concealed contacts are more desirable, as the live wires are protected.

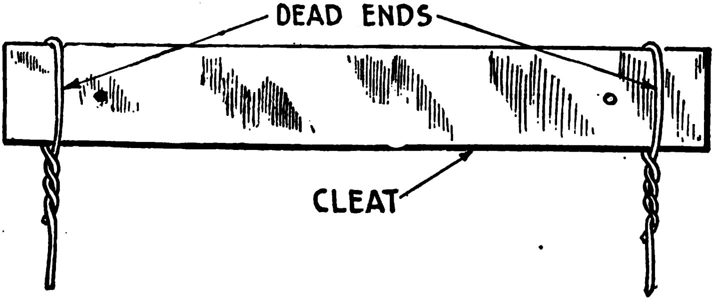
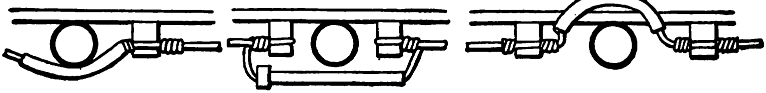


FIG. 6,960.—Method of *dead ending* wires on cleats. The line is simply secured by the cleats, the ends are wound around the wires on the cleats. Four or five turns will do.

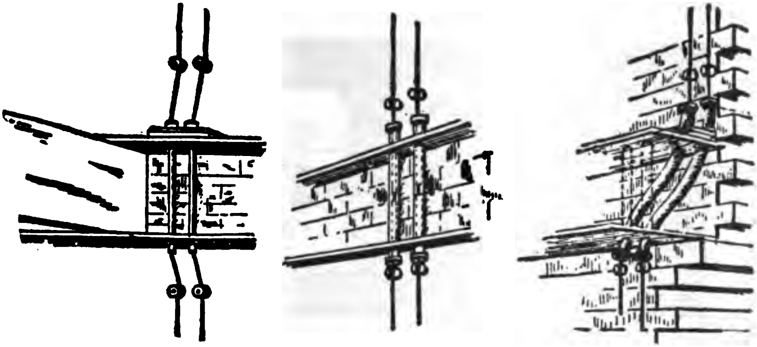
supports, lead shields may be used but wood plugs are quicker and more secure.

Spacing of Cleats.—They should be spaced not over 4½ ft. apart, the wire at all times being taut and insulated from the surface wired over. In practice it will be found that it is impossible to maintain the standard spacing of 4½ ft., so therefore in order to make the job appear neat and workmanlike the cleats should be installed so that their spacing is symmetrical.

Running the Wires.—The kinks should first be removed from the wires, otherwise they will appear slack and poorly installed. This is best done by running the handle of a hammer over the wire. The wires are then secured to the first and last cleats of the run and drawn up as tight as possible. This is only accomplished by pulling the wires by hand; never use pliers as this method causes the wire to kink and break. The cleats should be screwed down as firm as possible so that the wire will not slip through. If nails be used on long runs for securing the cleats, it is advisable to use screws on the first and last cleats, as nails have a tendency to



FIGS. 6,961 to 6,963.—Wiring across pipes. The wires should preferably run over rather than under the pipes. Fig. 6,961 shows crossing with circular loom, and fig. 6,962, one in which a tube is used. Both of these methods are satisfactory in the case of gas pipes, but for steam pipes or water pipes which are liable to leak or sweat and drip moisture, the crossing should be above as shown in fig. 6,963. On side walls where vertical wires run across horizontal water pipes, the latter should be enclosed and the moisture deflected to one side.



FIGS. 6,964 to 6,966.—Wiring through floors. *The bushing must be continuous.* Porcelain tubes may be used as in fig. 6,964, or short bushings may be arranged on iron pipes as in fig. 6,965. Fig. 6,966 shows method employed in case of offset in the wall. Sometimes the floor can be taken up and an iron conduit, properly bent, put in place, the wires being reinforced with flexible tubing. Another method is to attach the wires to insulators; in this case the floor must not be put down until the wiring has been examined by the inspector.

work loose. The intermediate cleats are then installed so that the spacing is symmetrical.

Cross Overs.—When crossing over wires, metal beams, protruding pipes, the wires should be protected by porcelain tubes. Where it is impossible to install tubes, loom can be used. Always place tubes or loom over instead of under dripping pipes so that the moisture will not ground the wires.

Side Wall Protection.—On side walls the cleats should not be run down any further than 7 ft. from the floor line. At this point they must be protected from mechanical injury by installing them in wood moulding or in conduit, or by boxing in.

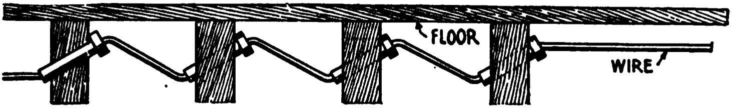
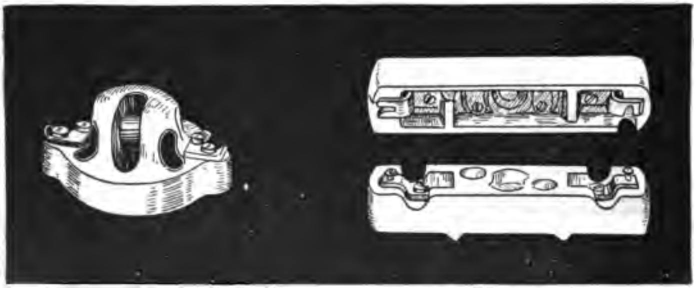


FIG. 6,967.—Exposed wiring passing through beams, showing the usual objectionable method of boring the holes at an angle as practiced by workmen not equipped with the proper boring tool. Insist on the holes being bored parallel to the floor. When the holes are bored at the middle of the beam, that is, through the neutral axis, the beam is not perceptibly weakened by the cut. Porcelain tubes are used where the wire passes through the beams.



FIGS. 6,968 to 6,970.—Open and concealed contact drop cord rosettes for cleat wiring. The open type is the most economical to use as it is in one piece but the covered or concealed is the safer.

Passing Through Floors.—The same methods are employed as in knob wiring, as shown in figs. 6,964 to 6,966. The same kind of protection applies to passing through partitions and large beams. Loom must never be used unless it be actually impossible to use tubes.

Cleats in Cellars.—Cleats must never be attached to cellar joist unless protected by a guard strip 2 ins. high on each side, or they may be mounted on a running board of pine not less than 4 in. × ⅞ in. Before using running board or guard strip it should first be ascertained whether it is possible to run the wires on cellar beams. These generally run through the center of the cellar

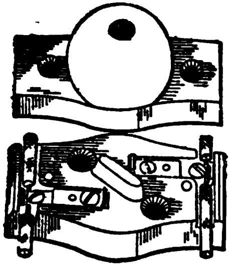


Fig. 6,971.—Receptacle suitable for use with open wiring, the requirement being that the contact ears should not be exposed.

Practical Points Relating to Exposed Wiring

1. In interior wiring no wires smaller than No. 14 B. & S. gauge should be used, except as allowed by the underwriters, and no more than 660 watts should be allowed to a circuit.

2. Tie wires should have an insulation equal to that of the conductors which they secure.

3. In all cases, whether the wires be run on knobs, split insulators, or cleats, the wires should be supported at intervals of at least 4½ feet, and if exposed to mechanical injury, the supporters should be placed at closer intervals.

4. Wires run on bare ceilings of low basements, especially where they are liable to injury, should be protected by two wooden guard strips as shown in fig. 6,951. The protective strips should be at least ⅞ inch in thickness and slightly higher than the knobs, insulators, or cleats. Wires should not be run closer than 6 inches apart and 2 inches from the surface wired over. Wires run near water tanks must be rubber covered so as to render them moisture proof.

5. Cleats should be used for the wiring of stores, offices, or buildings having flat ceilings, provided the wiring is installed in dry locations.

6. When the installation is exposed to dampness or acid fumes such as those developed in stables, bakeries, etc., the wires should run on knobs or split insulators, and should be rubber covered.

7. When wires are run at right angles to beams which are more than 4½ feet apart, a running board should be used and the wires cleated to it as shown in fig. 6,949. It is desirable, however, to avoid the use of running boards, whenever possible by running the wires parallel with the beams, thus reducing the cost of insulation.

8. In factories or other buildings of open mill construction, mains of No. 8 B. & S. gauge or larger wire, where they are not exposed to injury, may be placed about 6 inches apart and run from timber to timber, not breaking around, and may be supported at each timber only

9. The best location for feeders is on the walls. In dry buildings the fire and weather proof wire can be used with safety; but covered wire must be used on buildings subject to any form of dampness. In all cases where feeders are run on the walls, they should be protected from mechanical

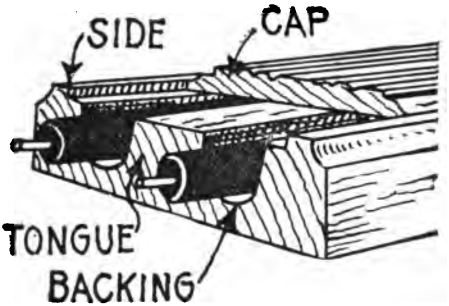


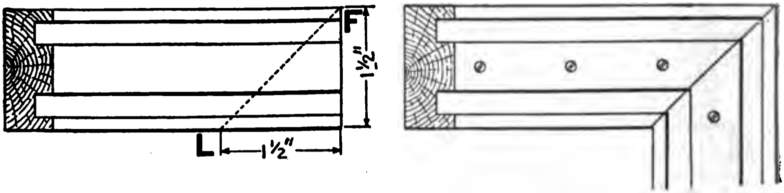
Fig. 6,972.—Standard wooden moulding for encasing wires. Only rubber covered wires are permitted in wooden molding.

injury by boxings at least 6 feet high on each floor. If floor switches be used, they may be mounted on the front of the boxing. In such cases, the holes in the boxing through which the wires pass to the switches should be provided with porcelain bushings.

10. The rosettes, receptacles, sockets, snap switches, etc., used in connection with exposed wiring should conform in all respects to the standards specified by the underwriters.

2. *Wiring Run In Mouldings*

There are two general classes of moulding: 1, wooden, and, 2, metal. Wiring in wooden mouldings is one of the cheapest forms of finished inside work.



Figs. 6,973 and 6,974.—Cutting mitered corners of wooden moulding. All standard moulding is 1½ ins. wide. Hence, measure 1½ ins. from end obtaining point L, and cut on line drawn from L to F. Similarly cut other pieces and they will go together as in fig. 6,974. A miter box will save much time and is more accurate.

Wooden Moulding.—Although it is fastly becoming outlawed in many states, wooden moulding is still largely used in small towns for store and office wiring.

Before installing wooden moulding, the *Code* should be consulted to see if it be permissible for the proposed installation.

The moulding consists of a capping and backing.

The wires are laid in the backing and are then covered by the capping. The moulding may be obtained in many colors but the most common forms are the natural and shellaced.

Only rubber covered wire must be used in wooden moulding.

Wooden ceiling moulding is secured by finishing nails about 2 inches long, the capping being secured by small brads 1 inch long.

To save time, moulding having wire holding grooves, or clips should be used, as much time will be saved. Moulding having plain grooves require nails to hold the wire in place until the capping is nailed on. Sometimes it is forgotten to remove these nails and they are the cause of numerous grounds and short circuits.

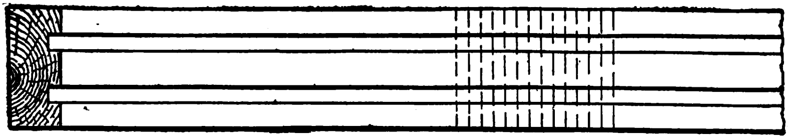


Fig. 6,975.—Slits sawed in wooden molding before bending.

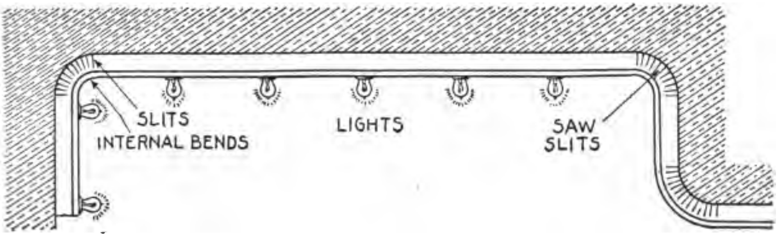
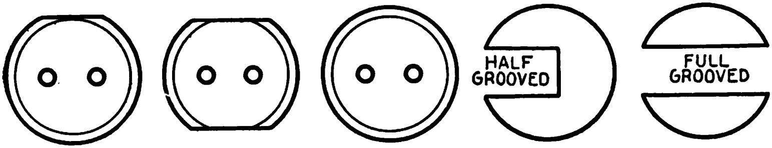


Fig. 6,976.—Internal and external bends in wooden molding. After cutting as in fig. 6,975 the molding will readily bend to shape, care being taken that the cuts are not made too deep.



Figs. 6,977 to 6,981.—Fixture blocks with grooves for the molding so the block fits over the molding. Fig. 6,977, half proved for end outlets; fig. 6,978, full grooved for molding passing through; fig. 6,979, solid block for concealed work; figs. 6,980, and 6,981, bottom views of half grooved and full grooved blocks.

Installing Wooden Moulding.—The backing is cut to length and secured to the ceiling by nails or screws all depending upon conditions. All

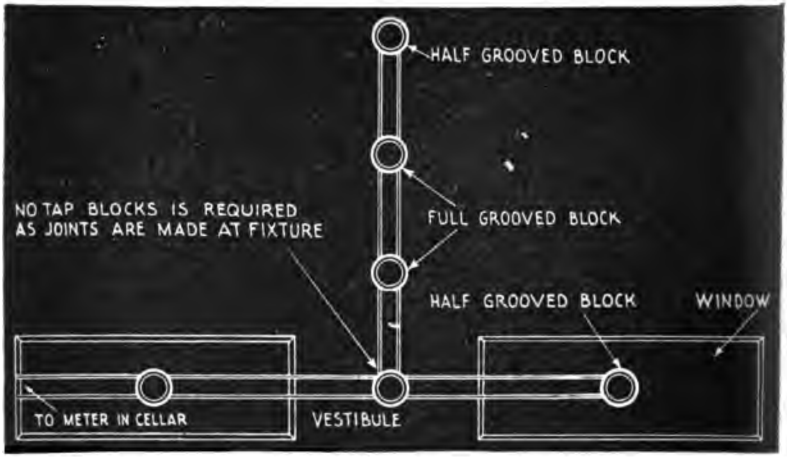
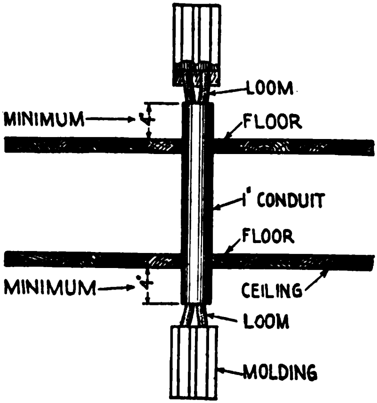


Fig. 6,982.—Typical and symmetrical store layout for wooden moulding wiring, showing half grooved and full grooved blocks.



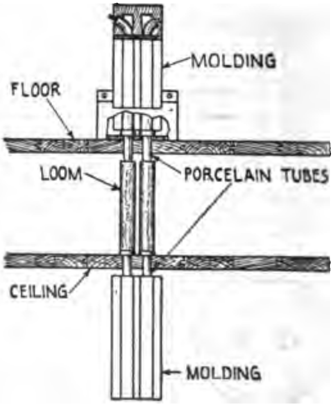
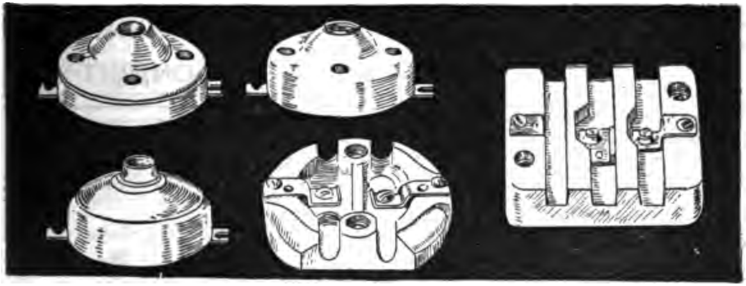


Fig. 6,983.—**Wooden moulding wiring passing through floors. *1st method.* The wires are encased in loam and further protected by a conduit. Note that conduit must extend 4 ins. above floor and 4 ins. below ceiling.**

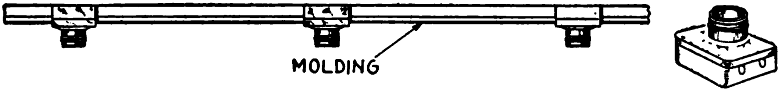
Fig. 6,984.—**Wooden moulding wiring passing through floors. *2nd method.* Here a kick box is used, the wires being protected by loam and porcelain tubes as shown.**

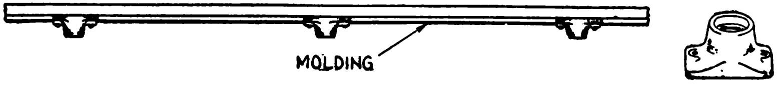
turns or corners should be made square by cutting a miter. A chalk line should be snapped on the ceiling so that the moulding should be run in a straight line or if the ceiling be wooden sheathed, the seams may be used as a guide. After the backing has been secured, the wires should be laid in by hand or forced in with a rubber mallet. After the wires have been installed and run to the various outlets, the capping should be put on. Always, cover moulding joints (where two pieces of moulding come together) with the capping.

Fixture outlets are made on specially prepared fixture blocks with grooves for the moulding so that the block fits over the moulding.



FIGS. 6,985 to 6,989.—Moulding fixtures. Fig. 6,985, pendant cap; fig. 6,986, bracket cap, female outlet; fig. 6,987, bracket cap, male outlet; fig. 6,988, two wire base; fig. 6,989, three wire base.





FIGS. 6,990 and 6,991.—Assembly of moulding with type fitting requiring moulding to be cut for base of fitting, and view of fitting.

FIGS. 6,992 and 6,993.—Assembly of moulding with type fitting which does not require moulding to be cut, and view of fitting.

Approved tap blocks must be used as the *Code* does not allow the making of taps inside of wooden moulding. With this type of fitting it is possible to make taps from existing circuits.

No splices are permitted in wooden moulding installations unless the splices are accessible at all times, which means that no joints can be covered up beneath the capping. Splices are permitted at fixture outlets, under rosettes, receptacles. Where it is desired to extend a wooden moulding circuit, an approved splice block must be used.

In passing through floors, the wires should be run through porcelain tubes. The moulding must then be protected by a metal kick block.

Wooden mouldings must never be run on brick walls unless they are secured to an additional backing which must first be secured to the wall. This is to exclude dampness.

When securing the moulding to brick wall, use short nails for the backing so that the nails will not double up and bend back and puncture the insulation of the wires. This is a common occurrence.

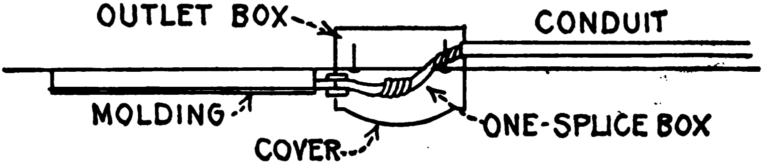
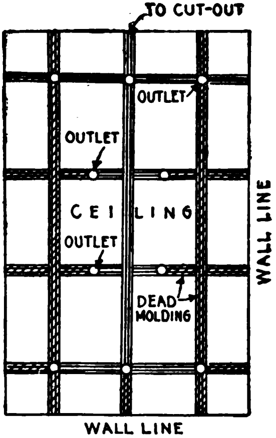


Fig. 6,994.—Method of tapping outlets for feeder circuits when wiring with wooden moulding.



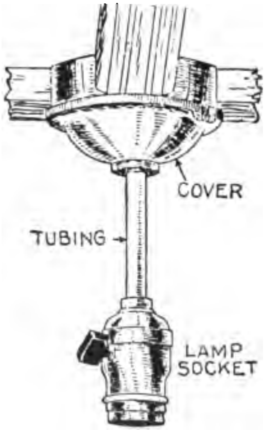
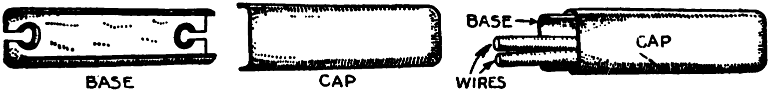


Fig. 6,995.—Treatment of moulding work on ceilings. ***All installations*** should be planned out so as to comform to symmetrical designs. as far as practicable with the proper distribution of the lights, etc., and all runs finished off, whenever necessary, by "dead" mouldings continued to the walls to improve the appearance.

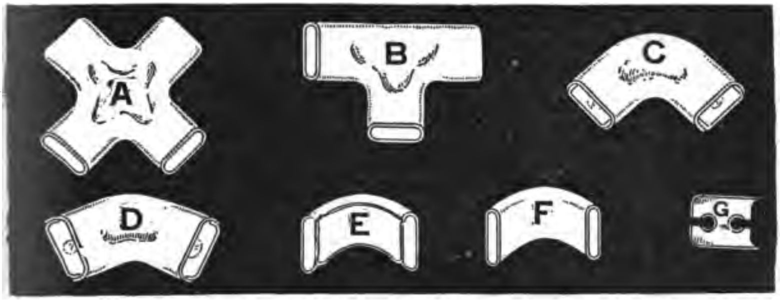
Fig. 6,996.—Circular fixture block for outlet from moulding work on ceiling.

In running wooden moulding through a wall, porcelain tubes or loom should be used. Wooden moulding should not be run in damp cellars or other places which are subject to much dampness, or on the outside of a building. Use conduit.

Metal Moulding.—This kind of casing for wires, also known as *raceways*, consists of a base and capping or cover made of steel. It is $\frac{31}{32}''$ wide and $\frac{7}{16}''$ high, shipped in lengths of 8′ 4″, with twelve lengths per unit package.



Figs. 6,997 to 6,999.—Metal moulding. An approved form consists, as shown, of two pieces: base (fig. 6,997), and cap (fig. 6,998), so formed as to snap together, the cap snapping over the base as in fig. 6,999. The entire moulding should be galvanized or coated with a rust preventive. When the base is held in place by screws or bolts from the inside, depressions must be provided so that the heads of the screws will be flush with the surface of the moulding.



Figs. 7,000 to 7,006.—National metal moulding fittings. Fig. **A**, cross; fig. **B**, tee; fig. **C**, 90° flat elbow; fig. **D**, 45° flat elbow; fig. **E**, external elbow; fig. **F**, internal elbow; fig. **G**, fitting coupling.

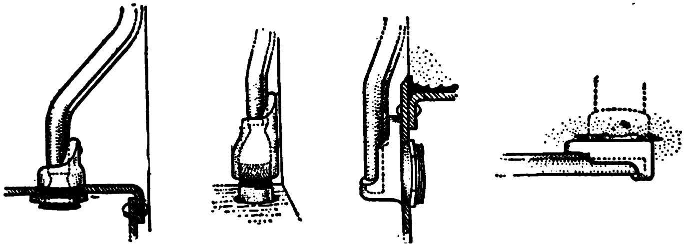
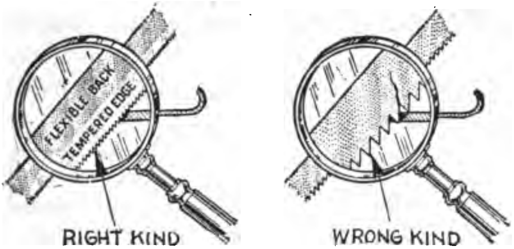


Fig. 7,007 to 7,010.—Various outlet connectors for attaching molding to conduit outlet boxes.

Code Requirements.—Metal moulding is permitted in circuits requiring not more than 1,320 watts with not over 300 volts. Splices are not allowed; use approved junction boxes or outlet plates. Four No. 14 wires with approved rubber insulating covering may be installed in the moulding. All sections must be secured together both mechanically and electrically, and must be grounded. Moulding can be used on plastered walls, side walls with proper protection; must not be used in cellars, damp places, hot rooms, or for outside work.



Figs. 7,011 and 7,012.—Right and wrong kind of hack saw blade for cutting metal molding showing effect of using a coarse tooth blade. A blade with fine teeth as in fig. 7,011 will *ride* the molding and prevent stalling or catching.

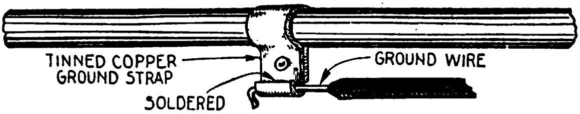
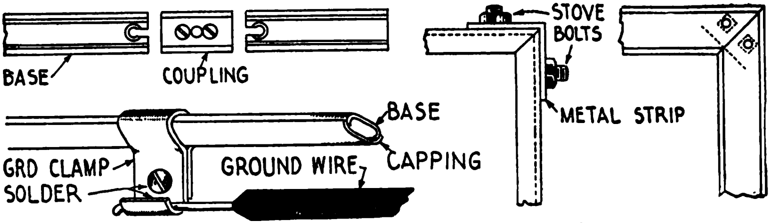
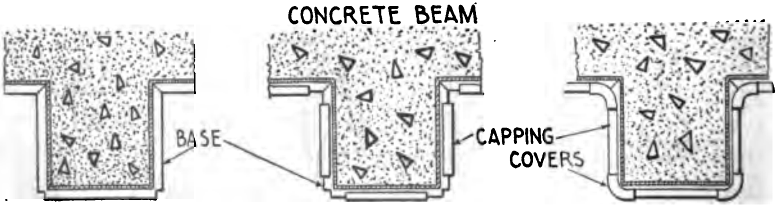


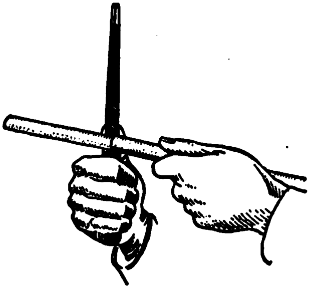
Fig. 7,013.—Metal molding ground clamp.



Figs. 7014 to 7,019.—Method of bonding and grounding metal moulding.



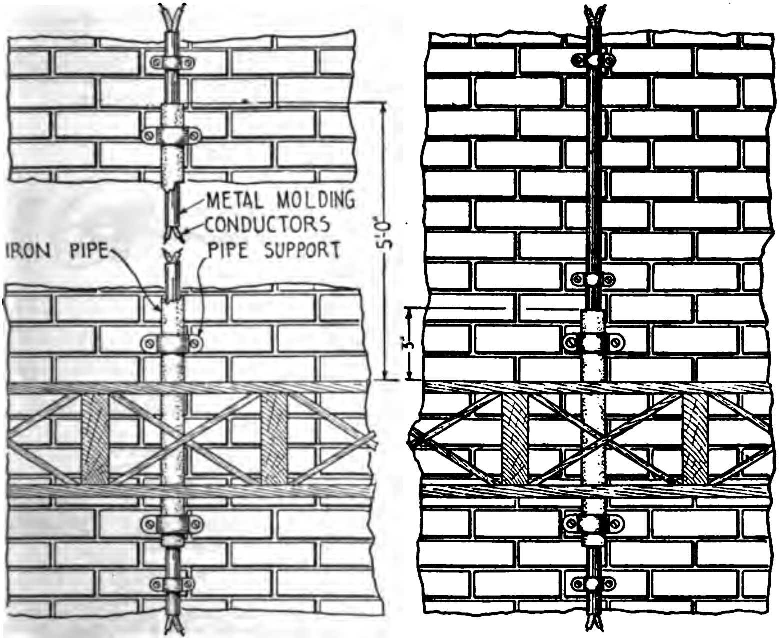
Figs. 7,020 to 7,022.—Method of running metal moulding around beams.



Where metal moulding passes through floors it should be encased in a pipe to prevent scrub water entering and to afford additional mechanical protection. On side walls, the continuous length of iron pipe should, where the moulding might be exposed to mechanical injury, extend a distance of at least 5 feet above the floor and downward from floor to a few inches below ceiling.

Installation of Metal Moulding.—There are two methods of

FIG. 7,023.—Method of cutting metal moulding with three cornered file. ***In cutting,*** use a small piece of capping for a straight edge, as shown; mark the base or capping deeply and break it off, being very careful to mark the moulding deeply on both sides.



FIGS. 7,024 and 7,025.—Methods of protecting metal moulding in passing through a floor. Fig. 7,024, protection against mechanical injury; fig. 7,025, protection in exposed locations.

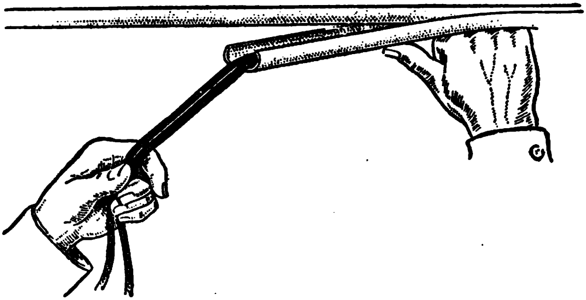
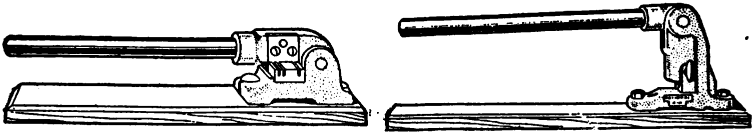
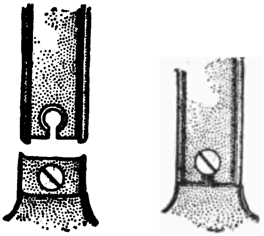
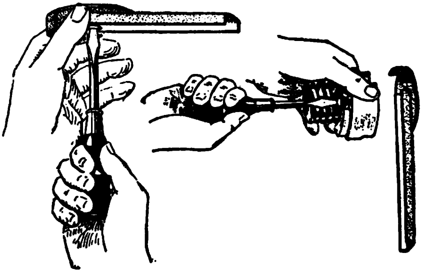


FIG. 7,026.—Method of installing wire in metal molding: first put up all base plates of fittings and then lay wire into each length of capping as it is snapped on, as shown.



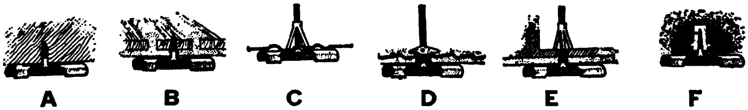
FIGS. 7,027 and 7,028.—Shear and punch for cutting and punching metal molding.





FIGS. 7,029 to 7,031.—Coupling and connecting ends of metal molding, showing screws and screw holes.

FIGS. 7,032 and 7,033.—Method of installing metal molding device at the end of a run.

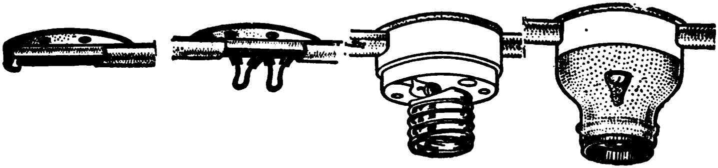


FIGS. 7,034 to 7,039.—Methods of supporting National metal molding. Fig. **A**, on wood surfaces use a No. 8 flat head wood screw; fig. **B**, on lath and plaster use a 1¼ in. No. 8 flat head wood screw; fig. **C**, on metal ceilings use cone toggle bolts 2 ins. long; fig. **D**, on plastered ceilings of metal lath, use flat toggle bolt; fig. **E**, on tile use flat toggle or cone toggle bolt; fig. **F**, on concrete use lead shields.

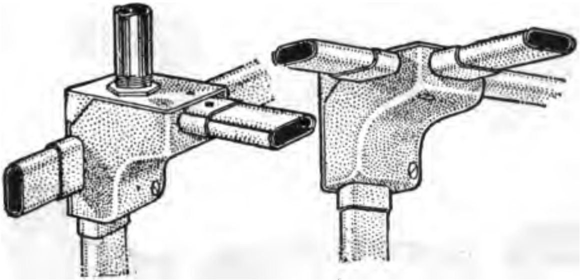
cutting the moulding—by hack saw or by a special shear.

If a hack saw be used, select only a fine toothed flexible back saw with tempered edges; coarse toothed blades crack and break on moulding.

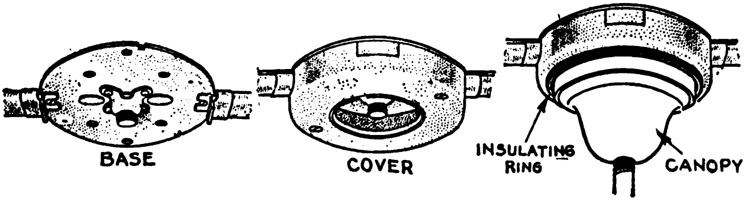
When cutting moulding with a hack saw it is not necessary to cut all the way into moulding, but only just nick the moulding so, if it be given a slight up and down motion it will break apart. Files also may be used, the three cornered being the best. Holes must be punched in the base for



Figs. 7,040 to 7,043.—Method of wiring receptacles for use on metal molding.



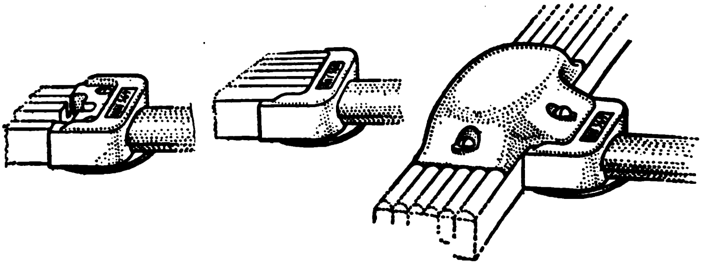
Figs. 7,044 and 7,045.—Metal moulding branching fittings. Fig. 7,044 shows the moulding running up the sidewall, branching both ways close up in the corner on the sidewall, running out onto the ceiling and a tap passing up through to the floor above in ½ inch conduit. Fig. 7,045 shows the moulding running up the sidewall, branching both ways close up in the corner on the ceiling and running out onto the ceiling.



Figs. 7,046 to 7,048.—Base, cover, and canopy for fixture outlets; note knock out holes in base for picking up concealed wiring.

screws, this can be made with a special punch or may be drilled by a twist drill in a brace or breast drill.

Bending.—The base and capping must be assembled and bent as one piece of moulding. The moulding is quite soft and is easily bent over the knee or the edge of a table; Hickeys may be obtained for this purpose.



FIGS. 7,049 to 7,051.—**Moulding adapters for connecting metal moulding to wooden moulding.**

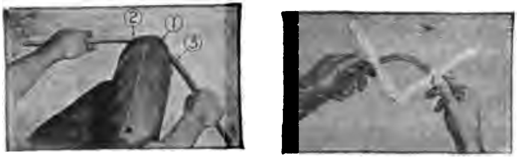
FIGS. 7,052 to 7,058.—**Various wiremold fittings. Fig. 7,052, 90° flat elbow; fig. 7,053, 45° flat elbow; fig. 7,054, external elbow; fig. 7,055, corner box; fig. 7,056, external elbow; fig. 7,057, tee; fig. 7,058, cross.**

After moulding is snapped together and bent, it should be separated by means of a screw driver pried under the end and pull down, do not separate by pulling apart by hand as this bends capping and base out of shape.

Installing.—The base is first put in place after which the wires are laid in the capping and snapped in place by slightly rapping capping with a light hammer. If capping persist in springing away on the ends, bend over edges with hammer so that they will fit base snugly.

Avoid crossing the wires in the capping as this causes capping to bulge and short circuit. The moulding is coupled together by means of special couplings.

In running around beams the base only is bent by cutting a 90° V with a hack saw at the bend. Both internal and external bends may be made



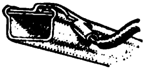
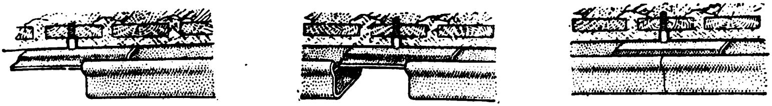
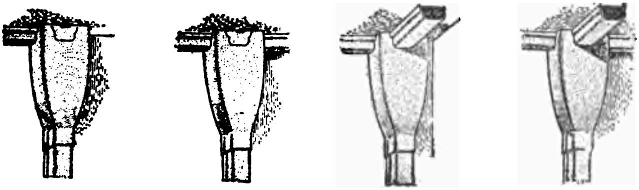


Fig.7,064.—Wire-mold ground clamp.

Figs. 7,059 to 7,063.—Knee method of bending wiremold. Fig. 7,059 shows a wireman starting offset at what will be the center of the finished bend; figs. 7,060 to 7,062 show the points selected for progressive "bites"; fig. 7,063, finished bend. On internal bends the capping will sometimes tend to spread if bent too fast but can be easily drawn into place again by tapping with the handle of a hammer or a heavy screw driver. Wiremold can also be easily offset to pass from side wall to the baseboard or to break around similar shallow obstructions, and through the exercise of a little care and the use of a bench vise can be offset edgewise to a limited extent when occasion demands.

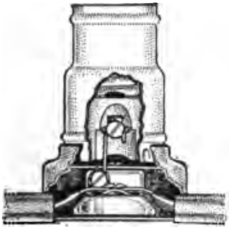


Figs. 7,065 to 7,067.—Method of coupling wiremold by use of coupling fitting



Figs. 7,068 to 7,071.—Various wiremold corner boxes.

by means of these notches. The capping is then laid in place after which the corners are covered over with special elbow covers.



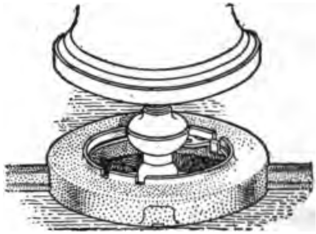
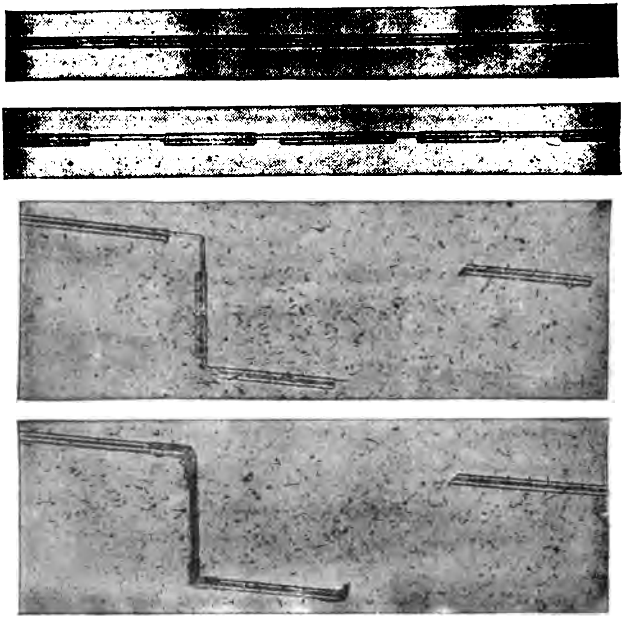


Fig. 7,072.—Method of joining receptacle to wiremold.

Fig. 7,073.—Round fixture outlet base for wiremold.

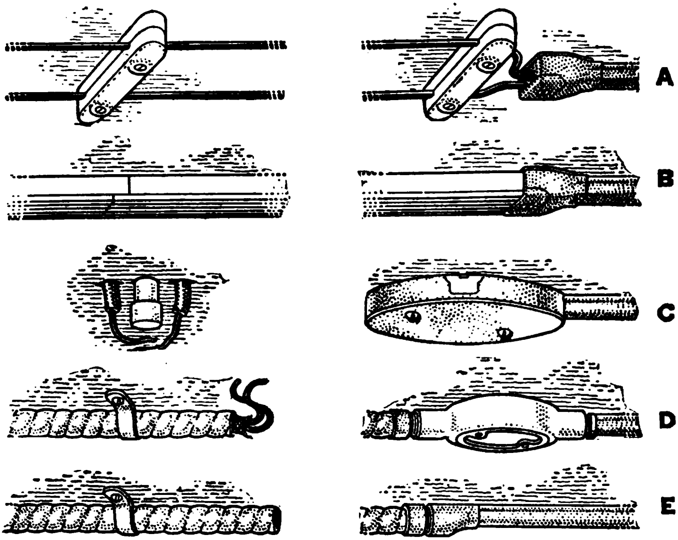


Figs. 7,074 to 7,077.—Method of passing around beams with wiremold. Mark off the face and depth of beams on a length and slot the capping only on these centers. Take out two 1⅝ in. sections of capping where wiremold is to break around the bottom of the beam, and two 4 in. sections where it breaks from the ceiling, as in fig. 7,075. Bend base to form around beam as in fig. 7,076 and fish in wires. Snap on external and internal elbows as in fig. 7,077.

All fittings are connected to the moulding by means of a set screw which clamps down the moulding.

"Wiremold" Metal Moulding.—This is a form of metal moulding raceway that is quickly installed.

It is smaller than the usual type of metal moulding and only two No. 14 wires can be inserted in it. It is in reality a form of conduit, only it is not air or water proof.



FIGS. 7,078 to 7,087.—Methods of tapping various wiring systems with wiremold. A, cleatwork; B, wooden molding; C, concealed knob and tube; D, armored cable; E, metallic flexible conduit.

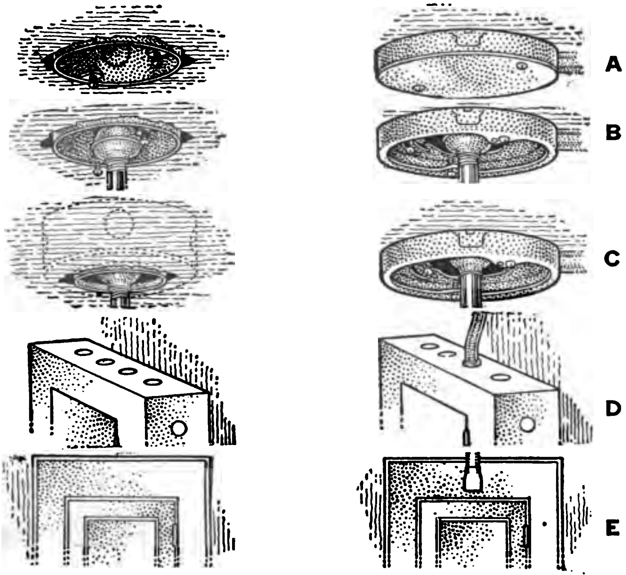
The wires are fished or pushed through the raceway. There is no base or capping, they being permanently assembled at the factory.

Code Requirements.—Wiremold is permitted on circuits of not over 300 volts or 1,320 watts. It must be grounded to a water pipe. No splices are allowed inside of wiremold, use junction boxes. It must not be concealed or installed in damp or very hot places, such as bakeries.

Installation of Wiremold.—Use a fine tooth hacksaw for cutting. The ends of wiremold must be brushed to prevent the rough edges cutting into the wire.

In coupling lengths of wiremold, a coupling fitting is used which serves also as a support; it is first fastened to the ceiling or wall before making the joint.

Wiremold can be easily bent without the use of any special tools or hickey and with a little practice can be worked down to a 3 in. or a 3½ in. radius without trouble, particularly on internal bends. It is also easily worked in passing around beams, etc.



FIGS. 7,088 to 7,097.—Method of tapping various fittings with wiremold. A, concealed conduit box no fixture; B, concealed conduit box with fixture; C, concealed conduit box having open cover ¾ in. deep; D, metal surface type switch and cut out cabinet; E, metal concealed type switch and cut out cabinet.

2. Concealed Knob and Tube Wiring

This is one of the cheapest forms of house wiring in use today, but it is fast becoming outlawed in many cities by municipal rules.

The objections being that it is subject to mechanical injury, is liable to interference from rats, mice, etc., and as the wires are liable to sag against beams, laths, etc., or likely to be covered with shavings, a fire could easily result in case of an overheated wire or short circuit.

The advantages are cheapness, especially in wiring completed buildings and the absence of any wires or mouldings on the walls. Knob and tube wiring consists in running the wires concealed between the floor beams and studs of a building, knobs being used to support the wires when run parallel to the beams or studs, and porcelain tubes, when run at right angles through the beams or studs as shown in fig. 7,098.

Code Requirements.—Wires with rubber covered insulation must be used, and rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Wires must be 5 ins. apart, taut, and separated from contact with the walls of floor timber and partitions through which they pass by insulating tubes of glass or porcelain. Maximum spacing for rigid supports of horizontal wires 4½ ft.

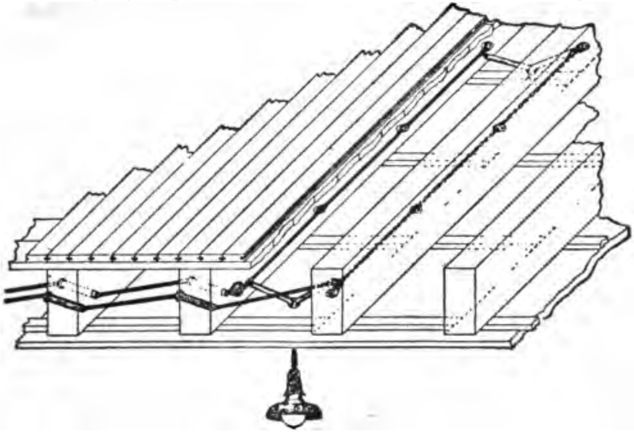


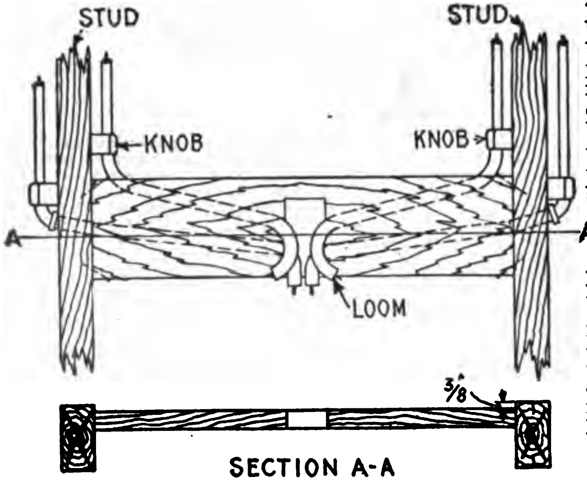
Fig. 7,098.—Concealed knob and tube wiring. The wires are carried on porcelain knobs attached to the beams. If run perpendicular to the beams, holes are bored in the latter and porcelain tubes with a shoulder at one end, inserted in the holes through which the wires pass. The knobs should support the wires at least one inch from the surface over which they run, and should not be spaced further than 4½ feet apart. The use of split knobs does away with the necessity of using tie wires. The conductors must be at least 5 inches apart and it is better to support them on separate beams when possible. Each wire must be encased in a piece of flexible tube at all switches, outlets, etc., and this piece of tubing should be sufficiently long to extend from the last insulator and project at least one inch beyond the outlet.

Installation of Knob and Tube Wiring.—Usually nothing need be disturbed on the first floor as the various outlets can be reached from the basement and from the second floor.

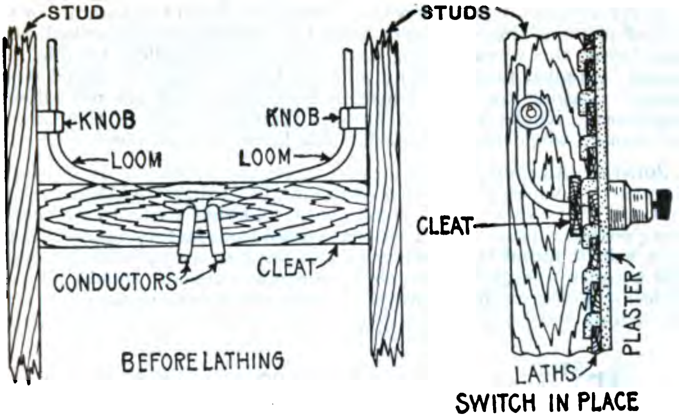
In boring holes in floor beams for the porcelain tubes they should be bored at the center of the beam to prevent nails being driven into the tubes and cutting the wires. A competent workman will have a special boring machine so that the holes can be bored parallel to the floor instead of at an angle as is done with the ordinary brace and bit. This latter method is very objectionable and should not be tolerated on first class work. In wiring, say the first floor, a strip of flooring is removed from the floor above so as to expose the beams. Then two holes are bored through each of the beams spaced 5 ins. apart, the porcelain tubes inserted in the holes and the wires threaded through these tubes, the outlets made, as later described, and the strip of flooring replaced. Where it is impossible to insert a tube, loom may be used.

Fig. 7,099.—Porcelain tube as used in knob and tube wiring. The standard tube as used in house wiring comes in all lengths and is 5/16 in. in diameter.

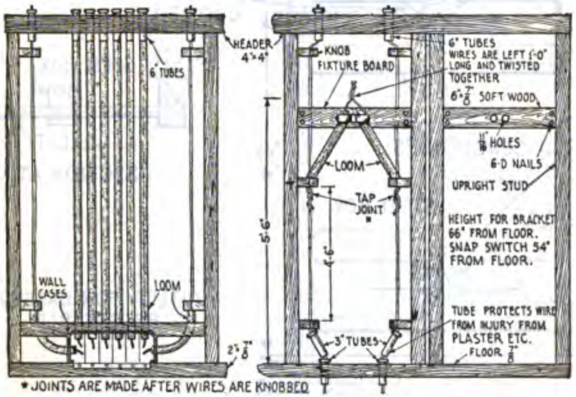
When passing through floors with wires, an additional tube must be placed over the wire so that the wire will be encased and protected at least 4 ins. from above the floor so that the wires will be protected from falling plaster and other objects. When passing through portions that contain brick, tile or concrete fire stops, the wires should be encased in loom and should then be encased in a metal pipe, the loom being in one continuous piece and extending from knob to knob.



Figs. 7,100 and 7,101.—Elevation and sectional view showing arrangement of switch outlet in concealed knob and tube wiring.



Figs. 7,102 and 7,103.—Arrangement of surface switch in concealed knob and tube wiring. For a surface snap switch outlet, an iron box is not necessary, but a ⅞ in. cleat must be installed to hold the tubing in place and to provide a proper support for the screws that hold the switch. In wiring old buildings where supporting cleats were not provided back of the plaster, a ¾ in. wooden block or plate should be installed on the surface, to which the switch can be attached.;



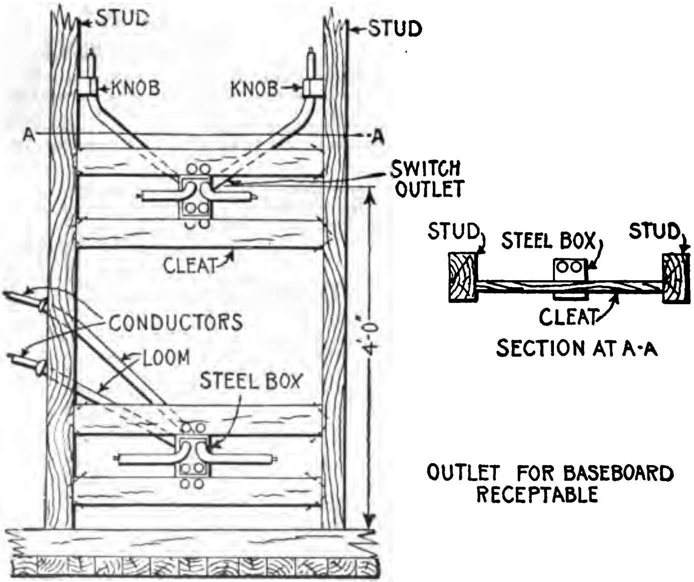
* JOINTS ARE MADE AFTER WIRES ARE KNOBBED

Fig. 7,104.—Method of installing wires where spacing of 5 ins. cannot be made. ***All wires spaced less than 5 ins., must be encased in loom.*** The loom must be continuous and in one piece from the tube to the wall case where at this point it must be secured by a clamp to the box. As shown, there is room for wires on the side of the studs; these wires need not be encased in loom.

Fig. 7,105.—Method of avoiding cross stud by locating wall cases a little above center of partition.

Never attempt to pull wires taut with the claw of a hammer or with a pair of pliers as these methods cause the wire to become kinked which in turn break the wires causing open circuits and endless trouble. Wires should be pulled taut by hand and the knobs should be nailed down sesurely. Sagging wires are considered violations and are not allowed by inspectors. Knobs with two grooves should be used as they save time and money when making taps for side lights or base plugs.

Joints.—All joints should be well taped and soldered. In houses under construction where there are no windows, it is suggested as a time saver, that all joints should be covered with soldering paste to prevent them being coated with a film of acid that comes from factory smoke and fumes, as it will be found that solder will not stick to joints unless protected in this manner. A gasoline torch of one pint capacity should be used for soldering joints as in this mode of wiring there are numerous joints and much time will be saved if all the joints are soldered and then taped, as



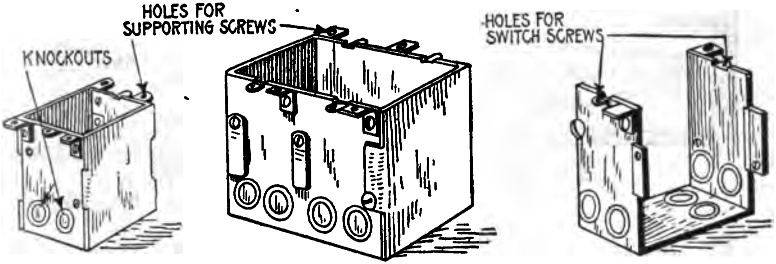
FIGS. 7,106 and 7,107.—Arrangement of switch and receptacle outlets in knob and tube wiring. ***In wiring for switches,*** flexible tubing must be used on the conductor ends from the last porcelain support, as shown, the same as on conductor ends for other outlets. A pressed steel switch box should be used to encase each flush switch mechanism, even though it already be encased in porcelain. A ⅞ in. wood cleat or cleats are arranged to support the switch box. These wooden cleats should not be set out flush with the outer edges of the sheets, but should be set about ⅝ in. back as shown to allow a space in which the plaster can "grip."

if the wiremen go to a joint and solder it and then tape it, he will lose much time and will waste gasoline.

Wall Cases.—These are metal boxes for supporting and encasing flush switches and receptacles, switches and receptacles should not be installed without these as they are a great protection against starting fires from sparking switches.

Wall cases in sections are called gangs, thus a wall case for two switches would be called a two gang box.

When installing bare receptacles, a board ⅞ in. thick should be cut out the same size as the wall case—the ears of the wall case should be adjusted so that the front edge of the wall case will extend out ⅞ in., the wall case should then be screwed to the board (not nailed) and the board is then nailed against the upright studs, so that the front surface of the box will be 1¾ ins. from the edge of the studs. This will bring the wall case or box just flush with the finished base or mop board. Thicknesses of base boards are about ⅞ in., but this should be ascertained before installing the wall case. The above directions are based on base boards having a thickness of ⅞ in. A good rule to remember is that lath and plaster take up ⅞ in. Wires entering wall case should be encased in loom, which should in turn be secured to the box by clamps.



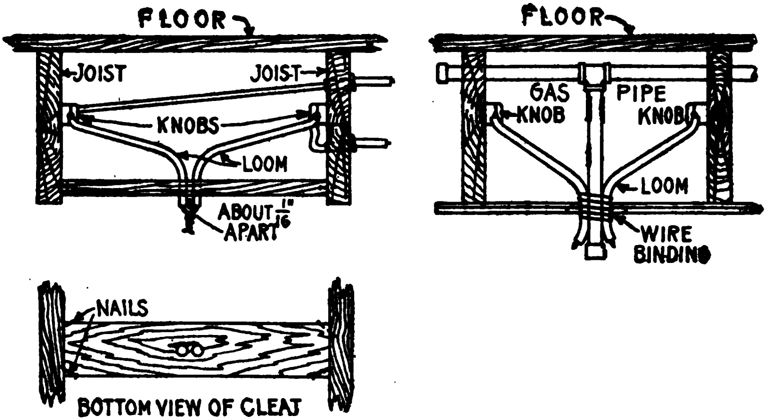
FIGS. 7,108 to 7,110.—Switch boxes for concealed knob and tube wiring. These are for flush switches and are formed from sheet steel. A single switch box can be expanded for any number of switches, by using the proper number of spacers. Single and double switch boxes can be supplied already assembled and are used where feasible, because it is cheaper to buy them this way than to assemble them. Holes partially punched, which can be knocked out with a hammer blow, are provided in the sides and back through which the flexible conduit wire protection can be extended.

After wires are brought into a wall case they should be twisted and marked so that they will easily be identified when the switches are to be installed. Switches and receptacles are never installed in wall cases until after all the plastering has been done. All wall cases should be stuffed with newspaper or rags so that they will not be filled with plaster and should have a stick extend at least 4 ins. out of them so that they will not be plastered over, the stick serving as a mob mark.

Wall cases should be installed so that the front edge of the box extends ¾ in. from the edge of the studs. Wall cases should be supported on strips of wood which are not less than ⅞ in. thick. Laths will not do. The strips should be placed so that they are flush with the front edge of the studs.

Fixture Supports.—A good method of installing a fixture support is to take a piece of wood ⅞ in. thick by 6 ins. wide and nail flush with the lower edge of the beams; this is for straight electric fixtures.

In case of a combination gas and electric fixture no board is required. The looms should be secured to the gas pipe so that they will not slip down, the wires at all outlets should be twisted together so that they will not be lost singly.



FIGS. 7,111 to 7,113.—Methods of making fixture outlets in concealed knob and tube wiring. A cleat consisting of a piece of board at least ⅞ in. thick, should be nailed between the joists or studs into which the wood screws supporting the electrolier can be secured. Holes are then bored through the cleat, through which the flexible tubing can pass. With a combination gas and electric fixture as shown in fig. 7,112, no cleat is necessary, because the gas pipe supports the fixture. The flexible tubing should be wired to the gas pipe, to prevent displacement by artisans who have occasion to work around the outlet.

In some cities municipal laws require the use of outlet boxes for loom at all outlets in knob and tube work, although not shown in the drawings, they are not required by the *Code* but they only recommend their use.

Location of Outlets.—The standard height for side wall outlets are 66 ins. from the floor. Flush switch outlets should be installed at a standard height of 54 ins. from the floor to the center of the switch box.

Wall receptacles, such as used for electric irons, etc., should be installed at the same height as switch outlets.

Base plug outlets should be installed in the center of the base board, not lower than 2 ins. from the floor.

Points on Wiring Houses Under Construction.—The plans and specifications of the house should first be gone over very carefully.

For one family houses it is suggested that a separate circuit be made for each floor, the cellar light being taken off at the first floor circuit, attic light being taken from second floor circuit.

Cellar light sometimes can be tapped off of base receptacles or vice versa.

Always arrange the circuits so that they will drop down over the meter or distribution panel.

Fig. 7,114.—Boring machine for boring porcelain tube holes in knob and tube work. It will bore a hole parallel with the floor (avoiding slanting tubes) and in less time than with a brace.

Fig. 7,115.—Electrician's bit designed for rough usage. *It has* a coarse worm and sharp cutter so that it will pull itself into the wood without much effort. Ordinary fine worm carpenter's bits are not suitable as they easily clog in the hole.

Always try to place base plugs under switches as this saves wire and labor. Group as many switches as possible at one point, this also saves labor and material.

The holes should be bored with a ***boring machine.*** If this be not possible it is suggested that the wireman have the apprentice bore the holes. All holes should be bored before wiring is begun.

For 2 in. joists, 3 in. tubes should be used; for 3 in. joists 4 in. tubes should be used.

Tubes should be inserted as the holes are bored; this saves time in going back to the same place to insert tubes.

A time saver is to have the wireman wear an apron that is similar to those worn by carpenters with two compartments, one for tubes, the other for knobs.

Always make joints as branch circuits or taps are made; this saves time. Also cover joint with soldering paste as soon as made.

In general on knob and tube work there are many details that should be borne in mind mainly that time must be saved; this is only accomplished by having a system about your work such as outlined above. Never go back to an outlet; always finish the work at one particular spot, going back and forth is costly.

Always locate centers of rooms for outlets and install outlet boards for fixtures supports before wiring, install wall cases, receptacles, etc. Soldering should not be attempted until all the joints and all wires have been run.

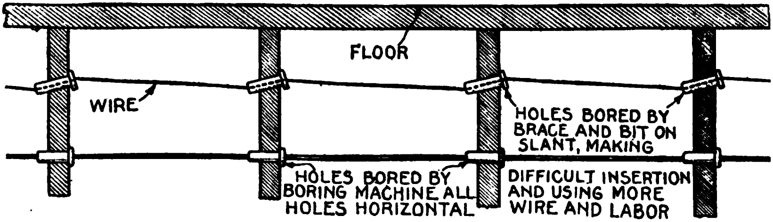


Fig. 7,116.—Comparison of porcelain tube holes as bored with brace and bit and with boring machine. The use of a brace and bit is not only a waste of time but makes an objectionable job.

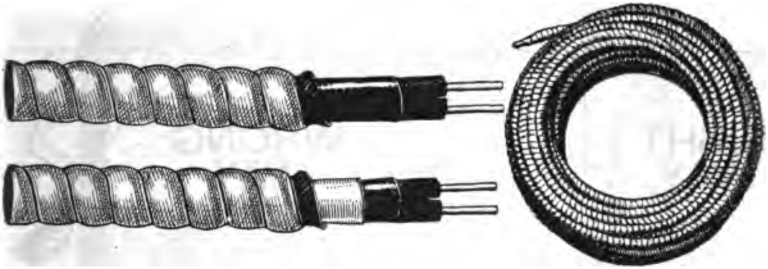
As a final reminder neatness counts, tight wires and neat joints insure a good installation. Always trace out all circuits before house is considered as finished.

5. Armored (B.X.) Cable Wiring

Armored cable, hereafter called by its trade name, B.X. Cable, consists of a duplex or two wire cable covered by a specially wound steel casing. B.X. cable is manufactured in long lengths (coils of 250 ft. and less) and may be obtained with either 2 or 3 conductors, also with a lead covering for outside and underground wiring.

B.X. cable is flexible and the conductors are well protected from mechanical injury. While this form of wiring has not the advantage of the conduit system—namely, that the wires can be withdrawn and new wires inserted without disturbing the building in any way whatever—yet it has many of the advantages of the flexible steel conduit, and it has some additional advantages of its own. For example, in a builidng already erected, this cable can be fished between the floors and in the partition walls, where it would be impossible to install either rigid conduit or flexible steel conduit without disturbing the floors or walls to an extent that would be objectionable.

B.X. cable is less expensive than the rigid conduit or the flexible steel conduit, but more expensive than cleat wiring or knob and tube wiring, and is strongly recommended in preference to the latter.



Figs. 7,117 and 7,118.—Greenfield flexible armored (B. X.) cable and length of cable coiled.

Fig. 7,119.—Greenfield flexible armored cable, lead covered conductors (B.X.L.) for use in wet places.

Code Requirements.—Must be continuous from outlet to outlet. Must be equipped at every outlet with an approved outlet box or plate. Must have metal armor grounded. Must have approved terminal fittings when entering junction boxes. Armor must not be injured in bending; minimum bend, 1½ ins. inner radius.

Installing B.X. Cable.—In order to properly remove the metal casing or armor, a fine toothed hack saw should be used.

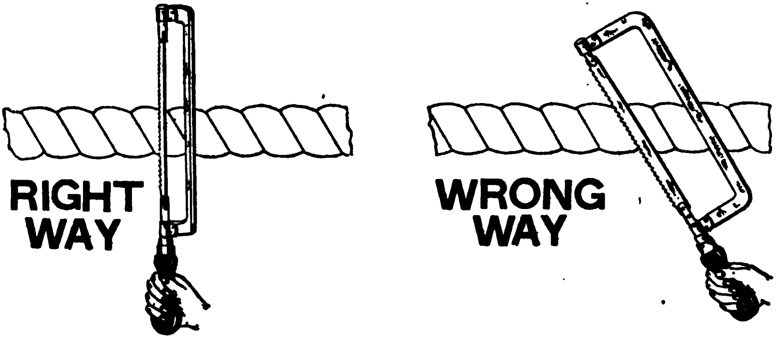
The armor is cut diagonally across. The cut should not entirely cut through the sheath, but should be deep enough so that it will break if given a slight inward bend. Do not cut too deep as this may sever the wires or puncture the insulation.

After armor sheath has been removed, the outer protecting braid must be removed from the duplex conductors. This is best done by making a slit one inch below the sheath about one inch long, and then by pulling on the outer braid it will readily come off without much effort.

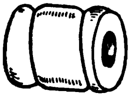
Before the cable is installed it should be examined at each end to see whether any parts of the sheath punctures the insulation.

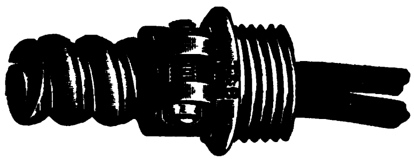
This is very important as grounds and short circuits are often thus accidentally made.

In installing on concealed work, the cable is drawn through a hole in every joist and beam that it passes through, notching out or cutting grooves in joists is not permitted. Care should be taken that the cable should be installed so that no nails will puncture the armor when the floor is laid



Figs. 7,120 and 7,121.—Right and wrong way to cut B.X. cable with a hack saw.





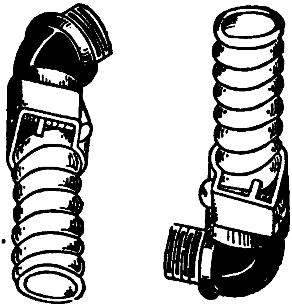


Fig. 7,122—Cable connector for securing B.X. cable to outlet boxes, etc.

Fig. 7,123.—Bushing for B.X. cable. Where the cable enters wall cases, they should be securely clamped to the box and be equipped with a bushing.

Figs. 7,124 and 7,125.—45° and 90° elbows for making sharp turns from outlet box with B.X. cable.

back as nails will cause short circuits and grounds, which are very difficult to find.

It is not necessary to draw the cable through the joists in blind attics; the cable may be laid on top of the joists.

By blind attics it is meant where the cable would not be disturbed by walking around.

No junction boxes are permitted to be concealed under floors or walls. Make all splices at fixture or switch outlets, if junction boxes be necessary they should be installed in a clothes closet or pantry or in open accessible attics.

Where the B.X. cable enters an outlet box, plate, or cabinet the cable should be securely fastened to it by B.X. connectors; also, it is important that these connectors be screwed up as tightly as possible, as it is essential that the entire installation be one straight metallic system.

Figs. 7,126 and 7,127.—*Dead ground* cable boxes. For straight electric work male boxes should be used, these come already with a threaded fixture stud. A female or combination box is used where the electric fixture is attached to a gas pipe.

When running B.X. through floors, it also must be protected by a piece of pipe which should extend at least 4 inches above and below the floor.

B.X. should be supported by straps or clamps which should be spaced about every 18 ins.

B.X. can be run on top of cellar joists without any running board. It is advisable to strap the cable at every other joist.

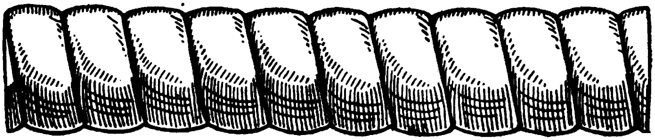
On exposed work the cable should be secured by straps, nails being prohibited.

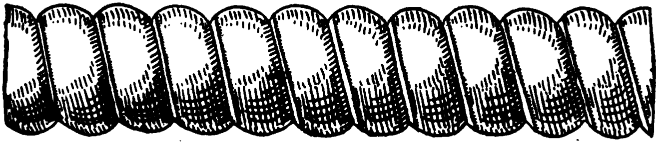
B.X. cable must never be run in damp cellars, or exposed to the weather or laid in concrete, in which the concrete is poured, unless it is lead covered

(B.X.L.). B.X. cable however may be run against brick walls or may be laid in plastered walls and ceilings provided however that they are dry. Never bend B.X. cable in any manner whereby the sheath may become injured, as this may cause a ground: ***minimum inner radius*** 1½ ins.

Where it crosses water, a steam or water pipe, for ordinary common 2 or 3 wire B.X., ¾ pipe will easily slide over. The sleeve should also be screwed so that it will not slide away. This can be best done by strapping both ends of the sleeve to the cable.

When wiring for 3 way switches 3 wire cable should be used, as it is more economical to use one 3-wire cable instead of two 2-wire cables. By following the general outline for concealed house wiring, little trouble will be experienced in installing a good job.





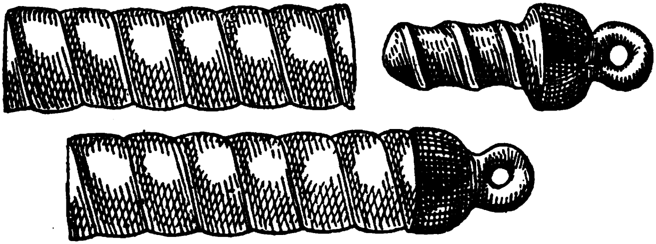
FIGS. 7,128 and 7,129.—Greenfield flexible steel conduit; fig. 7,128 single strip type; fig. 7,129 double strip type. The former (fig. 7,128) is formed with a single strip of galvanized steel, interlocked and gasketed in such a manner as to be suitable for concrete construction. The double strip type (fig. 7,129) is constructed of a concave and convex steel strip, spirally wound upon each other in such a manner as to interlock their concave surfaces. Thus the convex surfaces of the two strips form respectively the outer and inner surfaces of the conduit. This construction insures a smooth interior surface, thus reducing the possibility of friction in the drawing in of conductors. A gasket is provided between the inner and outer strips rendering the conduit moisture proof. This form of flexible conduit is especially adapted to use where the wiring is installed after completion of building, because it is very flexible.

5. Flexible Conduit Wiring

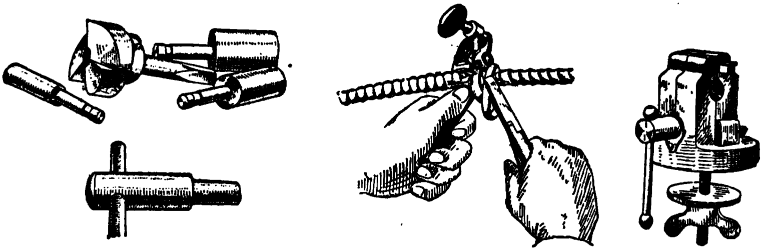
Flexible conduit is a continuous flexible steel tube composed of convex and concave metal strips, wound spirally upon each other in such a way as to interlock their concave surfaces.

It possesses considerable strength and can be obtained in long lengths (50 to 200 feet); elbow fittings are not required as the conduit may be bent to almost any radius. The fissures of the conduit provide some ventilation; this is an advantage in some places and a disadvantage in others.

Flexible conduits are used to advantage in many cases where rigid conduits would not be desirable. It is especially adapted to completed buildings where it is desired to install the wiring by "fishing" without greatly disturbing



FIGS. 7,130 to 7,132.—Greenfield flexible steel conduit and fish plug, showing method of insertion. Fish plugs are made for ⅜ inch, ½ inch, and ½ inch conduit and are useful in drawing in the conduit in finished buildings where it is desired to fish it under doors or in partitions. After the conduit has been cut off square in the special vise, the fish plug may be screwed into the tube and the fish wire or drawing in line should then be attached to the eyelet on the end of the plug.



FIGS. 7,133 to 7,137.—Greenfield flexible conduit tools. Special tools are necessary for installing this type of conduit. Fig 7,133, bushing; fig. 7,134, reamer; fig. 7,135, bushing tool; fig. 7,136, cable armor cutter; fig. 7,137, vise for holding conduit. To remove cable armors, clamp the conductor firmly in the armor cutter and with a pair of cutting pliers back the armor off, one strip at a time, to the point of contact with the cutting edge of the tool. The vise for holding conduit takes all sizes. The conduit can be cut with an ordinary hack saw. To protect the insulation against any possible injury while the wire is being drawn in, a soft metal bushing should be inserted in the end of the tube and secured permanently thereto by means of the bushing tool. The bushing provided for this purpose has an outside thread, which permits its being screwed into the end of the tube and then expanded by the use of the tool. The tool should always be used after the bushing has been screwed into the pipe, then the bushing tool should be inserted.

the walls, floors, or ceilings. It should not be used in damp places because of the fissures.

In installing flexible conduit, it is "fished" under floors, in partitions between the floor and ceiling, by making pockets in the floors, walls or ceilings, say every 15 or 20 feet, and fishing through first a stiff metal wire called a "snake," and then attaching the conduit to same and pulling the conduit in place from pocket to pocket.

On vertical runs, a chain or weighted string is used which is dropped from the outlet to the floor and its lower end located by sound of the chain end or weight striking the floor.

Black Enameled and Galvanized Rigid Conduit

CONDUIT					
Size	Diameters		Thickness	Wt. Per Foot	Threads Per Inch
	External	Internal			
¼	.540	.364	.088	.425	18
⅜	.675	.493	.091	.568	18
½	.840	.622	.109	.852	14
¾	1.050	.824	.113	1.134	14
1	1.315	1.049	.133	1.684	11½
1¼	1.660	1.380	.140	2.281	11½
1½	1.900	1.610	.145	2.731	11½
2	2.375	2.067	.154	3.678	11½
2½	2.875	2.469	.203	5.819	8
3	3.500	3.068	.216	7.616	8
3½	4.000	3.548	.226	9.202	8
4	4.500	4.026	.237	10.889	8
4½	5.000	4.506	.247	12.642	8
5	5.563	5.047	.258	14.810	8
6	6.625	6.065	.280	19.185	8

FIG. 7,138.—Rigid conduit. The dimensions of the various sizes are given in the table at the left, from which it will be seen that the dimensions and threads are the same as for standard (so called) wrought iron pipe.

6. Rigid Conduit Wiring

Rigid conduit, commonly called pipe (but different from ordinary pipe used for other purposes) comes in lengths of 10 ft. or less, and must never be used in sizes smaller than one-half inch pipe or nominal size.

There are two kinds of rigid conduit, the unlined and the lined. Unlined conduit consists of an iron or steel pipe, similar in size; thickness, and in every other way to gas pipe, except that special precautions are taken to free it inside from scale or any irregularities; it is then coated inside with enamel. outside it is sometimes enameled and sometimes galvanized.

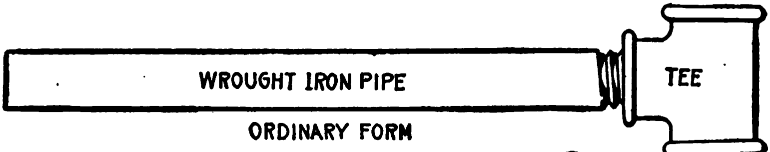
Lined conduit usually consists of a plain iron pipe lined with a tube of paper which has been treated with an asphaltic or similar compound.

this paper tube is cemented or fastened to the inside of the iron pipe so that it forms practically an integral part of the same.

As compared with lined conduit, unlined conduit is cheaper, because having no lining, a smaller size of conduit can be used for any given size of conductor; it is also cheaper to install, as it can be bent, threaded, and cut more readily than the lined conduit. Wires may be more easily inserted and withdrawn as the inside is smoother than that of the lined conduit.

A disadvantage of unlined conduit is that the *Code* requires the use of double braided conductors instead of single braided which are allowed for lined conduits.

The installation of wires in conduits not only affords protection from mechanical injury, but also reduces the liability of a short circuit or ground on the wires producing an arc which would set fire to the surrounding material; the conduit being of sufficient thickness to blow a fuse before the arc can burn through the conduit.



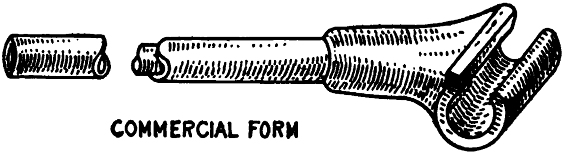


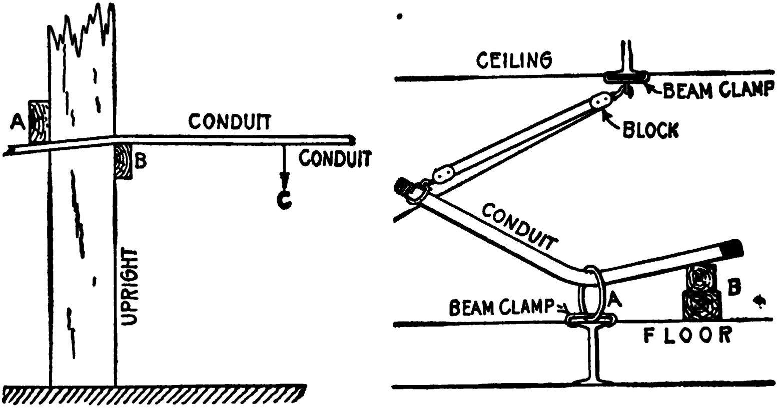
Fig. 7,139.—Ordinary form of hickey or conduit bender. It consists of a piece of one inch steam pipe about three feet long with a one-inch cast iron tee screwed onto one end of the pipe. This device is used as follows: the conduit to be bent is placed on the floor and the tee slipped over it. The workman then places one foot on the conduit close to the tee, and pulls the handle of the bender towards him. As the bending progresses, the workman should take care to continually move the bender away from himself, to prevent the buckling of the conduit.

Fig. 7,140.—Commercial form of hickey or conduit bender.

Code Requirements.—Rigid conduit must be continuous from outlet to outlet or to junction bores, and must properly enter and be secured to all fittings, and the entire system be mechanically secured in position. In case of service connections and main wires, this involves running each conduit continuously into a main cut out cabinet or gutter surrounding the panel board as the case may be. Conduits must be equipped at every outlet with an approved outlet box or plate. Outlet plates must not be used where it is practicable to install outlet boxes. The outlet box or plate must be so installed that it will be flush with the finished surface, and if this surface be broken, it shall be repaired so that it will not show any gaps or open spaces around the edge of the outlet box or plate.

In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission, providing the conduit ends are bushed and secured. It is suggested that outlet boxes and fittings having conductive coatings be used in order to secure better electrical contact at all points throughout the conduit system.

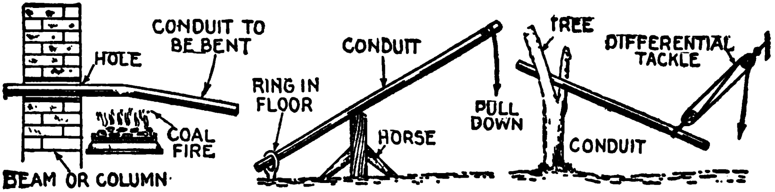
Metal conduits where they enter junction boxes, and at all other outlets, etc., must be provided with *approved* bushings or fastening plates, fitted so as to protect wire from abrasion, except when such protection is obtained by the use of *approved* nipples, properly fitted in boxes or devices.



Figs. 7,141 and 7,142.—Methods of bending large conduits. A substantial support is necessary which may consist, as in fig. 7,141, of two pieces of 2×4 studding A and B, securely fastened to an upright. The conduit is placed under the block A and over the block B, and then bent by a downward pressure exerted at C, the conduit in the meantime being gradually advanced in the direction C, to give a curve of the required radius. The method shown in fig. 7,142, may be used wherever a ring A, can be attached to a beam or girder by means of clamps or otherwise to serve as a support. In this case the conduit is slipped through the ring and placed on the top of blocking B. The bending is accomplished by means of a block and tackle rigged to an overhead beam as shown. Where ring supports cannot be arranged, the application of frame bending methods give the most satisfactory results.

Conduits must have the metal of the conduit permanently and effectually grounded. Conduits and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connections. If conduit, couplings, outlet boxes or fittings having protective coating of insulating material, such as enamel, be used, such coating must be thoroughly removed from threads of both couplings and conduit and from surfaces of boxes and fittings where the conduit is secured in order to obtain requisite good connection.

Where boxes used for centers of distribution do not afford good electrical connection, the conduits must be joined around them by suitable bond wires. Where sections of metal conduit are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection. Junction boxes must always be installed in such a manner as to be accessible. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow must not be less than 3½ ins. Must have not more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.



FIGS. 7,143 to 7,145.—Methods of bending large conduits. Fig. 7,143, by heating. Large conduit such as sizes above 3" may be bent if they be first filled with dry sand to prevent kinking and heated until cherry red over a coal fire, then bending as shown. In fig. 7,144, the conduit is inserted into a ring secured to the floor and bent over a horse by pulling down on the end. The pipe will not kink as the wooden horse is softer than the pipe. Another method, as shown in fig. 7,145, consists of inserting the conduit in the V of a tree and bending by attaching block and tackle, worked by team of horses, or preferably by a differential tackle as shown.

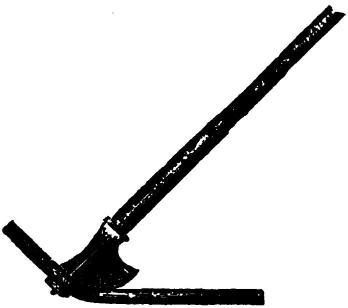


FIG. 7,146.—Rittenhouse conduit bender.

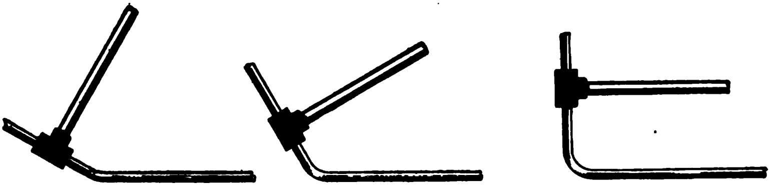
Installing Rigid Conduit.—Cutting should be done with a hack saw unless the pipe be thoroughly reamed to remove the burr.

The presence af a burr with its sharp edges might cut into the insulation of the wire and cause short circuits or grounds.

Bends.—The best method of bending small size conduit is by the use of a bending tool called a *hickey*, of which there are various types. A cheap and serviceable hickey can be made out of a 1 in. tee screwed on to a piece of 1 in. water pipe about 36 ins. long.

In place of a hickey, a vise, or the conduit may be bent by drilling a hole in a large upright or horizontal beam. Some wiremen bend ½ in.

FIG. 7,147.—Machine for making quarter bends. This type of a tool should be used on large jobs where a number of bends the same size is desired.



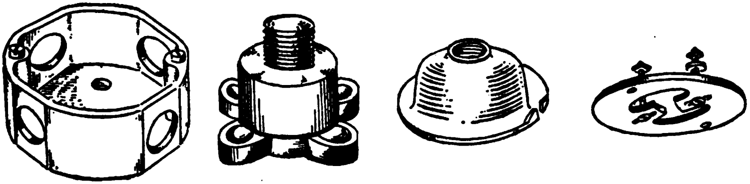
FIGS. 7,148 to 7,150.—Correct method of making a quarter bend with a hickey. The pipe should be marked at the place where the bend is to be made, grasp pipe with hickey and raise pipe from floor a few inches, shift hickey and bend conduit a little more; keep shifting hickey until the proper bend is made. Unless hickey be shifted, the pipe will be kinked, thus making it difficult to pull the wires through the pipe; kinked bends will not pass inspection. ***To make an offset:*** Stand hickey on floor in an upright position with the bending part up, insert pipe into opening and pull down on the pipe, using the length of the pipe as a leverage, having made the bend as far as desired, turn the bend up and repeat as above.

conduit over the knee, small offsets and saddles for particular work should be bent with a hickey.

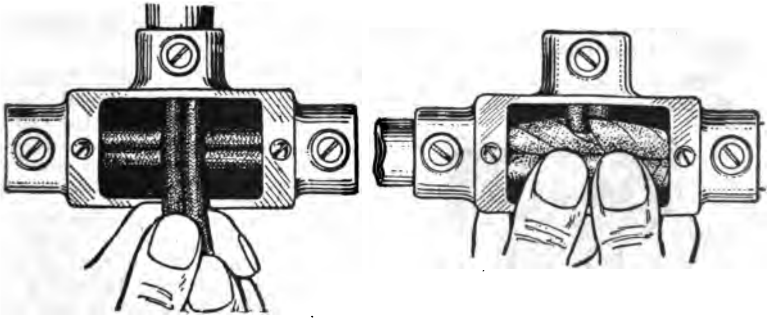
Other methods consist in utilizing trolley tracks, crutches of a tree, spaces between cast iron sewer pipes and catch basins, street man hole covers, machinery, etc.

Always make sure that the bends are true, otherwise the offset will have a crook or bow in it.

For small and close work use a hickey, but for rough work use a hole in a wall, etc.



Figs. 7,151 to 7,154.—Conduit fittings. Fig. 7,151, round style outlet box; fig. 7,152, insulated fixture stud for use in outlet boxes (note insulated studs are used instead of insulating joints); fig. 7,153, outlet box cone; fig. 7,154, spider cones for snap switches and receptacles to fit round boxes.



Figs. 7,155 and 7,156.—Conduit tee fitting. Fig. 7,155 shows method of pushing wires through conduits from tee fitting, and fig. 7,156, how a splice or branch tap appears from the fitting—note method of tapping.

Instead of bending the conduit standard elbows or bend fittings may be used. These have female threads at each end into which the threaded ends of the conduit is screwed.

These are very valuable for the larger sizes above 1 in., but for smaller sizes ½ to 1 in., it is best that the conduit itself should be bent.

Water and gas pipe fittings are not permitted to be used in electrical and conduit work as they are not constructed to receive electric wires.

Threading.—To successfully cut threads, the dies should be sharp and ***plenty of lubricant should be used***, otherwise the dies are overheated, lose their temper and soon become dull with resulting poor thread and much physical effort required to cut the threads. Do not expect to obtain perfect threads unless the dies be ground to the correct cutting angle—as usually manufactured this angle is not correct.

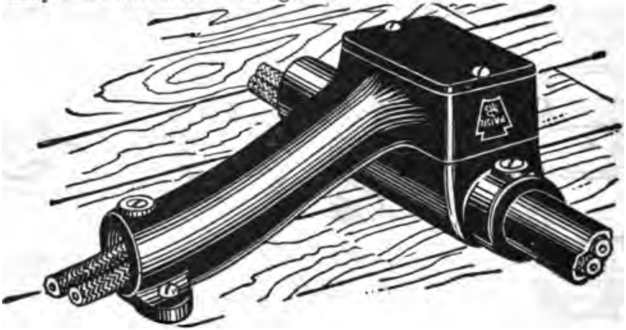


Fig. 7,157.—Fitting for tapping a branch circuit from an existing conduit installation.

In joining conduit lengths, ***running threads*** *are used for the same purpose as the thread on unions in steam fitting.*

The proper method for making a running thread is to cut a thread on the conduit the same length as the length of the coupling; the thread should be made loose so that the coupling will turn easily. A lock-nut is placed in back of the coupling to lock coupling in place.

Fig. 7,158.—Method of securing conduit to outlet or junction boxes. *Two locknuts and a bushing must be used* as shown.

In cutting, do not lubricate by the spasmodic flooding with oil, as this immediately runs off and does little good. Instead of oil provide a small can of lard and apply to pipe end with a brush. Evidently as the die advances, the heat of cutting progressively melts the lard, thus giving a continuous supply of lubricant with no waste. Only right hand threads are used for electrical work.*

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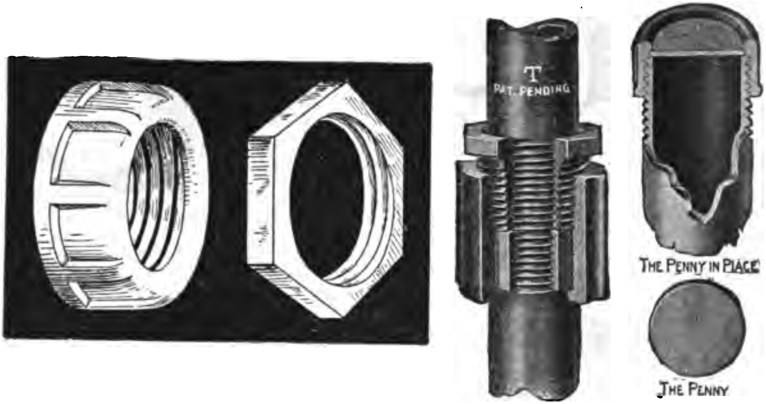
*NOTE.—Pipe threading and fitting methods are treated at considerable length in Chapter 82, on Pipe, Fittings, and Pipe Fittings, in Guide No. 7, a reading of which is recommended.

In this joining together lengths of conduit butt the ends of conduit together and run coupling over pipe to be coupled, after running the coupling up as far as it will go, lock the coupling with the lock nut so that a good tight joint will be made.

Running threads should not be made on pipe for underground purposes, unless joints are tight and painted with lead and conductors in conduit are lead covered.

Outlets.—All conduits should be secured to all outlet boxes by means of two lock nuts and a bushing, the lock nuts to prevent shifting of the pipe, and the bushing to protect wire from abrasion. The lock nuts must be made up as tightly as possible to make the conduit system one.



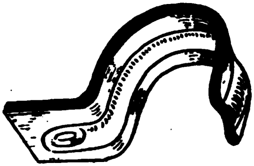
Figs. 7,159 to 7,163.—Conduit fittings. Fig. 7,159, lock nut; fig. 7,160, bushing; fig. 7,161, Erickson's coupling or running thread union; figs. 7,162 and fig. 7,163, penny plug to prevent foreign objects falling into conduit.

The ends of all conduits where they terminate such as on meter loops, motors, and apparatus must be equipped with a porcelain or other insulated bushed fitting. Plain iron bushings are not to be used only on conduits protecting ground wires.

Where it is desired to install a number of conductors in one large conduit and distribute them from a central point, *junction boxes* should be used. These should be used on long conduit runs as *pull boxes* to facilitate installing the wires in the conduit.

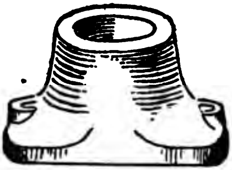
Laying Conduit.—For concealed work in houses, a strip of the flooring is removed and the joists are all notched out by making saw cuts and setting in the conduits so that the conduit is flush with the top of the joists. Pan cake boxes are used so that all wires enter at the back of each box.

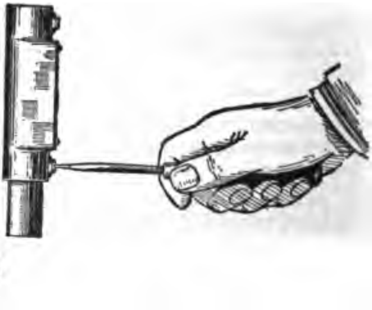
In laying conduit in concrete, it should be bent at each end and brought into the back of the outlet boxes and secured by locknuts and bushings. Pancake of flush boxes should be used. The pipe is looped from outlet making all joints at outlets.



Figs. 7,164 and 7,165.—Conduit clamps. Fig. 7,164, old style requiring two screws; fig. 7,165, new style, single screw.

Fig. 7,166.—Conduit ground clamp.





Figs. 7,167 and 7,168.—Receptacle wired to a conduit fitting and receptacle cover. Note method of securing wires to terminal screws.

Fig. 7,169.—Method of locking fitting to conduit by screws.

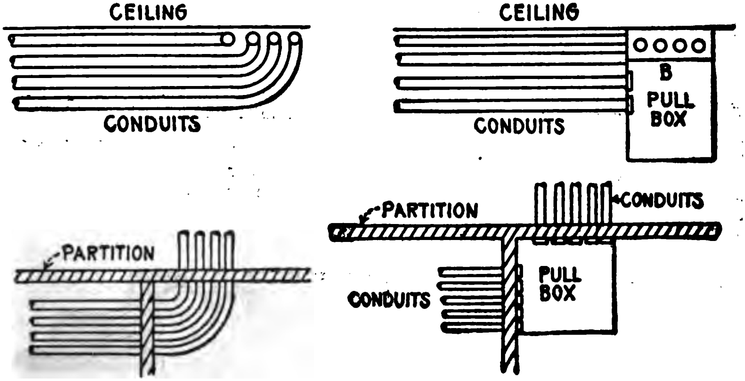
Lofts and factory buildings of beam construction offer much difficulty in installing conduits. Bending the conduit to pass around beams requires a lot of labor, causes difficulty in pulling in the wires, and presents an unsightly appearance. These objections may be overcome by the use of fittings called ***pipe taplets*** which can be obtained in various types. In this method short lengths of scrap pipe may be utilized; all the pipe may be cut to measure on the bench and installed in sections.

The wires are easily pushed through and extra extensions may be made from these fittings.

Methods of Securing Conduits.—On wood or plaster ceilings conduit should be secured by means of straps. These may be obtained in various forms and may be fastened either by nails or screws.

On metal ceilings toggle bolts should be used, the same on ceilings of metal lath. On concrete ceilings wooden plugs or lead shields should be inserted into holes dulled by means of brick drills.

Conduits may be secured to iron beams or girders by means of specially constructed beam clamps.



Figs. 7,170 to 7,173.—Pull boxes and their use in conduit work. A pull box is a convenient device used for the purpose of avoiding the disadvantages of having too many bends in one continuous line of conduit; too many bends will give trouble when the conductors are drawn in. Pull boxes are also useful in places where the arrangement of the conduit is such that trouble would be experienced in bending it to a fit, and also in the case of conduits which are first run on a side wall and then have to be carried across the ceiling at right angles to the wall. Fig. 7,170 shows an example of objectionable bends, and fig. 7,171, the method of overcoming the difficulty by the use of a pull box. It is evident that it would be impossible to make some of these bends so as to permit the drawing in of the conductors. This difficulty is overcome, as shown, by placing a pull box on the wall, with its top close to the ceiling. A board B, having the proper size holes for the conduits is fastened to the front of the box and close to the ceiling. After the conductors have been drawn into the conduits along the wall as far as the pull box, they can be readily pulled away from the box through the holes in the board into the corresponding conduit on the ceiling. Fig. 7,173, shows the use of a pull box in a case where it is necessary to run conduit through partitions at right angles to each other.

Grounding of Conduits.—Ground connections should be made either by ground clamps or by special methods in which ground clamps are not used. In installing ground clamps at least one clamp is used on the conduit and one on the pipe which affords the ground. A ground wire is arranged between the two and soldered in the lug of each. More than one ground is desirable. At all combination outlets, ground the outlet box to the gas pipe. Ground wires should be large enough to give ample mechanical strength, No. 10 copper wire being the smallest that should be used.

Pulling Wires in Conduit.—The wires should be free from all kinks and bends and should be straightened out and laid parallel as they enter the conduit, and wherever possible they should be pushed in by hand.

Never push wires up in vertical conduits as this is double work, pushing against gravity; always push down whenever possible.

Never apply oil or grease to wires so that they will slide easy, this rots the insulation. Powdered talcum or soap stone should be used especially in the hot weather when the insulation is sticking.

If wires can not be pushed by hand they shold be pulled or snaked in by attaching them to snake wires.

Do not attempt to pull wires into runs of conduit that have extra long lengths as it is much easier to insert a pull box at certain points in the run to relieve excess labor in pulling in wires.

FIG. 7,175.—Special branch or tee conduit fitting which requires no splicing of wires.

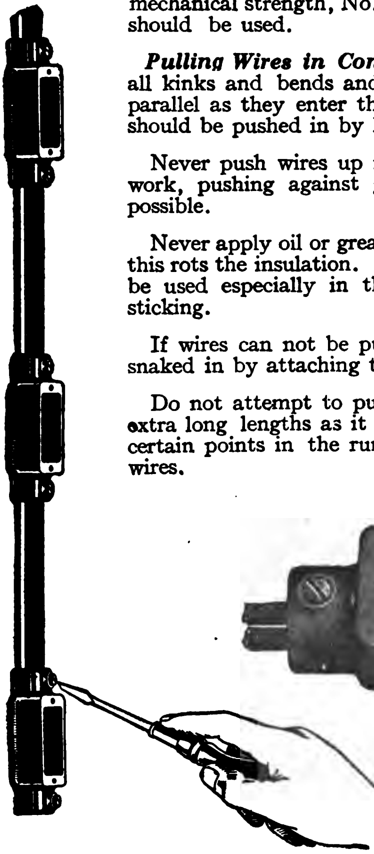


FIG. 7,174.—Method of making a border of lights with conduit fittings. Set screws permit aligning fittings in place.

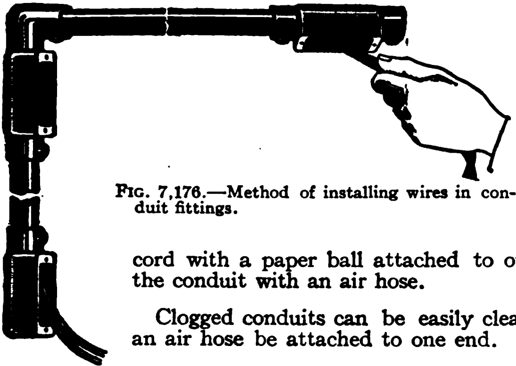


FIG. 7,176.—Method of installing wires in conduit fittings.

The obsolete method of hooking snakes pushed in from each end of the conduits, requires a lot of labor, which may be avoided by the use of pull boxes properly placed.

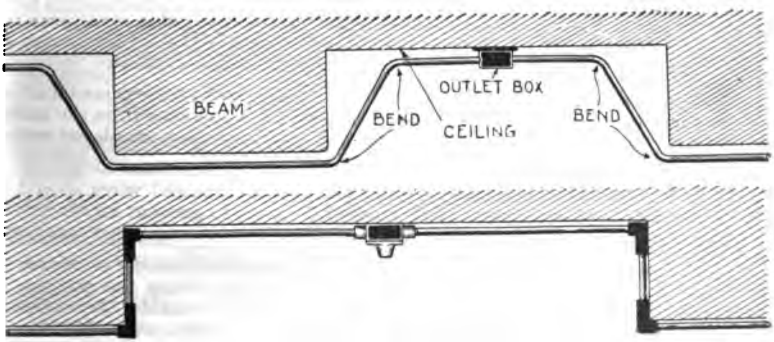
In pulling wires in long conduits, much time can be saved if a cord with a paper ball attached to one end is blown through the conduit with an air hose.

Clogged conduits can be easily cleaned of foreign objects if an air hose be attached to one end.

Wire Supports in Vertical Conduits.—All wires in vertical conduits are required to be supported as follows:

No. 14 to 0 inclusive every 100 feet. No. 00 to 0000 inclusive every 80 feet. Above 0000 to 350,000 C. M. inclusive every 60 feet. Above 350,000 C. M. to 500,000 C. M. inclusive every 50 feet. Above 500,000 C. M. to 750,000 C. M. inclusive every 40 feet. Above 750,000 C. M. every 35 feet.

In supporting wires approved clamping devices are used or insulating wedges are inserted in the end of the conduits. On long vertical runs



FIGS. 7,177 and 7,178.—Two methods of passing around ceiling beam with conduit. Fig. 7,177, bending method—laborious and presents unsightly appearance. Fig. 7,178, using fittings instead of bending the conduit. An easy and neat way and one which permits using scrap or short lengths of conduit.

junction boxes may be inserted at the required intervals in which the insulating supports are installed.

Practical Points Relating to Inside Conduit Wiring.—The following instructions apply to the installation of wiring in both rigid and flexible conduit:

1. All conduits should be made continuous from one junction or outlet box to another, or to the various fixtures. A conduit installation is made a complete system by the use of outlets, outlet boxes, switch or junction boxes, and panel boxes with doors and locks, which serve to thoroughly protect the circuit at all points.

2. In the installation of interior conduit wiring, the tubes are usually put in place as soon as the partitions of the buildings have been constructed. In non-fire proof buildings, the tubes are usually supported from the underside of the floor beams, but in fire proof buildings they are placed on top of the floor beams and under the floor as in fig. 7,197.

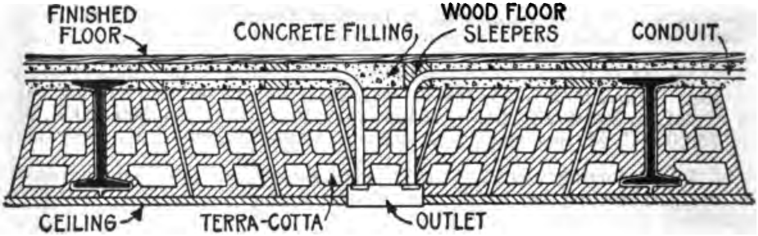


FIG. 7,197.—Method of installing conduits in fire proof buildings. ***The installation*** of the conduit includes the placing of all outlet boxes, and when this has been completed, the lathing or plastering work is executed, and after that is finished, the wire is pulled into the tubes, and the receptacles, switches, etc., put in position. The work of pulling in the wires may be greatly facilitated by the use of *pull boxes* as shown in figs. 7,171 and 7,173.

3. When conduit is used in damp places, lead encased wires should be used, and the wires drawn in very carefully so as to prevent any injury to the casings.

4. For wiring installations in buildings constructed entirely of reinforced concrete, the preliminary work should be laid out during the progress of the building operations so as to avoid, as much as possible, the necessity of drilling holes in the finished concrete work.

5. For concealed wiring, the location of all the outlets should be marked by sheet iron tubes large enough to hold the conduits. These tubes should be properly plugged, and set in the false work before the concrete is poured

in. In a similar manner, threaded pieces of conduit of the proper size, should be placed in the false work for risers.

6. For exposed wiring on concrete walls and ceilings, suitable cast iron supports should be set in the moulds at regular intervals. When liberally used, these supports will also serve as good supports for other pipes.

7. Where a conduit line terminates on the outside of a building some suitable fitting such as a pipe cap should be used, as shown in fig. 7,180, to prevent the entrance of moisture into the conduit system.

8. Where it is desirable or necessary to continue open wiring from conduits, or where the character of the wiring makes it necessary to bring the wires over from the conduit, as in an arc lamp, neat and safe work can be done by use of a suitable form of *condulet* as shown in fig. 7,181.

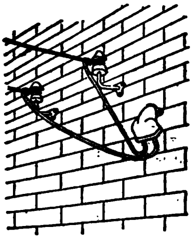


FIG. 7,180.—Service entrance to interior conduit system; showing method of preventing moisture reaching the interior of the conduit system.

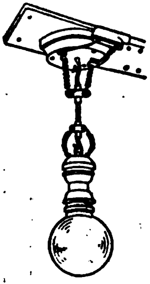


FIG. 7,181.—Outlet to arc lamp from conduit by use of condulet. The wires are brought out from the conduit system at a distance of 2½ inches apart. Conduits are made in a great variety of design with interchangeable porcelain covers which render them adaptable to almost all cases requiring the installation of outlet boxes.

9. Where a conduit line terminates in a switch or panel box, the lining or casing of the panels should be of iron, and the conduit firmly secured to

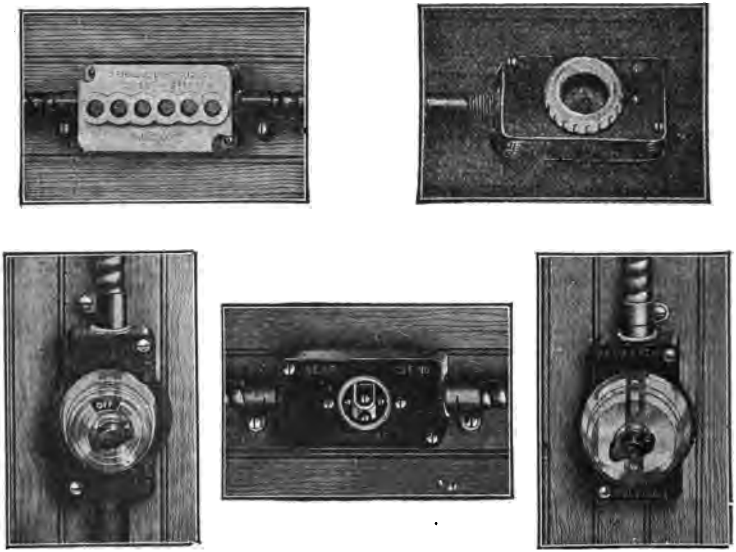
CORRECT METHOD

INCORRECT METHOD

CORRECT METHOD WHERE THE BOXES ARE LESS THAN 12" APART

FIGS. 7,182 to 7,184.—*Right* and *wrong* methods of installing conduit to outlet boxes. When the conduit hole is in the center of the box, a much neater job is made if the conduit be bent at each outlet where the pipe enters the box. On borders or decorative work where the outlets are close to each other, as in fig. 7,184, short pieces of pipe need not be bent, because of the considerable labor required in making a multiplicity of bends. Fig. 7,183 show incorrect method where boxes are over 12 ins. apart.

it so as to make good electrical contact. Vertical lines of conduit should be fastened to the wall or other supports in such a manner as to prevent the weight of the conduit coming on the panel box, and each length of conduit installed should be fastened so as to bear only its own weight. The best method of fastening conduit to brick walls is by the use of expansion



Figs. 7,185 to 7,189.—Sprague multilet covers. Fig. 7,185, six wire porcelain cover; fig. 7,186, P & S. rec. cover; fig. 7,187, cover for five ampere snap switch; fig. 7,188, G. E. and P. & S. rec. cover; fig. 7,189, cover for ten ampere snap switch.

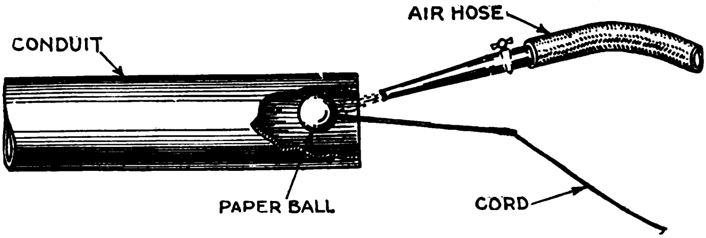


Fig. 7,190.—Method of cleaning clogged conduit, previous to pulling in wires, by blowing through the conduit a paper ball attached to a cord; using an air hose.

bolts and screws. In the case of fire brick ceilings or other plastered walls, toggle bolts should be used. When conduits are run on wooden or iron beams, various kinds of pipe hanger may be employed.

10. There are numerous devices on the market for bending conduit for the making of elbows, offsets, etc., but the majority possess the disadvantage that the conduit must be taken to them to be bent. In the case of the smaller sizes, this difficulty is avoided by the use of some form of conduit bender such as shown in figs. 7,139 and 7,140.

11. In all cases, the interior diameter of the conduit installed should be amply sufficient to permit of the wires being drawn in easily, thus providing a substantial raceway for the conductors. The practice of pulling wires through conduit by means of a block and tackle is very objectionable. It is evident that if the wires be pulled in by the application of much force the insulation is very liable to become damaged; furthermore, much difficulty will be experienced in pulling them out again, especially in warm places where the heat tends to soften the lining of the conduit, and also the rubber covering of the wire. Powdered soapstone put in the pipe while the wires are being drawn in will lessen the friction and permit the wire to go in more readily.

CHAPTER 110

Wiring Finished Buildings

The wiring of finished houses is not as easy as it may appear, as there are no two houses built alike, and there are no two wiremen who would wire the same house in the same manner.

Then there are numerous setbacks that make it difficult to proceed with the work quickly, such as parquet floors, double floors, clogged partitions and other obstructions which are outlined so that if the instructions are carefully followed no difficulty will be experienced.

By laying out the job and drawing a rough sketch much labor and material will be saved.

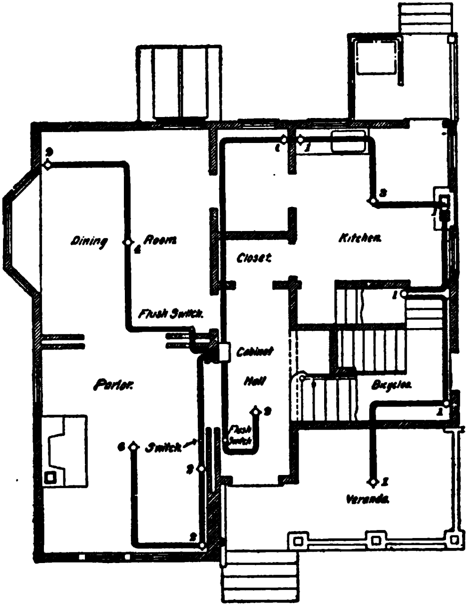


FIG. 7,191.—Plan showing one floor of a dwelling house wired with conduits. The numbers on the various outlets indicate the number of lamps supplied. The wiring is carried out on the loop system, and it will be noticed that no branches are taken off between outlets. Four circuits are used in order that there may not be more than ten lamps on any one circuit.

In many cases the only instructions given the electrician who does the wiring is simply a plan showing the location and number of lights, from which he must figure out how to install them using the least amount of material and labor consistent with a good installation that will pass inspection.

It should be ascertained how many sockets are to be attached to each outlet, as the code allows only 660 watts to each 2 wire circuits on 40 watts per socket, base plugs are counted as sockets.

After having laid out the number of lights per circuit and the number of circuits, the center of distribution should then be found—if a large house having over 4 circuits, it is advisable to install a panel board that will feed the various circuits, this panel should be installed at a central point.

Panel boards in loft buildings or in any building requiring 8 to 10 circuits to a floor should be distributed one to a floor.

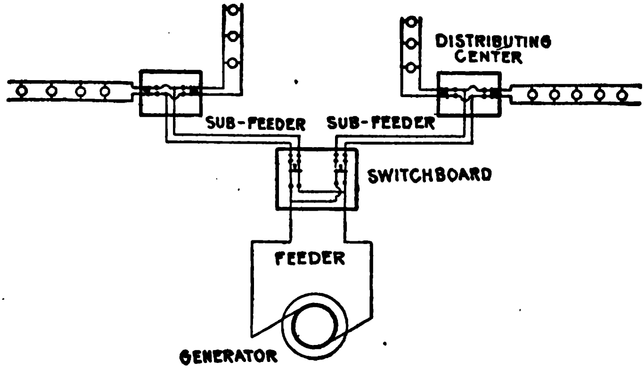
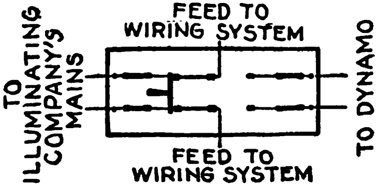


FIG. 7,192.—Two wire parallel system as used with isolated plant.



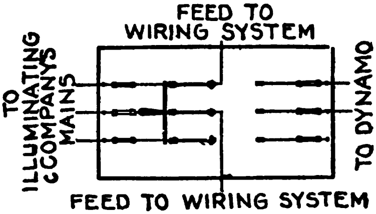


FIG. 7,193.—Double throw switch for use in isolated plants when auxiliary power is used from the central station is case of breakdown.

FIG. 7,194.—Double throw three pole switch for use in isolated plants where auxiliary power is brought in through three wire system. The side of the switch controlling the current is bridged as shown.

In a building covering a large area it is often advisable to install two panels or centers to a floor, with two sets of feeders. It is advisable to keep circuit lengths down to 100 feet or less, and the judicious laying out of circuit centers will save many feet of wiring.

The distributing centers or cut out cabinets should be installed near a partition that is so located as to make the running of risers easy, and should be on an inside wall to guard against dampness.

If only one distributing point be used, it should be either in the cellar or attic and risers run to the different floors.

In private houses it is sometimes advisable to install only one panel for the entire house. This is good practice for a three story house not requiring over twelve circuits.

In some cases it is not advisable to install a panel, but to bring the wires

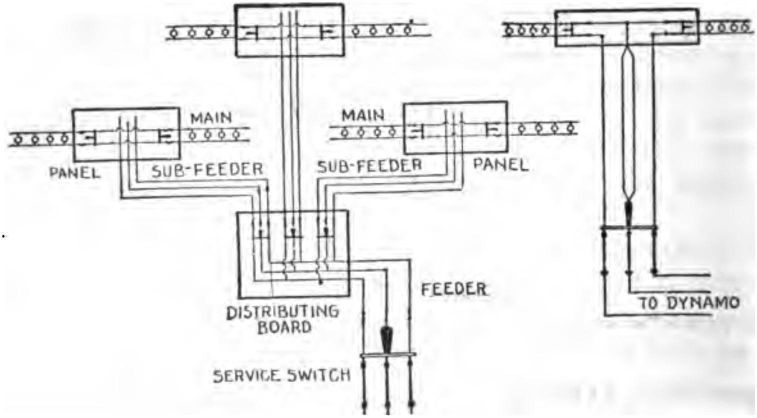


FIG. 7,195.—Three wire convertible, or three wire two wire system; used to advantage where power is supplied from an outside source and brought in through the three wire system. The only difference between the three wire convertible, and the straight three wire system is that the center, or neutral, wire of the mains and feeders should have a current capacity equal to the other two. ***The reason*** for this is that it allows the system to be readily changed over to a two wire system for use in connection with a private plant. It sometimes happens that after using power from the local electric illuminating company for some time, conditions arise which make it expedient for the owners to install a private electric plant. If a straight three wire system had been originally installed, the mains and the feeders when used on a two wire system would not be heavy enough by 25 per cent., as the neutral wire of a straight three wire system is the same in size as one of the two outer wires, and theoretically carries one-half the current or less.

FIG. 7,196.—Diagram showing reinforcement of neutral wire necessary to change regular three wire system to two wire system. The capacity of the neutral wire must equal that of the sum of the two other wires.

down to the cellar, to the meter board where fuse blocks for the various circuits are installed on the meter board.

Feeders and Mains.—Making a feeder layout for a large building, a good method is to draw an elevation of the building as in fig. 7,197, and note on each floor the current requirements.

The best plan is to furnish a feeder for every floor, especially in large installations. In smaller installations one or two feeders are sometimes all that are required.

Feeders for motors should be independent of lighting feeders. In calculating sizes, feeders requiring over 2 inch pipe should not be used. It is better to subdivide them, especially if there be many bends or offsets, since two inch pipe is about the limiting size for economical handling.

Feeders should radiate from a distributing panel, having a proper sized switch and fuse for each feeder.

If the system of wiring be such that auxiliary power is taken from a local lighting company, it is a good plan to have each circuit corntolled by a double throw switch so that in case of overload, any circuit can be fed from the illuminating company's mains as in fig. 7,193.

It is advisable to install feeders and mains in conduit even though the circuit wires be run otherwise. Since the former carry the main supply of current it is important to have them well protected as they usually run up side walls.

The underwriters make numerous restrictions against open or moulding work on brick walls and require good protection, and this is an additional reason for piping the mains and feeders.

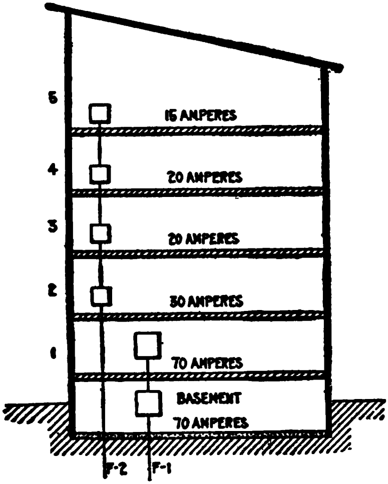


FIG. 7,197.—Diagram showing current required on each floor of building. A sketch of this kind is useful in laying out the feeder system. In the building here shown it will be seen that the basement and first floor require the most power. In such a case a feeder is run for these floors, and a sub-feeder from the basement to the first floor. It is not worth while to reduce the size of the sub-feeder unless the amount of current used on the sub-feeder be a small percentage of that used in the feeder. Another reason is that in changing the size of a wire, the underwriters require a fuse to be inserted. This makes it necessary to install a larger panel with larger trim, etc., and the consequent expense easily offsets any gain made by installing a smaller wire.

In laying out the branch circuits, it is not good practice to use up the underwriters' circuit allowance of 660 watts.

If a circuit be wired with the full allowance of lamps, no additions could be made without violating the *Code* requirements.

Locating Outlets.—If concealed wiring is to be installed, the outlets should be marked on the ceilings and walls with a pencil cross at the spot, marking also the location of switches, etc.

If a ceiling outlet is to be placed at the center of the ceiling, it is first located on the floor and then transferred to the ceiling by means of a plumb bob.

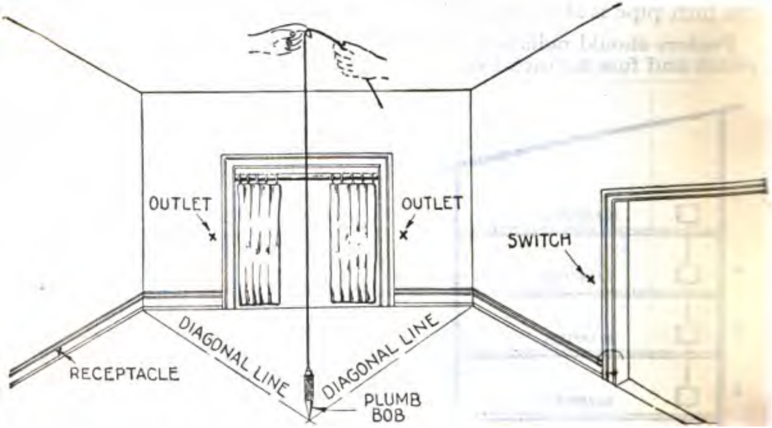
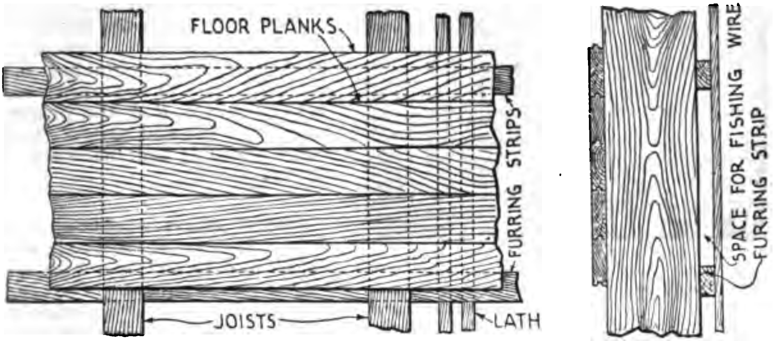


Fig. 7,198.—Marking for outlets and method of locating ceiling outlet on floor and transferring it to the ceiling with plumb bob.

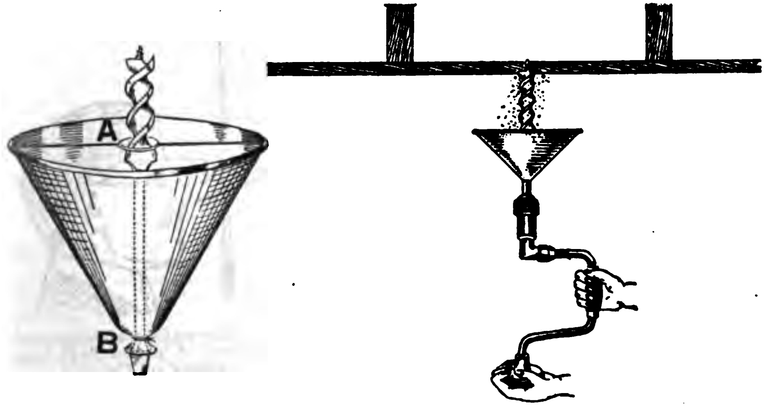
Furring Strips.—After locating the outlets a small portion of flooring is removed to find out whether or not there are seventh-eighths inch furring strips between the joists and the ceiling plaster.

If house have hot air registers set in the floors, they may be lifted up. instead of taking up flooring. If it be found that there are furring strips, much labor will be saved, as the wires may then be fished from outlet to outlet and little flooring need be removed. All houses however are not so built, so in case there be no furring strips it will be necessary to take up the floor and bore a hole in each joist or beam.

Cutting the Outlets.—After locating the centers for the outlets, the plaster must be cut out so that the outlet box will set in.



FIGS. 7,199 and 7,208.—Floor and joists with *furring strips* showing space between lath and joist introduced by the furring strips permitting wires to be fished without taking up flooring and boring joists.



FIGS. 7,201 and 7,202.—Cone dirt catcher for bit and application in boring ceiling outlets. *It consists of* a suitable size cone, made of stiff cardboard and provided with a guide A, to hold it central with the bit. Attached to the lower end is a cloth tube B, which is fastened with a string to the shank. Fig. 7,202 shows the cone in use.

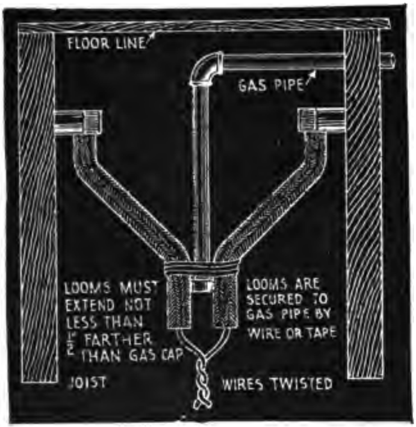


FIG. 7,203.—Method of making a ceiling outlet for a combination gas and electric fixture.

For this purpose a special tool has been designed, this plaster drill is constructed so that it may be fitted over a gas pipe, the cutters are adjustable so that any size hole may be cut. A bell shaped cup catches any dirt that may be removed so that a neat and clean job is made, if drill of this type is used. But if a plaster drill be not obtained, the outlet box should be traced over with a pencil and the plaster should be chiseled around this mark with a ¼ inch blade screw driver.

Outlet Boxes.—After the plaster has been removed, the outlet box should be set in, so that it will fit snugly. The *Code* requires that the lower edge of all outlet boxes should not be set back in plaster any farther than ¼ inch.

The box should be fitted to the hole in the plaster, and the lath should then be marked and notched out with a jack knife to allow the cable to properly pass through into the box. Securing outlet boxes to laths is not allowed as this is not considered as a support, and in time loosens up the plaster.

The only places where a board is not required is where an outlet happens to be located on a beam, joist or stud. Side lights can be located on upright studs which are the best supports to be obtained, but it is not always possible to locate outlets on joists, and still have the outlet in the center, for this reason outlet boards should be installed. These should be very carefully installed so as not to mar the ceiling.

Where the outlet is to be made to existing gas pipe outlets combination boxes should be used. No board is required, except that the box be securely fastened to the gas pipe.

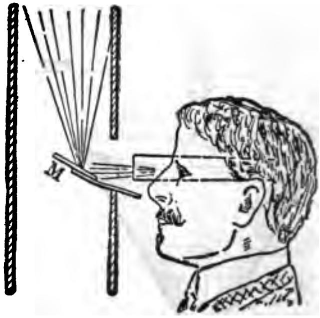


FIG. 7,204.—Device for examining partition interiors. A pocket flash lamp and a little mirror are the only apparatus required to inspect the interior of a wall or partition which would ordinarily be inaccessible. For fishing wires, retrieving cable and inspecting finished work, the lamp and mirror will be found most useful.

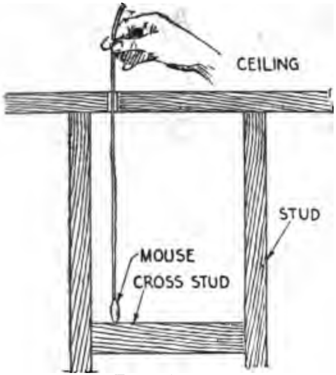
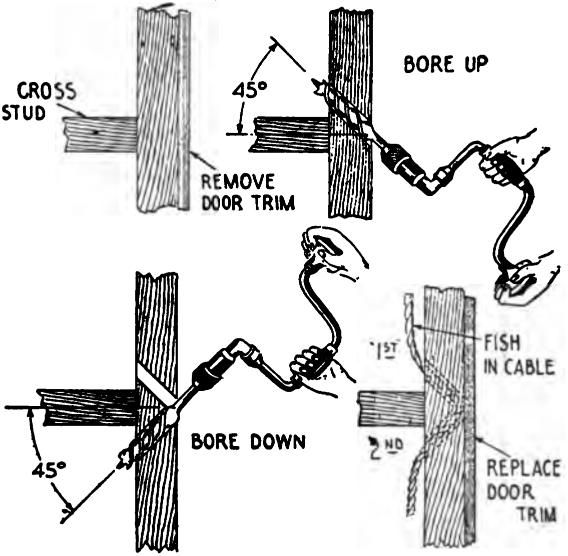


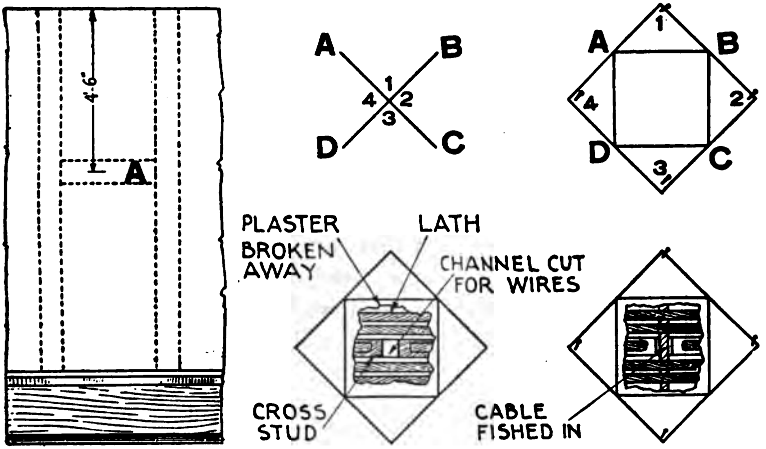
FIG. 7,205.—Exploring in partition for cross stud.

The *Code* requires that the box; should fit snugly around the plaster, where the plaster is broken, it should be mended with plaster of paris.

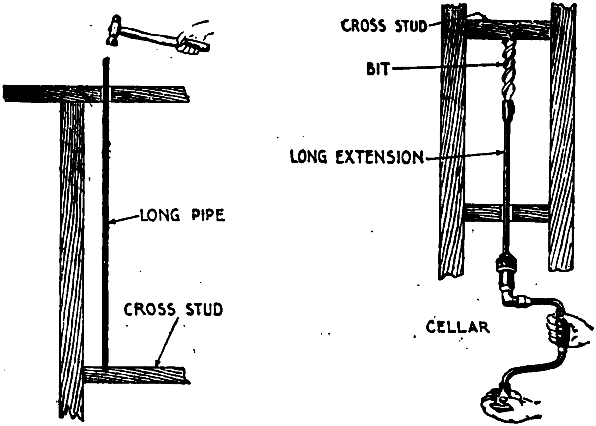
Obstructions in Partitions.—In the older houses constructed when builders had some regard for strength, partitions were reinforced with cross studs so that it is impossible to get by them.



FIGS. 7,206 to 7,209.—Method of passing by cross stud in partition when wires are run next to a door.



FIGS. 7,210 to 7,214.—Method of passing by cross stud in partitition when plaster must be cut. Locate cross stud as in fig. 7,210, 4½ ft. below ceiling. With a sharp knife cut wall paper along two diagonals AC, and BD. Thoroughly moisten paper with a sponge. Peel back the ends 1, 2, 3, 4, to the position shown in fig. 7,212 and fasten with pins. Cut out the plaster in the square thus opened up and cut a channel in the cross stud as in fig. 7,213 Fish in the cable as in fig. 7,214, replaster and fold back wall paper, pasting it to cover the square just plastered.



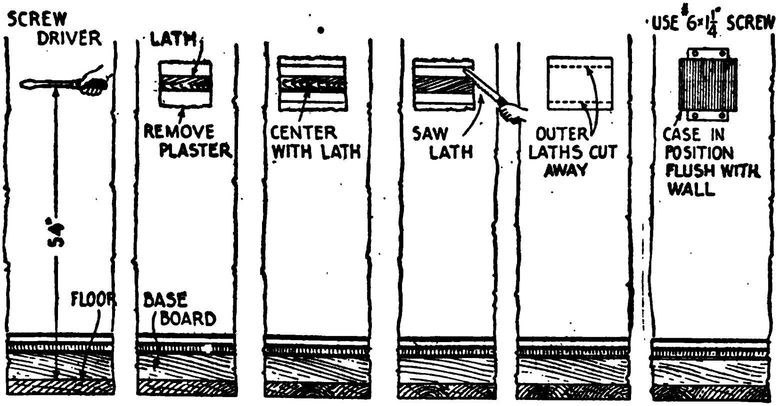
FIGS. 7,215 and 7,216.—Two methods of passing by cross stud in partition: *1,* by inserting from above a long pipe and breaking stud by hammering; *2,* by boring up from cellar with brace and bit having a long extension.

When a cross stud is encountered, the switch outlet may be located above the stud, the standard height being 54 inches above the floor.

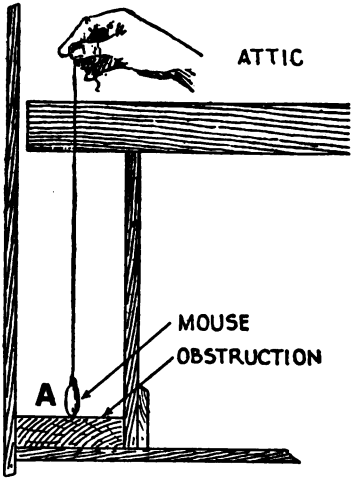
Before attempting to drop down a partition it should first be ascertained whether or not a cross stud or concrete, mineral wool, brick or rubbish filling, is in the partition. A hole is drilled in the top header of the partition and a string with a lead weight lowered if the weight reach the floor (this can be ascertained by sound) the partition is clear.

Cutting Out Wall Case or Switch Outlets.—This is a difficult operation and must be performed carefully.

After having first ascertained that it is possible to drop down the partition, 54 inches is measured up from the floor, the plaster is punctured with a screw driver, if the screw driver go between the lath, another hole should be punctured, and so on until the plaster has been broken away and shows a whole lath; now take the wall case and center the lath with the center of the wall case, with a pencil, run over the outer edges of the wall cases. Now with a hammer and screwdriver, carefully chisel out the plaster on the pencil lines. After the plaster has been removed, with a fine key hole saw, carefully cut away the center whole lath, after this has been cut away, the other lath should be trimmed with a sharp jack knife so that the box fits snugly. The ears of the box should be adjusted so that the box fits just flush with the finished plaster. Now screw box to lath with 1¼ inch No. 6 wood screws, any larger than these will crack the lath.



FIGS. 7,217 to 7,222.—Method of cutting out wall case outlet as described in the accompanying text.



Dropping Wires Down Outer Walls.—First a hole should be bored in the header and the mouse lowered until it reaches the cellar, or hits an obstruction.

Usually obstructions are encountered as fire stops are placed at each floor to prevent the enclosed space acting as a flue in case of fire. These stops usually consist of 2 × 4 strips or brick. To reach them the baseboard must be removed. This is easily pried off with a floor chisel, sometimes it is necessary to set in the nails with a nail set. If walls be of brick, the entire distance from attic to cellar may be fished with a steel fish or snake wire, as the laths are attached to a ⅞ strip which is nailed to the brick.

FIG. 7,223.—Exploring between inner and outer walls with mouse. At A, an obstruction is encountered. This must be cut or bored to permit wires to pass. It may be reached by removing the base board, or may be bored from above with a multi-extension bit.

Fishing.—This is a method of running wires through walls, floors and ducts by the aid of another wire called a *snake* or fish wire attached to the conductors, threaded and drawn through in advance

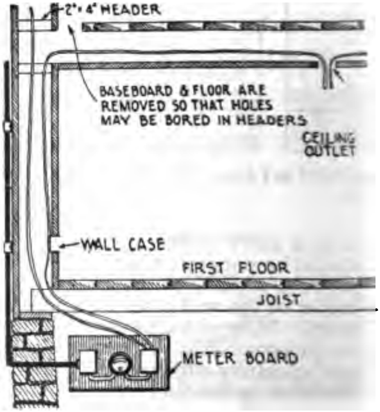
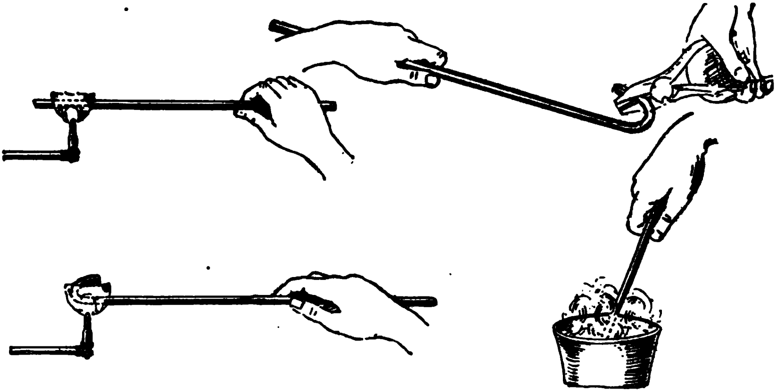


FIG. 7,224.—Method of dropping down a partition that has headers, also showing method of bringing circuits down to meter.

Snake or fish wires are made of the best steel and tempered in oil. All snakes should have a hook bent at each end, and to do this the wire must first be annealed.

The proper method of annealing is to hold the end of the snake in the flame of a torch until it becomes cherry red, then bend into shape, heat again to cherry red color and quickly insert the heated end in a pail of water; this hardens the wire. so that the hook will not pull apart.



FIGS. 7,225 to 7,228.—Method of making a snake. Hold wire in flame till cherry red (fig. 7,225) bend to shape (fig. 7,226); heat again (fig. 7,227), and submerge end in cold water while cherry red (fig. 7,228).

Snake wire may be obtained in various shapes but the type best adapted for house work is 1/8 inch wide, 1/16 inch thick.

The proper way to attach the wires to be pulled into the snake is to just loop them through the hook of the snake and fold them over with pliers.

If wires are to be pulled through a long run, they should be taped.

FIGS. 7,229 and 7,230.—Open and closed snake hooks. ***The open hook*** is used in hooking one snake to another. ***The closed hook*** is used for fishing.

In fishing in a house constructed with furring shifts between the joists and ceilings there will be plenty of room to draw through the loom or cable.

Furring strips in old houses having single floors will be found to run parallel with the floor boards.

After having cut the outlet as just described, a steel wire or snake is inserted into the hole so that it may be pushed into the space made by the furring strip, having inserted the end of the snake, it is gently pushed as far as desired; if the snake encounter an obstruction, it may be caught against a piece of plaster or become twisted.

With a little practice a snake may be fished over 50 ft. with ease, having reached the outlet, another snake or piece of wire is pushed up into the hole at the outlet and the snake is *hooked*, and then gently drawn through the outlet; the wires are then attached and pulled through. If a man be at each end considerable labor will be saved.

Fig. 7,231.—Method of taping end of snake.

Fig. 7,232.—Method of attaching wires to snake for pulling.

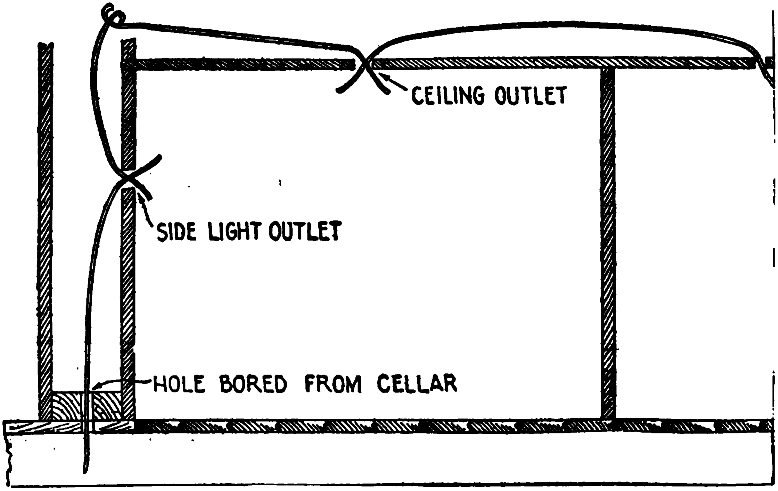


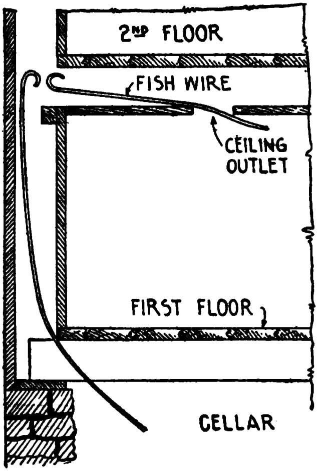
Fig. 7,233.—Fishing from outlet to outlet.

When pulling through the wires it is also necessary that some one be at each end so that one will feed the wires in and the other will pull them out.

The wires should be gently pulled so no damage will be done to the plastered ceiling.

If, in pulling the snake, the wires get stuck, the snake and the wires should be pulled back and forth as most likely the wires are caught against a plaster clinker. This operation will break off these clinkers.

Sometimes a whole house may be fished without taking up any floors, but it may be necessary to take off base boards and flooring to drop down to the meter board or switch outlets.



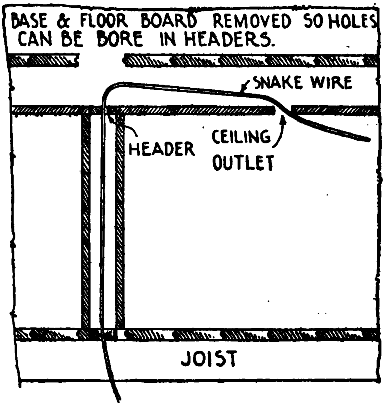


Fig. 7,234.—Method of fishing in wires without removing floors or base board. The fish or snake wire is pushed up from cellar and hooked as shown. This method is only possible when there are no headers.

Fig. 7,235.—Method of fishing in wires through headers.

Sometimes it is necessary to use two snakes on long runs and hook them underneath the ceiling.

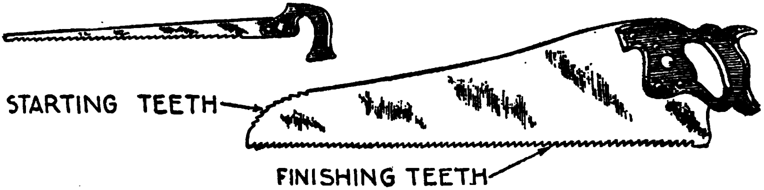
In this case the ends of the snakes should be connected to a bell and battery so the bell will ring when the ends touch each other.

Taking Up Floor.—Various kinds of flooring are to be encountered in wiring houses.

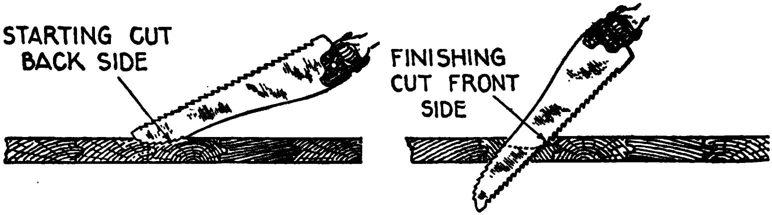
In those built previous to 1875 the floor boards are as wide as 10 to 12″ and are smoothed edged, unlike the present day type of board which has a tongue and groove. This type of flooring is very simple to take up.

If when cutting the outlets, a small hole be bored through the ceiling and the bit pushed up till it comes in contact with the flooring of the room above, and this flooring be also bored, it will show where to take up the flooring to install the wires when they run parallel with the joists. When the wires must run perpendicular to the beams all the flooring must be taken up so that the holes can be bored in the joists through which the wires must pass.

Floor planks are properly removed by driving the nails down with a nail set and lifting up the board. If double floors be encountered, it will be found very difficult as double floors are constructed of hard wood such as oak, or maple, and must be handled with extreme care and patience. For this type of floor, the tongue is split by inserting a carpenter's floor scraping blade, which is a sheet of steel about $4\times6\times\frac{1}{64}''$. These can be purchased at any hardware store at a small sum.



Figs. 7,236 and 7,237.—Floor saws. Fig. 7,236 ordinary compass saw. It should be about 8 to 12 ins. long, very thin blade and tapered to ¼ in. at the end; fig. 7,237, special double edge saw for finished floors.

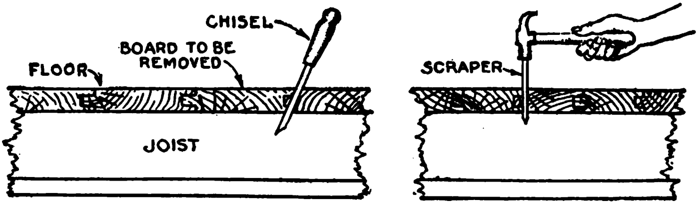


Figs. 7,238 and 7,239.—Method of working the double dge saw. Fig. 7,238, starting the cut with back edge; fig. 7,239 finishing cut with front edge.

The scraper should be hammered down so that the tonque is split, both sides of the board should be split, so that no difficulty will be experienced when lifting up the board.

After both sides of the board that is to be removed has been treated as above, a floor chisel should be inserted where the ends of the board meet with another and the board gently raised.

In raising the board, it is better to take more time and proceed



Figs. 7,240 and 7,241.—Two methods of cutting tongue of floor planks. Fig. 7,240, with chisel at angle—this cuts off tongue and also lower lip of adjacent plank; fig. 7,241, with scraper making a vertical cut.

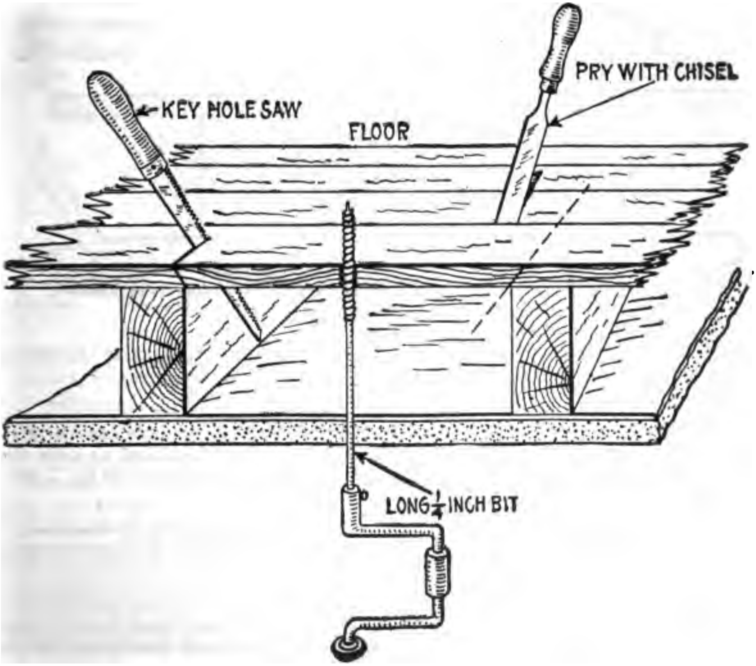


Fig. 7,242.—Sectional view showing method of cutting a pocket or opening in floor for the insertion of wires.

cautiously, as the finest floors may easily be ruined by having one board split, chipped or marred.

After the boards have been removed, they should be numbered or marked so that they will go back in place without any confusion. They should be placed away in a safe place until ready to lay back the floor.

Holes for wires should be bored in the center of the joists so that when laying back the flooring, the nails will not penetrate the metal sheath and short circuit or ground the wires.

Cutting Pockets.—The center of each pocket is indicated by the small hole which was bored in through the flooring when cutting the ceiling outlets.

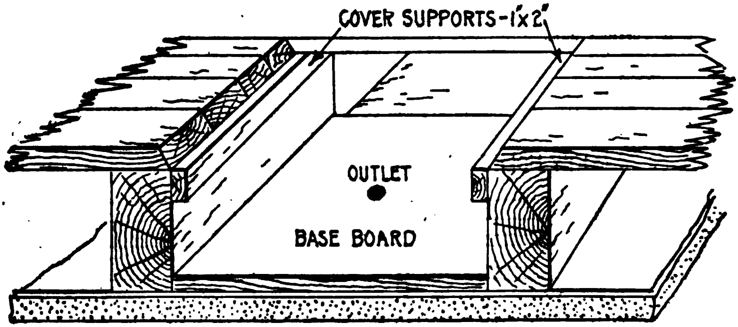


FIG. 7,243.—View of outlet pocket showing base board, and cover supports in position.

In opening a pocket ¼ in. holes are bored to insert a keyhole saw through the joint between two boards at each end of the pocket, and as near the beams as possible, then the board is cut at an angle as indicated in fig. 7,242.

Next saw the tongue of the matched board on each side of the pick and pry up the boards with a chisel as shown. Having taken up the boards, nail a cleat on the side of each joist as in fig. 7,243 so that when the floor is laid back there will be a good support.

A baseboard is next installed as in fig. 7,243 to give a secure hold for the screws used in fastening the fixtures. Two holes are then bored diagonally with a 11/16 inch bit inserting the bit in the small hole bored in the ceiling as in fig. 7,242. The outlet wires are then tied around the knobs and the upper ends being bared and tapped on to the main wire. A piece of loom is slipped on each outlet wire after which it is thrust through the outlet as in fig. 7,244.

Replacing Floors and Trim.—In replacing floors, small finishing nails should be used; these are inconspicuous and will not split the wood when being driven.

When replacing base boards and other finished trim that has been pried off do not attempt to drive back the nails, but cut them off with cutting pliers, as driving the nails back will knock off large chips from the trim.

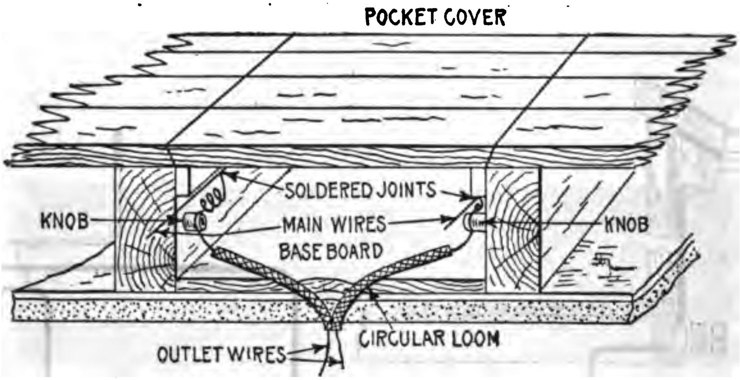


Fig. 7,244.—View of completed pocket and ceiling outlet showing method of bringing out the wires.

After the nails have been cut off, the head of the nail should be set in with a nail set and a new nail driven in the same hole.

Hard wood floors and trim should be gone over with floor wax to remove all scratches and mars.

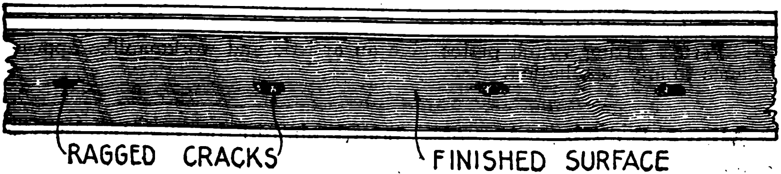


Fig. 7,245.—Appearance of a varnished base board after nails are driven out. The proper way is to leave nails in the board, cutting them off close with cutting pliers.

Installing Flush Switches and Receptacles in Wall Cases.—Care should be taken that the switch fits flush with the edge of the plaster.

In order for the switch to fit flush, the case should fit flush, otherwise it will be necessary to insert small washers under the switch ears.

Switch plates will not fit properly unless the switch be flush; if the switch be not flush, the plate will buckle and bend in the center.

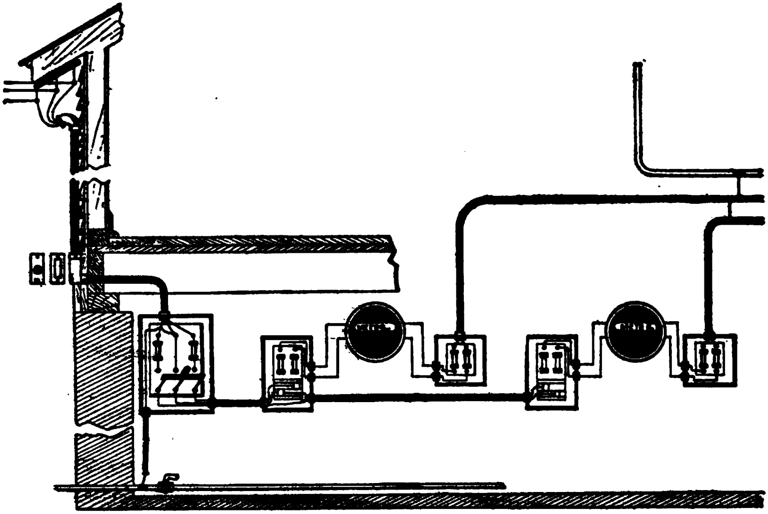


FIG. 7,246.—Two family house meter board arrangement as used throughout Connecticut; note method of service pipe and meter loop arrangement.

Perfect fitting switch plates give an artistic and workmanlike appearance to any installation.

Meter Boards.—A meter board should be constructed of seven-eighths inch soft wood (pine) of sufficient size to accommodate the meter and cut-out boxes.

Secure the board against the foundation wall of the building. Paint board two coats of black asphaltum or other insulating paint.

Do not nail boards to foundation wall unless there be an air space back of it. The use of 2×4 studs makes a secure board.

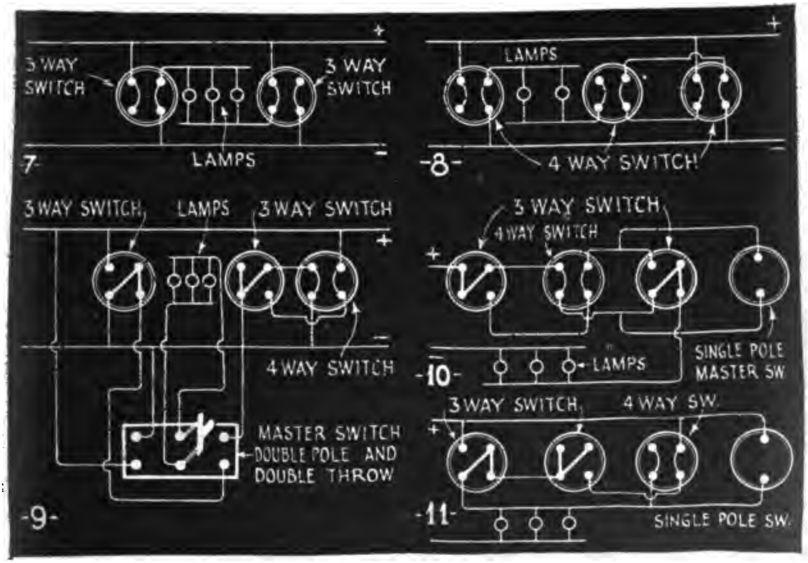
For one single meter, a board 24×18 is amply large with room to spare for future additions.

The main switch is mounted on the left side of the board.

All modern meters feed the left for mains, and feed out to the right for house cut outs.

Do not place a meter board any higher than 7 ft., or lower than 4½ ft.

Service Connections.—This includes the wiring from the street supply to the meter board.



FIGS. 7,247 to 7,257.—Wiring arrangements for controlling lamps from two, three, or more positions. *1,* standard 3-way current for two points of control; *2,* standard circuit for *3,* point of control, using 3-way and 4-way switches; *3,* standard circuit for two-point of control, using 4-way switches instead of 3-way surtches; *4,* standard system for 3 points of control using 4-way switches throughout; *5, Carter* system for two point control; *6, Carter* system for control at three points; *7, Carter* system for control at two points using 4-way instead

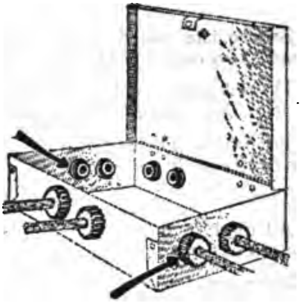
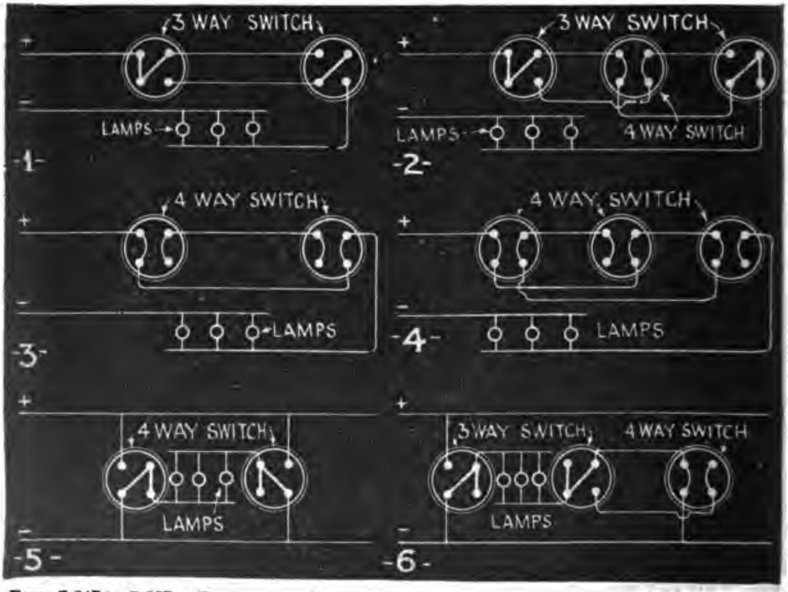


FIG. 7,258.—Method of **installing switch in box; Blades are dead when switch is open; gravity** closes cover of box.

FIG. 7,259.—Method of bushing wires that pass through switch and cut out boxes. Arrows point to porcelain bushings.



FIGS. 7,247 to 7,257.—*Text continued.*

of 3-way switches; 8, *Carter* system for control at three point, using 4-way switches; *9, Carter* circuit arranged for master control at a fourth point; *10,* standard circuit arranged for master control at a fourth point; *11,* another arrangement for multi-point control with additional master switch position.

The wires outside should be run only in galvanized conduit, although the black enamelled form is approved.

The service pipe should be run up the side of the building where directed by the local lighting company.

The top of the service cap must be equipped with a service cap or pipe cap; this cap must have a non-combustible, non-absorbtive bushing where the wires pass through.

Where the conduit enters the building the right angle turn may be made by using an approved pipe fitting, or by a goose neck bend.

The *Code* requires that all wires, where they enter a building be protected by a fusible switch and cut out.

In case it be impossible to place this at point of entrance, a cut out can be placed there and submains run to the meter board.

All switches and cut outs must be mounted in iron boxes with a hinged cover deep enough to cover the switch and cut out and large enough so that a switch can be opened or closed in the box. Also wide enough to allow a space around the switch or cut out.

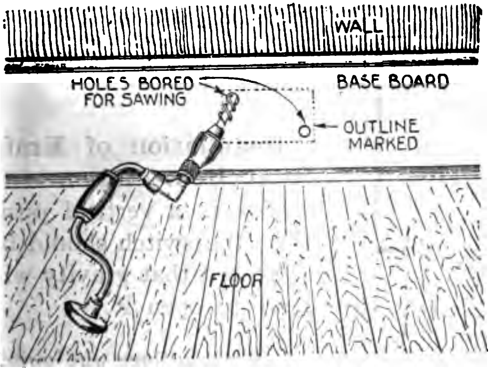


Fig. 7,260.—Installing switch box in base board. 1, mark outline of box on base board; 2, bore two holes as shown to start saw; 3, saw to outline; 4, clear opening to bring box flush; 5, install box in opening after removing suitable knock outs.

Switches for Lighting Installations.—Plug fuse switches are only approved for use on voltages up to 125 volts and to stand a load of 30 amperes.

In the case of a fair size residence a 30 ampere switch of the plug type could probably be used (note types of switches are optional with local central stations).

In the case of a large installation having a load exceeding 30 amperes, cartridge fuse switches and cut outs must be used.

These are designed for pressures up to 600 volts.

Cut out boxes usually have ½ in. knock outs; if a larger size conduit be used, these knock outs must be enlarged by reaming unless boxes with larger size knockouts be obtained. The conduit is secured to the box by two locknuts and a bushing.

Wires leaving the cut out box should pass through porcelain insulators or bushings.

The box should be secured to the board by means of ¾″ wood screws.

The switch or cut out should be secured in the box by means of holes drilled or punched through the box, wood screws passing through the cut out box and screwed into the wood meter board will securely hold any cutout or switch.

Installation of Knife Switches.—When installed in a vertical position, the switch should be so placed that gravity will tend to open it.

Where a three wire switch is used, the middle or neutral fuse clip must be made solid, so that no fuse may be installed in the center clip (this is for lighting installations on a single phase, or a *d.c.* system).

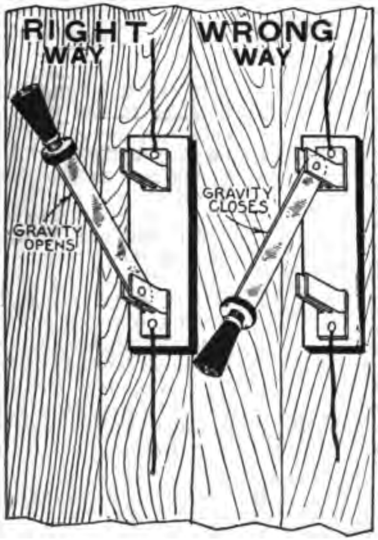


Fig. 7,261.—***Right*** and ***wrong*** way of installing knife switches. They should always be installed so that gravity tends to open them, otherwise when the hinges become worn, the switch might close.

Drop Cords.—According to the *Code*, only reinforced cord not smaller than No. 18 can be used for drop cord purposes and must be used without adjusters.

Only 3/8 sockets may be used equipped with a porcelain bushing, or sockets with pendant caps, or all porcelain sockets must be used.

Hard rubber or composition bushings are not allowed.

Where the wires enter a socket, rosette, or an outlet box, they should be relieved of any strain by making an Underwriter's knot so that the weight of the socket, shade and lamp will not be on the joint

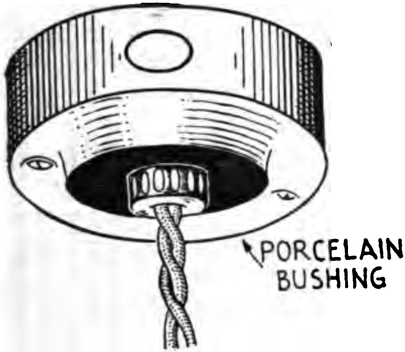


Fig. 7,262.—Drop cord fixture leaving conduct outlet box cover. A porcelain bushing must be used with all metal covers.

Fig. 7,263.—Fixture stud for supporting fixtures to outlet boxes.

Square or granny knots are not approved, sockets may be obtained with strain relief devices attached.

Stripping Drop Cord.—With a sharp knife cut around the outer braid just deep enough to cut the braid and re-enforced rubber covering. Then cut a slit parallel with the cord just deep enough to cut only the outer braid. Remove outer braid and with each hand pull on each wire and re-enforced rubber braid will fall away. About 2 ins. is sufficient for sockets, and rosettes; 6 ins. to be allowed where the cord is to be spliced to other wires such as in outlet boxes, etc.

Uses of Drop Cord.—For inside of residences, re-enforced cotton cord

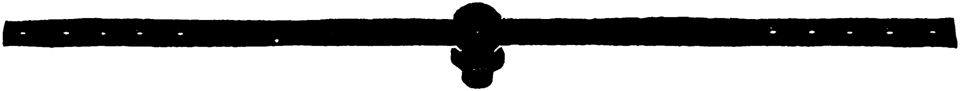


FIG. 7,264.—Austin straight bar hanger and stud. The stud is slotted allowing free movement along the bar, yet may be easily tightened by the locknut in any selected place, making it possible to set box at desired spot although conduit may bear a little off length.

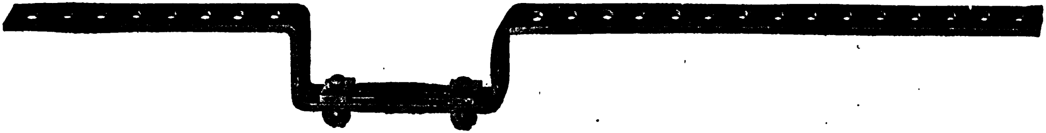
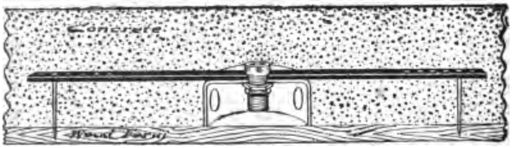
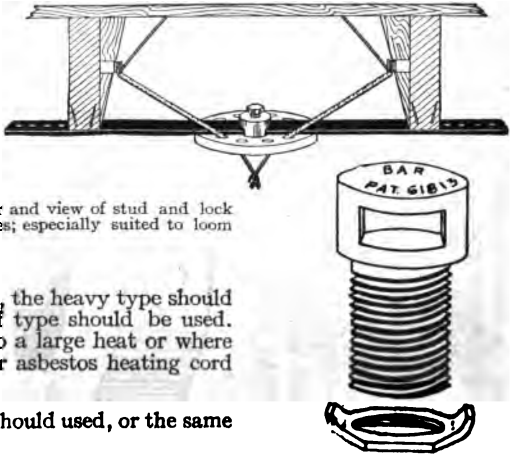


FIG. 7,265.—Austin universal box cleat used chiefly for side wall construction can also be used on ceiling work. By nailing across the front of joists a flush position for the box is obtained.

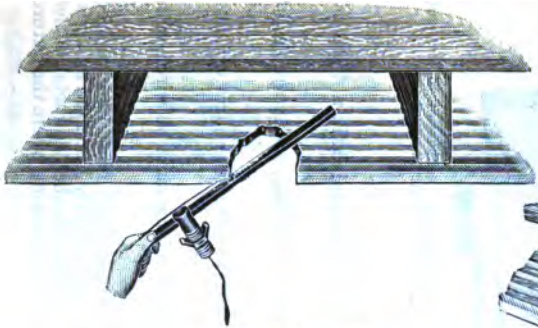


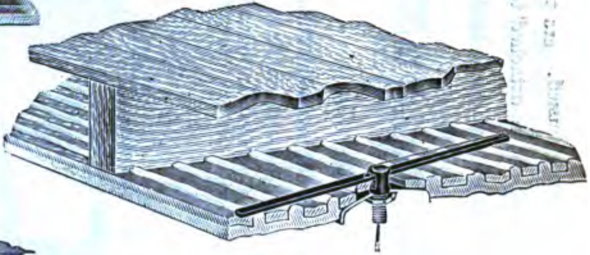


FIGS. 7,266 to 7,269.—Application of Austin straight bar hanger and view of stud and lock nut. All four knock outs are accessible in standard outlet boxes; especially suited to loom box, all eight knock outs can be used.

can be used with a light outer braid. For factories, the heavy type should be used. For cellars, the slicked or weatherproof type should be used. For bakeries or places where they are subjected to a large heat or where the cord is attached to heating appliances, regular asbestos heating cord must be used.

For auto garages, extra heavy marine deck cable should used, or the same encased in a specially wound metalic sheath.





FIGS. 7,270 and 7,271.—Austin "Economy" old work hanger. ***Application:*** The plaster is opened only large enough to permit the stud to pass through. The stud is then slipped to the end of the bar as shown and the assembly slipped through the hole. When the box is in a horizontal position, the wire leader is drawn through the stud. This slides the bar into position and centers the stud on the bar. The outlet box is fastened to the stud with a lock-nut and secured tightly in place.

FIG. 7,273.—Adapting ring.

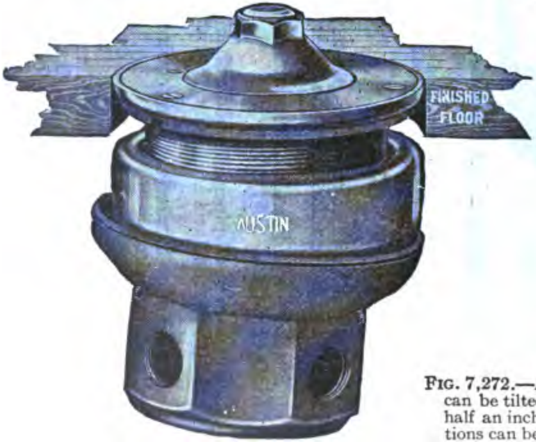


FIG. 7,272.—Austin adjustable floor outlet box. It is water tight. The cover can be tilted half an inch in any direction and raised or lowered more than half an inch. All adjustments are made on the inside. Electrical connections can be made in the box without breaking joints at the floor flange.

For show windows B. X. drop cord must be used.

Clusters of more than one light must not be attached to drop cords.

Drop cords may be extended from their outlets to another position by means of ceiling buttons.

Fixture Wiring.—Chain fixtures must be wired with flexible cord preferably single conductors so that each one may be laced through each link of the fixture chain.

Chain fixtures are suitable for show windows.

One-eighth inch trade size sockets should be used so that loops may be screwed into the socket caps.

Chain fixtures that are attached to concealed knob and tube wiring or wooden moulding may be attached with fixture crow feet or tripods.

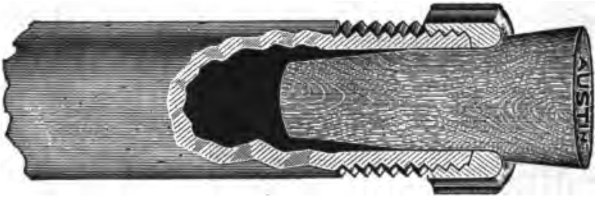


Fig. 7,274.—Austin conduit plugs for corking conduit systems during construction to keep out dirt, plaster, concrete, etc. These plugs are especially needed in poured concrete work.

If the ceiling be of metal or plaster containing metal lath, a fibre or rubber canopy insulator must be used.

Brackets or side wall fixtures must be wired with No. 18 fixture (solid wire) or larger.

The ends of all pipes and bodies being reamed so that the burrs will not cut into the insulation.

Pendants or fixtures that are constructed of tubing must be wired with solid fixture wire.

Combination fixtures that are attached to gas pipes must be equipped with insulating joints so that the fixture will be perfectly insulated and free from grounds, likewise must all fixtures that are attached to metal outlet boxes of B. X. and conduit wiring or knob and tube wiring where the fixture is to be secured to a gas pipe.

Fusing of House Circuits.—For lighting circuits no fuse larger than 10 amperes may be used except with special permission from the local inspector or where all the lights are controlled by one switch; also no lighting circuit should have a load in access of 660 watts except in factories where all the lights are connected with porcelain sockets and a wire not smaller than a No. 14 is used, but in houses the 660 watt rule must prevail.

Thus on a 110 volt system it is best to figure 7 amperes per circuit.

For each circuit a cut out must be provided. These cut outs must be

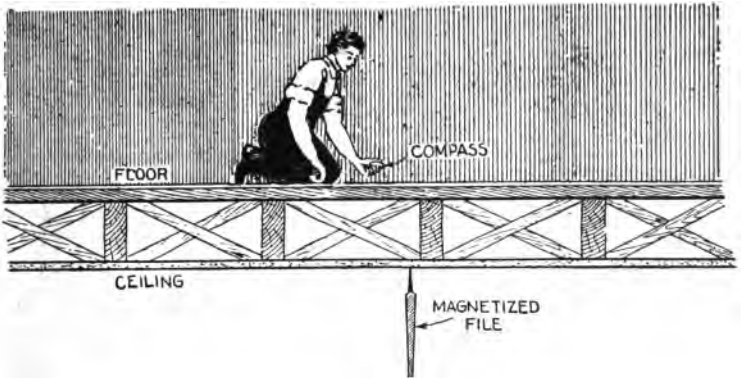


FIG. 7,275.—Method of locating outlet with a compass. A strongly magnetized file is placed at the point selected for outlet, then by exploring on the floor above with a compass, the needle will be agitated when moved directly over the file.

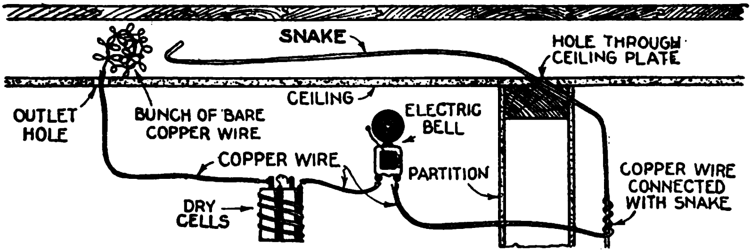
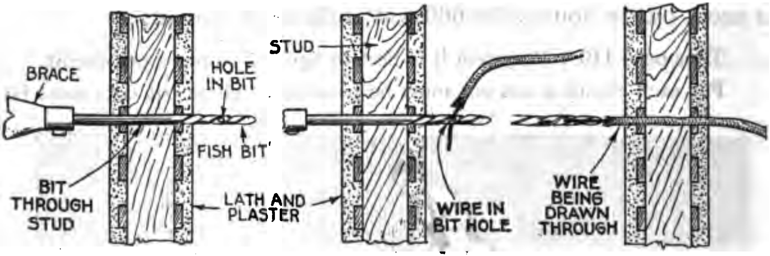


FIG. 7,276.—Method of fishing with snake and electric bell.

installed in metal cabinet or boxes and preferably mounted directly on the meter board. Cut out boxes should not be mounted any higher than 7 ft. from the floor and no lower than 4½ ft.

If the cut outs be grouped in one box, all over 4 circuits must have a box with a gutter around it unless a box be made so that the wires enter opposite the cut out terminals.

The use of water or gas pipe fittings on services are prohibited.



Figs. 7,277 to 7,279.—Method of using steel fish bit. After boring through as in fig. 7,277, thread end of wire through hole in bit (fig. 7,278), and withdraw bit bringing with it the wire that is to be passed through the bored hole as in fig. 7,279.

Main switches should be fused in accordance with the carrying capacity of the wires to which they are connected, according to the following:

Fusing Table

Load (amperes).....	1	3	6	10	15	20	25	30
Fuse (amperes).....	3	6	10	15	20	25	30	35

Types of Fuses.—Plug fuses are largely used for loads up to 30 amperes at pressures up to 125 volts.

Cartridge fuses are used up to 1,000 amperes and up to 100,000 volts. Drop cord rosettes used in mills are fused with fuse wire or links which screw under the terminals on the rosette. The largest size fuse wire permissible is 3 amp. size.

Fig. 7,280.—Method of exploring between floor and ceiling with flash lamp and mirror.

Small transformers for wireless work, bell ringing, etc., should be fused with the minimum size fuse permissible, which is 3 amperes.

Three and Four Way Switches.—These are used for controlling one or more lights from two or more points.

Wiring diagrams for different types of switches are shown in the accompanying cuts. Three way switches are always installed with hall lights. Three wire cable should always be used, as, if one wire be used in a cable, it will heat up due to the inductive effect of the grounded cable. This is an important matter and should not be overlooked.

Three way switches are similar to 3 point return call bell push buttons.

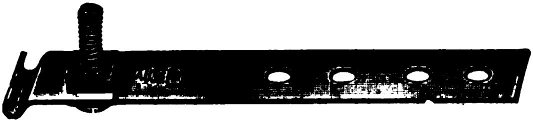


Fig. 7,281.—Austin tempered steel fish tape. *It is made* of flat tempered spring wire. The flat shape lends to its flexibility which is necessary for long runs of conduit having several bends. The tempering prevents the tape curling after long use. *It comes* in lengths, multiples of 25 feet.

One side of the circuit is in contact all the time, the mechanism of the switches serving also as a reversing switch. The two wires connected between each switch are called the travelers.

Four way switches are used where more than two 3 way switches are required, 4 way switches operate the same as 3 ways, but are connected differently, the 4 ways being placed in the traveler wires; any number of 4 way switches may be installed with a set of 3 way switches.

In connecting up 4 ways care should be taken that one wire of the travelers is reversed to the switch, otherwise the switches will not operate.

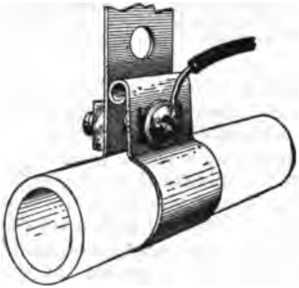
Figs. 7,282 to 7,284.—Austin Hickeys. Fig. 7,282, adjustable; fig. 7,283, "bull dog" non-skid; fig. 7,284, Lakin for short bend in awkward positions.

Wiping Joints.—Large splices can best be soldered if the solder be first roughly applied with a good gasoline torch. Then a moleskin or canvas joint wiping pad is quickly run around the joint so that it will be smooth. By melting a little paraffin wax on the joint, it will appear smooth and shiny.

Surplus solder should be removed, when soldering large joints, a metal drip pan to catch the dripping should be placed underneath the joints so that the drippings can be caught and melted over again.

Taping.—The *Code* states that the same form of insulation must be placed on joints as removed. Thus if rubber covered wire be used, rubber tape must be put over the joint and this covered with friction tape. In taping at least three layers of each kind of insulation must be wound tightly over the splice.

Always hold the hand over a splice that has been taped so the heat of the hand will vulcanize the tape.



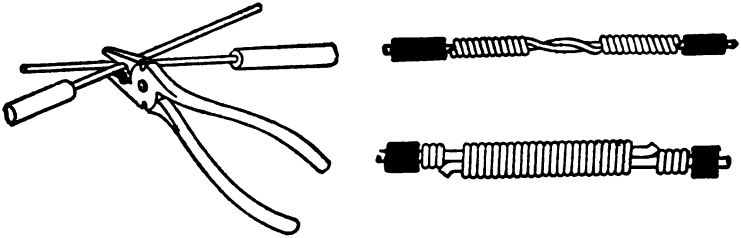
FIGS. 7,285 and 7,286.—Austin adjustable ground clamps, made in three sizes being adjustable in various ranges from three-eighths to three inch pipe.

On large size cables and wires, after the wires have been taped it is suggested that all joints should be painted over with two coats of insulating paint or black asphaltum especially where the joints are exposed to the weather.

Wire and Cable Splicing.—In splicing a cable the insulation must first be removed. To do this a sharp knife is necessary, as it is impossible to hold an edge on a knife it is suggested that a knife having extra hard steel be used so that it will hold its edge longer than the inferior type, old files, ground down to an edge and fitted with a suitable handle, make very excellent knives.

Removing Insulation.—First, mark off the desired amount of insulation that is to be removed and with a sharp knife cut all around the insulation just deep enough so that it barely touches the metal of the wire, then hold the joint of the knife parallel with the wire and cut a long gash into the insulation as deep as the blade will enter. With a pair of pliers pull off the insulation and it will be found that the insulation will come off easily leaving the wire clean and bare. If the insulation be removed as with solid wire, it will be found that the insulation will stick to the wire and will be very difficult to remove. Note flexible re-enforced drop cord insulation should be removed in the same fashion as stranded wire.

The insulation of stranded cable should be removed in the same fashion as stranded wire. Use a hack saw to cut around the wire and a large hunting knife or razor to cut the insulation.



Figs. 7,287 to 7,289.—***Splicing.*** **Figs. 7,287 and 7,288, making a wire splice, and the twist completed; fig. 7,289, a wrapped joint on large wire. The joint should be carefully tinned and soldered in order to give good electrical contact and to avoid corrosion along the contact surface. Where wires are too large to be twisted together, the ends are given a short bend and the two wires wrapped firmly together with a smaller bare copper wire, after which the joint is thoroughly tinned and soldered, preferably by pouring hot solder over the joint. The joint is then insulated by wrapping it with two layers of pure rubber, and three layers of tape, sufficient to make the insulation thickness equal to that of the wire, after which the whole joint should be painted with water proof paint.**

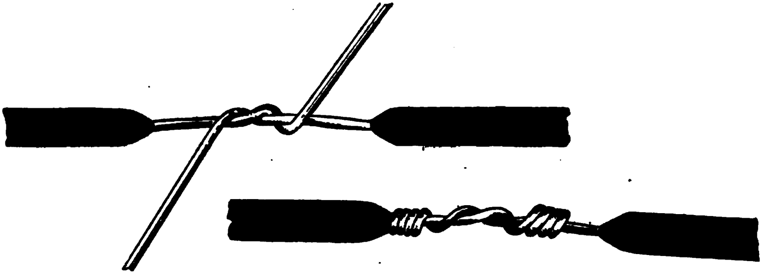
Splicing.—The Western Union type of joint is used for making running splices such as are used for continuing a run of wire Figs. 7,290 and 7,291, show the method of making the joint, and fig. 7,292, a tee or branch tap joint.

Pig Tail Splice.—This splice is used for making splices in junction boxes, fixture outlets, and all other places where a number of wires terminate.

The insulation is removed on all the wires, the same amount of insulation being removed from each wire so that the wires all come out evenly skinned. Bunch them all together and with a long pair of pliers twist them all together either to the right or left, keep twisting them until they are all tight, with the cutting edge of the pliers, trim off the ends so that there are no sharp points.

Soldering.—Small size solid and stranded wires can be soldered with the heat of alcohol torch although a gasoline torch gives better results.

In order that the solder will properly stick, it is essential that the wire should be thoroughly cleaned. Having cleaned the wires they should be coated with a thin film of a non-corroding soldering paste; this is to further remove the dirt and oxidization that is on the wire; unless soldering paste be used, the solder will not stick to the joint, apply the heat and do not apply the solder until the soldering paste on the joint begins to bubble,



FIGS. 7,290 and 7,291.—Western Union joint. ***In splicing*** ends of the wire both being properly cleaned, are twisted together in opposite directions, as in fig. 7,290, then take one end and wind it around 4 or 5 times around the bare surface of the other wire, treat the other end in the same manner, use pliers in pulling the wire around the turns, otherwise they will not be tight, be sure that the ends of the splice terminate at the insulation, do not make the joints too long or too short, 4 or 5 times on each end, as in fig. 7,291, is sufficient.

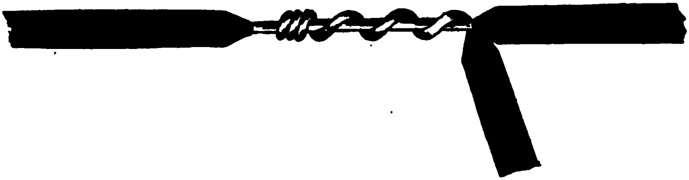


FIG. 7,292.—Tee or branch tap joint. This joint is used in junction boxes. The splice is made the same as the running butt splice only all the wires are wound around the same wire. ***In splicing,*** the wire to be tapped is skinned so that just enough insulation is removed so that the proper number of turns may be wound around it. Hold the new wire that is to be tapped parallel with the wire that is already installed, and with a pair of pliers wind the wire around 4 or 5 times and clinch end of wire so it will not protrude.

then apply a little solder until the solder runs, turn the wire all around so that the solder runs all around the joint. Allow joint to cool.

Joints also may be dipped in a pot of solder, provided they are covered with paste before dipping.

Remember that the metal to be soldered must be as hot as the solder and vice versa.

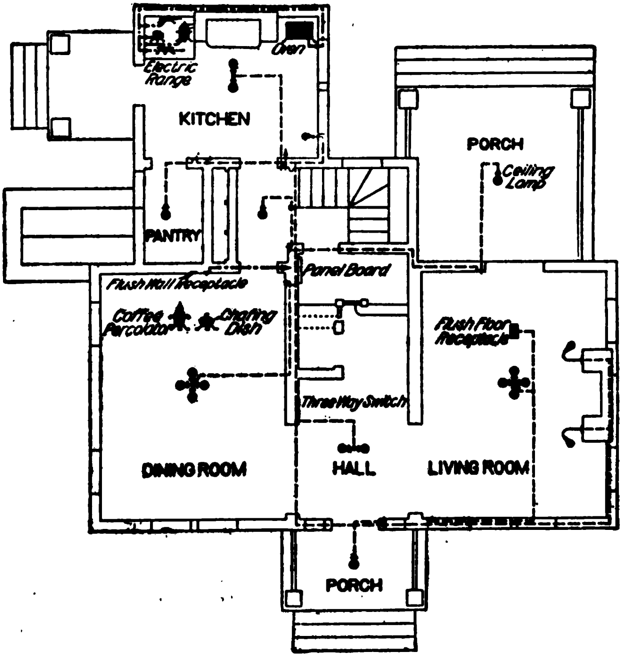
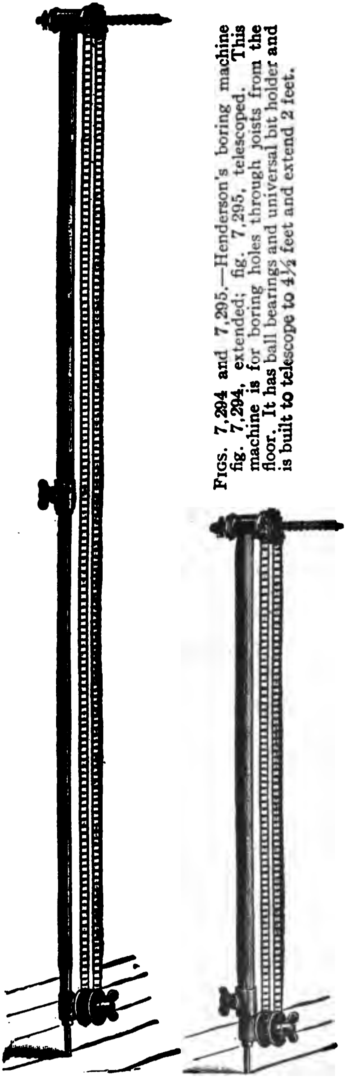


FIG. 7,293.—Wiring for heat appliances; plan of first floor. The location of the outlets is of importance. Usually a flush receptacle in the base board meets the requirements. Where several heating circuits are used it is essential that an appliance taking a large current be not placed on the regular lighting circuit. To guard against this possibility, special receptacles should be installed, constructed for plugs which will not fit any other receptacle.

NOTES

NOTE.—Sewer catch basin covers and street manhole covers may be used as a bending device, the pipe being inserted through the holes in the covers, and weight born down on pipe.

NOTE.—*To prevent terminal lugs becoming dirty* and covered with solder they should be covered with laundry soap before applying heat of torch.



FIGS. 7,294 and 7,295.—Henderson's boring machine fig. 7,294, extended; fig. 7,295, telescoped. This machine is for boring holes through joists from the floor. It has ball bearings and universal bit holder and is built to telescope to 4½ feet and extend 2 feet.

NOTE.—***A handy angle soldering copper*** may be made from an ordinary soldering copper by cutting a 90° V notch at about the middle of the copper and bending over 90°.

NOTE.—***Metal tubing*** may be easily broken apart if a notch be filed all around the outer surface with a 3 cornered file.

NOTE.—***An old umbrella*** inverted and hung on a gas fixture will prevent dirt and plaster falling on the floor while cutting out around gas pipes.

NOTE.—***Temporary service*** may be obtained from burnt out plug fuses by inserting a penny under the blown out fuse and screwing same down well.

NOTE.— ***To prevent ceilings and walls becoming scorched*** while soldering with a torch, a sheet of asbestos board should be held around and above joint to be soldered; sheet tin may be substituted.

NOTE.—By cutting off the head of a ten penny nail and inserting nail in a brace, it may be used as a wood drill through any kind of soft wood; try it.

NOTE.—***Broken screws or bolts*** may be removed if a slot be cut into the screw with a hack saw, use the thumb nail as a guide for the saw, after a deep slot is cut, insert screw driver into slot and remove broken screws.

NOTE.—***Locking screws that work loose*** such as on fans, and motors may be locked in place if chisel marks be made opposite the slots.

NOTE.—***Mica washers*** may be obtained from old burnt out fuse plugs, for repairing electric irons and appliances.

NOTE.—***When short a lock nut*** rather than go back to the shop, cut a lock nut from a coupling with a hack saw.

NOTE.—***Porcelain tubes*** may be cut off if they be scratched with a file and heated in a flame, a sharp blow at joint of scratch, when cooled will break off part not desired.

NOTE.—***Pulling in wires*** in fixture arms after first having tried to push wires in. If found difficult, drop a piece of pull chain, such as used on pull chain sockets, this will easily slide through any bend, attach wires to end and pull through.

NOTE.—Splits in hard wood floors and trim may easily be repaired by using common pins in the same manner as nails.

NOTE.—Plaster of Paris may be prevented hardening by mixing a little lime with the plaster. Plaster surfaces may be smoothed off with a brush soaked in water.

NOTE.—Stillson wrench jaws that do not grip can be made like new by filing out the jaws with a three cornered file.

NOTE.—A ***brick drill*** may be easily made from any piece of scrap water pipe by cutting a number of knotches on the end; use a hack saw and a three cornered file.

NOTE.—***Wood bits*** may be sharpened with a fine manicuring file, never file the outer surface of a bit as it makes the cutters smaller and will be more difficult to turn bit through hole, as twist of bit is larger.

NOTE.—Vinegar (white) may be used as a substitute soldering flux, so may bicarbonate of soda or borax.

NOTE.—***Stripped threads*** on screws or bolts may be replaced by filling in worn and stripped threads with hard solder and rethreading.

NOTE.—***Driving a nail in brick walls.*** If it do not hold, another nail should be driven diagonally across the nail so that it will cross and bind the nail, this method is very effective and secure.

NOTE.—***A 20 penny nail*** makes a good substitute for a prick punch for punching holes in cut out boxes. Nails also may be used as nail sets.

NOTE.—***A good meter board*** paint may be made from dissolving lamp black in gasoline. This also makes a good motor paint.

NOTE.—***Cutting line shafting.*** To cut off a section of line shafting, a hack saw should be held on the place to be cut and the shaft should be run by power. this will cut off the shaft smoothly and quickly.

NOTE.—Old broom sticks cut up into pieces 4 inches long are good plugs for concrete walls to fasten outlet boxes and pipe, etc.

NOTE.—***Knife sharpener.*** A common porcelain tube may be used for the frequent sharpening of a knife blade dulled by scraping insulation and wires.

CHAPTER 111

Outside Wiring

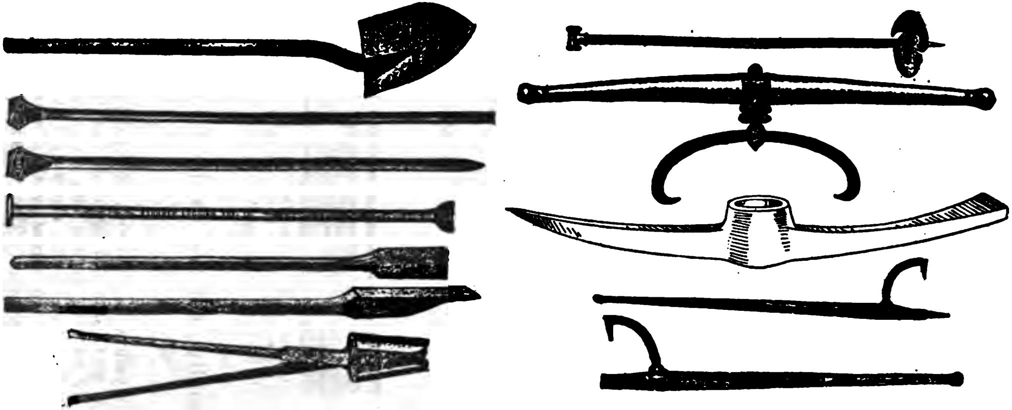
Materials for Outside Conductors.—Copper wire is now considered to be the most suitable material not only for the transmission of current for electric light and power purposes, but also for telegraph and telephone lines, in place of the iron wire formerly employed.

Tensile Strength of Copper Wire

Size of wire B. & S. gauge	Tensile strength, lbs.	Size of wire B. & S. gauge	Tensile strength, lbs.
0000	9971	9	617
000	7907	10	489
00	6271	11	388
0	4973	12	307
1	3943	13	244
2	3127	14	193
3	2480	15	153
4	1967	16	133
5	1559	17	97
6	1237	18	77
7	980	19	61
8	778	20	48

Hard drawn copper wire is used in outside construction, because its tensile strength ranges from 60,000 to 70,000 pounds or about twice that of soft copper. This is desirable to withstand the stresses to which the wire is subjected which, in the case of long spans, are considerable

Pole Lines.—Various species of northern pine, cedar and cypress, because of their size and straightness, are suitable for large poles.



FIGS. 7,295 to 7,306.—Pole construction tools. Fig. 7,295, long handled digging shovel; fig. 7,296, digging bar, fig. 7,297, crow and digging bar; fig. 7,298, tamping and digging bar; 7,299, wood handle tamping bar; fig. 7,300, slick digging tool; fig. 7,301, post hole auger; fig. 7,302, carrying hook; fig. 7,303, tamping pick; fig. 7,304, split wooden handle post hole auger fig. 7,305, cant hook; fig. 7,306, socket peavey.

The preservation of wooden poles is important. Decay of the pole occurs especially at or near the soil line. There are several preservation processes, such as creosoting, burnettizing, kyanizing, carbolizing, and vulcanizing. The application of pitch and tar oftentimes results in more harm than good.

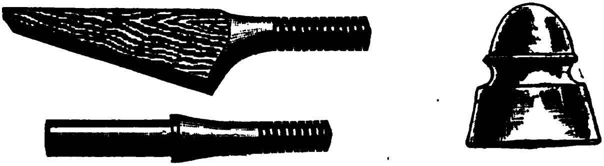
Methods of Setting Wooden Poles.—Where poles have to be planted in low, swampy ground, or where the climatic conditions are such that timber decays rapidly it has been found advantageous to place the poles in concrete settings.

This method is often used in the Southern States, square poles being placed in settings about 7′ deep and 3½′

square. In very soft ground the employment of a concrete setting is sometimes impracticable. In such cases piles are driven deep into the soil, and the pole bolted to the part of the pile extending above the ground.

Reinforced Concrete Poles.—Untreated wooden poles must be replaced by new poles about every six years whereas reinforced concrete poles will last indefinitely.

One form of reinforced concrete pole consists of a skeleton frame work of four corrugated iron rods covered with ordinary concrete. The pole is octagonal in shape, 30 feet long, and provided with mortises for cross arms, the latter being fastened in place by means of iron bolts. It is stated that they are less expensive than pine poles, and that each pole can be manufactured at the point on the line at which it is to be installed or planted.



Figs. 7,307 to 7,309.—Glass insulator and insulator pin and bracket. The insulator here shown is of the pony double petticoat type. Insulator pins are used with cross arms, brackets are attached direct to the pole.

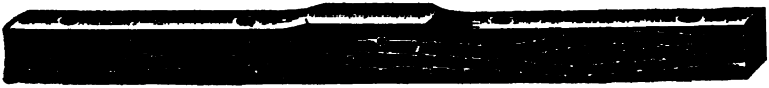


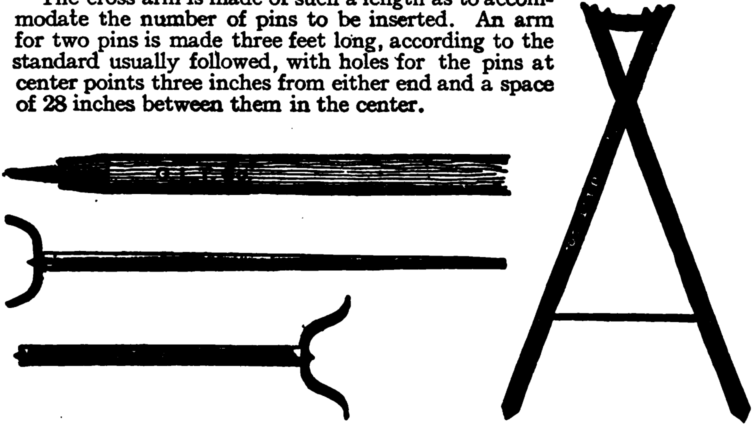
Fig. 7,310.—Cross arm which carries the insulator pins. The standard cross arm is 3¼×4¼ inches, double painted, and bored for 1½ inch pins and two ½ inch bolt holes. Telephone arms are 2¾×3¾ inch, bored for 1¼ inch pins and two ½ inch bolts.

Cross Arms.—These are usually attached to the poles before they are erected.

They are commonly made from yellow pine wood, generally 3¼×4¼ inches, and are freely coated with good mineral paint as a preservative. Attachment is made to the pole by cutting a *gain* one inch deep and of sufficient breadth to allow the longest side of the cross arm to fit accurately. It is then secured in place by a lag screw, with a square head, so that it may be driven into place with a wrench. The cross arm is further secured to the pole by galvanized ¼×1¼ flat iron braces.

The cross arms are bored with holes for the insertion of the insulator pins, which are made of locust wood and threaded at the upper end to receive the glass insulator.

The cross arm is made of such a length as to accommodate the number of pins to be inserted. An arm for two pins is made three feet long, according to the standard usually followed, with holes for the pins at center points three inches from either end and a space of 28 inches between them in the center.



Figs. 7,311 to 7,314.—Pole line construction tools. Fig. 7,311, pike pole; fig. 7,312, raising fork; fig. 7,313, mule pole support; fig. 7,314, jenny pole support.

Fig. 7,315.—Guy anchor log in position.

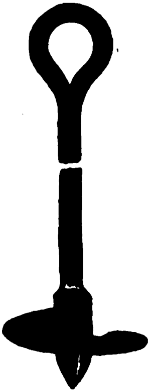


Fig. 7,316.—Stombaugh guy anchor. It is made of cast iron and can be screwed into the ground like an auger.

Light and power wires must not be strung on the same cross arm with telegraph or telephone wires.

Spacing the Poles.—This is governed by the weight of the lines the poles must carry, the heavier the lines, the greater the number of poles.

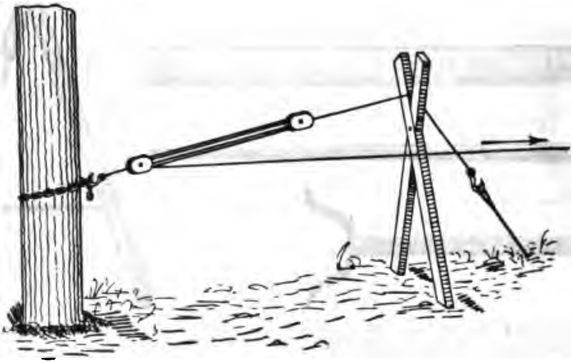


Fig. 7,317.—Method of pulling an anchor into place before the guy wire is fastened to the top of the pole, thus obviating the liability of pulling the pole out of plumb.

The spacing of poles also depends on their liability to injury from storms and wind in any given locality, and the nature of the service. Poles for a telephone line may be spaced twenty to fifty to the mile—that is, from about 260 to 100 feet apart.

Erecting the Poles.—The holes must be dug to as nearly the required depth as possible.

Holes for poles are dug very little wider than their diameter at the butt, and the depth is usually computed according to the nature of the soil and the weight of the proposed line. Excavation, while sometimes accomplished with patent post hole augers, or even dynamite, is usually done with a long handled digging shovel, and the earth removed with a spoon shovel.

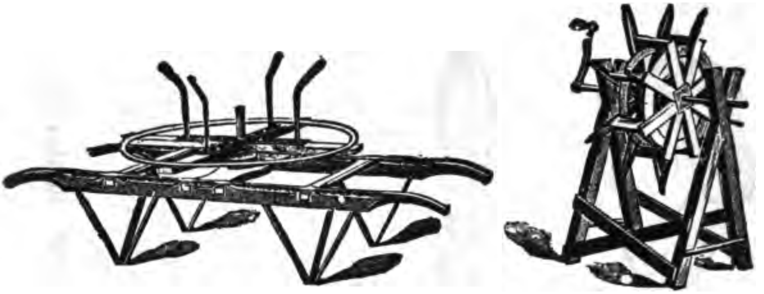
The poles are rolled or carried on hooks to the holes. In erecting, a piece of timber is inserted in the hole as a slide to prevent crumbling of the earth as the pole is slid into place. The end is raised by hand sufficiently to allow the "dead man," or pole hoist, to be placed beneath, and

FIGS. 7,318 to 7,322.—Lineman's tools. Figs. 7,318 and 7,319, Eastern pole climbers, with and without strap for attaching to legs; fig. 7,320, portable vise with strap for pulling up the slack in splicing; figs. 7,321, one form of "come along." The wire is inserted between jaws and is held fast when tension is applied to the ring; fig. 7,322, an improved form of "come along" or wire stretcher. The jaws which grip the wire are smooth and remain parallel in closing, thus the wire is not scratched or indented, as with circular jaws having teeth.

this is moved along regularly as the pole is lifted with pike poles, until it slides into place through the force of gravity.

Guys for Poles.—These are attached near the top and secured either to the base of the next pole, to a suitable guy stub or post, or to a guy anchor, which is buried about eight feet in the earth and held down by stones and concrete.

Wiring the Line.—In stringing the lines, either one or the full number of wires may be put up at the same time.



FIGS. 7,323 and 7,324.—Pay out reels. Fig. 7,323, type used for telephone or telegraph work; fig. 7,324, type used for electric light work.

FIG. 7,325.—Lineman's block and fall with "come alongs" for stretching wire and holding same when making splices.

FIG. 7,326.—Wireman's "come along" with hook and tackle.

Trolley wires.—National Electrical Code.

12-*i*.—Must not be smaller than No. O. B. & S. gauge copper or No. 4 B. & S. gauge silicon bronze, and must readily stand the strain put upon them when in use.

12-*j*.—Must have a double insulation from the ground. In wooden pole construction the pole will be considered as one insulation.

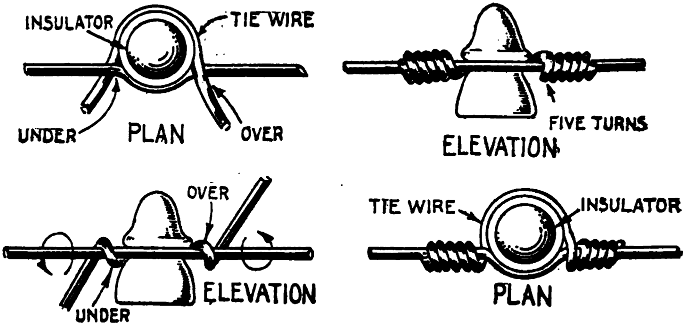
12-*k*.—Must be capable of being disconnected at the power plant or of being divided into sections, so that in case of fire on the railway route, the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to feeders.

12-*l*.—Must be safely protected against accidental contact where crossed by other conductors.

Where guard wires are used they must be insulated from the ground and electrically disconnected in sections of not more than 300 feet in length.

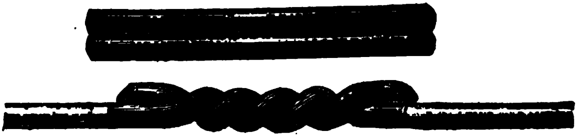
When one line only is to be strung, the operation consists simply in reeling the wire and running it off from a hand reel. At each pole the wire is drawn up to its place, pulled out to the desired tension, and attached to the insulator.

In the operation of stringing a number of lines at once, the method is different. The reels are placed at the beginning of a section, each wire

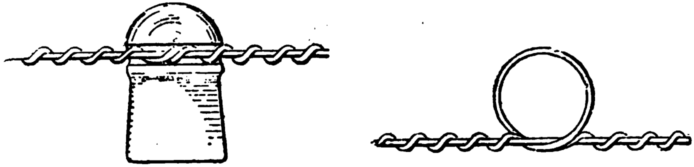


Figs. 7,327 to 7,330.—Methods of tying in wires to insulators. A separate wire is used for *tying in* the wire to the insulator. This is called a tie wire it should be about 18 to 24 ins. long, must be of hard drawn wire, and of the same size wire as the line wire. The wire is twisted around the main wire, as in fig. 7,327, but it is more difficult to make the tie in than it appears. A tight tie in can not be made by hand, pliers must be used. First the tie wire is looped around the insulator, one end of the wire over and the other end under the main wire, as in fig. 7,327, separately each end is wound around the line wire with pliers, five turns or more, so that the strain will be both ways.

Fig. 7,331.—American wire joint. This is a simple method of connecting the ends of the sections of wire by tightly twisting the ends around each other for a few turns; it is *the standard Western Union* wire joint.



Figs. 7,332 and 7,333.—McIntire sleeve and sleeve joint. An approved method of making the joints of telephone lines is by the use of some form of sleeve, such as is shown in fig. 7,332. *This consists of* two copper tubes of the required length, and of sufficient inside diameter, to admit the ends of the wires to be joined, fitting tightly. The tubes are then gripped with a tool, shown in fig. 7,336, and twisted around one another, so that the wires are securely joined and locked, as shown in fig. 7,333.



FIGS. 7,334 and 7,335.—Approved method of attaching wire to an insulator; elevation and plan of insulator and tie. The line wire is first laid in the groove of the insulator, after which a short piece of the same size of wire is passed entirely around to hold it in place, then it is twisted to the line at either side with pliers.

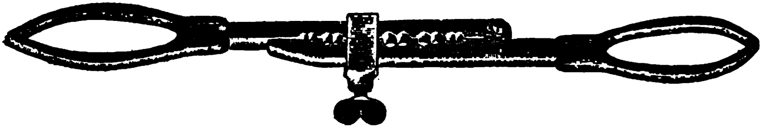


FIG. 7,336.—McIntire's twisting clamp for wires 00 to 16 B. & S. gauge.

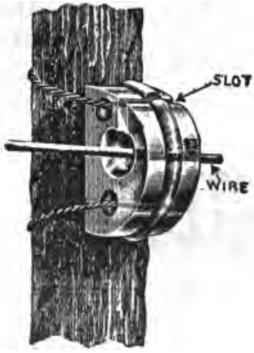


FIG. 7,337.—Tree insulator for temporary or repair work. *It is made* of a single piece of glass, and is provided with a slot which the wire cannot leave accidentally. The back of the device is concave and provided with ribs which prevent sliding. It can be readily slipped over wires already in place, is available for electric light circuit, and will take wires up to ½ inch, in diameter.

FIGS. 7,338.—Overhead cable construction. *In some cases,* particularly on short lines exposed to inductive disturbances from power and other electrical circuits, it is usual to string the cables on poles such as usually carry the bare conducting wires. It is not necessary, however, to insulate the cable in any way; consequently it is merely hung to a supporting wire rope or cable, called the "messenger wire," being attached either with some form of hanger or by loops of tarred marline. The marline is sometimes wound over the cable and messenger wire from a bobbin, but frequently it is merely wound on by hand.

being inserted and secured through a separate hole in a board, which is perforated to correspond with the spacing of the insulators on the cross arms. A rope is then attached to this running board, which is drawn by a team of horses through the stretch to be wired, being lifted over each pole top in turn. When a certain length has thus been drawn out, the wires are drawn to the required tension between each pair of poles and secured to the insulators.

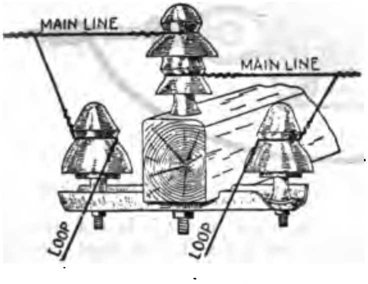
In applying tenting to the wires in stringing, some sag must be allowed. A general rule is to make the tension on a wire equal to ⅓ of its breaking load. The sag usually allowed is given in the following table:

Sag Table

Span in Feet	Temperature Fahr. 30°	Temperature Fahr. 60°	Temperature Fahr. 80°
	Sag in Inches		
75	1⅜	2½	3⅛
100	3	4¼	5⅜
130	5⅛	7	8⅝
150	6⅜	9	11¼

In drawing out the wire, it is customary to use a wire clamp, or "come along." This tool is attached to a block and tackle, or drawn in by hand, and, as soon as the proper force has been applied, the wire is held, while the lineman secures is to the insulator.

Another contrivance for this purpose is the pole ratchet, by which the wire is drawn tight and held until attached to the pole.



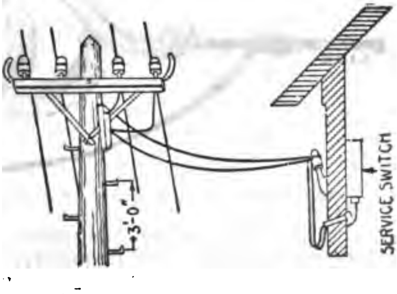


Fig. 7,339.—Method of making a series "loop" service connection.

Fig. 7,340.—Parallel service connection. Service wires tapped to the main wires, are run to inslators on an auxiliary cross arm, thence to insulators on the side of the building, and thruough the drain tube to the service switch.

The methods of attaching wires to insulators, splicing, etc., are shown in the accompanying cuts.

Transpositions.—Due to rapid current changes in telephone and telegraph lines, transpositions are necessary to avoid inductive disturbances.

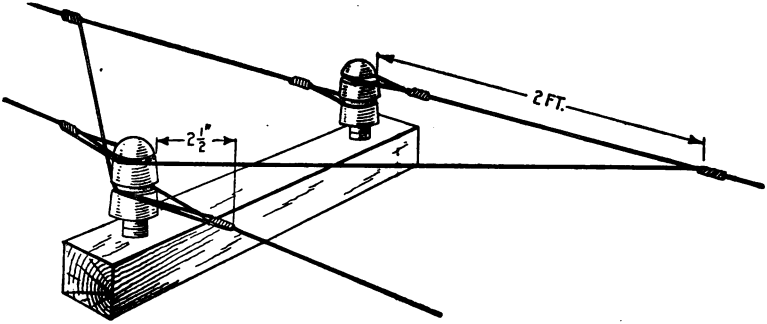


FIG. 7,341.—Method of making a "transposition." This is usually done by means of *transposition insulators*, which are either double insulators, one being screwed to the pin above the other, or else such caps as are shown in fig. 7,344. Such insulators are intended to act as circuit breakers, the particular wire to be transposed being cut and "dead ended", or tied around, on both the upper and lower grooves of the cap. The free end of each length is then passed back and around the insulator and twisted, or sleeve jointed to the other limb of its own circuit.

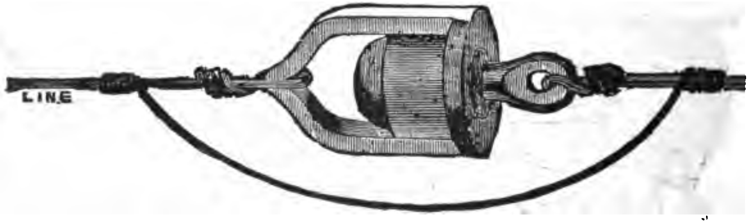


FIG. 7,342.—Clark's "antihum"; a device designed to prevent the humming of telegraph wires.

For short lines and pole systems with only a few wires it is not necessary to transpose very frequently. On longer lines it has been found amply sufficient to transpose once every quarter mile; that is to say to change the relative position of the wires of the different circuits at posts situated about that distance apart. This does not mean, however, that each pair of wires is transposed so often, but that on ordinary sized systems, the transposition of some one circuit is amply sufficient to secure balanced relations and effectually counteract the effects of cross induction. It is a matter which must be carefully calculated and planned in each particular instance in order to secure the best advantages.

Insulators.—Glass and porcelain are employed almost universally for supporting overhead wires.

Fig. 7,343.–Telegraph and telephone line glass insulator.

Fig. 7,344.—Type of insulator used in making a transposition.

Insulators made of these materials are superior to those made of other material such as hard rubber, or various compounds of vegetable or mineral matter, with the exception perhaps of mica insulators used on the feeders of electric railway lines..

CHAPTER 112

Underground Wiring

In large cities, the best method of running wires for all varieties of electrical power transmission is to place them underground.

The expense of installing an underground system is very great in comparison with that of overhead construction, but the cost of maintenance is much less and the liability of interruption of service greatly reduced.

The various underground systems may be divided into three classes:

1. Lead encased cables laid directly in the ground;
2. Solid or built in systems;
3. Drawing in systems.

Where cables are laid directly in the ground, the metallic covering, consisting usually of a lead tube, which is placed over the insulation is depended upon for mechanical protection.

Such cables are largely used for short private lines and the first cost is less than that of the others, but in case of repairs it has to be dug up.

In the drawing in systems, the cables are drawn in after the conduits are built.

The conduit of the drawing in system may consist of various forms of pipe or troughs of iron, earthenware, concrete, wood or fibre, while those of the solid or built in systems are composed of either iron tubes or concrete trenches.

Vitrified Clay Pipe.—Various forms of vitrified clay conduit appear to possess the qualifications, desirable in underground construction, to a higher degree than any other type.

They are made in both single and multiple duct, the single type being about 3½ inches in diameter, or 3½ inches square, and 18 inches long. Multiple conduit is made in two, three, four, six and more sections, ranging from 2 to 3 feet in length.

Single conduit is best suited where there is great crowding of gas, water and other pipes, as the conduit can be divided into several layers so as to cross over or under such pipes.

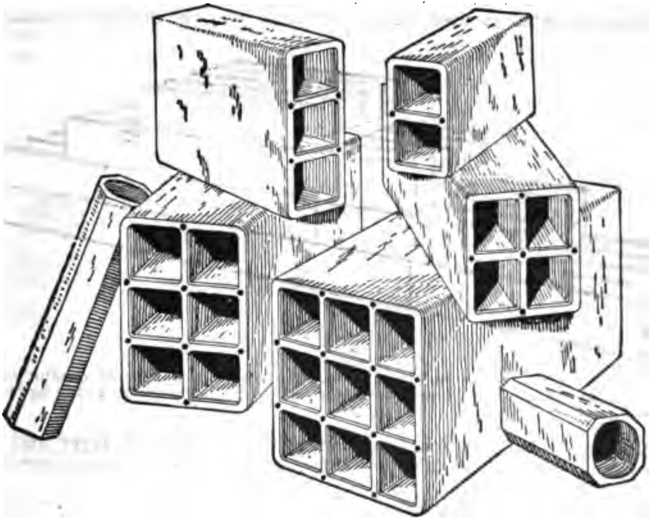


FIG. 7,345.—A few forms of vitrified clay pipe conduits; view showing single and multiplex types. The dimensions of each duct are about 3½ ×3½. The lengths vary from two to three feet.

The multi-duct conduit can be laid somewhat cheaper, especially in lines of about two to four ducts; it is best suited to districts free from sub-surface obstructions.

In laying conduit, a trench is dug, usually sufficiently wide to allow the placing of three inches of concrete on each side of the ducts, and sufficiently deep to hold at least thirty inches of concrete on top of the upper layer of concrete forming the conduit, and to allow for three inches of concrete in the bottom. The trench is graded from some point near

the middle of the block to the manhole at each intersection, or from one manhole to the next manhole, at a gradient not less than 2 inches to 100 feet.

The tiles of the several ducts are placed close together, and the joints plastered and filled with cement mortar consisting of one part of Portland cement to one part of sand. When the conduit is being laid, a wooden mandrel about four or five feet long, three inches in diameter, and carrying a leather or rubber washer from three to eight inches larger at one end is drawn through each duct so as to draw out any particles of foreign matter or cement which may have become lodged in the joints, and also to insure good alignment of the tiles.

Single duct conduits are usually laid by brick layers. This fact accounts for the somewhat greater cost of the single over the multiple conduit which is usually laid by ordinary laborers. One good brick layer and helper, however, will lay from 200 to 300 feet of single duct conduit per hour.

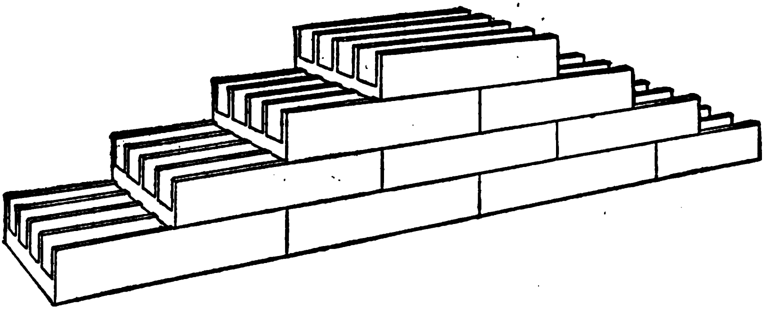


FIG. 7,346.—Vitrified clay or earthenware trough conduit; this type of conduit consists of troughs either simple or with partitions, the latter type being shown in the figure.

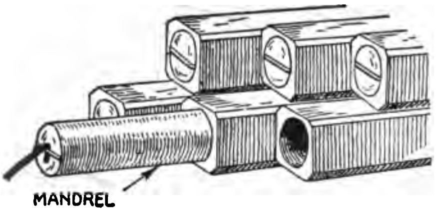
Vitrified Clay or Earthenware Trough Conduit.—It consists of troughs either simple or with partitions as shown in fig. 7,346.

They are usually made in tiles 3 or 4 inches square for each compartment, with walls about one inch thick. The length of the tiles ranges from two to four feet. Each of the two foot form duct troughs weighs about 85 pounds. When laid complete, the top trough is covered with a sheet of mild steel, about No. 22 gauge, made to fit over the sides so as as to hold it in position, and then covered over with concrete.

In laying multiple duct earthenware conduit, the ducts or sections are centered by means of dowel pins inserted in the holes at each joint, which is then wrapped with a six inch strip of asphalted burlap, or damp cheese cloth, and coated with cement mortar as shown in fig. 7,348. Economy of space and labor constitutes the principal advantages derived from the use of multiple duct conduit.

Concrete Duct Conduits.—These are usually constructed by placing collapsible mandrels of wood or metal in a trench where the ducts are desired and then filling the trench with concrete.

After the concrete has solidified, the mandrels are taken out in pieces, leaving continuous longitudinal holes which serve as ducts. Some builders produce a similar result by placing tubes of sheet iron or zinc in the concrete as it is being filled into the trench. These tubes have just enough strength to withstand the pressure to which they are subjected, and are, therefore, very thin and liable to be quickly destroyed by corrosion, but the ducts formed by them will always remain unimpaired in the hardened mass of concrete.



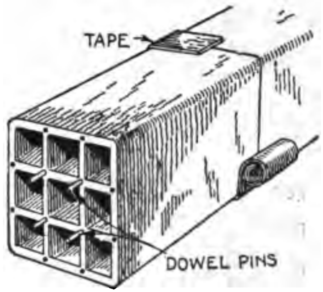


FIG. 7,347.—Method of laying single duct vitrified clay conduit. The tiles of the several ducts are placed close together as shown in the figure, and the joints plastered and filled with cement mortar consisting of one part Portland cement and one part sand.

FIG. 7,348.—Method of laying multiple duct vitrified clay conduit. The section are centered by the dowel pins shown in the cut.

Wooden Duct Conduits.—In this type of conduit, the ducts are formed of wooden pipe, troughing, or boxes, and constitute the simplest and cheapest form of conduit.

A pipe conduit consists of pieces of wood about 4½ inches square, and three to six feet long, with a round hole about three inches in diameter bored through them longitudinally. As shown by fig. 7,349 a cylindrical projection is turned on one end of each section, which, when the conduit is laid fits into a corresponding recess in one end of the next section. The sections are usually laid in tiers, those of one tier breaking joint with those of the tiers above or below.

The trough conduit consists of ducts about 3 inches square made of horizontal boards and vertical partitions, usually of yellow pine about one inch in thickness. This form of conduit can be laid in lengths of 10 and 12 ft., or it can be built along continuously. The life of wooden conduit may be increased by the application of sterilizing processes. Wooden conduit is best adapted for temporary installations.

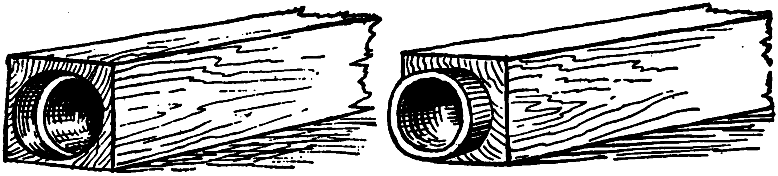
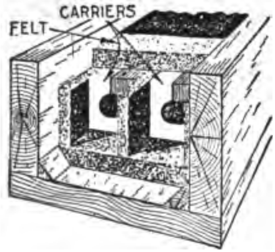


FIG. 7,349.—Wooden pipe type of conduit. ***It consists of*** **pieces of wood about 4½ inches square, and three to six feet long, with a wide hole about three inches in diameter, bored through them longitudinally.**



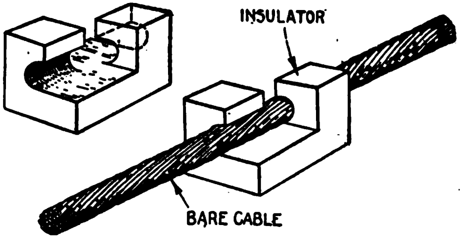


FIG. 7,350.—**Perspective view of wooden built-in conduit.** ***It consists of*** **an outer rectangular casing of wood which is lined inside with impregnated felt**

FIGS. 7,351 and 7,352.—**Porcelain bridgework or carriers for supporting underground conductors.**

Wooden Built-in Conduits.—The chief advantage of these are high insulating quality, the capability of using bare wire and rods for underground conductors, and reduced cost.

In construction, a wooden trough is laid in a trench about 18 inches deep. Porcelain carriers are placed in the trough at intervals of 4 to 5 feet, to act as bridgework for supporting the conductors. This bridgework is placed on and is surrounded by impregnated felt or similar material, and the spaces between the carriers, after the conductors have been placed in position on them is filled with voltax, which hardens rapidly and forms a solid insulating material throughout the conduit.

Wrought Iron or Steel Pipe Conduits.—These are formed of pipes similar to gas or steam pipes, with screw or other connections.

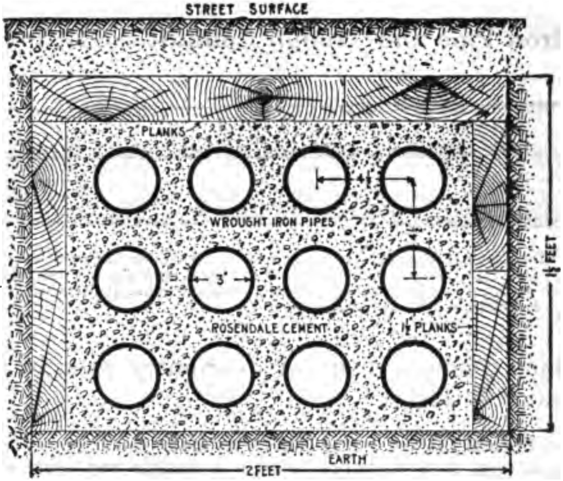


Fig. 7,353.—Cross section of wrought iron pipe conduit laid in hydraulic cement.

They are laid either simply in the earth, or in hydraulic cement, and are the strongest and one of the most satisfactory forms of underground conduit. In construction, a trench, the width of which will depend upon the number of pipes to be laid, is first dug in the ground, and after its bottom has been carefully leveled, is braced with side planking and filled to the depth of two to four inches with a layer of good concrete, consisting of two parts of Rosendale cement, three parts of sand, and five parts of broken stone capable of passing through a one and one-half inch mesh. This concrete is well secured in place and forms the bed for the lowermost layer or tier of pipes.

Ordinary wrought iron pipe is employed, in 20 foot lengths about three to four inches in diameter, depending upon the size and number of cables they are intended to carry. After the last tier of pipes have been put in place, and a layer of concrete from two to four inches placed over it, a layer of two inch yellow pine planking is laid over the whole.

The principal object of the top covering is to protect the conduit against the tools of workmen making later excavations.

Practical experience shows that workmen will dig through concrete without stopping to investigate as to the character of the obstruction, but under similar circumstances, will invariably turn away from wood.

In best construction the pipes are lined with a layer of cement ⅝ in. thick and containing no sand.

Cast Iron Pipe and Trough Conduit.—Cast iron pipe for underground conduits is similar to ordinary wrought iron pipe, except that it is thicker.

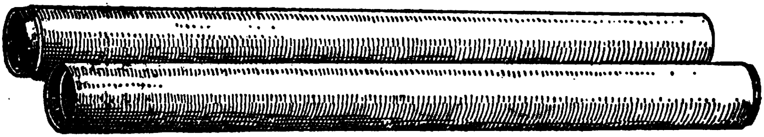


FIG. 7,354.—Fibre conduit. It consists of pipes made of wood pulp, having about the same thickness as cast iron pipe. Slip joint conduit for electrical subways is three inches inside diameter. The socket joints keep the lengths centered and make it easier to lay than a mere butt joint. It is laid in cement like iron pipe.

The additional thickness is necessary to make the strength equal to that of wrought iron; it is therefore heavier to handle and more expensive.

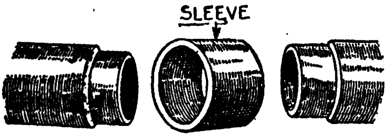
The trough conduit consists of shallow troughs of cast iron in six foot lengths, laid directly in the earth so as to form a system of continuous troughing in which the conductors are placed and then covered over by cast iron covers which are bolted to the trough.

The advantages are that the cables can be laid directly in place, thus eliminating any chance of injury during the process of drawing in, and second, the cables are easily accessible at any point by simply removing one or two of the sectional cast iron covers, thus permitting of their being readily inspected and repaired.

Fibre Conduits.—This form of conduit consists of pipes made of wood pulp impregnated with a bituminous preservative and insulating compound.

These pipes are laid in concrete in a manner similar to iron pipe. Fibre conduits are made in sizes ranging from 1 inch to 4 inches in diameter and from 2½ to 5 feet in length, with walls ranging from ¼ to ½ inch in thickness.

In laying the socket joint type of fibre conduit, after the trench has been dug to the required width and depth, depending upon the number of pipes to be placed in a tier and the number of tiers, a bed of concrete about 3 inches deep is placed on the bottom and a line drawn on one side for the alignment of the first line of pipes. The other lines of pipe or ducts are laid parallel to the first line, and are separated from it and from each other by means of ¼ inch or ½ inch wooden or iron pegs.



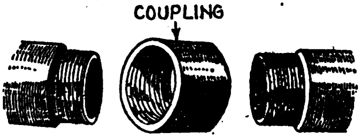


Fig. 7,355.—Sleeve joint type of fibre. Both the socket type and the sleeve type are easily aligned without the use of a mandrel.

Fig. 7,356.—Screw joint type of fibre conduit. *This method* of connection will form a tight line and is suitable for running under the lawns of private houses and parks, under the streets of towns and villages, and in other places where the cost of building electric subways is prohibitive.

The pipes are well grouted and covered with a layer of concrete to the depth of ¼ or ½ inch, and the next tier laid in place in the same manner.

When the final tier of pipes has been installed, it is covered with a layer of concrete about 2 to 3 inches deep.

When necessary to cut a length of pipe to break joints or to enter a manhole, the remaining part of the length may be utilized by using a fibre conduit sleeve having an inside diameter ½ inch greater than the pipe being used on the system.

Edison Tube System.—This arrangement consists of a series of iron tubes or pipes containing one or more copper conductors which are placed therein before each complete section or pipe leaves the factory, so that they only need to be joined together to form a continuous line of underground conduit with conductors in place.

Underground Cables.—Electric light and power cables for use in conduit may be divided into two classes: *moisture proof*, and *non-moisture proof*, according to the character of the insulator.

In the moisture proof cables, the insulation consists of some form of rubber, or of bitumen, and a metal sheath or covering, usually of lead, is provided to protect the cable from mechanical or chemical injuries. The non-moisture proof cables are insulated with paper impregnated with oil, wax, or resinous compounds.

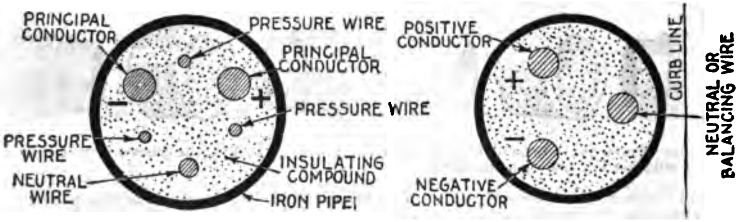


FIG. 7,357.—Cross section of Edison "feeder" tube. This runs from the power station to the centers of distribution, and contains two principal conductors and a smaller conductor to serve as a neutral wire and also three insulated cables of seven strands of No. 19 B. W. G. wire each. These cables form independent circuits and enable the voltages at the distant end of the feeder to be read at the central station. For this reason they are commonly called pressure wires.

FIG. 7,358.—Cross section of Edison "main" tube. A number of these tubes, which radiate from the center of distribution and loop the ends of the feeders together, have three conductors of the same size. These tubes are placed in the ground so as to bring the positive and negative conductors on one side of the center of the tube, and the neutral conductor on the other side. The mains are always laid with the neutral conductor adjacent to the curb line and for convenience, this side of the tube is commonly called the *inside*. The feeders are always laid with the positive conductor on the right hand side.

Metal Sheaths on Underground Cables.—Metal sheaths are used on rubber covered cables to protect the insulating compounds from the deteriorating effects of electrolysis and various kinds of acids and gases which, under present methods of construction, are ever present in the underground conduits.

It is a fact, however, that the lead sheath on a low tension cable, which is used as one side of a grounded circuit, has been, in some cases the cause of, instead of, cure for electrolysis. The proper cure lies in the omission of the sheath altogether, but as this is not practical except in the case of very large conductors, the best thing that can be done is to interrupt the continuity of the sheath by some form of insulating joint.

Pot Heads.—The upper end of a lateral cable is equipped with a discharge bell, which is commonly called a pot head.

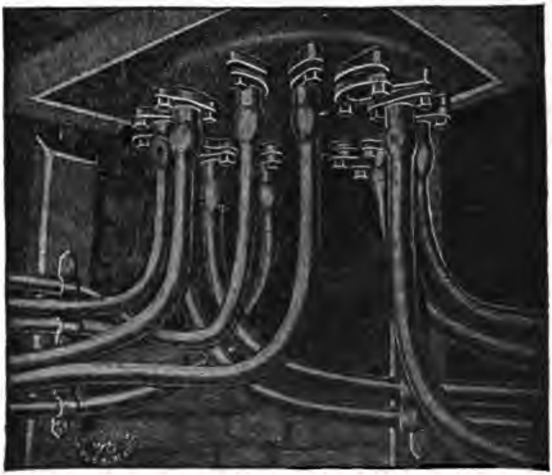


FIG. 7,353.—Bottom of General Electric manhole junction box; view from manhole interior. The cables enter the bottom of the box as shown through composition nozzles to which the lead sheathes are united by a wiped solder connection, forming a permanent water and gas tight joint. Stuffing boxes are sometimes substituted, doing away with the wiped joint, rendering the boxes suitable for use with unleaded or braided cables. The normal position of the distributing cables is in the upper ducts so that they may be brought to the junction box without crossing other lines. The entrance nozzles and seats are so arranged that all terminals are soldered to cables outside of box and any cable may be removed without disturbing any soldered joint. The wiped joints unite electrically the lead sheathes of all cables entering the box and by connecting a single earth bond to the shell of the box all cable sheathes are solidly grounded. Incombustible shields prevent the arc from a blown fuse making a ground connection to the shell or inner cover.

The purpose of a pot head is to hermetically seal the end of the cable and bring the conductors out in such a manner as to permit of their being conveniently connected to the primary service boxes.

Pot heads are usually made in three parts, the base being of cast brass, having a diameter depending upon the size of the conductors, with a hole in the lower end threaded within in such a manner as to make a tight fit on the cable.

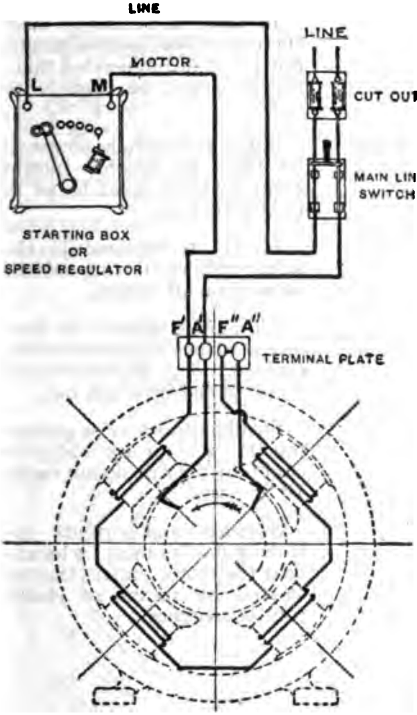
In connecting the head to a cable, after the cable has been bent in to the proper position, the brass base is slipped down over it with the larger end up, and then screwed down on the lead sheath. The threads cut down into the lead sheath to a distance of about ½ inch along the sheath, thus making an air tight connection without necessitating the making of a wiped joint.

The separate conductors are now bared of their insulation for a distance of about two inches, and then spliced to heavy rubber covered braided wire of sufficient length to reach the primary service boxes. The joints connecting these rubber covered wires and the cable conductors are spliced in the same manner as straight splices, the paper sleeves used being of sufficient diameter to be backed out of the way over the rubber insulation.

When the splice is completed, a brass shell threaded at one end to fit a female thread in the upper end of the brass base, is slipped over the end of the rubber covered wire and screwed into the base. A hood of sheet copper having the form of a quarter section of a ball is slipped over the top of the frame and its lower edge tracked in position below the horizontal shelf. This hood makes the pot head water, snow, and insect proof

CHAPTER 113

Power Wiring



Wiring of Motors.—The following general suggestions should be followed in wiring motors, in order that the installation will conform to the requirements of the *Code*.

All motors must be protected by means of a metal box unless motor is of the enclosed type. The frames of all stationary motors must be grounded whenever possible unless attached to an insulated base.

All portable motors of 500 volts or less must have the portable cord size be of the same current capacity of the fuses.

All motors bear a name plate showing current consumption of the motors. Size of wire can be determined from this or from

FIG. 7,360.—Wiring diagram of ***series motor***. The reference letters are: L, line; A, armature; F, field. Never start a series motor without load as it may attain a dangerous speed. ***To stop the motor***, open the main line switch and let the rheostat operate automatically. The lever will not be released by the magnet at once but will be held until the motor has slowed down somewhat, when it will fly back to *off position*. Never attempt to force starting lever to off position as this would damage the rheostat. ***Never open field circuit while motor is running***—this will cause motor to run away and flash at the commutator. ***To reverse a series motor***, change jumper so as to connect F" to A' instead of to A" and bring the wire from the switch to A" instead of to A'. Where a motor is to be reversed frequently, a special form of controller is required.

the accompanying tables which show current consumption of all sizes and types of motor.

Motors of ¼ *h.p.* or over must not be installed on the same circuit that contains electric lights. Also all small portable motors must have a double pole switch to control them so that both sides of the line will be made or broken at the same time. The smallest size of cord to be used on small motors is No. 14, which must be of the heavy reinforced type.

In store installations where there are more than two electric fans, it is recommended that a special circuit be used to the fans.

Single pole switches must not be used to control motors. Snap switches must be of the indicating type.

It is recommended that safety motors starting switches be used on all motors.

All motors should be fused in accordance with their current consumption. All motors must be protected by a cut out.

Small motors may be grouped together and protected by one cut out if the fuse do not exceed 10 amperes.

Switches and cutouts controlling motors must be located near the motor, unless they are started by means of remote control switches.

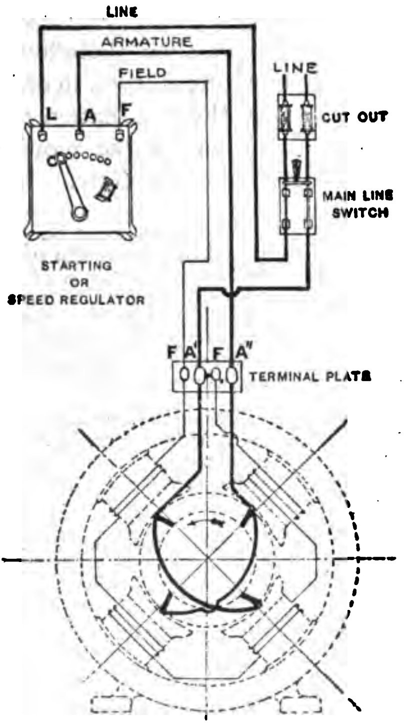


FIG. 7,361.—Wiring diagram of ***shunt motor***. ***Before starting*** a shunt or compound motor for the first time, the field circuit should be tested to see that it is closed. ***To test,*** open armature circuit by removing from rheostat lead marked *arm*, being careful to insulate the loose lead with tape. Then move the rheostat lever over to the last button where it will be held if the field circuit be closed. ***After testing,*** open main line switch and replace the disconnected lead. ***In starting*** motor for first time allow it to run a few minutes without load. ***To reverse a shunt motor,*** change the jumper so as to connect F′ to A′, and change rheostat field lead from F′ to F″.

General Suggestions for Installing Motors.—Make the run from mains or distribution center as short as possible to save materials and to reduce loss of voltage.

Locate starting boxes about 54 ins. from floor to bottom of starter. Conduit should be used to run down walls across floors to motors. If the length of conduit be less than 10 ft. it need not be grounded, but if there be several lengths of conduit and their total length is over 10 ft. it is suggested that they be all bonded together as if they were one continual piece of conduit.

When installing a motor always level the motor, as, if motor be not levelled it will make a lot of noise and cause the bearings to wear on one side; also the belt will have a tendency to slip off.

If a motor is to be set on a ceiling of plaster, first secure a couple of planks not less than 2×4 to the joists, by means of lag screws that are screwed in, not hammered in, so that they will be secure. The motor should then be taken apart and assembled. First the base is screwed to the planks, then the frame is secured to the base. One end plate is installed, the armature inserted, then the other end plate is put on. Always make sure that the oil wells are in the proper positions.

The use of flexible metallic

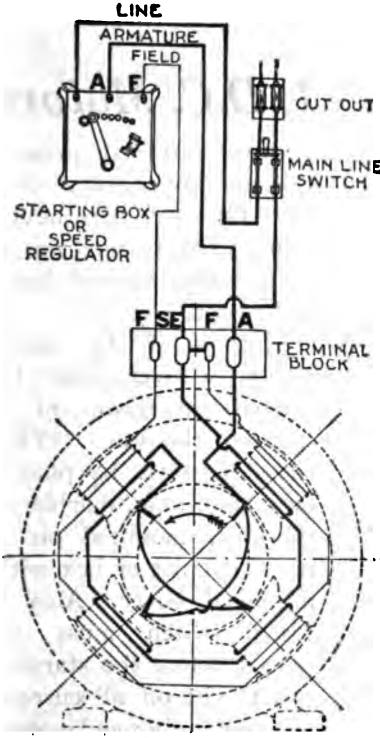


FIG. 7,362.—Wiring diagram of *compound motor*. The reference letters are: A, armature; F, shunt field; SE, series field. *In compound motors*, the series and shunt windings must always be kept in the same relation with regard to their polarity. Where such a motor is to be run in only one direction, the terminal plate has only four binding posts. If it be necessary to reverse the machine, *shift the brush holder rocking ring through one-quarter of a revolution*. For frequent reversing the machine should be connected as in fig. 7,363. *Before starting* for first time, the polarity of the fields should be tested to determine that they be in proper relation. A needle or small drill suspended by a thread makes a good indicator.

conduit known as Greenfield cable is suggested when it is impossible to bend conduit in awkward positions.

The use of special cable connectors at motor outlets is suggested so that in case the motor is to be removed it will be easy to disconnect it.

The use of loom from wall to the motor is not recommended, as it is more desirable to run conduit up to motor terminal block than to loom across.

Always secure motor to the floor or foundations with lag screws or bolts; never use nails.

1. D.C. Motors

Direct current power systems are always two wire, the three wire never being used except on a combination load of light and power.

Motors of ¼ horse power or over must be started by means of a starting rheostat. This rheostat must be placed on a slate base, marble or asbestos, mounted on a metal cabinet or box with a hinged cover. Also a fused switch must be placed before the starting box to cut off all current entering the box and motor. All switches must be installed in a metal cabinet.

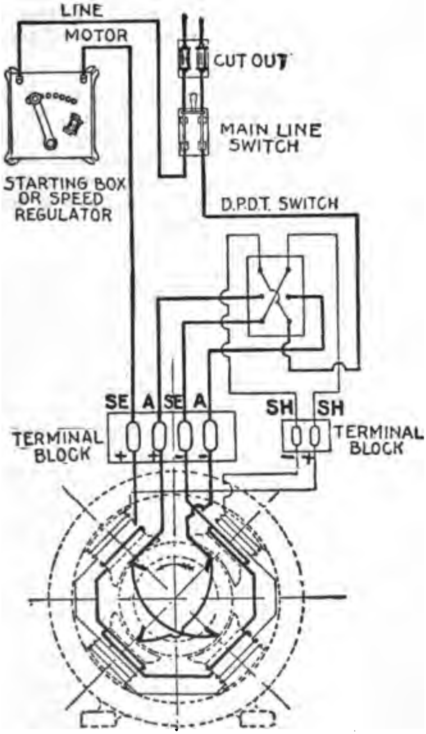


FIG. 7,363.—Wiring diagram of **compound** reversing motor. ***In this arrangement*** there are six terminals and a reversing switch connected as shown. This switch reverses the motor by reversing both field windings.

All motors controlled by controllers, self starters, etc., must also have an additional switch to cut off the power supply. This switch is not necessary if an automatic circuit breaker be placed in the circuit before the starting box.

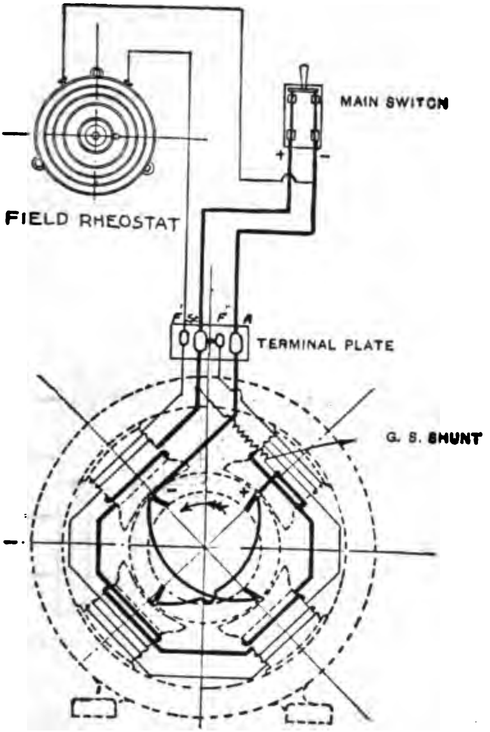


FIG. 7,364.—Wiring diagram of ***compound*** dynamo. ***Failure to generate.*** 1, This may be due to an opening in the field circuit or field rheostat. Test with magneto bell or pilot lamp; 2, shunt field not properly connected. This may occur when the machine is reversed. Reverse the shunt field by changing the jumper so as to connect Se to F′ instead of to F″, and bring the wire from the field rheostat to F″, instead of to F′. If the dynamo give the required voltage at no load and falls off very rapidly as the load is put on, the series field is connected so as to buck the shunt field and should be reversed. ***To reverse*** the series field, interchange the leads which are connected to the brush studs on the rocking ring. Should the dynamo refuse to pick up after the series field has been reversed, reverse the shunt field as explained above or bring it back to its original condition if it has already been changed. 3, Poles being in opposition, *i. e.*, two adjacent poles of the same polarity. This may be tested by means of a compas or a magnetized needle suspended by a fine thread. 4, An open in the armature. Test with magneto bell. 5, Poor contact of brushes with commutator. 6, Brushes not set at the proper place.

The full load current or the amount of current consumed by the motor while running can be found on the motor—name plate or by consulting the tables at end of this chapter.

D.c. motors over ¼ *h.p.* should be connected to 220 volts or over if available.

Small motors under ¼ *h.p.* may operate at 110 volts, but any size above ¼ *h.p.* results in poor efficiency of the motor.

Series motors consume 1.5 more current in starting than in running. The load to be carried by the main is calculated thus:

Full load running current of one 3 *h.p.* motor = 25 amperes
Full load running current of one 5 *h.p.* motor = 38 amperes
Full load running current of one 10 *h.p.* motor = 80 amperes
Full load running current of one 25 *h.p.* motor = 150 amperes
Starting current 25 *h.p.* motor = 150 × 1.25 = 188 amperes

Total current = 331 amperes

Size wire to carry 331 amperes is from table on page 3,791-**431,** circular mils or No. 000, B.W.G.

Where the run from power panel or distribution center to motors is of considerable length it is necessary to increase the size of wire in accordance with the drop, otherwise the loss of voltage will reduce the speed and efficiency of the motor.

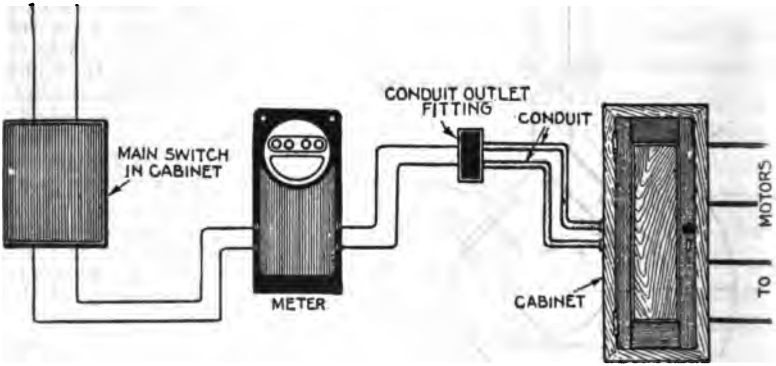


Fig. 7,365.—Wiring diagram for four *d.c.* motor installation, where meter board is not placed at the central point of distribution.

It is suggested that a main distribution be installed at a central point where the wires enter the building or near the generator. From this point, sub-mains can be run to various sub-feeders, to distribution panels, to feed the various motors.

The following table gives full wiring data for *d.c.* motors ¼ to 25 horse power:

WIRING DATA FOR DIRECT CURRENT MOTORS

HORSE POWER	VOLTAGE	AMP. FULL LOAD	SIZE RUNNING FUSES	SIZE WIRE	SIZE SWITCH AMP.	SIZE CONDUIT 2 WIRES	HORSE POWER	VOLTAGE	AMP. FULL LOAD	SIZE RUNNING FUSES	SIZE WIRE	SIZE SWITCH AMP	SIZE CONDUIT 2 WIRES
1/4	110	2.2	5	14	30	½	20	110	148	200	00	200	2
	220	1.1	5	14	30	½		220	74	100	3	100	1¼
	550	.50	5	14	30	½		550	34	50	8	60	1
1/2	110	4.3	8	14	30	½	25	110	185	275	200,000	400	2
	220	2.2	5	14	30	½		220	93	125	0	200	1½
	550	1	5	14	30	½		550	43	60	4	60	1¼
3/4	110	6.2	10	14	30	½	30	110	220	275	300,000	400	2½
	220	3.1	5	14	30	½		220	110	125	0	200	1½
	550	1.5	5	14	30	½		550	50	60	4	60	1¼
1	110	10	12	14	30	½	35	110	255	325	400,000	400	3
	220	5	6	14	30	½		220	125	175	000	200	2
	550	2	5	14	30	½		550	60	80	3	100	1¼
2	110	20	30	10	30	½	40	110	285	400	500,000	400	3
	220	10	15	14	30	½		220	145	200	200,000	200	2
	550	4	6	14	30	½		550	67	90	2	100	1¼
3	110	25	30	10	30	½	45	110	320	400	500,000	400	3
	220	15	15	14	30	½		220	160	200	200,000	200	2
	550	8	8	14	30	½		550	75	100	1	100	1½
5	110	38	60	6	60	1	50	110	350	450	600,000	600	3
	220	19	30	10	30	½		220	175	225	0000	400	2
	550	8	10	14	30	½		550	83	125	0	200	1½
7½	110	60	80	4	100	1¼	60	110	420	550	800,000	600	3½
	220	30	40	8	60	1		220	210	275	300,000	400	2½
	550	12	15	14	30	½		550	99	125	0	200	1½
10	110	80	100	3	100	1¼	75	110	520	800	1,400,000	1000	4½
	220	40	50	6	60	1		220	260	325	400,000	400	3
	550	17	20	12	30	½		550	122	175	000	200	2
15	110	112	150	0	200	1½	100	110	700	900	1,600,000	1000	5
	220	56	70	4	100	1¼		220	350	450	600,000	600	3
	550	24	35	10	30	½		550	160	200	200,000	200	2

Where the starting box is exposed to flying chips of metal or metal dust, it must be enclosed in a metal box, otherwise the metal will short circuit the resistance wires, resulting in a serious damage to the motor and starting box.

A good suggestion is to place the switch and starter in the same cabinet. This saves an extra box and makes a much neater and compact job.

Calculation of Mains for D.C. Motors.—To illustrate the proportioning of the wires assume a load of four 3 *h.p.* motors with meter board arranged as in fig. 7,365.

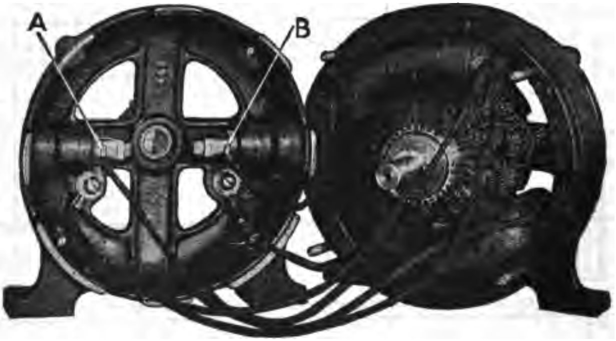


FIG. 7,366.—General Electric fractional horse power *d.c.* motor showing method of reversing. The motor shown is compound wound with only two binding posts. If the motor be shunt wound with either two or three binding posts, or compound wound with three binding posts, the inner connections will be different. ***In all cases,*** to reverse the motor interchange connection at A and B.

This arrangement is all right if the meter board be placed at a central point of distribution to all the motors.

Now a 3 *h.p.* motor at 110 volts consumes 25 amperes at full load. Thus a No. 10 wire which carries 25 amperes must be run from the fuse panel to the motor. The mains should be calculated as 4×25 amperes = 100 amperes which would require a No. 1 wire.

Assume now another installation having a mixed load of various motors of different sizes.

The proper method for calculating mains for such an installation is to add the total running current of the smallest motors to the starting current of the largest motor. Shunt and compound wound motors take 1.25 more current in starting than in running.

2. A. C. Motors

In figuring wire sizes for one motor *a.c.* installations, the following from the *Code* should be noted:

> Where a rubber covered wire carries the current of only one *a.c.* motor of the type requiring large starting currents, it may be protected by a fuse or circuit breaker without time limit device, rated in accordance with table of carrying capacities of weather proof wires on page 3,637.

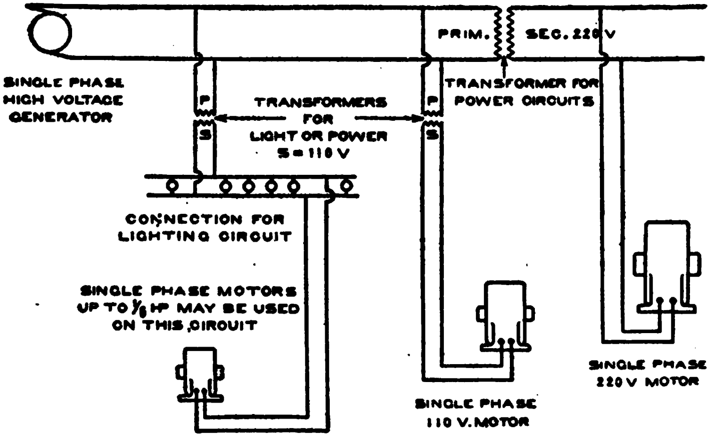
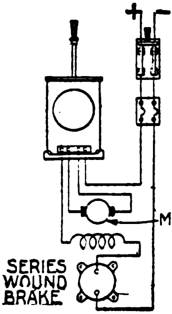
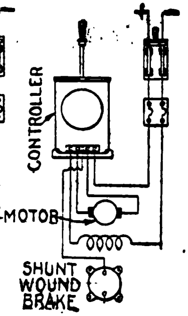


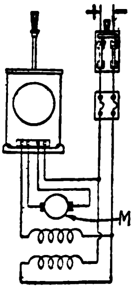
FIG. 7,367.—Wiring diagram showing method of connecting single phase motors on *single phase* circuit.

Its rating is higher than the values given in the table for rubber covered wires. The motors referred to above requiring large starting current are: 1, ***single phase,*** *split phase* types above 5 *h.p.* consume two times as much current in starting as in running; 2, ***two and three phase*** *squirrel cage* and *slip ring* types require a starting current 1½ times the running current.

The foregoing rule has been adopted so that wires may be fused for a higher rating to allow for the heavy momentary starting current. In this connection it should be noted that the motor while running must be protected with a running fuse rated in accordance with the carrying capacity of the wire.







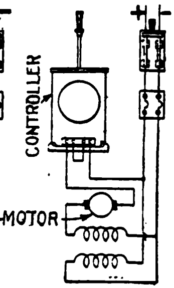
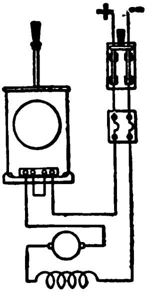


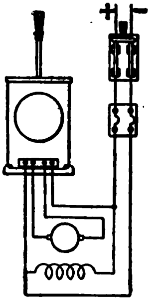
FIG. 7,368.—Diagram showing controller connected to *Crane* series motor and series brake. ***In operation,*** motor reverses when controller is reversed. Brake is applied with controller in off position and is released on first step of controller.

FIG. 7,369.—Diagram showing controller connected to *Crane* series motor and shunt brake. ***In operation,*** motor reverses when controller is reversed. Brake is applied with controller in off position and is released on first step of controller. Extra contact rings or flexible conductor required for shunt brake.

FIG. 7,370.—Diagram showing controller connected to *Crane* compound motor, so arranged that motor reverses when controller is reversed.

FIG. 7,371.—Diagram showing controller connected to *Crane* compound motor so arranged that motor does not reverse when controller is reversed.





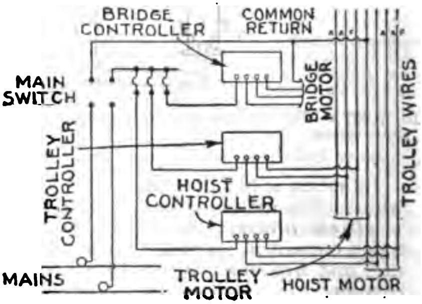


FIG. 7,372.—Diagram showing controller connected to *Crane* series motor so that motor does not reverse when controller is reversed.

FIG. 7,373.—Diagram showing controller connected to *Crane* shunt motor so that motor reverses when controller is reversed.

FIG. 7,374.—Diagram of connections of three motor electric overhead travelling Crane.

Wiring for Single Phase Motors.—Nearly all single phase motors of standard manufacture are equipped with windings leads brought out to the terminal block of the motor so that the motor windings may be transposed to a higher or lower voltage.

For instance, a 110-220 volt motor may be run on either voltage by simply transposing connections. The same applies to a 440 volt motor that may be transposed to a 220 volt connection.

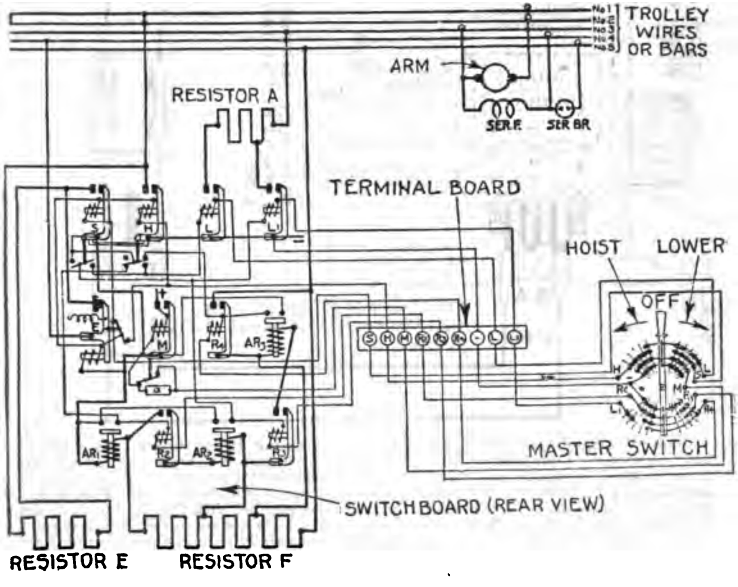


FIG. 7,375.—Wiring diagram of General Electric full magnetic form H controller for dynamic braking.

If both voltages be available, it is suggested that the motor be attached to the higher voltage as the motor will consume approximately half as much current while running, and will also operate at a higher efficiency; another consideration is that it will require a smaller size wire for connecting than if it was used on a lower voltage; also smaller sizes of wire require smaller sizes conduit.

Single phase motors up to 3 *h.p.* may be started by means of double pole switches; they should be of the knife type, which also must be enclosed in an iron box.

Above 3 *h.p.* motors must be started by means of a resistance starter so that the starting currents will be reduced to a minimum. Also this starter must be equipped with a no-voltage release so that if the current

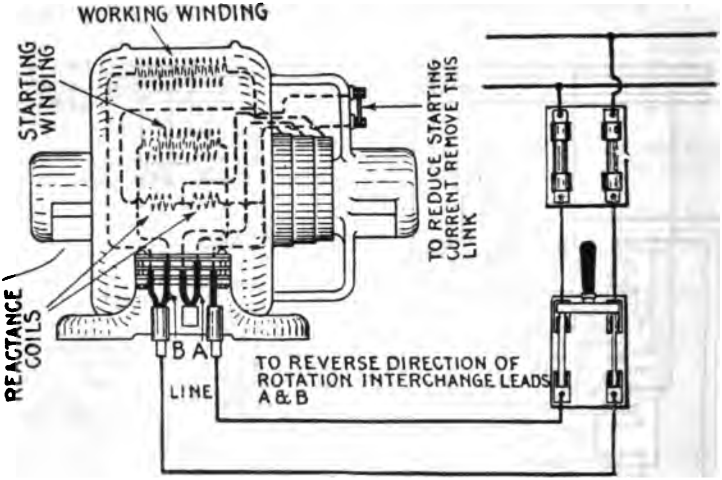
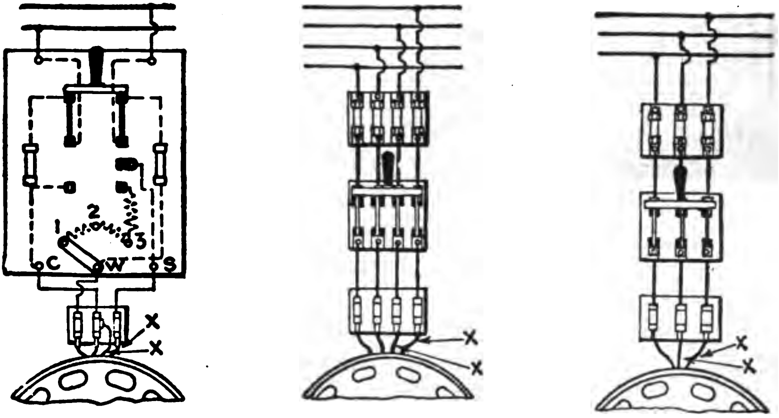


FIG. 7,376.—Wiring diagram and directions for operating Holzer-Cabot single phase self-starting motor. **Location:** The motor should be placed in as clear and dry a location as possible, away from acid or other fumes which would attack the metal parts or insulation, and should be located where it is easily accessible for cleaning and oiling. **Erection:** The motor should be set so that the shaft is level and parallel with the shaft it is to drive so that the belt will run in the middle of the pulleys. Do not use a belt which is too heavy or too tight for the work it has to do, as it will materially reduce the output of the motor. The belt should be from one-half to one inch narrower than the pulley. **Rotation:** In order to reverse the direction of rotation, interchange leads A and B. **Suspended Motors:** Motors with ring oil bearings may be used on the wall or ceiling by taking off end caps and revolving 90 or 180 degrees until the oil wells come directly below the bearings. **Starting:** Motors are provided with link across two terminals on the upper right hand bracket at the front of the motor and with this connection should start considerable overloads. If the starting current be too great with this connection, it may be reduced by removing the link. **Temperatures:** At full load the motor will feel hot to the hand, but this is far below the danger point. If too hot for touch, measure temperature with a thermometer by placing bulb against field winding for 10 minutes, covering thermometer with cloth or waste. The temperature should not exceed 75 degrees Fahr. above the surrounding air. **Oiling:** Fill the oil wells to the overflow before starting and keep them full. See that the oil rings turn freely with shaft. **Care:** The motor must be kept clean. Smooth collector rings with sandpaper and see that the brushes make good contact. When brushes become worn they may be reversed. When fitting new brushes or changing them always sandpaper them down until they make good contact with the collector rings, by passing a strip of sandpaper beneath the brush.

fail while the motor is in operation the no-voltage release will release the handle, a spring causing it to fly back to its original starting position.

Small motors of 3 *h.p.* or more should be protected by means of a no voltage release circuit breaker that is connected in the mains. This does not apply to elevator motors.

It should be noted that in installations having only one motor, the main switch at point of entrance must not be used for starting or stopping the motor, but that an independent switch must be placed in accessible place near the motor to control same.



SINGLE PHASE TWO PHASE THREE PHASE

FIGS. 7,377 to 7,379.—**Wiring diagrams and directions for operating Holzer-Cabot slow speed alternating current motors. Erecting:** In installing the motor, be sure the transformer and wiring to the motor are large enough to permit the proper voltage at the terminals. If too small, the voltage will drop and reduce the capacity of the motor. **Oiling:** Maintain oil in wells to the overflow. **Starting: Single phase** motors are started by first throwing the starting switch down into the starting position, and when the motor is up to speed, throwing it up into the running position. *Do not hold the switch in starting position over 10 seconds.* Starter for single phase motors above ½ H.P. are arranged with an adjusting link at the bottom of the panel. The link is shown in the position of least starting torque and current. Connect from W to 2 or W to 3 for starting heavier loads. *Two or three phase* motors are started simply by closing the switch. These motors start full load without starters. The motor should start promptly on closing the switch. It should be started the first time without being coupled to the line shaft. If the motor start free, but will not start loaded, it shows either that the load upon the motor is too great, the line voltage too low, or the frequency too high. The voltage and frequency with the motor running should be within 5% of the name plate rating and the voltage with 10 to 15% while starting. If the motor do not start free, either it is getting no current or something is wrong with the motor. In either case an electrician should be consulted. **Solution:** To reverse the direction of rotation interchange the leads marked "XX" in the diagrams. **Temperature:** At full load the motor should not heat over 75 degrees Fahr. above the temperature of the surrounding air; if run in a small enclosed space with no ventilation, the temperature will be somewhat higher.

Split phase and other types of single phase motors may be reversed by shifting brushes or their connections.

Motors that are started by means of starters or regulators must have a switch to cut off any power entering motor or devices. This switch shall be placed at a point before live wires enter either motor or device.

Where single phase motors are attached to lighting circuits of 110-220 volts service, 3 wire system, the lighting load should be evenly distributed to two or more circuits so that the load shall be equally balanced on both sides of the 3 wire system. The lights being connected to the 110 volt sides while the motor is connected to the 220 volt side, as in fig. 7,380.

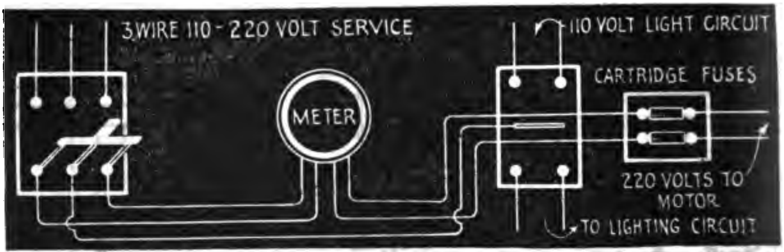


FIG. 7,380.—Wiring diagram for a 110-220 volt three wire circuits for light and power.

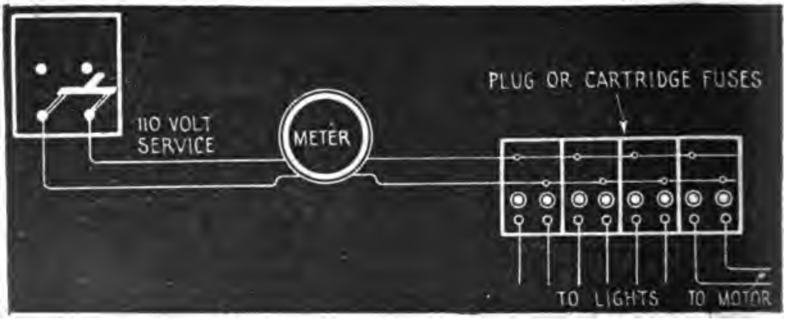
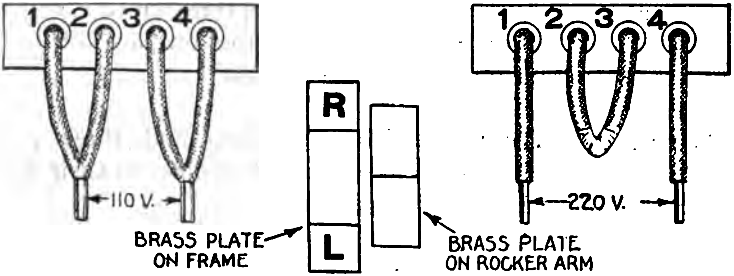


FIG. 7,381.—Wiring diagram for motor on 110 volt lighting circuit.

For loads of lights and motors, where the service is 2 wire, 110 volt, use diagram fig. 7381, making a special circuit for motor.

Figs. 7,389 and 7,390 show method of connecting single phase motors to polyphase systems.



Figs.—7,382 to 7,384.—Bell single phase motor terminal block and method of connecting. There are four leads marked 1, 2, 3 and 4 as shown. If motor is to operate on 110 volts, connect leads No. 1 and 2 together, and 3 and 4 together as in fig. 7,382, and then connect to lines. If motor is to operate on 220 volts, connect No. 2 and 3 leads together, and tape them up, and connect No. 1 and 4 to the lines, as in fig. 7,383. For right hand operation, loosen the screw that holds the rocker-arm that supports the brushes, and turn same so that mark on brass plate on rocker-arm is opposite mark on brass plate on frame marked R, then tighten screw. For left hand operation, move rocker-arm until mark on brass plate is opposite mark on brass plate on frame marked L. Always start motor at first without belt on pulley, and see that it comes up to speed, and that the short-circuiting device short-circuits the commutator. The motor may then be tried with load upon same. If it then fail to bring the load up to speed, it has either too much load upon it, or the brushes should be moved a very slight bit either backward or forward. A position can be found in which the motor will start with maximum power. Be sure to use fuses large enough to start motor under its full load.

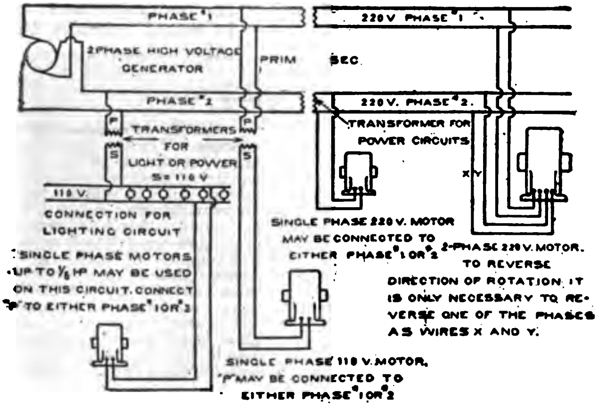


Fig. 7,385.—Wiring diagram showing method of connecting single and two phase motors on *two phase* circuit.

The rules just given apply also to Edison three wire *d.c.* system.

The table of data for single phase motors on page 3,806—**446** gives the requirements according to the *Code:*

Wiring for Polyphase Motors.—Two and three phase motors are practically alike in principal but differ in their windings. The following are the requirements:

Polyphase motors over 7½ *h.p.* must be started by means of a starting compensator.

Motors up to 3 *h.p.* may be thrown directly on the line by means of knife switches; from 3-5 *h.p.* special starting switches must be used.

All starters of the knife switch type must be enclosed in metal cabinets.

Running fuses of starting compensators although mounted on compensators must be enclosed in metal cabinets the same as other cabinets.

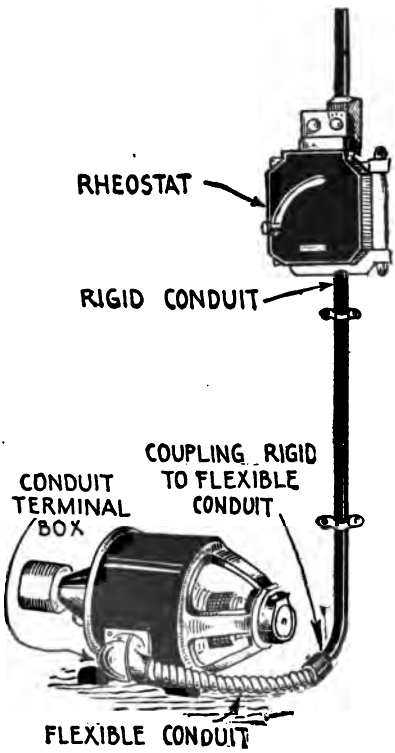


FIG. 7,386.—Method of wiring motor using rigid and flexible conduit between rheostat and motor.

NOTE.—***Transformer sizes for a.c. motors.*** For the larger motors, the capacity of the transformers in *kw.* should equal the output of the motor in *h. p.* Small motors should be supplied with a somewhat larger transformer capacity, especially if, as is desirable, they be expected to run most of the time near full load, or slight over load. For commercial motors from three phase systems, three single phase units or one three phase unit are recommended. The three phase transformer is very compact and the wiring simple, but the advantage of using three single phase transformers is that in case one burn out, the motor may be operated with the other two at reduced speed.

All frames of compensators must be grounded.

Starting switches of motors of the compensator type must have an additional switch to cut off all current from the motor.

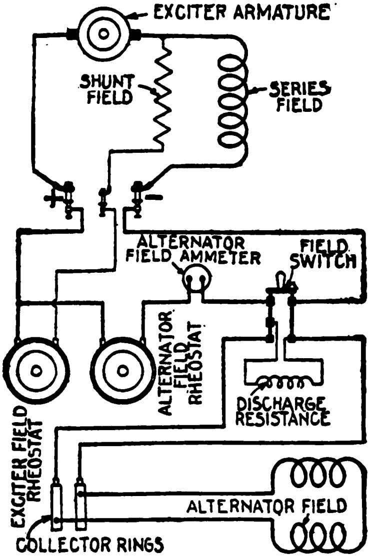


FIG. 7,387.—Connections of a single phase alternator and exciter.

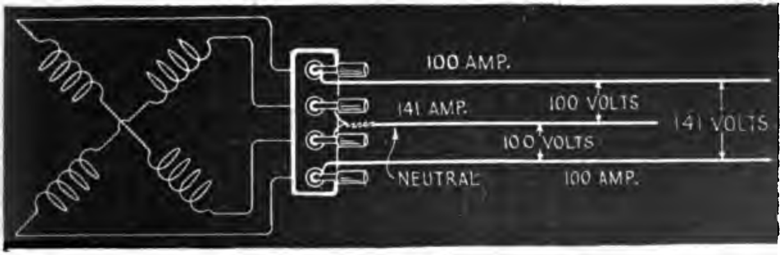


FIG. 7,388.—Two phase three wire alternator terminal connections. This system is used principally on power loads, where the load is balanced. The central wire of a 2 phase 3 wire system carries 1.41 more current than each of the two outside wires. The voltage across the two outside wires is 1.41 more than the voltage across any of the two outside wires and the neutral wire. Single phase current should never be taken from a three wire two phase system as this will unbalance the line and cause the prime mover to heat up and a low power factor.

All compensators must be equipped with no voltage releases.

Small motors of 3 *h.p.* or more must be protected by a no voltage release circuit breaker in the mains or each individual motor may be equipped with a no voltage release.

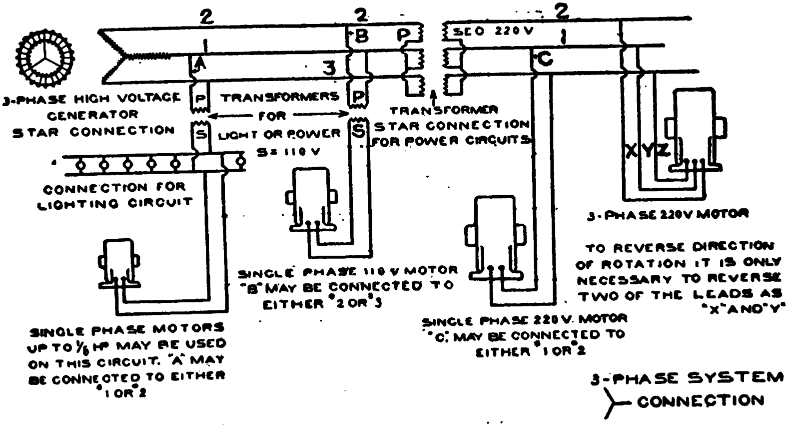


FIG. 7,389.—Wiring diagram showing method of connecting single phase and three phase motors on *three phase star connection* circuit.

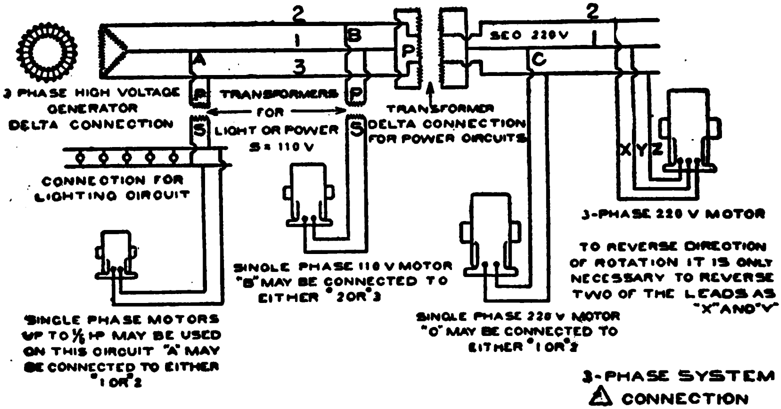


FIG. 7,390.—Wiring diagram showing method of connecting single phase and three phase motors on *three phase delta connection* circuit.

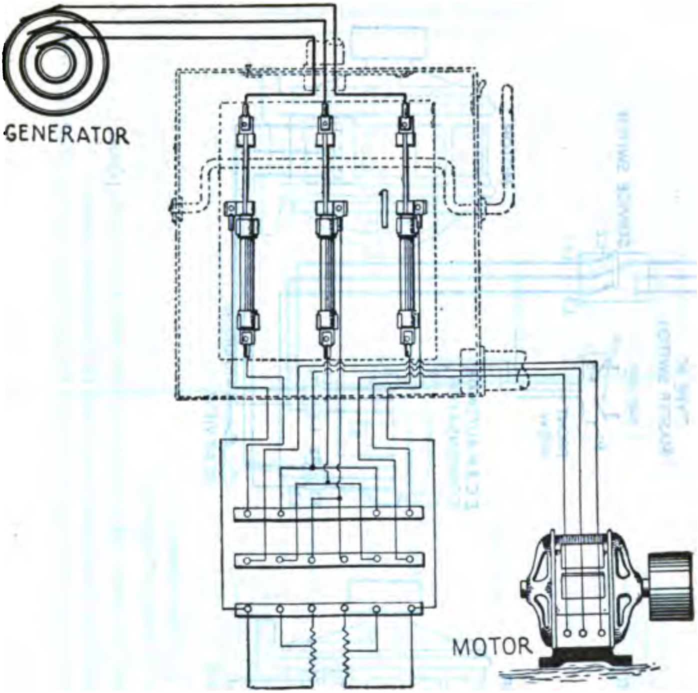


FIG. 7,391.—Diagram showing square D compensator switch connected ahead of a starting compensator on a three wire two phase system.

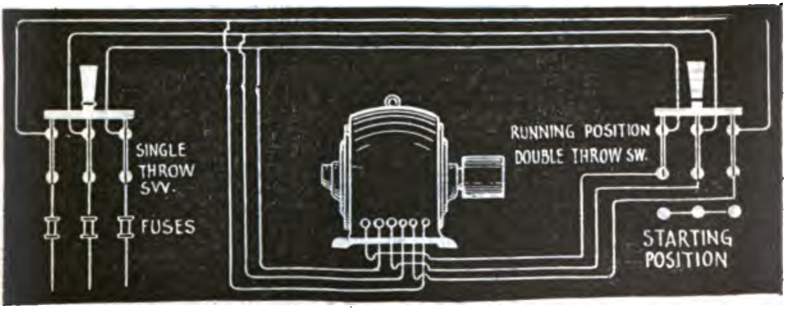
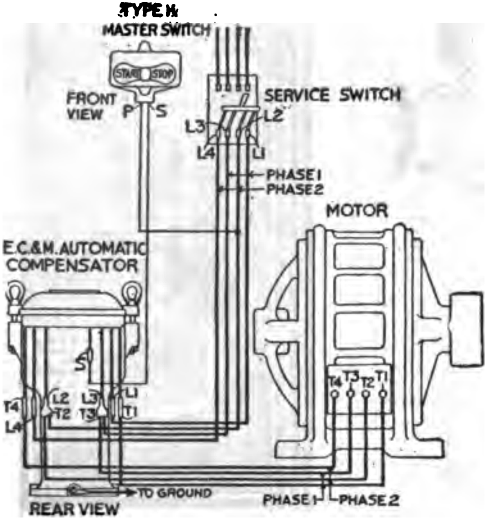


FIG. 7,392.—Diagram of connections for three phase motor YΔ connections.



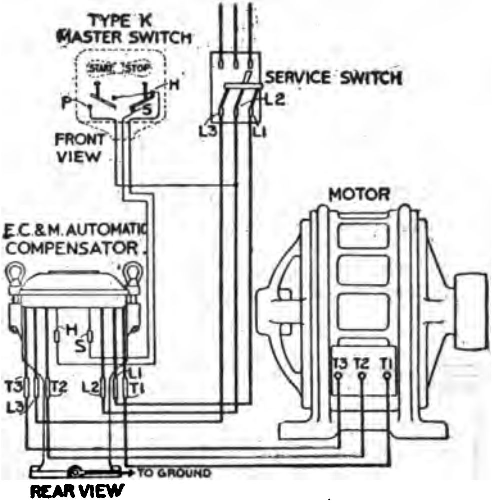


Fig. 7,393.—Connection diagram of two phase no voltage release.
Fig. 7,394.—Connection diagram of three phase no voltage protection.

Two phase motors may be reversed by means of transposing one wire from each phase.

Three phase motors may be reversed by transposing any one of the phase wires.

Calculations of mains for polyphase motor installations should be calculated as described in wiring for *d.c.* motors.

The following tables of data for polyphase motors give the requirements according to the *Code*:

Current per Phase in Motor Circuits

H.P.	110 Volts			220 Volts			440 Volts		
	1-ph.	2-ph.	3-ph.	1-ph.	2-ph.	3-ph.	-ph.	2-ph.	3-ph.
1	12.72	5.57	6.43	6 36	2.78	3.22	3 18	1 39	1 61
2	23.80	10.10	11.54	11.90	5.05	5.77	5 95	2 52	2.89
3	34.30	14 24	16.44	17.15	7.12	8.22	8.53	3 56	4.11
5	52.30	22.92	26.50	26.15	11.46	13.25	13 07	5 73	6 63
7½	68.75	34.42	39.70	34.37	17.21	19.85	17 19	8 60	9 93
10	90.60	45.30	52.40	45.30	22.65	26.20	22.65	11 32	13.10
15	132.8	66.40	76.80	66.4	33 20	38.40	33 2	16 60	19.20
20	175.2	87.4	101.3	87.6	43.70	50.70	43.8	21 85	25.35
25	219.0	109.6	126 7	109 5	54.8	63.4	54 7	27.4	31.70
30	263.0	131.5	152.0	131.5	65 8	76 0	65 8	32.9	38.0
35	321.0	160.5	185.8	160.5	80.2	92.9	80 0	40.1	46.4
40	350.0	175.0	202.1	175.0	87.5	101.0	87 5	43.7	50.5
45	394.0	197.0	227.6	197.0	98.5	113.8	98 5	49.3	56.9
50	428.0	214.0	247.2	214.0	107.0	123.6	107.0	53.5	61.8
60	513.0	256.5	296.2	256.5	128.2	148.1	128.2	64.1	74.1
70	611.0	306.0	353.0	305.5	153.0	176.5	152 7	76.3	88 3
75	656.0	328.0	379.1	328.0	164.0	189.5	164 0	82 0	94.7

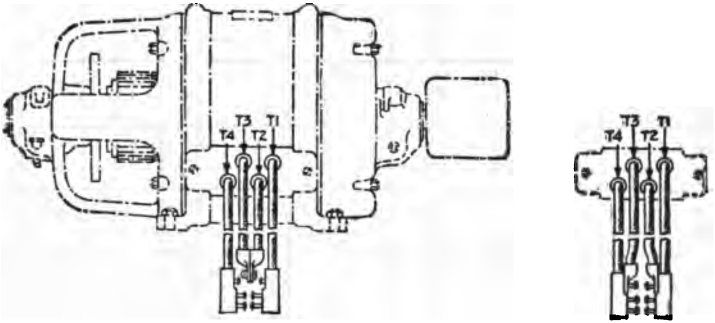


FIG. 7,395.—General Electric single phase, constant speed repulsion induction motor. For standard direction of rotation (220 volts) connect line leads to large terminals T4, and T1, as shown. For 110 volts standard rotation, connect T3 to T4, and T2 to T1. *Clockwise rotation:* To reverse standard rotation, simply shift yoke to reverse running mark; no change of leads is necessary.

The following table will be found useful in determining size of wire, carrying capacity of fuses, and setting of circuit breakers; it considers the average efficiency and power factor of the motor in each case and indicates, in amperes, the current flowing in each wire of the motor circuits:

SINGLE PHASE MOTOR WIRING DATA

HORSE POWER	VOLTS	AMPS	SIZE FUSES RUNNING	SIZE FUSES STARTING	SIZE WIRE	SIZE CONDUIT 2 WIRES	SIZE SWITCH AMP'S
1/4	110	4	10	10	14	½	30
	220	2	5	5	14	½	30
	550	.8	3	3	14	½	30
1/2	110	7.5	20	20	12	½	30
	220	3.75	10	10	14	½	30
	550	1.5	3	3	14	½	30
1	110	12.5	15	25	10	½	30
	220	6.25	8	15	14	½	30
	550	2.5	5	8	14	½	30
2	110	24	25	50	6	1	60
	220	12	15	30	10	½	30
	550	4.8	8	10	14	½	30
3	110	34	45	70	4	1¼	100
	220	17	25	35	8	1	60
	550	7	10	15	14	½	30
4	110	43	60	85	2	1¼	100
	220	22	30	40	6	1	60
	550	9	15	20	12	½	30
5	110	55	60	125	0	1¼	200
	220	28	35	50	6	1	60
	550	11	15	25	10	½	30
7½	110	80	90	150	00	2	200
	220	40	60	75	4	1¼	100
	550	16	20	30	10	½	30
10	110	105	125	200	200,000	2	200
	220	53	60	100	1	1½	100
	550	21	25	40	6	1	60
15	110	145	150	250	300,000	2½	300
	220	73	75	150	00	2	200
	550	29	30	60	4	1¼	60
20	110	200	225	400	500,000	3	400
	220	100	125	200	200,000	2	200
	550	40	50	75	3	1¼	100
25	110	250	275	500	700,000	3½	600
	220	125	150	250	300,000	2½	400
	550	50	60	100	1	1¼	100
30	110	295	325	550	800,000	3½	1000
	220	148	175	300	400,000	3	400
	550	59	75	125	0	1½	200
40	110	370	400	750	1,200,000	4½	1000
	220	185	200	375	500,000	3	400
	550	74	100	200	200,000	2	200

WIRING DATA FOR 2 PHASE MOTORS

3 WIRE OR 4 WIRE SQUIRREL CAGE TYPE

HORSE POWER	VOLTS	RUNNING AMPERES OUTSIDE	RUNNING AMPERES NEUTRAL	STARTING AMPERES OUTSIDE	STARTING AMPERES NEUTRAL	SIZE WIRE OUTSIDE	SIZE WIRE NEUTRAL	SIZE RUN FUSES OUTSIDE	SIZE RUN. FUSES NEUTRAL	SIZE START FUSES OUTSIDE	SIZE START FUSES NEUTRAL	SIZE CONDUIT 3 WIRE	SIZE CONDUIT 4 WIRE
½	110	3.2	4.8	6.4	9.6	14	14	5	8	8	10	½	½
	220	1.6	2.4	3.2	4.8	14	14	3	3	5	6	½	½
	440	.8	1.2	1.6	2.4	14	14	3	3	3	3	½	½
	550	.6	1.	.3	2.	14	14	3	3	3	3	½	½
1	110	6.2	9.3	12.4	19.6	14	12	8	10	15	25	½	½
	220	3	4.5	6.	9.	14	14	3	6	8	10	½	½
	440	1.6	2.4	3.2	4.8	14	14	3	3	5	6	½	½
	550	1.2	1.8	2.4	3.6	14	14	3	3	3	5	½	½
2	110	10	15	20	30	12	10	15	20	20	30	¾	¾
	220	5	7.5	10	15	14	14	6	10	10	15	½	½
	440	2.5	4.25	5	9	14	14	6	6	6	10	½	½
	550	2.	2.5	4	5	14	14	3	3	5	6	½	½
3	110	14.	21.	28	42	10	6	20	25	30	50	1	¾
	220	7.	10.	14	20	14	12	12	20	15	20	½	¾
	440	3.6	5.4	7.2	10.8	14	14	5	8	8	12	½	½
	550	2.8	4.	5.6	8	14	14	3	5	6	10	½	½
5	110	24.	36.	48	72	8	5	30	40	50	80	1	1
	220	12.	17.	24	34	10	8	15	20	25	35	1	¾
	440	6.	9	12	18	14	12	8	10	15	20	½	½
	550	5.	7.5	10	15	14	14	6	10	10	15	½	½
7½	110	33	49.	66	98	8	8	35	60	70	100	1	1
	220	17	24.	34	48	8	6	20	30	35	50	1¼	1
	440	9	13.	17	26	14	10	10	15	20	30	¾	½
	550	7	11.	14	22	14	12	10	15	15	25	½	½

WIRING DATA FOR 2 PHASE MOTORS—*Continued*

HORSE POWER	VOLTS	RUNNING AMPERES OUTSIDE	RUNNING AMPERES NEUTRAL	STARTING AMPERES OUTSIDE	STARTING AMPERES NEUTRAL	SIZE WIRE OUTSIDE	SIZE WIRE NEUTRAL	SIZE RUN. FUSES OUTSIDE	SIZE RUN FUSES NEUTRAL	SIZE START FUSES OUTSIDE	SIZE START FUSES NEUTRAL	SIZE CONDUIT	
												3 WIRE	4 WIRE
10	110	47	72	94	144	3	1	50	80	100	150	1½	1¼
	220	23	32	46	64	8	6	25	40	50	70	1	1
	440	12	18	24	36	12	8	15	20	25	40	¾	¾
	550	10	15	20	30	14	10	12	20	20	30	½	½
15	110	70	105	140	210	1	00	80	125	150	225	1½	2
	220	35	53	70	106	6	2	40	60	70	125	1¼	1¼
	440	18	24	36	48	8	8	20	25	35	50	1	1
	550	14	21	28	22	10	10	15	25	30	25	¾	¾
20	110	90	135	180	270	0	000	100	150	200	275	2	2
	220	45	68	90	136	4	1	50	75	90	150	1½	1½
	440	23	36	46	72	8	5	30	40	45	75	1	1
	550	18	27	36	54	8	6	20	30	40	60	1	1
25	110	112	168	224	336	00	300,000	125	175	225	350	2½	2½
	220	56	83	112	168	2	0	60	90	125	175	1½	1½
	440	28	42	56	84	6	4	30	50	60	90	1¼	1¼
	550	23	34	46	68	8	6	25	40	50	70	1	1
30	110	132	195	264	290	000	200,000	150	200	275	300	2½	2½
	220	66	98	132	196	1	0	75	125	150	200	2	2
	440	33	48	66	96	6	3	40	60	70	100	1¼	1¼
	550	26	38	52	76	6	5	30	45	60	80	1¼	1¼
35	110	154	228	308	456	0000	400,000	175	250	325	475	3	2½
	220	77	112	154	224	0	00	90	125	175	225	2½	2
	440	39	56	78	112	5	2	45	70	80	125	1¼	1¼
	550	31	45	62	90	6	4	40	50	75	90	1¼	1¼

WIRING DATA FOR 2 PHASE MOTORS—*Continued*

HORSE POWER	VOLTS	RUNNING AMP. OUTSIDE	RUNNING AMP. NEUTRAL	STARTING AMP. OUTSIDE	STARTING AMP. NEUTRAL	SIZE WIRE OUTSIDE	SIZE WIRE NEUTRAL	SIZE RUN. FUSES OUTSIDE	SIZE RUN. FUSES NEUTRAL	SIZE START FUSES OUTSIDE	SIZE START FUSES NEUTRAL	SIZE CONDUIT 3 WIRE	SIZE CONDUIT 4 WIRE
40	110	175	260	350	520	300,000	500,000	200	275	350	525	3	3
	220	88	132	176	264	0	000	90	150	175	275	2	2
	440	44	65	88	130	4	1	50	75	90	150	1½	1½
	550	35	48	70	96	6	3	40	60	75	100	1¼	1¼
50	110	216	320	432	646	400,000	600,000	225	350	450	650	3½	3½
	220	108	158	216	316	00	0000	125	175	225	325	2	2½
	440	54	79	108	158	2	0	60	90	125	175	1½	1½
	550	43	64	86	128	4	1	50	75	90	150	1½	1½
75	110	324	475	648	950	600,000	1,000,000	350	500	650	1000	3½	4
	220	162	240	324	480	0000	400,000	175	275	325	500	2½	2½
	440	81	120	162	240	0	000	90	90	175	250	2	2
	550	65	96	136	192	1	0	70	70	150	200	2	2
100	110	432	609	864	1218	900,000	1300,000	450	625	875	1500	5	4
	220	216	305	432	609	400,000	600,000	225	325	450	625	3½	3½
	440	108	152	216	304	00	0000	125	175	225	325	2½	2½
	550	86	121	172	242	0	000	90	125	175	250	2	2
150	220	324	456	648	912	600,000	900,000	350	475	650	925	4	4
	440	162	207	324	414	0000	400,000	175	225	325	425	3	2½
	550	129	181	258	362	0000	300,000	150	200	275	375	2½	2½
200	220	432	609	864	1218	900,000	1300,000	450	625	875	1500	5	5
	440	216	305	432	610	400,000	600,000	225	325	450	625	4	3½
	550	173	243	246	486	000	200,000	175	250	350	30	2½	2½

WIRING DATA FOR 2 PHASE MOTORS - 2,200 VOLTS

HORSE POWER	VOLTS	RUN AMP OUTSIDE	RUN AMP NEUTRAL	START OUTSIDE	START NEUTRAL	WIRE OUTSIDE	WIRE NEUTRAL	RUN FUSE OUTSIDE	RUN FUSE NEUTRAL	START FUSE OUTSIDE	START FUSE NEUTRAL
25	2200	6	9	12	18	14	12	10	15	15	20
30	2200	7	11	14	20	14	12	10	15	15	20
40	2200	9	14	18	27	14	10	10	15	20	30
50	2200	11	17	22	34	12	8	15	20	25	35
60	2200	13	19	26	38	10	8	15	20	30	40
75	2200	16	24	32	48	8	8	20	30	35	50
100	2200	22	33	44	66	8	6	25	35	45	70
125	2200	27	41	54	82	6	4	30	50	60	90
150	2200	32	48	64	96	6	3	35	60	70	100
175	2200	38	57	76	114	5	2	40	70	80	125
200	2200	43	64	86	128	4	1	50	75	90	150
250	2200	54	79	108	158	2	0	60	90	125	175
300	2200	65	96	130	192	1	0	75	110	150	200
400	2200	87	129	174	258	0	0	100	150	175	300
500	2200	108	150	216	300	00	200,000	125	175	225	300

3 PHASE MOTOR WIRING DATA

HORSE POWER	VOLTS	RUNNING AMPS	START AMPS	SIZE WIRE	SIZE RUNNING FUSE	SIZE START FUSE	SIZE CONDUIT
½	110	3.6	9	14	6	10	½
	220	1.8	4.5	14	3	6	½
	440	.9	2.3	14	6	6	½
	550	.7	1.7	14	3	6	½
1	110	7.2	19	14	25	20	½
	220	3.6	9.5	14	10	10	½
	440	1.8	4.5	14	3	6	½
	550	1.4	3.5	14	3	6	½
2	110	12	30	14	20	30	½
	220	6	16	14	10	20	½
	440	3	7.5	14	6	10	½
	550	2.2	5.5	14	6	6	½
3	110	18	46	18	30	50	1
	220	9	23	12	15	25	½
	440	4.5	11.2	14	6	15	½
	550	3.3	9	14	6	10	½
5	110	28	66	6	30	70	1¼
	220	14	33	10	15	35	¾
	440	7	17	14	10	20	½
	550	5.5	13	14	10	15	½
7½	110	40	100	3	45	100	1¼
	220	20	50	8	25	50	1
	440	10	25	14	15	25	½
	550	8	20	14	10	20	½
10	110	52	130	1	60	150	1½
	220	26	65	6	30	65	1¼
	440	13	32	8	15	35	1
	550	11	26	10	15	30	¾
15	110	76	152	0	80	160	2
	220	38	76	5	40	80	1¼
	440	19	38	8	20	40	1¼
	550	15	30	10	20	30	¾
20	110	102	204	00	125	225	2
	220	51	102	3	60	125	1¼
	440	25	50	8	30	50	1
	550	21	42	8	25	45	1
25	110	126	252	000	150	250	2
	220	63	126	2	70	125	1½
	440	31	63	6	35	65	1¼
	550	25	50	8	30	50	1
30	110	154	308	0000	175	300	2½
	220	77	154	1	85	175	1½
	440	34	77	5	45	80	1¼
	550	31	62	6	35	65	1¼
35	110	180	360	300,000	200	375	2½
	220	90	180	0	100	200	2
	440	45	90	4	50	90	1¼
	550	36	72	5	40	75	1¼
40	110	210	370	300,000	225	375	2½
	220	105	185	0	125	200	2
	440	52	92	3	60	100	1¼
	550	42	74	5	45	75	1¼
50	110	250	375	300,000	400	375	2½
	220	125	187	0	150	200	2
	440	62	125	2	70	125	1½
	550	50	75	5	60	75	1¼
75	110	380	570	500,000	425	600	3
	220	190	285	200,000	225	300	2½
	440	95	142	1	125	150	1½
	550	76	114	2	90	125	1½
100	110	490	734	700,000	525	750	3½
	220	245	367	300,000	275	375	2½
	440	123	183	2	150	200	1½
	550	98	146	1	125	150	1½
150	110	728	1092	1,200,000	800	1100	4½
	220	364	546	450,000	400	550	3½
	440	182	273	000	200	275	2½
	550	145	214	00	160	225	2
200	110	970	1254	1,400,000	850	1300	5
	220	485	627	600,000	550	700	3½
	440	242	313	0000	275	350	2½
	550	194	250	000	225	275	2

CHAPTER 114

Cable Splicing

Due to the adoption of higher voltages a large amount of engineering attention has been given to the general problem of joints because of the difficulties under which they have to be made. Such difficulties are: 1, the necessity of working in cramped positions in moist manholes, 2, the lack of positive control of the workmanship in making joints, and 3, the required niceties in the work of handling and installing the conductors themselves.

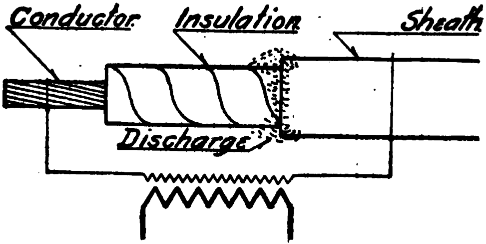


FIG. 7,396.—Diagram of experiment showing discharge between cable conductor and sheath. When high voltages are applied an electric discharge will take place between conductor and metal sheath which in a dark room will be indicated by a glow of light (corona effect). This causes the formation of *ozone* which tends to destroy the insulation.

Also a great deal of attention and study has been given, not only to the materials by which the cable itself is insulated but also to the question of securing a suitable compound with which to fill the joints of the cable. Obviously the standard of dependability of the joint must be equal to that of any part of the cable itself.

A chain can be no stronger than its weakest link, and the weakest links in a cable system are apt to be the joints unless the latter are made with the greatest care.

On the average there is about one joint for every 300 feet of lead covered underground cable installed in the various duct systems throughout the United States. There are of necessity a large number of joints in an underground cable systems of even moderate size.

One of the most widely used methods of insulating joints on cables is to first wrap (after the metallic conductors have been properly soldered

Fig. 7,397.—Standard saturated paper jointing tubes. ***In making,*** specially prepared and treated, compressed, machine laid paper is used, thoroughly saturated with an impregnating compound similar to that used in high voltage paper insulated cables, and coated on the outside with an insulating compound.

Fig. 7,398.—Standard copper connector. The metal is annealed so that it may be easily closed tight around the conductors. The ends are bevelled to avoid sharp edges and thus prevent static or corona discharges. The connector is slotted as shown to allow the solder to flow freely into and around the connector and the cable strands, and to permit a good mechanical connection before soldering. The connector is tinned all over to facilitate soldering.

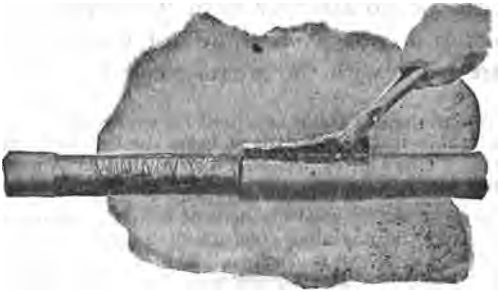


FIG. 7,399.—***Cable splicing with Ozite: 1. Removing the lead sheath.*** The cable ends having been brought into position and cut off square so as to just nicely butt together, they should be marked at the point to which the lead is to be removed which should be approximately 7 inches back from the end of one cable and 10 inches back from the end of the other. At the points marked, the lead should be scored or cut entirely around. (Experienced jointers accomplish this result with a plumbers chipping knife and hammer.) The lead is then cut lengthwise of the cable, from the circular score to the end with the chipping knife and the piece of lead removed with a pair of pliers. ***Caution:*** great care must be exercised in removing the lead so as not to injure the cable insulation. The circumferential cut should be made by nicking the lead only part way through and then tearing or pulling it apart with pliers. The longitudinal cut should be made by inserting the knife tangentially with the inside curve of the lead sheathing, that is, so that the knife will pass between the insulation and the lead and not cut the insulation. After the lead has been removed, the edge of the lead sheath where it was scored should be carefully examined and all sharp edges or projections which might penetrate the cable insulation, removed with a knife. The ends of the sheath should then be slightly belled out, using some blunt instrument such as the end of the pliers.

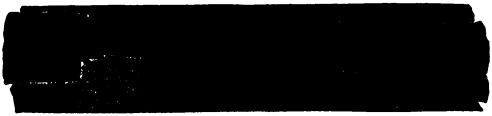
FIG. 7,400.—***Cable splicing with Ozite: 2. Removing the insulation and tinning the conductors. Remove*** belt insulation of cable to a point about 1½ inches from the edge of the lead sheath. The inner layers of belt insulation should be torn rather than cut so as to avoid damaging insulation of individual conductors. Pull jute fillers back and cut off at a point close to end of belt insulation. The individual conductors will now be found to be about 3 inches longer on one cable end than on the other. Strip the individual conductors of insulation for a distance equal to ⅝ of the length of the copper sleeve. ***Tin*** conductors thoroughly with hot solder applied with a ladle as shown.

together) each of the exposed sections at the joint with some form of insulating tape which is built up in successive layers to the desired thickness. After the conductors are insulated singly, there is a further belt of insulation wrapped around the outside of the three conductors in the same manner as the insulation placed on the individual conductors. These wrappings although they may be put on as carefully as the limited facilities in the field will permit, cannot be applied as tightly uniformly or with the same certainty of the highest grade of workmanship as the insulation on the undisturbed section of the cable. The various uncertainties that creep into the making of cable joints in the field are due partly to the cramped conditions under which such joints are made, the occasional unfavorable weather and the impossibility of always insuring the first class quality of material and workmanship.

FIG. 7,401.—***Cable splicing with Ozite: 3.*** *Putting on lead sleeve and paper tubes, and sweating connectors to conductors.* ***The lead sleeve*** which will later be used for jointing should be thoroughly scraped with a shave hook or rasp for about 2 inches and the cleaned portion thoroughly smeared with some convenient flux (usually stearine) which, by preventing formation of the usual film of lead salts, insures a close union between the lead and the wiping metal which is used to make the joint between sleeve and cable sheath. Thread the lead sleeve, prepared as described above, over one of the abutting ends of the cable and move back out of the way. Thread large enclosing joint tube, when used, over the cable end and push back out of the way. Thread small jointing tubes over the individual conductors of the longer cable end and push back far enough to leave the bare conductor ends easily accessible. ***Sweating connectors:*** Insert ends of conductors to be joined into the split copper connectors opened slightly, which should preferably be of such size that even when compressed upon the conductor the longitudinal split will remain open 1/16 or 3/32 of an inch. Pour hot solder from the ladle over the copper connector keeping the split in connector uppermost and, after thoroughly heating, compress the sleeve. Then sweat the connector and conductor thoroughly together keeping the joint as full of solder as possible. Wipe off all fins or points before solder sets. Do not file off fins or sharp points unless the copper connectors and the insulation of all of the conductors are protected from falling particles of metal. Do not move the copper connector or joint until thoroughly cooled, otherwise the solder, if it be at the critical temperature when mealiness appears, may not unite the parts satisfactorily.

Effects of Air Pockets.—An additional factor of vital importance, but not affected by either moisture or careful workmanship is the necessity of excluding all air from the wrapped insulation as it is built up, or from the space within the sleeve which is supposed to be entirely filled with compound.

FIG. 7,402.—*Cable splicing with Ozite: 4. Boiling out tape and cable ends.* Fill space between ends of copper connector and conductor insulation on each side with loosely woven and easily impregnated cotten tape. Apply similar tape in one layer over the copper connector for its entire length. Boil out tape and adjacent cable ends carefully with "Ozite" insulating compound. As the tape must have its moisture boiled out, in case any be present and be thoroughly impregnated besides, nothing but very hot compound will suffice.



FIGS. 7,403 and 7,404.—*Cable splicing with Ozite: 5. Placing tubes in position.* After all the conductors have been joined, place each of the small jointing tubes so as to completely cover the joint on the conductor. Proper position of jointing tube is such that the middle of the tube is over the middle of the copper connector, or so the tube equally overlaps the original conductor insulation at each end. Secure the tubes in position by means of flax twine stretched tightly over each and tied at each end to the conductor. Place the enclosing or large jointing tube over the smaller tubes, so that its middle point is over the middle points and bind it in this position with flax twine as in the case of the small tubes Do not put wrappings of any sort, either paper, linen or rubber over the tubes as this prevents the filling compound entering the spaces between tubes and conductors and between inner and outer tubes which entrance is absolutely essential to complete success in a joint of this type.

The result is occasional, although small air pockets in the insulation which invite the slow formation of ozone and consequently ultimate deterioration due to the resultant chemical action.

The net result with the best of workmanship, material and conditions is uncertain as to the dielectric quality of the joint. This uncertainty is particularly emphasized in the higher voltage cables due to the more rapid formation of ozone.

Function of Compounds.—This was formerly thought to be that of an insulator which could be put in place in liquid form and which, when so placed, could be sealed in against the possibility of escape.

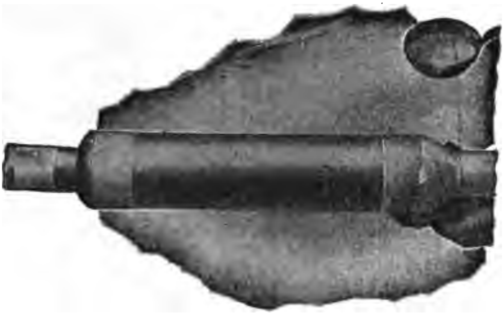


FIG. 7,405.—*Cable splicing with Ozite: 6. Placing lead sleeve in position and wiping the joint.* Move lead sleeve into proper position so that each end equally overlaps the lead sheathing of the abutting cables. Press down ends of sleeve to fit snugly around cable sheathing. Wipe joint between sleeve and sheath carefully with edges of wipe at least ¾ inch from the line at which the sleeve and sheath meet. Cut two holes, one at each end and on top of the lead sleeve. One of these is for pouring in the hot compound and the other for its overflow. The one selected for filling should be on the end farthest away from the paper tubes and so located that the stream of hot compound will strike the belt insulation of the jointed cable.

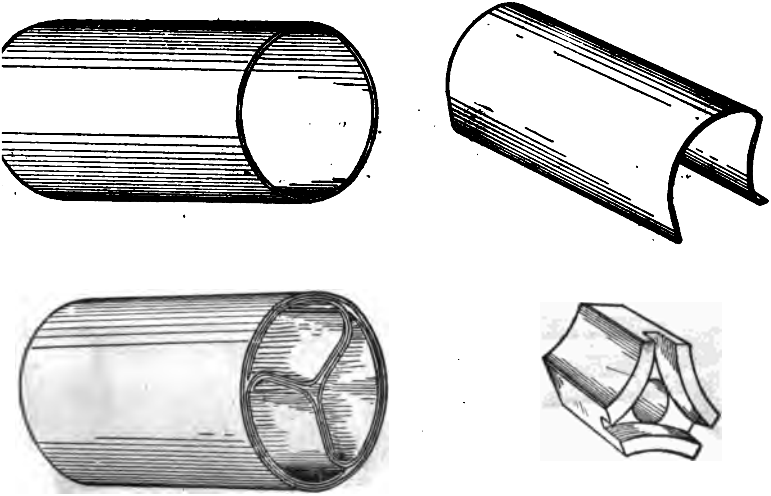
No further requirements were considered necessary. Later investigation however, has shown that the problem of preventing the occurrence of voids and air bubbles is one of the greatest importance, because, due to corona effect, ozone is formed in these air bubbles and this formation results in a slow chemical deterioration of the insulation.

Cable Insulation.—Underground transmission cables as now manufactured are insulated with paper tape applied evenly in several layers to build up the desired thickness and then impregnated with rosin oil compound.

Tests of this kind of insulation indicate that owing to characteristics of the rosin oil compound, the critical temperature above which a cable cannot be safely operated is between 70° and 80° C. (158° to 176° F.). Beyond these temperatures the dielectric losses increase very rapidly, causing deterioration of the insulation and eventual breakdown.

FIG. 7,406.—*Cable splicing with Ozite: 7. Filling and completing the joint.* Before pouring in the hot "Ozite", the joint should be slightly tilted so that one end will be slightly higher than the other. As it is necessary to pour the hot insulating compound into the hole at the lower end of the joint, an iron filling cup, one end of which is belled out to make a funnel, should be screwed into the filling hole at the lower end of the joint. This cup or funnel must be long enough to bring its top on a higher level than the overflow hole in the other end of the sleeve when the joint is in the inclined position. The object in placing the joint in this inclined position and pouring the compound into the lower end is to drive all air and moisture upwards in the natural direction and away from the soldered joints, the hand applied insulating tape and tubes. The "Ozite" insulating compound having been heated to the pouring temperature indicated on the label on the container (which temperature should be determined by thermometer) it should be poured slowly and steadily into the filling funnel at the lower end of the lead sleeve. At least two or three gallons of compound should be allowed to flow through the overflow hole or until the portion overflowing is entirely free from bubbles. The joint should not be allowed to settle for at least four or five hours cold, covered with a canvas pad, oil cloth or other protection from cold air, dirt moisture, etc., and to prevent chilling too rapidly. When the joint has cooled sufficiently to prevent cracking of the soldered wipe, the lower end should be raised so that the joint is level, for further settling, and the joint placed in its permanent racked position. The joint having thoroughly settled and cooled, refill it through the same filling hole as before so as to fill up all air spaces due to shrinkage in the original filling. Solder up the filling holes and the joint is completed.

Unsatisfactory Compounds.—Hard or waxy compounds are unsatisfactory fillers as they require very high temperatures keep them in a fluid state so that they will run freely into all rts of the joint, and high temperatures as already explained e to be avoided as far as possible, so as not to endanger the sulation of the cable, particularly the insulation lying directly



FIGS. 7,407 to 7,410.—*"Conducell."* This method of insulating underground cable joints for three conductor cable consists of an outer seamless tube, fig. 7,407, and three similarly formed curved inner separating pieces, fig. 7,408. The several parts when assembled as in fig. 7,409, form three separate cells for the conductors. The insulating parts are interlocked among themselves, and *the conducell* compound is held in a positive relation with reference to the conductors by means of spacing pieces, one being shown in fig. 7,410.

FIG. 7,411.—*Cable splicing with Conducell: I. Removing the lead sheath.* This is done by first marking the lead with a plumber's chipping knife, *care being taken* not to cut through the lead and thus damage the insulation on the cable, and then by cutting the lead lengthwise to a point close to the mark or score previously made. In making this cut, care should be taken to see that the knife will pass between the insulation and the lead sheath and not cut the insulation. The lead sheath having been removed, the end of the lead should be carefully examined and all sharp points or edges removed, if not sufficiently belled in the process of removing the section of the sheath, it may be done by the use of some blunt instrument, or better still, by using a specially formed blunt wedge, preferably made of fibre.

in front of the filling hole, against which the compound is poured at its highest temperature.

Excluding Moisture in Joint Making.—Moisture in the material of the cable itself, or on and in the copper connectors tapes, insulating tubes and lead sleeves must be thoroughly removed and thereafter kept away.

FIG. 7,412.—***Cable splicing with Conducell: II. Removing the paper belt.*** The outer paper belt on each section is removed by first slightly scoring it and then carefully cutting or preferably tearing it off to the scored point; all these precautions are taken so as not to damage the insulation on the conductors.

FIG. 7,413.—***Cable splicing with Conducell: III. Placing in position the outer tube, lead sleeve, spaces, copper connections.*** The conductors are now spread apart slightly so as to make room for the porcelain spacing pieces. To avoid the possible chipping or cracking of these pieces, in bending or forming the conductors while preparing the ends, it is suggested that a forming piece made of fibre or some other such material be provided. The figure shows the lead sleeve and the outer tube of the *Conducell* together with the porcelain spacing pieces. The insulation on each of the conductors of both sections having been securely tied with twine, is cut entirely through to the copper strand, and the lead sleeve placed over one end of the cable, the outer *Conducell* sleeve over the other end. The tapered copper connections are then applied and soldered care being taken to remove all surplus solder and sharp metallic points after the connectors are soldered and the paper insulation on each conductor is then carefully tapered so as to avoid any sharp points or corners.

Moisture may result from many causes such as perspiration on the hands of the jointer, drippings from the wall or roof of the manhole or room in which the joint is made, condensation in a damp atmosphere upon the materials and tools used in jointing and on the cable itself. *Moisture* may be guarded against by having the jointer keep his hands dry, by protecting the joint against drippings, and by warming the tools and materials to a temperature which will prevent condensation.

A convenient method of protecting the tapes or other fibrous insulating materials against moisture in the air is to have a metal box with a cover, filled with transformer oil in which they can be immersed. The small tools may also be immersed in a similar manner. Peculiar local conditions may produce dangers from moisture from sources other than those mentioned. These conditions must be carefully studied and methods provided for guarding against their bad effects.

General Jointing Instructions.—After the interior of the cable and the copper connectors, tapes, tubes, etc., used in making the joints have been exposed to the atmosphere, all operations should be carried through as rapidly as possible consistent with good reliable workmanship.

FIG. 7,414.—***Cable splicing with Conducell: IV.*** *Cell assembly* **held in place by the porcelain spacers and ready for the outer tube to be drawn over.**

A little care in this direction will greatly reduce the opportunity for the entrance of moisture into the joint. When the joints are made on a cable installed directly in a trench, as in the case of armored cable, a large roomy excavation should be made where the joint is to be installed, and the bottom and sides of this excavation covered with a good sized tarpaulin or piece of clean canvas so as to prevent dirt getting on the joint material. Only the most skilled workman can produce reliable joints, particularly where the working voltages are high. Only proper tools, carefully maintained in condition, are permissible and they must be kept clean and dry. Knives or cutters used for cutting the insulation should be kept sharp so that the insulation may be cut readily without tearing.

The removal of the lead sheath must be performed in such a manner as to absolutely prevent any cut or indentation in the insulating belt underneath. Lead cutters or chipping knives should be used so as to cut the lead without producing an indentation in the underlying insulation. The belt insulation must also be carefully removed and cleanly cut so as to avoid any cutting of the insulation on the insulated conductor; and finally, in taking off the insulation from the conductor, strict attention must be paid by the jointer so that no cuts or nicks are made on the bare copper conductor.

FIG. 7,415.—***Cable splicing with Conducell: V. Joint insulation assembled*** and ready for the outer lead sleeve to be slipped over and wiped in the usual manner. ***Filling the joint:*** To insure a completely filled joint, experience has shown that unless facilities are provided for the escape of the gases, which are produced when pouring all compounds, an efficient and homogeneous filling cannot be assured. For this reason the openings through which the joint is filled should be large so as to permit of the compound being readily poured and also to provide means for the free escape of the gases. Further, it is desirable to provide means for raising the level of the compound above the level of the lead sleeve so as to insure that the joint will be completely filled. As a ready means for providing large fillng holes and a higher level for the compound the special tools shown in figs. 7,417 to 7,420 have been devised. ***In filling the joint,*** the compound should be poured into the joint slowly through two openings and at about 140° C. (284° F.). Four or five pourings at intervals of a minute or two each should be made. To positively insure a completely filled joint, experience has shown that facilities must be provided for the escape of the gases which are generated when pouring. For this reason the openings through which the joint is filled should be large so as to permit the compound to be readily poured and also to provide means for the free escape of the gases. Furthermore it is most desirable to provide a means by which to raise the level of the compound above the level of the lead sleeve if a completely filled joint is to be insured.

Solder and insulating compound, as well as the pots and kettles in which they are melted, must be carefully watched and constant attention given to them, so as to avoid the presence and accumulation of dirt and foreign matter of any kind in these very important materials. A very slight quantity of metallic particles or other more or less conducting materials, in the insulating compound which is poured into a joint, will often result in a breakdown.

Making the Joint.—The various operations to be performed in joint making are illustrated in the accompanying series of cuts entitled ***"Cable Splicing with Ozite,"*** these operations being fully described under the cuts, and also in a second series of illustrations entitled ***"Cable Splicing with Conducell,"*** being the instructions given by the manufacturers of insulating compounds known by the trade names "Ozite" and "Conducell."

FIGS. 7,416 to 7,420.—***Cable splicing with Conducell: VI.*** *Boss raised on sleeve and special tools used for this purpose.* By performing two simple operations with these tools, a boss is raised and recessed so as to take the sealing cap and at the same time a 1 inch hole is made for filling. The discs or caps which fit in the recess of the boss being cut or punched from the scrap lead which was removed from the cable end.

CHAPTER 115

Sign Flashers

There are two advantages in favor of using a flasher: 1, it causes the passerby to look at the sign, and 2, reduces the cost of electricity, because the lamps are switched off periodically.

There are numerous kinds of flasher, and they may be classified according to construction of the switch contacts, as:

1. Carbon
2. Brush
3. Knife

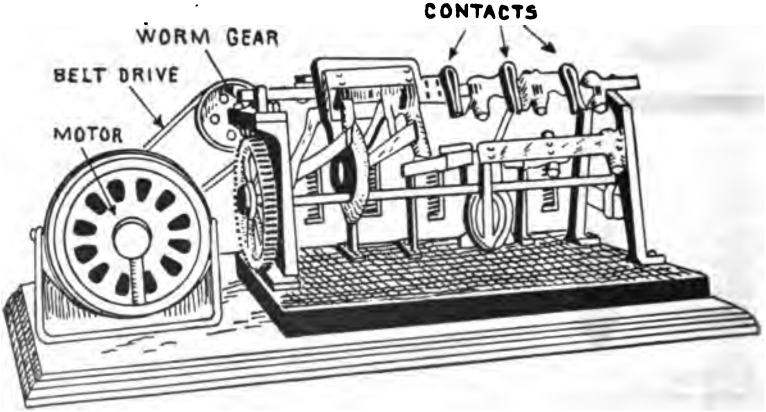
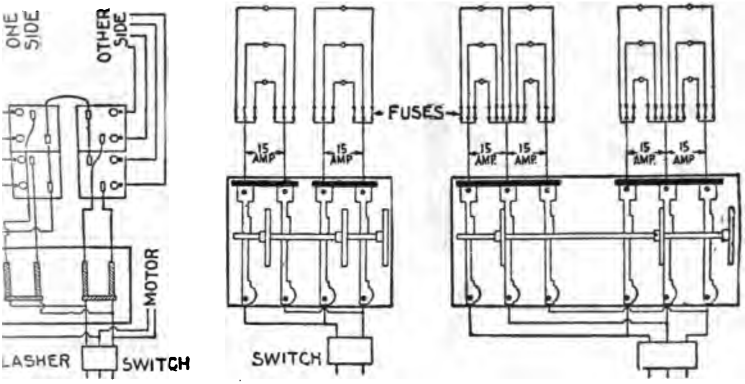


FIG. 7,421.—Dull's carbon type flasher. This is a main line flasher; that is, it is set into the main wires instead of carrying down each circuit. The circuits are opened and closed on carbon contacts, reinforced with standard knife switches. The blades are opened and the current broken by gravity alone. Each switch can be made to hold the lights for any period from 18% to 81% of a revolution of the shaft. They can throw on the circuits progressively or all on and all off together. Again, the circuits may be closed progressively, remain on a few seconds, and then be opened progressively. No circuit or circuits can be closed more than once per revolution.

n, with respect to operation or the electrical effects, they be classified as:

1. Simple on and off
2. High speed
3. Lightning
4. Script
5. Chaser
6. Thermo
7. Carriage
8. Talking
9. Electric.

arbon Flashers.—In this type of flasher, carbon breaks provided, that is, the arc which is formed when the circuit is broken, falls on carbon, while metal switches are provided to carry the load. Thus the carbon gets the arc which prevents the switches burning, while the switches carry the load to prevent the carbons becoming heated and disintegrated. The carbons must



gs. 7,422 to 7,424.—Wiring diagrams for Dull's carbon flashers. Fig. 7,422, usual method of wiring. The load is balanced by running the neutral wire around the machine, to the cut outs, breaking the outside "legs" only of a 220-110 volt sustem. While this method of wiring is entirely feasible, it is no harder on the contacts, and permits the use of a cheaper machine, but it is technically a violation of the underwriters' rules, which say that all circuits of more than 660 watts must be broken double pole. If the load be balanced there would be double pole break at 220 volts, and the lamps would be in series, but if the load be not exactly balanced, there would be single breaking to the extent of the amperes over the average balance. In other words, it is a double break and it is not according to circumstances, and the use of this machine wired as above is a matter that should be taken up with the local inspector before installing. Fig. 7,423, diagram for connecting a straight two wire carbon flasher on a two wire system. Fig. 7,424, diagram for connecting a straight three wire carbon flasher on a three wire system and breaking the neutral.

be adjusted occasionally according to the load they are carrying. Carbon machines are made either double, triple, or series break.

Brush Flashers.—These machines are provided with brush contacts. These bear on cams constituting a drum, and they are usually made of several strips of copper. Brush flashers are generally used for spelling out signs one letter at a time, or work of a similar nature.

Knife Flashers.—This type of construction is cheaper than the carbon type. The switches are of the knife type with metal contacts. One manufacturer states that it is not advisable to build knife flashers for more than 15 amperes per double pole switch, as they cannot be depended upon to break a greater load for any length of time.

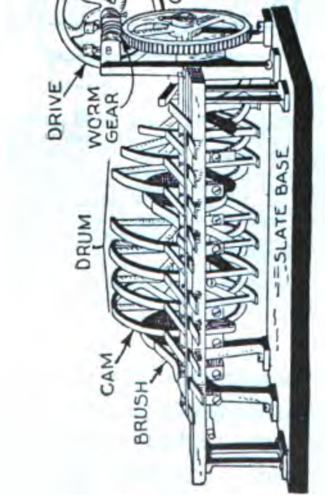


FIG. 7,425.—Reynolds' brush type flasher. The brush type, as its name indicates, is of brush construction and is limited to 5 amperes capacity on each switch. The cams constituting a drum are of heavy construction while the brushes are of fine copper several leaves thick. It is most commonly used for spelling signs, that is, for letter by letter flashing.

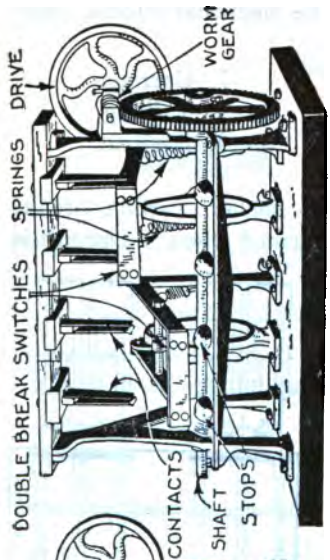


FIG. 7,426.—Reynolds' knife type of flasher with metal contacts. The construction is cheaper than the carbon type. It is mounted on a slate base, and is heavily built throughout. The switches are designed for 15 amperes capacity double break.

Simple On and Off Flashers.—These are used for flashing whole signs or heavy loads on and off. A flasher of this type

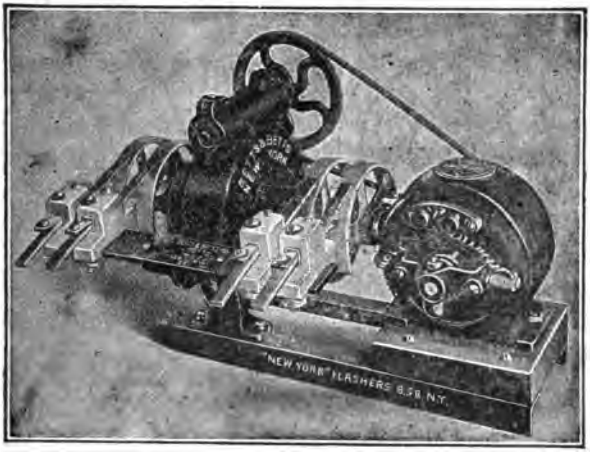


FIG. 7,427.—Simple on and off double pole flasher for "all on" or "all off" sign flashing. The machine is furnished with any number of switches ranging from 5 amperes up.

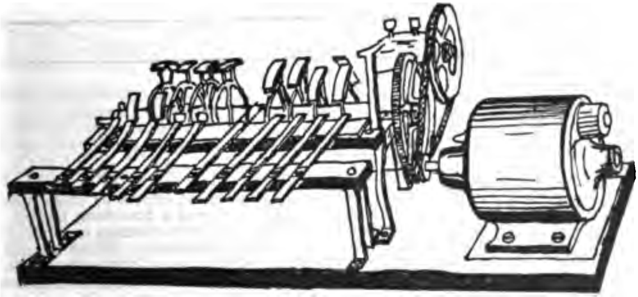
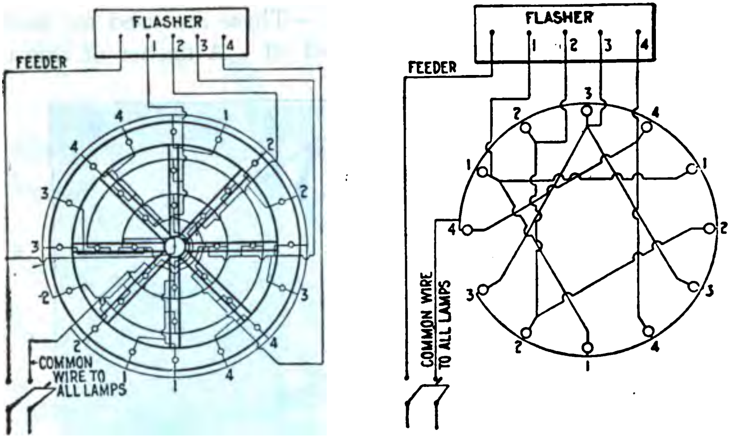


FIG. 7,428.—Dull's high speed flasher. It is mounted on a slate base 12 inches wide, the length being governed by the size of the machine. Motion is given to the rotary switches through worm and belt gearing. Iron cams are used, the current being taken therefrom by six-leaf brushes, provided with stiffeners. The wiring for the machine is simple; 4 *c.p.* lamps can be run on one wire. A border or ornament containing 160 lamps requires 12 wires between the sign and flasher. The flasher is made in 4 switch sizes only, viz.: No. 4, 8, 12, 16, etc. This is due to the fact that there are three parts of light to one of darkness.



Figs. 7,429 and 7,430.—Wiring diagrams for high speeds. Where a high speed flasher is used on a spoked wheel containing more lamps in the rim than the number of spokes, the extra rim lamps must be connected to the spoke circuits, so that the number of rim circuits will equal the number of spokes; otherwise, the rim will appear to travel slower than the spokes.

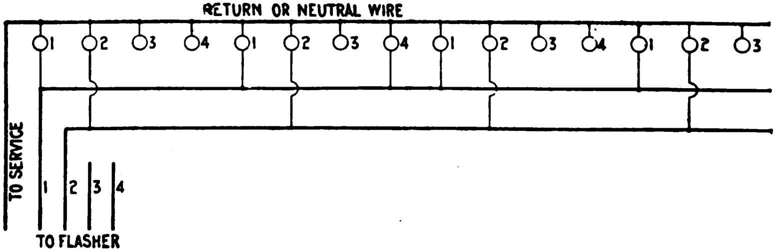
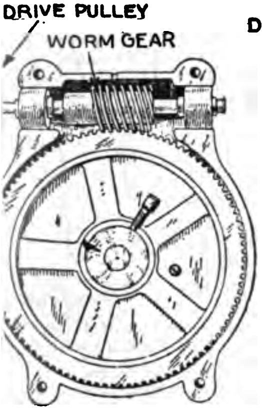
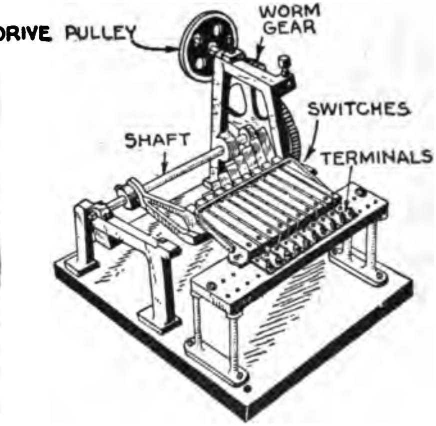


Fig. 7,431.—Diagram showing method of wiring for high speed effects on single lines. This wiring diagram would be carried out the same in the case of a travelling border, whether it be straight or otherwise. In the case of a fountain, begin numbering each stream at the bottom and carry out the same scheme to the end of that stream. When several streams are parallel, all the lamps may be connected in a row the same as though they were an individual lamp. Care should be taken not to get more than twenty No. 1 lamps on a circuit. Among the effects that may be obtained are a revolving wheel, a column of flame, and a straight travelling border with part of the No. 1 lamps from each effect to the same No. 1 wire, carry it back to any No. 1 switch on the machine, and the effect will come out right. *For instance*, in a flame effect with sixteen No. 1 lamps, four No. 1 lamps could be taken in the straight border, and put on the same wire, and the effect would come out right. The spacings for high speed effects vary, according to the size of the sign. Travelling borders around an ordinary sign 3×10 feet should have their lamps spaced about six inches apart. In a fountain fifteen feet high, the lamps should be spaced about nine inches apart.

;s essentially of a revolving double pole switch with re- ; gear and connection to a small motor for operating same. machine may have only one switch or any number of es. The connection to motor may be by belt or chain, motor may be directly connected to the worm gear.

h Speed Flashers.—Machines of this type are used for what is generally known as *high speed effects*, such as





32.—Sign flasher transmission gearing. The view shows an oil tight gear case with plate removed. The gears are equipped with ball bearings and run in graphite grease. ɜans of the worm gear the large speed reduction necessary between the flasher shaft otor is obtained without a multiplicity of gear wheels.

33.—Dull's lightning type flasher for giving the appearance of a streak of lightning across a display.

ɜins, water, steam, smoke and fire effects, whirling borders, ing wheels and work of a similar nature.

htning Flashers.—These machines are for giving the rance of a streak of lightning going across a display. There y little expense attached to their operation, because not more than two-thirds of the lamps are turned on at one time, and this number for only about one-sixth of the time, as compared with the sign burning steadily.

Lightning strokes can be utilized in various ways, either alone or with other advertising pieces. Alone they can be placed along a cornice, across the front of a building, up and down the corners leading to a doorway, etc. They can be used in the center of a sign with letters above and below. In this case, it is best to alternate the stroke with the letters, that is, flash the wording on and then off. As soon as it goes out, the stroke flies across in the darkness. then the wording comes up again, say six times a minute.

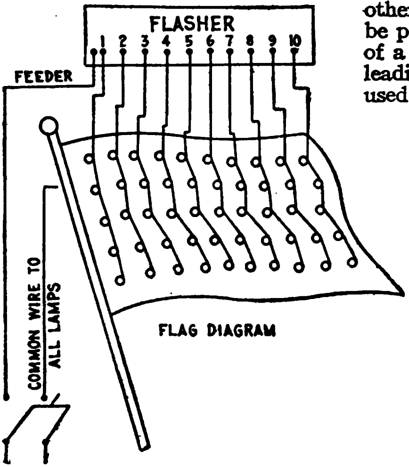


Fig. 7,434.—Wiring diagram for flags. These may be wired for high speed flashers by gradually increasing the lamp centers between the vertical rows from the flag staff to the end.

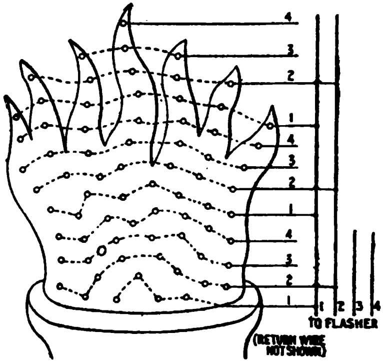
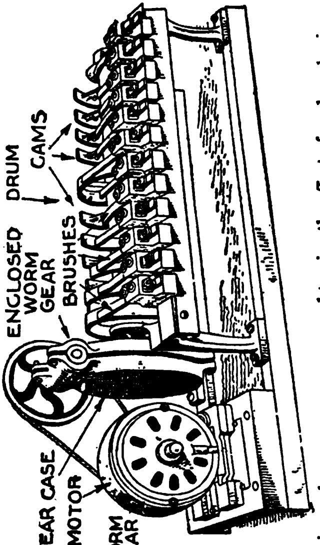


Fig. 7,435.—Method of wiring for a torch. This wiring diagram gives the correct method of wiring smoke, flames, steam, and water effects. It may be the flame in the top of a torch as here shown, liquid pouring out of a bottle, smoke rising from a cigar, or dust behind an automobile wheel. The only difference being in the direction each goes and the outline of the bank of lamps. Wire the lamps in unequal lines across; avoid any straight lines, because it gives a mechanical effect which is not natural. If the effect be to rise, mark the lower row No. 1, the next row above No. 2, etc. Pick up all the No. 1 rows until there are twenty lamps, and attach them to No. 1 wire which will go back to any No. 1 switch on the machine. Do the same with the other numbers. Do not overload line as this will decrease the life of the contacts.

In the case of a sign already in use, on the front of a building or over the sidewalk, a stroke can be placed leading to the sign from any point above. The flash goes down and when it hits the sign the latter lights up, holds a few seconds, goes out, and repeats about four times a minute.

Lightning flashes are not usually constructed for heavy loads, the one shown in fig. 7,433 being designed for two amperes.



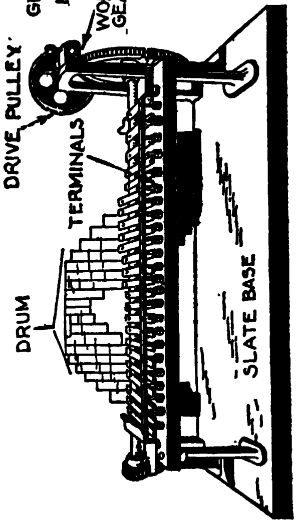


FIG. 7,436.—Reynolds' chaser type of flasher, as used on electric signs whose amps are arranged to give the effect of snakes chasing each other around the border of a sign.

FIG. 7,437.—Betts' script breaker (brush type). This flasher is especially designed for spelling out signs one letter at a time, or work of a similar nature. The brushes for the revolving cam contacts are of copper, several leaves thick and provided with special brush holder to prevent loose contact and abnormal burning.

Chaser Flashers.—This class of flasher is designed to operate signs whose lamps are arranged to give the effect of snakes chasing each other around the border.

This peculiar effect is produced by having a separate wire and a separate switch on the flasher for each two lamps in the border.

The mechanism so arranged that when the tenth lamp is lighted (assuming the snake to be ten lamps long) the first lamp goes out.

When the eleventh is lighted, the second goes out, etc., progressing in this way around the entire border.

In operation, the lamps are turned on and off so rapidly that it produces the effect of snakes.

It is not advisable to build these signs small nor cheaply, as in order to produce the desired effect, the curved path taken by the snake should cover at least 10 inches width, which would mean a total of 20 inches lateral space for the snake in addition to the electric letters in the center. In order to get the proper effect, the sign should be at least ten feet long.

Chaser signs are expensive because of the care required in their construction, large amount of wiring necessary and large flasher required.

There are several ways of operating these signs. The border is generally working continuously, while the center can be flashed or not, as may be desired. Flashing the wording reduces the current expense, which offsets in a measure the extra cost of the sign. The border, although working continuously consumes very little current.

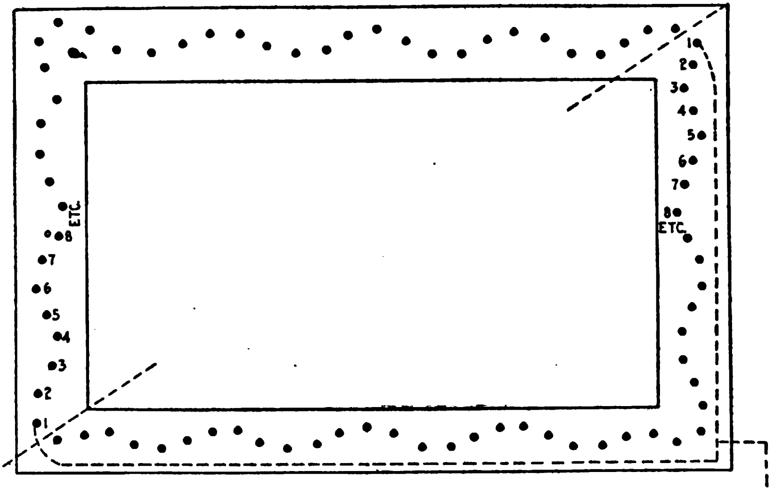


FIG. 7,438.—Chaser wiring diagram for two snakes. Draw a line diagonally through the sign (as shown in dotted line) so that one-half the total lamps will be on either side. Begin to number from one consecutively to the line. Over the line commence again at 1, and number as before. For three snakes, divide total lamps into three parts and number as before *In each case,* connect all lamps of the same number to the same wire whether the sign be single or double face. The wire containing all the No. 1, lamps goes to the No. 1 switch on the flasher, and the remaining sets are connected similarly.

Script Breakers.—Flashers of this type are used for breaking large script signs, one socket at a time; that is, each lamp is lighted one after another until all are on. After a few seconds they all go out simultaneously and repeat. This gives the appearance of an invisible hand, writing the name in the darkness, and is very effective. The result can be accomplished only with script, and to get the proper effect the smallest letter in a sign should be not less than two feet high; the larger the letter, the better the effect.

Script breakers are also used for fancy border signs of other kinds, and in order to produce these results, it is necessary that

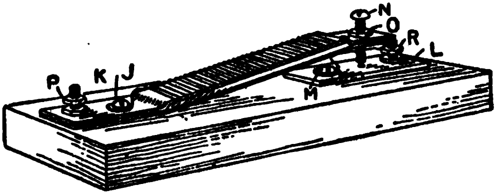


Fig. 7,439.—Thermo flasher. ***It consists of*** two metal strips, one of brass and the other of iron, about $5'' \times \frac{1}{2}'' \times \frac{1}{32}''$ each. The brass strip is provided with a winding of fine wire over asbestos and the two strips are connected to the base as shown. One terminal of the winding is connected to J, and the other end to M. At the end of the strips is a small contact screw N, with locknut O, and below is a contact plate L, fastened to the base and terminal post R. The flasher is connected at P and R, in series with the lamp it is to flash, and N, adjusted so that it clears the plate about $\frac{1}{32}$ inch when there is no current flowing in the winding. When the switch is turned on there will be a current through the lamp and winding in series. The brass strip will be heated more than the iron and it will expand more, thus forcing the point of the screw N, down upon the brass plate, which will result in the winding about the brass strip being shorted and the full voltage will be impressed upon the lamp, and it will burn at normal candle power. When the coil is shorted there will of course be no current in its winding and the brass strip will cool down, the screw N, will finally be drawn away from contact with the brass plate, and the winding again connected in series with the lamp. The lamp will apparently go out when the winding is in series with it, as the total resistance of the lamp and winding combined will not permit sufficient current to pass through the lamp to make its filament glow. The time the lamp is on and off may be varied to a certain extent by adjusting the screw N.

Fig. 7,440.—Thermal flasher. This simple flasher consists of a brass strip fixed at each end to a porcelain base and slightly arched upwards. The amount of this arching, however, is much less than is shown in the figure. The center of the strip carries a platinum contact on its upper surface, and opposite this is a platinum tipped contact screw which is carried in a brass angle piece fixed to the base. One terminal is fitted on one end of the strip, and the other is connected, through the angle piece, with the contact screw. The strip is wound from end to end with an insulated resistance wire, one end of this being soldered to the strip, and the other connected to the right hand terminal. When this device is switched into circuit with the lamps, the current first flows through the resistance, which cuts it down so much that the lamps are not visibly affected. The heat generated in the resistance causes the strip to curve still more, till at length contact is made, the resistance short circuited, and the lamps lighted.

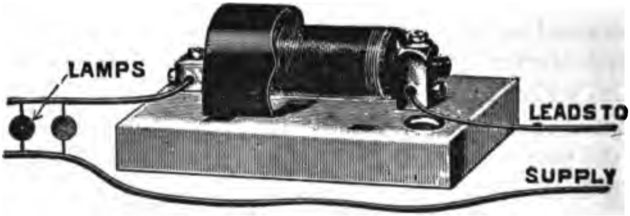


FIG. 7,441.—General Electric thermal flasher. ***It consists of*** a small brass cylinder fixed at its left hand end to one of the terminal blocks. The junction between the two is hidden by a portion of the cover, which is shown broken away. The right hand end of the cylinder carries a cross piece bearing a platinum contact; and opposite this is the platinum tip of a contact screw carried in the other terminal block. The cylinder is wound with a heating coil of manganin resistance wire, one end being soldered to the cylinder and the other to the right hand terminal. When the current is switched on, the coil and the cylinder warm up and the cylinder elongates sufficiently to make contact and light the lamps. The coil being then short circuited, it and the cylinder cool down and contact is broken, whereupon the coil is put in circuit once more, and warms up again. In some sizes of this flasher, the contact gap is shunted by a small condenser fitted beneath the base. This helps to eliminate the sparking at the contacts.

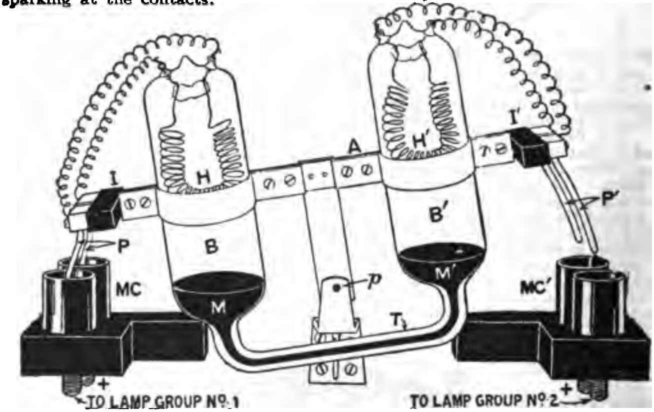
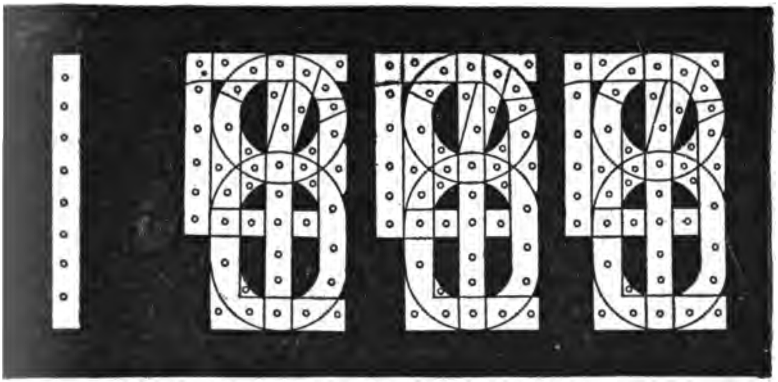
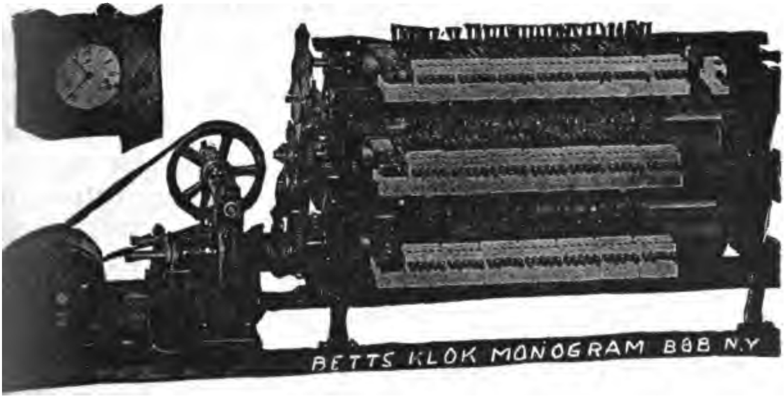


FIG. 7,442.—Two way thermal flasher. The moving portion consists of a rocking arm *A*, pivoted at *p*, and carrying two sealed bulbs, *B,B'*, whose bottoms are united by the tube *T*. Inside there is sufficient mercury *M*, to fill *T*, and the bottoms of the bulbs, the remainder containing air. At each end of *A*, is fixed an insulating block *I,I'*, carrying two contact prongs *P* and *P'*, which are connected together at the top through heater wires *H,H'*, sealed in the bulbs *B* and *B'*, respectively. *MC, MC'*, are pairs of mercury cups, the further one of each pair whose stud is marked +, being connected together to the positive pole of the circuit, while the front ones are joined up to the respective groups of lamps. ***In operation,*** if the apparatus be in the position illustrated, when the circuit is closed at the time *P*, is down, lamp group No. 1 will light up the current passing through *H*, on its way. The air in *B*, consequently expands, and gradually forces the mercury down in *B*, along *T*, and up in B'. The arm *A*, will gradually become horizontal, and will then over-balance, *P*, being withdrawn from *MC*, and *P'*, dipped into *MC'*. Lamp group No. 1 will consequently be extinguished and lamp group No. 2 lighted; *H*, will cool down, and *H'*, will warm up. Thus, in due course, *A*, will be titled the other way again.



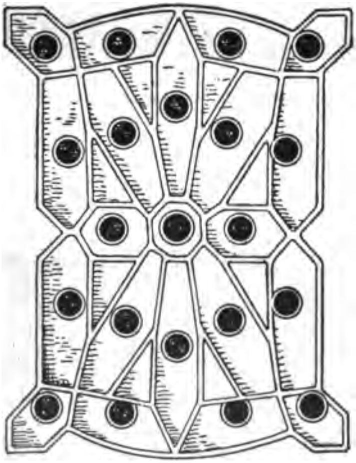
IG. 7,443.—**Clock monogram or electric sign clock, operated by the mechanism shown in fig. 7,444.**



IG. 7,444.—**Betts' clock mechanism for operating electric monogram time flasher. The secondary mechanism consists of a three cylinder flasher and is controlled by a master clock which transmits an electric impulse through a relay switch one each minute. This flashes the time in figures on the monogram, viz.: 11.45, 11.46, 11.47, 11.48, etc. The first monogram to the left consists simply of a vertical row of lights representing the figure one. Each of the other monograms of metal compartments so arranged that any figure may be produced by lighting the proper combination of lamps.**

the return wire of every lamp go back to the flashers independently, which means a wire for each lamp.

Thermo Flashers.—These flashers work on the thermo or heat expansion principle, that is, the movement of the contact points of the flasher necessary to open and close the circuit is obtained automatically by the alternate heating and cooling of the metal of the flasher, which causes it to expand and contract.



Carriage Calls.—These are used to avoid the confusion and noise at the theatre, club house or department store when vehicles are called by a megaphone. The flashing of a number is controlled by a keyboard or switch which may be placed in any convenient location. When the switch and call are connected together, any numeral may be flashed by pressing the corresponding key. The numeral automatically remains lighted until the releasing button is pressed.

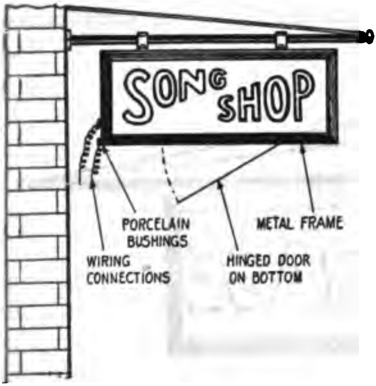
FIG. 7,445.—Monogram or unit for carriage call or talking sign. It consists of a collection of metal compartments each arranged to receive an incandescent lamp. The purpose of these compartments is to confine the light to a certain space, thus forming a clearly defined number or letter which can be read from a distance.

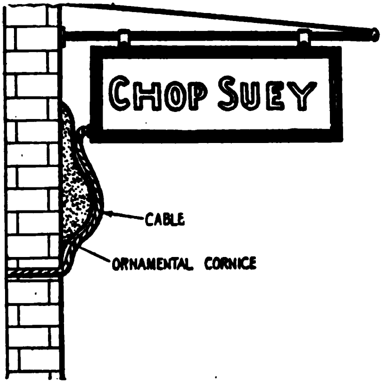
Constant Lighting Signs.—These signs, as shown in fig. 7,446, are usually placed over door of stores. The frames of all signs should be of metal, usually they are made on a frame of angle iron and covered over with sheet iron.

The use of metal is required by ordinances in all large cities.

Sign Wiring.—These are usually placed on separate circuits with a double pole if a 2 wire, and a triple pole switch, if three wire, to control sign.

Usually conduit or lead covered B.X. cable is used to connect the sign to the service mains. Fig. 7,447, shows how a difficult bend around a building cornice is made with Greenfield cable with lead covered wires inside.





G. 7,446.—Small constant lighting sign. A one inch pipe supports the sign. This pipe is set into a hole drilled into the building wall 6 in. or more, the size of the pipe depending upon the size of the sign, usually a 1 in. or 1¼ in. galvanized iron water pipe is used, an ornament or cap is placed over the end of the pipe to give it a finished appearance and to keep out water from the pipe. A stranded galvanized guy wire is attached to the end of the pipe to keep the weight of the sign, from the pipe also to keep the sign from swinging in all directions. Usually a turn buckle is used to adjust the tension on the guy wire. Note on all kinds of outside signs it is advisable to use none but galvanized fittings as fittings are always exposed to the weather and soon rust. The height of the bottom of the sign from the sidewalk is subject to city ordinances. These should be consulted before a sign is erected.

IG. 7,447.—Method of wiring the sign with lead covered B.X. cable or Greenfield cable with lead covered wires inside.

The wires are usually brought out from the frame of the sign in porcelain bushings, but on the larger types the conduit is usually brought directly into the sign. Sheet metal used in electric signs must not be less than No. 28 U. S. metal gauge. All metal must be galvanized, enameled or painted over three times with black aphaltum or tar paint to prevent rust. Only rubber covered wire is permissible on the inside of the sign. All wires must be soldered to the terminals of all receptacles. After the wires have been soldered to the terminals they should be painted over (the terminals) with black asphaltum or any other good insulating paint to prevent rust.

Special receptacles must be used for sign work and must be so installed so as to prevent them turning. When wiring the interior of signs great care should be taken to see that the wires are at least one inch from the entire surface wired over. Where the receptacles are placed over 4½ ft. apart they must be supported on cleats or knobs, where the receptacles are placed not over one foot apart and wires are secured to these receptacles, a support every 4½ ft. will not be required as above.

Not over 1,320 watts lamp load should be placed on any circuit.

Interior Wiring of Signs.—Constant burning signs are connected in parallel for small signs and in series parallel for large signs.

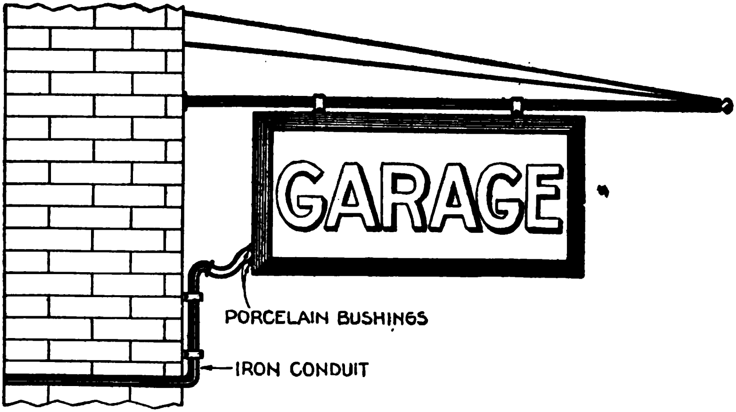
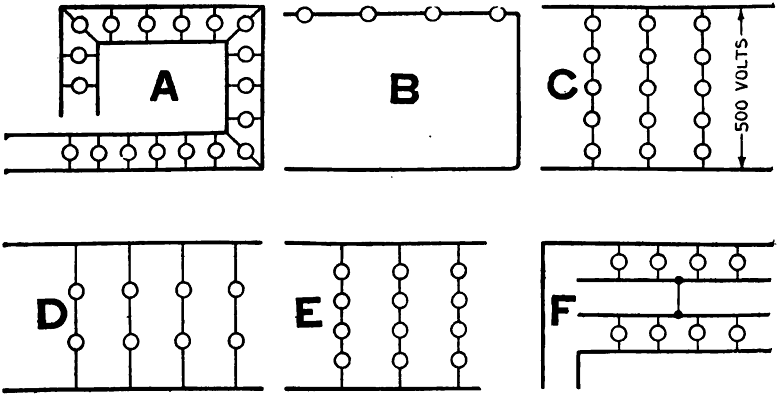


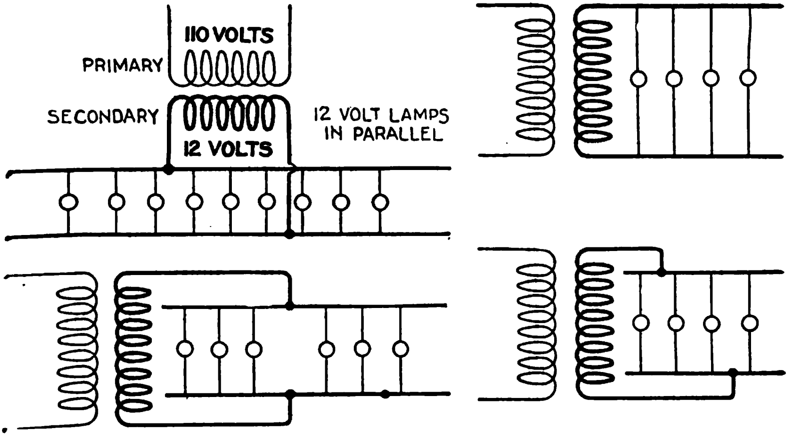
FIG. 7,448.—Method of wiring the sign with iron conduit.

Where 500 volt service is only obtained, the lamps should be wired in series 5—100 volt lamps of the same size as in fig. 7,451(C). Where it is desired to use more than 5 lights on 500 volt sign, they are connected in parallel series. Where only 220 volts 2 wire is available, 2-110 volts lamps may be placed in series, or 4-55 volt lamps placed in series. See fig. 5,452(D) and 5,453(E) or fig. 5,454(F) where lamps are wired parallel series.

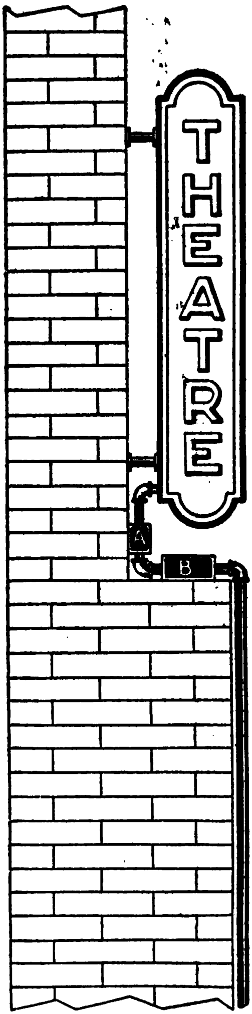
Where *d.c.* service is only available the lamps are wired in series or series parallel, 2 lamps to a series the same number of lamps must be in each parallel, otherwise they will burn dimmer or brighter than the others. Low voltage are used where a great number of lamps are used on a sign; these are placed in series of 10-12 volt lamps being used on 120 volt systems. The various wiring connections for signs are shown in figs. 7,455 to 7,458.



Figs. 7,449 to 7,454.—Various wiring connections for signs. Fig. **A**, parallel connection for a small sign; fig. **B**, 500 volt connection—5 one hundred volt lamps connected in series; fig. **C**, five 100 volt lamps; fig. **D**, two 110 volt lamps in series on 220 volts; fig. **E**, four 55 watt lamps in series on 220 volt; fig. **F**, ten 110 volt lamps on 220 volt circuit.



Figs. 7,455 to 7,458.—Various wiring connections for signs using transformers.



The principal objection to the use of the series parallel system is that if one lamp of a series burn out, the rest of the lamps do not burn as shown in fig. 7,453, where one letter of a sign forms a series, thus if one lamp should burn out the whole letter is dark.

When signs are to be supplied by *a.c.* current they should be wired in multiple using low voltage lamps (preferably 12 volt) in connection with a low voltage sign lighting transformer as shown in fig. 7,455.

The run from the transformer to the sign should be as short as possible. Most sign makers fasten the transformer on the bottom of the sign. The reason for this is to reduce the drop of voltage due to resistance of the wires having such an effect on this low voltage (12 volts). This is not noticeable on higher voltages but on 12 volts much difference can be noticed. Fig. 7,449 shows the improper way to connect a parallel as the first lamp will burn brighter than the last lamp due to the drop of voltage.

The parallel series connection is used on large signs without transformers such as on *d.c.* or *a.c.* where no transformer is desired. The only objection to this form of connection is that if one lamp will burn out it reduces the resistance causing the rest of the lamps in this multiple to burn brighter while the rest of the multiples will burn dim. To prevent this no less than 10 lamps should be placed in a parallel, so that very little difference will be noticed. Any number of lamps may be used in a multiple but each multiple must have the same amount of lamps and their power must not be any more than 10 multiples on a 120 volt system, using 12 volt lamps.

FIG. 7,459.—Flashing theatre sign and method of placing transformer and flasher near sign. A, transformer; B, metal cabinet containing motor flasher.

CHAPTER 116

Electric Lighting

Broadly speaking, electric lighting is a large subject, covering several branches of engineering, but the particular phase of the subject here to be considered is *the art of producing artificial illumination by means of electrical energy.* The items to be considered then are

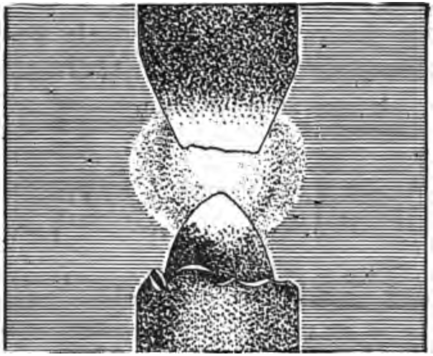


FIG. 7,460.—The electric arc. View of the two carbon electrodes showing the pointed end of the negative electrode and the hollow formation or "crater" on the end of the positive electrode.

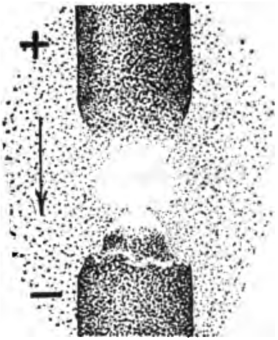


FIG. 7,461.—General appearance of an electric arc between two carbon electrodes when maintained by direct current passing from the upper carbon to the lower carbon, indicated by the arrow and signs. Most of the light issues from the tip of the positive carbon, and this portion is known as the *crater*, the temperature of which is from 5,432° to 6,332° Fahr., giving 80 to 85% of the total light. The positive carbon is consumed about twice as fast as the negative. If *a.c.* be used, no crater is formed, both carbons emitting the same amount of light and being consumed at about the same rate.

Arc Lamps;
Incandescent lamps;
Vacuum tube lamps;
Illumination.

The Electric Arc.—If two carbon rods be connected electrically to the terminals of a dynamo and the free ends of the rods brought together, the current from the dynamo will flow through the closed circuit thus established. Now, if the carbon rods be drawn apart so as to form a slight break of one-eighth of an inch or less in the circuit, *the current will jump from one rod to the other and the arc thus formed will be* ***maintained*** *across the gap in the circuit, by the conductivity of a bridge of* ***carbon vapor*** *allowing a continuance of current.*

Either *d.c.* or *a.c.* may be used, but the two carbon rods must be first brought into contact with each other and then separated in order to establish the arc, otherwise a pressure of several thousand volts would be required to make the current jump the air gap.

The arc usually consumes 10 amperes at 45 volts or 450 watts; its temperature is about 6,300° Fahr.

Carbons.—There are two kinds of carbons: 1, solid carbons, and 2, cored carbons.

The object of the core is to reduce the voltage required to maintain the arc by lowering the boiling point or the vaporizing temperature of the crater of the positive carbon.

Any size carbon may be used, but the sizes usually employed have an average resistance of .15 ohm per foot.

According to manufacture, carbons are classed as *moulded* or *forced*, the moulded carbons being used for constant current series circuits where cost is of importance.

Carbon Feed Mechanism.—There are two classes of carbon feed: 1, manually operated, and 2, automatic.

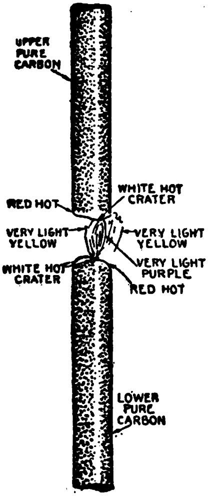
The first is used in the case of stereopticons, but for ordinary illumination the control must be automatic. These may be classed as: 1, slug feed; 2, shunt feed; 3, differential feed. The slug feed is used as constant pressure circuit only.

Cut Out and Substitutional Resistance.—In a series arc light circuit, it must be evident, that if anything happen to one lamp the entire system will be affected, unless *some provision be made to short circuit the disabled lamp and at the same time introduce into the circuit resistance of the same value as that of the lamp.* The necessary mechanism is usually a part of the lamp.

The Arc.—There are various kinds of arc and they may be classed

1. With respect to the placement of the arc, as
   - *a.* Open;
   - *b.* Semi-enclosed (*intensified arc*);
   - *c.* Enclosed.
2. With respect to the arc, as
   - *a.* Luminous;
   - *b.* Flaming.
3. With respect to the current, as
   - *a.* Direct current;
   - *b.* Alternating current.

The enclosed arc is the result of various attempts to reduce the rapid consumption of the carbons in the case of open arc, by enclosing the arc in a globe bulb of refractory glass protected by a large outer globe.



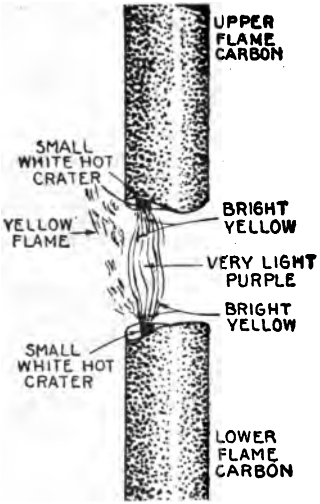
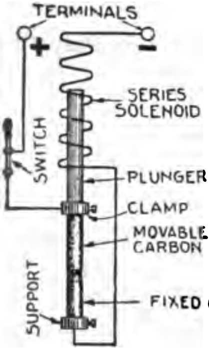


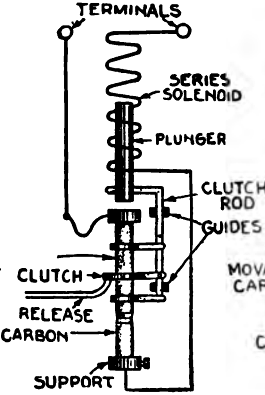
FIG. 7,462.—Enclosed carbon alternating current arc. Electrode life 100–125 hours; arc about ⅜ inch long and requires 70 to 80 volts; electrode ends nearly flat. There is drawn no marked crater and less light is produced per watt.

FIG. 7,463.—Long burning flame arc. Electrode life 100 or more hours. Electrodes are about ⅞ inch diameter by 14″ long, arc placed within a globe which restores the arc supply. The unused portion of the upper electrode is used for trimming the lower. 10 ampere arcs with "white" electrodes consume .74 watts per mean spherical candle power.

The semi-enclosed arc has a fairly tight fitting globe of moderate dimensions, the carbons used are of small diameter. Semi-enclosed arcs consume carbons much slower than open arcs and take about 75 volts at the arc.

The *a.c.* arc is not a continuous flame like the *d.c.* arc, but is lighted and extinguished at every reversal of the current, so rapidly as not to be noticed by the ordinary eye.





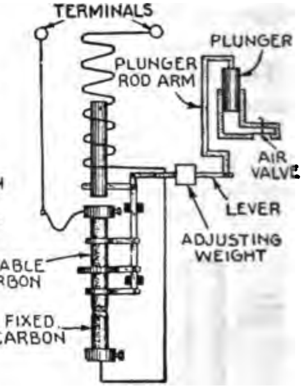


FIG. 7,464.—Elementary series control arc lamp. ***In operation,*** gravity tends to keep the carbons in contact while the pull of the solenoid tends to keep them apart. Equilibrium is established between these two opposing forces because of the weakening of the solenoid pull due to increasing resistance interposed as the upper carbon is drawn away from the lower or fixed carbon. The weight of the carbon and plunger, or the ampere turns on the solenoid must be so adjusted that an arc of proper length is established when equilibrium is reached.

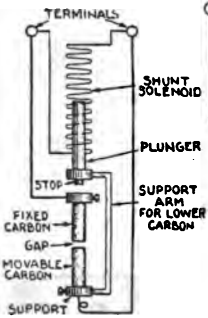
FIG. 7,465.—Elementary series control lamp with ring clutch rod feed. ***In operation,*** when the current is turned on, the plunger pulls up the clutch rod and the angular position assumed by the clutch causes it to grip the movable carbon separating it from contact with the fixed carbon. As the carbon is consumed the arc becomes lengthened which increases the resistance, cutting down the current and weakening the solenoid allowing the plunger to move downward. During the movement, when the end of the clutch strikes the release, its angular position is changed, causing it to release the carbon and allowing it to "feed" or fall thus reducing the arc. Since the resistance decreases as the arc length is reduced a stronger pull is exerted by the solenoid which overcomes the weight of the parts and raises the clutch rod freeing the clutch from the release and causing it to again grip the movable carbon pulling it away from the fixed carbon and restoring the arc length to normal.

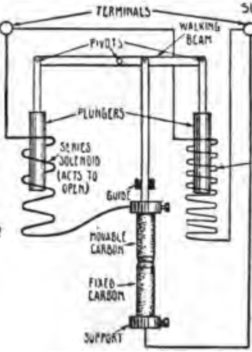
FIG. 7,466.—Elementary series control lamp showing dash pot and adjusting weight. ***In operation,*** before the carbons get hot, the sudden motion of the magnet draws them apart, breaking the circuit, and they fall together again, the result being a vibrating action exactly like that of a vibrating bell. To secure equilibrium, it is necessary to retard the upward motion of the movable carbon, and this is what the dash pot accomplishes. Thus as the solenoid separates the carbons, the dash pot plunger which is connected to the adjusting weight lever, moves downward, compassing the air which slowly leaks past the plunger, thus retarding the upward movement of the carbon. The function of the air valve is to admit air on the up stroke of the dash pot plunger, otherwise a partial vacuum would be formed which would retard the upward movement.

Series Arc Lamps.—Lamps connected in series are in satisfactory service both on *d.c.* and *a.c.* circuits.

In a series system evidently all the lamps must be designed to work with the same amount of current, and accordingly since the current is said to be "constant," meaning that the same amount at any given time is flowing through all the lamps, series systems are often called constant current systems, though ill advisedly so.

This so called constant current is obtained by designing the dynamo so





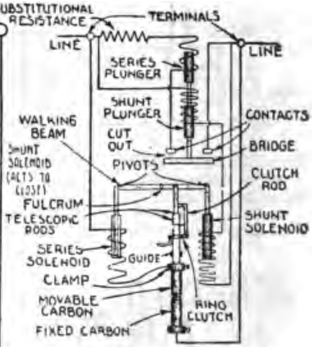


FIG. 7,467.—Elementary shunt control lamp. ***In operation,*** most of the current flows through the heavy wire connected in series with the carbon, the balance flowing through the shunt solenoid. Normally, when the current is off, gravity causes the plunger to drop against the stop, thus separating the carbons. When current is turned on it flows through the shunt solenoid and pulls up the plunger, and with it the lower carbon opposed by gravity. On contact, the current is short circuited around the shunt coil, the solenoid, thus weakened, allowing the plunger to recede and break contact of the carbons lengthening the gap until equilibrium is established.

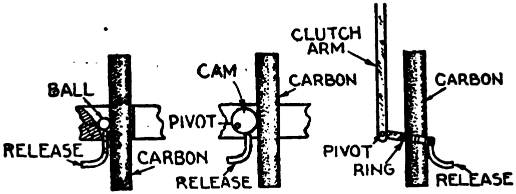
FIG. 7,468.—Elementary differential control lamp. ***In operation,*** the differential action is the resultant due to the difference between the force due to the series solenoid, tending to separate the carbons, and forces due to gravity and to the shunt solenoid tending to keep the carbon in contact.

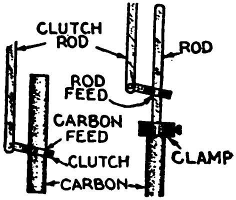
FIG. 7,469.—Elementary differential control lamp having ring clutch rod feed and automatic cut out and substitutional resistance. ***In operation,*** under normal conditions the current flowing through the shunt cut out winding is quite insufficient to raise the bridge against gravity, but if the resistance of the main circuit through the carbon suddenly increase beyond proper limit, the current through the shunt cut out winding will increase considerably raising the bridge and short circuiting the lamp. The entire line current will now flow through the series cut out winding causing the bridge to be held firmly against the contacts, and since this current must pass through the substitutional resistance, which in value is the same as the normal resistance of the lamp, it must be evident that the current and pressure in the external circuit will not be changed when the lamp is cut out in this manner.

that it will automatically generate a nearly constant current. Regulating devices are provided which either shift the brushes or vary the strength of the field, or both, to keep the current at a constant value.

In addition to these special regulators, such machines are so designed that they have considerable self-induction and resistance, all of which tends to prevent the current rising to a high value, even if the machine be short circuited.

Parallel Arc Lamps.—For electrically lighting large interiors





Figs. 7,470 to 7,472.—Various forms of clutch for feeding the carbon to compensate for its consumption. Fig. 7,470, ball clutch; fig. 7,471, cam clutch; fig. 7,472, ring clutch.

Figs. 7,473 and 7,474.—Carbon and rod feed. In the first instance the clutch operates the carbon direct, as in fig. 7,473. Sometimes the carbon is secured by a clamp at the end of a rod, the clutch operating the carbon through contact with the rod as in fig. 7,474.

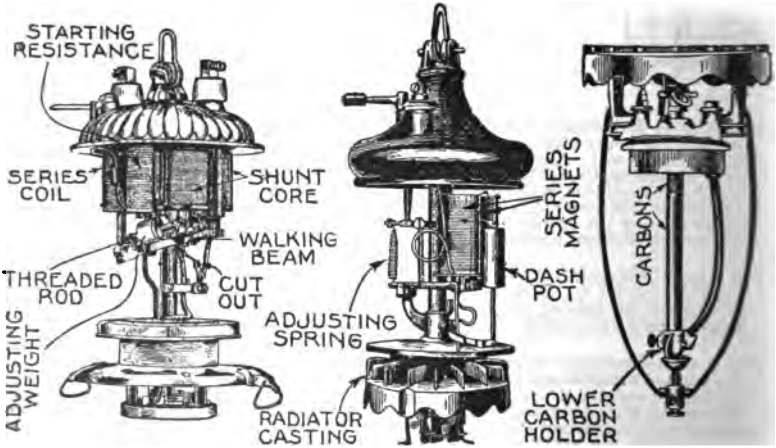
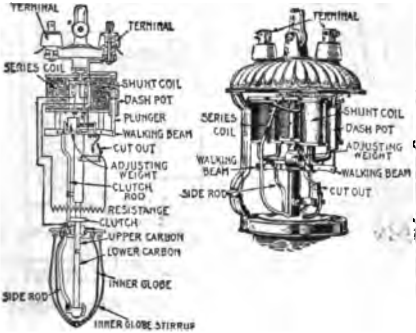


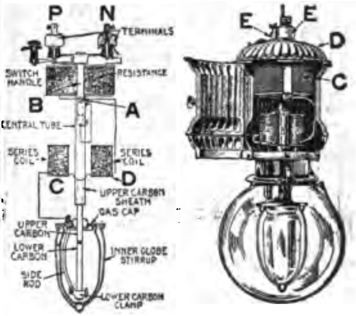
Fig. 7,475.—Westinghouse series circuit, differential control *a.c.* arc lamp.

Figs. 7,476 and 7,477.—Fort Wayne (special transformer type) parallel circuit series, spring control, *a.c.* enclosed arc lamp designed especially for service with small transformer.

the enclosed arc lamp is very often the most satisfactory method on account of its acknowledged ability *to produce a light that approaches more nearly to natural light than most other artificial illuminants*.

It is essential, therefore, that the arc lamp be designed to operate satisfactorily on the same circuits with incandescent lamps. This means that the arc lamp must be so designed that it will work on a 110 or 220 volt circuit parallel connection. Accordingly the *d.c.* lamp must include a suitable resistance because the working pressure at the arc (75 to 80 volts) is less than the pressure across the mains (110 volts). For 220 volt circuits additional resistance is necessary.





Figs. 7,478 and 7,479.—Westinghouse parallel circuit, series control *d.c.* enclosed arc lamp.

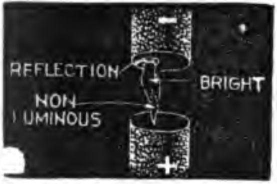
Figs. 7,480 and 7,481.—Westinghouse series parallel circuit differential control *d.c.* enclosed arc lamp. *In operation,* if for any cause, the arc become extinguished, the increased current passing through the shunt coils will cause them to raise their end of the rocker arm to its maximum height, thereby closing the cut out contacts. This action in turn closes a circuit through a resistance equal to that of the lamp when it is in operation and throws its mechanism out of circuit without disturbing the other lamps in the circuit.

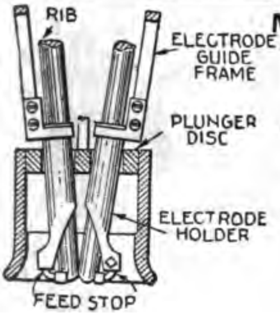
Series Parallel Arc Lamps.—In many localities, the only source of current for illuminating purposes is for *d.c.* power circuits nominally of 220 or 550 volts to which the ordinary forms of direct current lamp are not adapted.

This condition is often encountered in factories, foundries, mills, etc., where power is usually supplied at 220-250 volts, and the small number of lamp does not warrant the installation of separate lighting circuits.

The electrical illumination of street railway tracks, race tracks, pleasure resorts, etc., is often dependent upon a 550 volt trolley circuit.

It is to meet such conditions that lamps have been designed for series parallel working and known as series parallel lamps. Series parallel lamps are usually designed to operate two in series across 220 or 250 volt circuits, or five in series across 500 or 550 volt circuits.





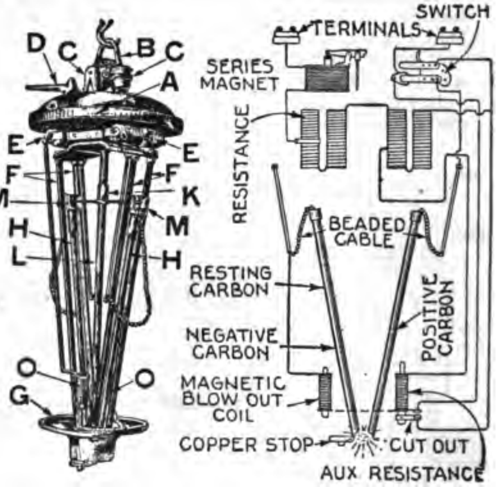


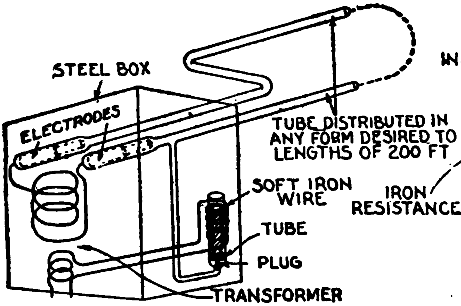
Fig. 7,482.—Electrode arrangement of Westinghouse metallic flame arc lamps. As shown, the larger portion of the light comes from the flame which always surrounds the negative electrode and the natural light distribution results when the negative electrode is arranged above the positive. This distribution, shows a maximum intensity at about 25 degrees below the horizontal.

Fig. 7,483.—Lower mechanism of Beck flaming arc lamp, showing electrode holders, feed stop, plunger disc and electrode guide frame.

Fig. 7,484.—Internal view and diagram of Helios flaming arc lamp showing mechanism and diagram of connections. ***In operation,*** as the resting carbon wastes away the free carbon feeds downwards, thus maintaining the arc exactly in the same place. The bottom casting is recessed to hold a resisting plate which protects the upper part of the lamp and also increases the life of the carbons. The blowing magnets are mounted on the bottom casting, and the magnetic field is so disposed that the arc is maintained in its proper position relative to the cores of the carbons. The series magnet which operates the mechanism for separating the carbons is located above the central tube. By means of a plunger and lever this magnet operates a rod which passes completely through the central tube, and terminates in a device arranged to operate a pressure for which serves to move the free carbons away from the resting carbon, thus springing the arc. When the carbons have been consumed, the sliding socket on the central tube reaches a stop which checks its downward movement, and at the same time the weight of the moving parts operates the automatic cut out, throws the auxiliary resistance into circuit, short circuits the arc and extinguishes the light. The operation of renewing the carbons resets the cut out device.

Luminous Arcs.—In the development of arc lamps various attempts have been made to increase the luminosity of the arc stream by *introducing some substance not carried by the ordinary carbon electrodes.*

In the latest types of arc lamp this is accomplished in one of two ways: by using in *d.c.* lamps, negative electrodes of a material the incandescent vapor of which gives a highly luminous spectrum; or by employing electrodes of such refractory material as will give a very high arc temperature, by the effects of which certain materials carried by the positive electrode will be converted into incandescent vapor of a high light giving power.



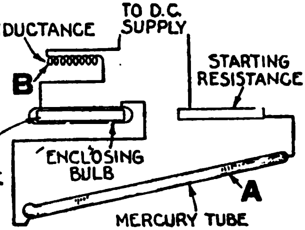


Fig. 7,485.—Moore vaccum tube lamp.

Fig. 7,486.—Cooper-Hewitt *d.c.* mercury vapor lamp.

Lamps operating on the first method are variously called *metallic*, *magnetite*, *titanium*, or in general *luminous arc* lamps; those working on the second method, *flaming arc* lamps.

Flaming Arc Lamps.—In these lamps both electrodes are of carbon.

In the *d.c.* lamps, the arc is made luminous by impregnating the positive carbon, or providing it with a core of calcium fluoride or borate, which when heated to the arc temperature becomes highly luminous. In the *a.c.* lamp, both carbons are provided with cores of calcium salts. In the former, the efficiency of light production depends upon the temperature of the positive electrode which controls the vaporization of the luminescing material.

The electrodes of these lamps are placed, usually, in a conveying position pointing downward, and the arc is sprung by means of a plunger disc or other suitable device operated by a series magnet which forces the carbons apart.

As the carbons waste away, the ribs waste away also, the carbons being fed downward by gravity with the ribs against the feed stops. This action maintains the arc always in the same place.

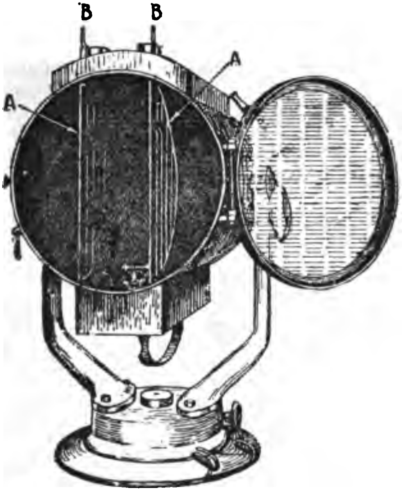


FIG. 7,487.—Marine search light for pilot house.

Search Light Projectors.—In these the arc is directed toward the reflector so that *the light rays are made* ***parallel***, thus giving greater penetrating qualities for locating objects on land or sea

The table below gives current and candle power of search lights, and

Current and Candle Power of Search Light

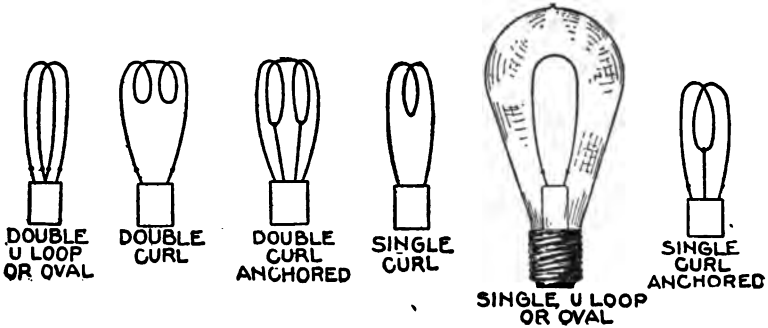
Diameter of case in inches.	Current in amperes	Candle power	Approximate price
14	10–15	3,000	$360
18	20–25	5,000	380
19	35–40	8,000	530
19	45–50	10,000	550
24	55-60	12,000	950
24	75	15,000	970
32	90	18,000	1,650
38	120	24,000	2,100

NOTE.—In the table it should be clearly understood that the prices quoted are merely a rough approximation which serve to give only a very general idea of the high cost of this class of apparatus.

pre-war prices showing the unreasonably high prices asked by some dealers for this class of apparatus.

Vacuum Tube Lamps.—When a static discharge of electricity is passed through a tube, *luminous effects are produced, which vary with the degree of exhaustion, the character of the gas in the tube, of the glass, or the solution surrounding it.*

The principal advantage is low intrinsic brilliancy (almost 12 *c.p.* per linear ft.) which makes it easy on the eyes, it has a high efficiency and gives good diffusion of the light.



FIGS. 7,488 to 7,493.—Forms of incandescent lamp filament. The standard filament is one that gives an average illumination of 16 candle power at right angles with the axis of the lamp from a very reliable spirit lamp. The 16 candle power 110 volt lamp consumes about one-half ampere and has a resistance of about 220 ohms. A filament having this resistance and sufficient cross section for mechanical strength, should be 8 or 9 inches in length. In the earlier lamps this filament was made in the shape of an U (fig. 7,492), but its excessive length which not only caused it to droop, thereby requiring a large bulb, also gave a poor distribution of light and various other forms of filament, such as those here shown were almost universally adopted. The curl forms are common in lamps for 100 to 125 volts and from 8 to 50 candle power. The U forms are generally used for large lamps from 100 to 300 candle power. In these cases the cross section of the filament is much greater as the current in a 100 candle power lamp is about six times greater than that in a 16 candle power lamp at the same voltage. Anchored filaments are used, when, owing to their length on account of the form of the bulb, the filament is liable to touch the glass and crack it, resulting in the destruction of the filaments by combustion. Anchored filaments are almost a necessity in the case of long tubular bulbs.

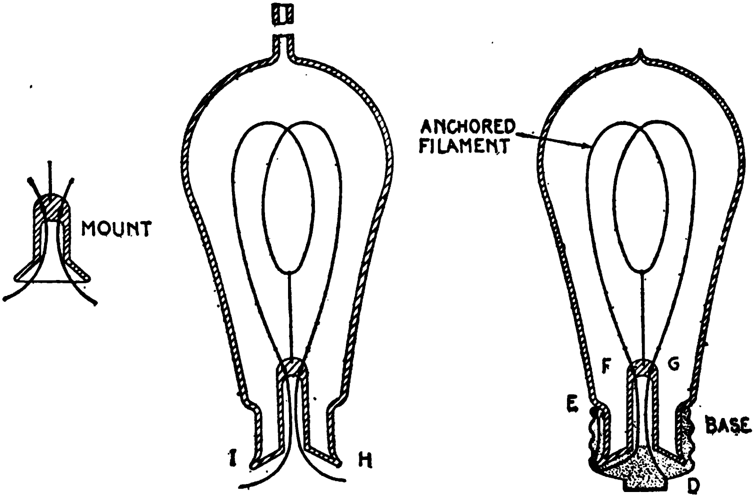
The disadvantages are: incomplete elimination of shadows; difficulties of repair; high initial cost, and lack of flexibility.

Incandescent Electric Lamps.—In an incandescent electric lamp the light is produced by ***passing*** *a current of electricity* *through a continuous conductor having a high resistance*, the current employed being sufficiently strong to raise the temperature of the conductor to the point of incandescence.

In construction, a slender filament of some conducting refractory material is enclosed in a glass chamber and connected to lead wires fused through the base of the chamber or "bulb." The bulb is exhausted of air as completely as possible and the exhaustion duct sealed. The object of placing the filament in a vacuum is to prevent oxidation.

The various types of incandescent lamp may be classed as:

1. **Carbon filament lamps;**
   - *a*. Plain carbon;
   - *b*. Treated carbon.
2. **Metallized carbon filament lamps.**



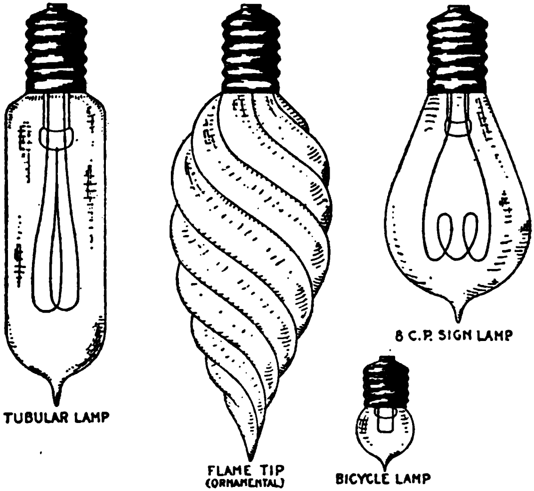
FIGS. 7,494 to 7,496.—Construction details of incandescent lamp. ***It consists of*** a closed glass bulb, containing a carbon filament, and having two terminals D and E, on the outside to which the filament is connected by the *leading in wires* F and G, of platinum which pass through the glass, which is sealed around the wires. Fig. 7,494 shows the stump of glass into which the leading in wires are sealed, and which ultimately becomes the enclosing part of the neck of the bulb; fig. 7,495 shows the bulb ready to have the air exhausted, and fig. 7,496 the complete lamp and base.

3. Non-carbon filament lamps.

   a. Osmium;
   b. Tantalum;
   c. Tungsten;
   d. Iridium.

The incandescent lamp is perhaps simpler than any other type of electric lamp and its general construction is shown in figs. 7,494 to 7,496.

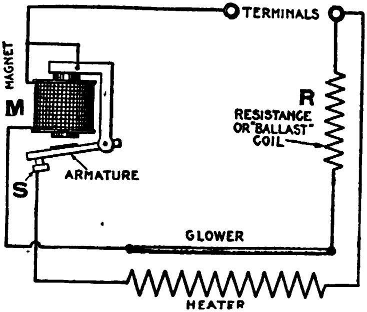
High Voltage Incandescent Lamps.—The superior distributing advantages of the 200 volt system resulted in the production of 250 volt lamps having an intitial consumption of 3.4 watts per candle power for the 16 *c.p.* and 20 *c.p.* lamps, while 3.1 watts per candle for higher candle powers are now made, which have an average useful life as good as that of the 100 volt 3.1 watt lamps, which is equal to about 450 hours.

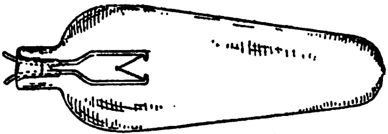


FIGS. 7,497 to 7,500.—Various forms of incandescent lamp. Fig. 7,497, tubular or elongated bulb lamp; fig. 7,498, ornamental flame tip; fig. 7,499, bicycle lamp; fig. 7,500, sign lamp.

Metallized Carbon or "Gem" Lamps.—This process consists in *heating the filaments to a very high temperature both before and after flashing,* using a carbon tube electric furnace for the purpose.

Treated Carbon Lamps.—In manufacture, a carbon filament is *heated with a volatile silicon compound instead of the usual hydrocarbon.*





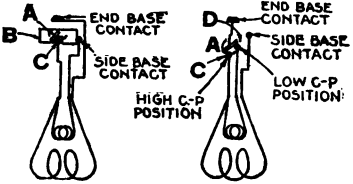


FIG. 7,501.—Elementary diagram of Nernst lamp. The light producing part of this lamp consists of a *glower* with an insulator of electricity at ordinary temperature and therefore necessitates the employment of some means to raise its temperature up to a point at which it will become a conductor. This is accomplished by means of a heater coil of fine platinum wire wound on a thin porcelain tube and embedded in cement to protect it from the intense heat of the glower when the latter becomes white hot by the passage of the current. The glower and the heater coil are connected in parallel in operation, and when the lamp is thrown into circuit for lighting, the current flows through the heater coil and raises its temperature to such a degree that the latter, in about 20 seconds, heats the glower to the conducting point. The current now passes through the glower and, raising its temperature to a white heat, makes it luminous. At this moment a sufficient amount of current passes through the glower to make it begin to light. The magnet M, which is in series with the glower is energized strongly enough to attract its armature, thereby breaking contact with the screw S, and throwing the heater coil out of circuit while the glower is left in circuit. Whenever the lamp is turned off by opening the circuit, the armature falls back by gravity into the position shown in readiness for action when it is necessary to relight the lamp. Since the resistance of the material of the glower decreases as its temperature increases, it is necessary to provide some means to prevent the resistance falling to a point at which a considerable current would flow and destroy the glower and its connections. This is accomplished by inserting a resistance coil in series with the glower. This resistance called "ballast" consists of iron wire which increases in resistance as its temperature increases, and thus compensates for the decrease in the resistance of the glower.

FIG. 7,502.—Nitrogen filled lamp. Tungsten lamps fail, not by breaking of the filament, but by reduction in light giving value due to blackening of the inner globe surface. With attempts to increase efficiency of lamp operation, this blackening process has been found to be greatly accelerated, thus heretofore placing a limit on the consumption efficiencies obtainable consistent with reasonable lamp life. It has been found that the introduction of an inert gas into the bulb at atmospheric pressure not only decreases the rate of filament evaporation, but by proper design of the lamp parts, the presence of this gas may be made to prevent blackening of those glass surfaces through which light is transmitted, the result being to make possible increased lamp life at high efficiencies.

FIGS. 7,503 and 7,504.—Turn down incandescent lamps. Three changes in candle power are provided, all obtained by operating the string alone. This switch is pivoted at its center B, and the lamp circuit is completed when connection is made at either of the contacts C or D. The switch makes contact at only one of these points at a time. When connection is made at D, both filaments operate in series and the small filament is lighted. When the switch is pulled over to C, the small filament is open circuited and the high candle power filament burns alone. By pulling the switch clear of both C and D, the lamp is put out.

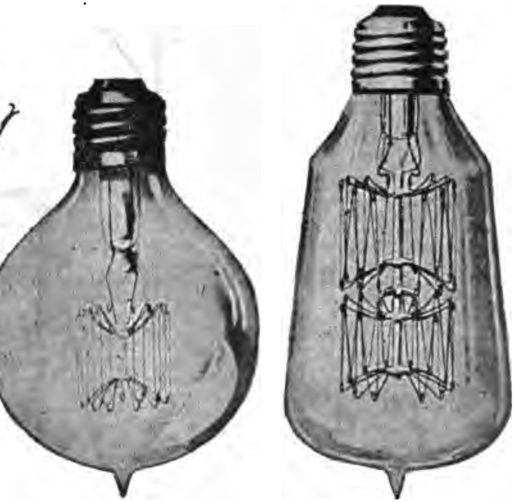
The interesting and promising feature of this lamp is that it opens the way to a new class of incandescent body more likely to have high specific resistance than true metals, and hence more likely to yield filaments of moderate length and conservative cross section.

Osmium Lamps.—The rare metal osmium appears as a by-product of the platinum industry.

It has, however, a very high melting point, and when formed into a filament by the process of union with a suitable binding material, squirting and heating, it possesses considerable endurance.

Osmium lamps have usually been for 40 to 55 volts, being adapted to burn two or three in series on ordinary circuits. The specific consumption is about 1.5 watts per *m. h. c. p.*, and the light is very white and brilliant

FIG. 7,505.—Tantalum filament which has been renewed. The tantalum lamp is not necessarily worthless as a lamp when the filament is broken or burned out. The wires often come in contact or can be brought into contact by jarring, thereby immediately welding them and re-establishing a circuit. Such a renewal may be accompanied by an increase in candle power.



IGS. 7,506 and 7,507.—Tantalum lamps. Fig. 7,506, round bulb 25 watt, 100-125 volt lamp; fig. 7,507 elongated bulb 50 watt, 220-250 volt lamp. The Tantalum lamp burns in any position and in ordinary lighting causes little or no trouble due to the strands of the filament touching and welding. This makes a rugged lamp which has proved well adapted for use under the severe conditions of shop, mill, steam ship and train lighting service. As regularly shipped, tantalum parallel lamps are selected for the specified voltage. However, if it be desired to burn lamps in series, a special selection can be made.

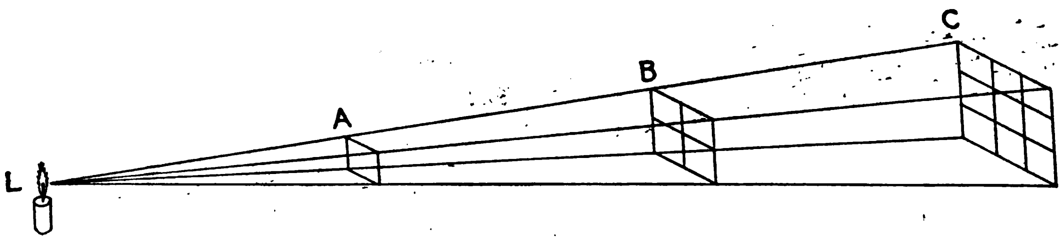
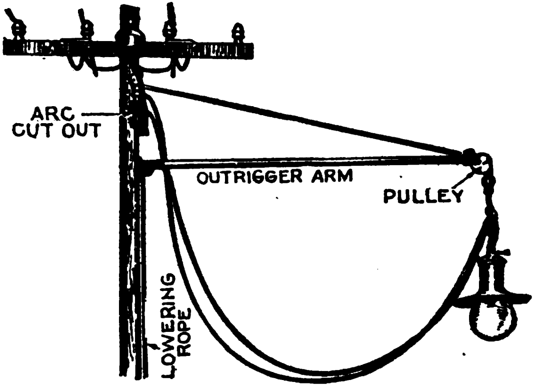


FIG. 7,508.—The law of inverse squares: ***The intensity of the*** illumination due to a given point source ***varies inversely*** as the ***square of the distance*** from the source. Since light travels in straight lines it must be evident that the candle L, will give four times more light at A, than at B, and nine times more at A, than at C, per unit area illuminated.



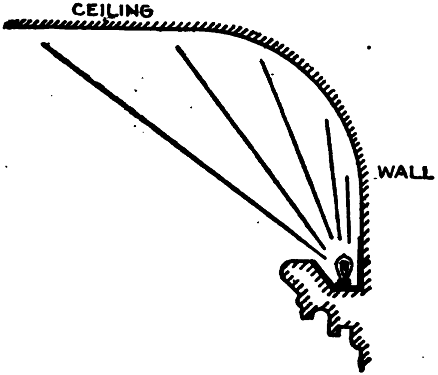
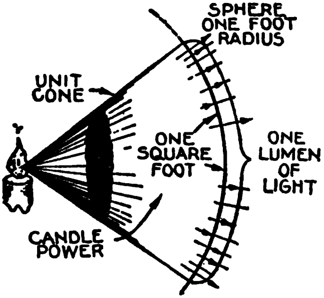


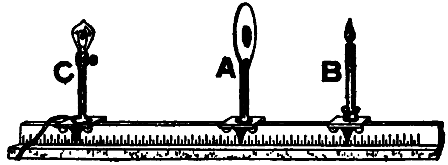
FIG. 7,509.—Out rigger suspension for arc lamp. The suspension rope is protected from the weather when it passes over the pulley by being enclosed in the out rigger arm.

FIG. 7,510.—Indirect system. An extravagant but very satisfactory system of lighting.

as compared with ordinary incandescents. Life of lamp at this efficiency about 1,000 hours.

Tantalum Lamps.—The filament used in the manufacture





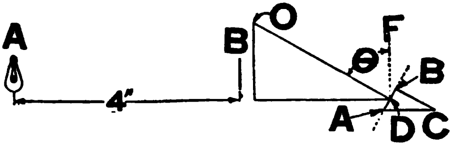


FIG. 7,511.—The unit cone. Imagine a standard candle as shown in the figure and a sphere of one foot radius with its center at the candle. One square foot of the surface of this sphere is contained inside of a unit cone, and such a unit cone contains one *lumen* of light flux. Therefore, one lumen of light flux passes through each square foot of the surface of the sphere; that is the light which radiates from the given lamp has a sectional intensity of one lumen per square foot *at a distance of one foot from the lamp*. This sectional intensity is sometimes called the *foot candle*. That is to say, the foot candle is the sectional intensity of a one candle power beam at a distance of one foot from the lamp. The *meter candle* is the sectional intensity of a one candle power beam at a distance of one meter from the lamp. The meter candle is one lumen per square meter and it is sometimes called the *lux*.

FIG. 7,512.—Bunsen's photometer. The principle upon which this instrument is based is that a *translucent spot in the center of a white screen will have the same appearance as the rest of the screen when the illumination on the two sides is equal*. A spot in a sheet of white paper may be made translucent by means of a little grease or oil. If this sheet be then held between the eye and a window or other source of light, the grease spot will appear brighter than the surrounding paper. On the other side of the paper the spot appears much darker than the paper. That is to say, *when the paper is viewed from the side of greater illumination, the oiled spot appears dark*, and *when it is viewed from the side of lesser illumination the spot appears light*. Accordingly when the two sides of the paper are equally illumined, the spot ought to be of the same brightness when viewed from either side, which, in fact it is. Hence to find the candle power of any unknown source it is only necessary to set up a candle on one side, and the unknown source on the other, as in the figure, and to move the spot to the position of equal illumination. The candle power of the unknown source will then be $\overline{CA}^2 \div \overline{BA}^2$.

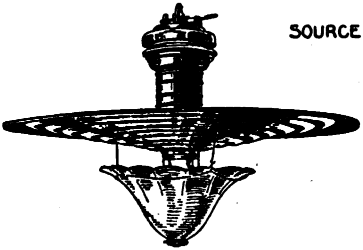
FIGS. 7,513 and 7,514.—The foot candle. If A, be a lamp giving 16 candle power in a horizontal direction, the illumination at the point B, four feet distant, would be $16 \div 4^2 = 1$ foot candle, since the intensity of light varies inversely as the square of the distance. To get the normal illumination at any given point, the candle power in the proper direction must be divided by the square of the distance to the point illuminated. If the surface illuminated be not at right angles to the direction of the light, the value of the illumination obtained as above must be multiplied by a reduction factor, taking into account the angle at which the rays strike. A beam of light coming in the direction OD, fig. 7,514, falls upon a plane AB, illuminating it with an intensity of 1 foot candle. Then the illumination on the plane AC, which intercepts the same amount of light as AB, would be less than 1 foot candle (as the light is spread over a larger surface) in the ratio of AB, to AC, which is the cosine of the angle ODF. Thus the illumination effective on any plane at a given point will be (candle power $\div$ distance^2) $\times \cos \phi$, where ϕ is the angle between the direction of the ray and a perpendicular to the plane considered.

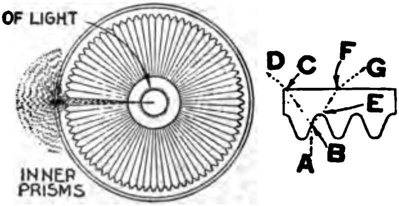
of tantalum lamps is composed of *the metal tantalum drawn into a fine wire.*

This wire is wound back and forth over a supporting framework which is fastened to the stem of the lamp.

Tungsten Lamps.—In the Kuzel process, *a colloidal solution of the metal is formed by maintaining an electric arc between tungsten terminals under water.*

This solution is then brought to a pasty consistency and squirted into a filament which is afterward treated by heating with the electric current. In operation, the filament will weld itself after a break, and since it is very plastic, the lamp is best used tip downward.





FIGS. 7,515 and 7,516.—Horizontal section through center of holophane globe, and magnifier cross section view of three adjacent internal prisms. In fig. 7,516 the single ray of light A, is diffused by being broken into two components—BEFG, by reflection and refraction and BCD, by refraction alone. The external prisms are arranged in a series of longitudinal grooves on the outside surface of the globe. In order to secure the best distribution of the light each groove is constructed according to the principle of geometrical optics, with reference to its position relative to the source of light. Therefore no two grooves are exactly alike, but the dimensions of each of the four faces of a groove or prism do not divide more than one thousandth of an inch from their calculated dimensions. This great accuracy is absolutely essential in the construction of the globes; for otherwise, the light is liable to be thrown back into the globe, thereby tending to decrease its efficiency.

FIG. 7,517.—Concentric diffuser and lower shade as attached to an enclosed arc lamp.

Illumination.—The term "illumination" may be defined as *the density of light flux projected on a surface*, and by extension, it denotes *the **art** of using artificial sources of light.*

The problem of illumination involves ***the selection and arrangement*** *of these artificial sources of light* so that the objects to be lighted will show up to the best advantage and with the minimum amount of artificial light.

Comparative Distribution of Light from Various Sources.—The incandescent, osmium and Nernst lamps send out about as much light upward as downward, and therefore, require the use of reflectors.

The electric flaming arc sends all of its light downward, but it gives very poor lateral illumination and strongly illuminates only a limited region below the lamp. The electric arc is best at about 30 degrees below the horizontal, but pretty poor immediately beneath. These curves indicate that the distribution from the inverted incandescent gas lamp is better than that from any of the other sources.

Globes for Arc Lamps.—These are made in a great variety of style for adapting them to varying conditions of service.

They are usually made in clear glass or opal as desired.

The light opal is the most suitable for interior illuminations as it absorbs some of the superfluous violet rays without materially decreasing the illuminating power. Where a very even distribution of light is essential the dense opal globe gives the most satisfactory results. Both the light opal and the clear glass globes can be employed for outdoor lighting although the light opal globe is preferable on account of its superior light distributing qualities.

Outer globes can also be obtained in dense opal, light opal, or clear glass. Almost all indoor lamps except those of the metallic arc or flaming arc type do not require outer globes, but their use is imperative with all types of outdoor lamp.

Diffusers.—One of the important requirements for interior lighting is the proper diffusion of the light so as to produce a soft even illumination, free from strong contrasts and deep shadows on the surface illuminated.

The distribution of light from enclosed arc lamps is much improved by the use of diffusers for either the concentric or inverted type.

Holophane Globes and Reflectors.—The object sought in the design of these devices is ***to obtain*** *the proper diffusion of* *the light, and to redirect the rays in useful direction and prevent loss of light by providing a minimum absorption.*

Good Illumination.—To secure good illumination certain conditions must be fulfilled, as follows:

1. There must be sufficient illumination. Since objects are seen by means of the light which they reflect, more light must be thrown on dark objects than on light ones.

2. There must not be too much illumination. Too strong a light tires the eye, partly due to the muscular effect of contracting the iris, and partly because of the strong light reaching the sensitive retina.

3. Intensely bright lights in the field of vision should be avoided. The iris closes somewhat in order to afford a protection from such lights and the amount of light received from illuminated objects is thereby so reduced that they cannot be seen clearly.

Table of Intrinsic Brilliancy of Light Sources

	Candle power per sq. in.
Moore tube	.3— 1.75
Frosted incandescent	2— 5
Candle	3— 4
Gas flame	3— 8
Oil lamp	3— 8
Cooper-Hewitt lamp	17
Welsbach gas mantle	20— 50
Acetylene	75—100
Enclosed A. C. arc	75—200
Enclosed D. C. arc	100—500
Incandescent lamps	
Carbon 3.5 watts per candle	375
Carbon 3.1 watts per candle	480
Metallized carbon 2.5 watts per candle	625
Tantalum 2.0 watts per candle	750
Mazda 1.25 watts per candle	875
Mazda 1.15watts per candle	1,000
Nernst 1.5 watts per candle	2,200
Sun on horizon	2,000
Flaming arc	5,000
Open arc lamp	10,000-50,000
Open arc crater	200,000
Sun 30° above horizon	500,000
Sun at zenith	600,000

4. Flickering lights should be avoided.

5. Lamps should be so placed that the light is not regularly reflected into the eye.

6. Streaks or striations in the illumination are undesirable. Arc lights with clear globes show this phenomenon. Open reflectors having smooth interior surfaces should be used only with frosted lamps.

7. A satisfactory light must be of a proper quality. It should have a continuous spectrum, that is, one containing every color, in order that the relative color values of objects illuminated may be the same as when seen by daylight.

TABLE SHOWING INCREASE OF ILLUMINATION*

Ceiling	Walls	Increase over calculated
Very dark...............	Very dark.................	0%
Medium...............	Very dark.................	15%
Medium...............	Medium.................	40%
Very light...............	Very dark.................	30%
Very light...............	Medium.................	55%
Very light...............	Very light.................	80%

TABLE OF PROPERTIES OF VARIOUS LAMPS

	"MAZDA"						Tantalum	Gem	Carbon 3.1 w.p.c.
Watts per lamp......	25	40	60	100	150	250			
Effective lumens per lamp............	95	160	250	420	630	1090			
Lumens per watt.....	3.8	4.0	4.2	4.2	4.2	4.3	2.5	1 8	1 5

The expression which determines the number of lamp given above, is, expressed as a formula

$$\text{Number of lamp} = \frac{\text{square feet} \times \text{required foot candles}}{\text{effective lumens per lamp}}$$

in which the numerator = total lumens.

TABLE OF SPACING OF UNITS FOR UNIFORM ILLUMINATION

Clear holophane reflectors	Heights above plane to be lighted
Extensive	$\frac{1}{2}$ D
Intensive	$\frac{4}{5}$ D
Focusing	$\frac{4}{3}$ D

D = distance between units = side of square, when units are placed in squares = average side of rectangle, when units are placed in rectangles.

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*NOTE.—*Example* to illustrate the use of the table of properties of various lamp. A store 60′ × 150′ × 14′ is to be lighted with "Mazda" lamps. Considering the goods to be sold (crockery, toys, notions, etc.) table on page 3,860-500 shows that 3.5 foot candles is sufficient illumination. If clear holophane reflectors be used the values for lumens effective on the plane, given in the table on this page may be increased by 10%, due to reflection from fairly light walls. Total lumens = 60 × 150 × 3.5 = 31.500.

TABLE SHOWING CONSUMPTION OF VARIOUS LAMPS

	"MAZDA"						Tantalum		Gem			Carbon			
												3.1 watts per candle		3.5 watts per candle	
Watts per lamp......	25	40	60	100	150	250	40	80	40	50	80	50	100	56	114
Candle power at rated efficiency..........	18.8	32	50	83.3	125	217.3	20	40	16	20	32	16	32	16	32
Amperes per lamp at 110 volts..........	.23	.36	.55	.91	1.09	2.27	.36	.73	.36	.45	.73	.45	.91	.57	1.04
Permissible number of lamp per cut out..	26	16	11	6	4	2	16	8	16	13	8	13	6	11	5
Candle power per cut out..............	490	510	550	500	500	435	320	320	255	260	255	210	190	175	160

TABLE OF REQUIRED INTENSITY OF ILLUMINATION

	Foot candles required		Foot candles required
Auditoriums, theatres.	1 to 3	General offices.........	3 to 4
Bookkeeping.........	3 “ 5	Offices with desk lights.	1½ “ 2½
Corridors, halls.......	½ “ 1	Post offices...........	2 “ 5
Depots, halls, churches	¾ “ 1½	Reading..............	1 “ 3
Draughting rooms....	5 “ 10	Residences............	1 “ 3
Desk lighting.........	2 “ 5	Stores (light goods)....	2 “ 3½
Engraving...........	5 “ 10	“ (dry goods).....	4 “ 6
Factories (individual drops).............	2 “ 3	“ (clothing).......	4 “ 7
Factories (no individual drops)..........	4 “ 5	Store windows.........	5 “ 20
Hotel halls...........	1 “ 1½	School rooms..........	2 “ 3
“ rooms..........	2 “ 3	Saloons, cafes.........	2 “ 5
Offices, waiting rooms.	1¼ “ 2½	Stations (waiting rooms)	1½ “ 2½
Private offices........	2 “ 3	Train sheds..........	1½ “ 2
		Ware houses..........	1½ “ 2

CHAPTER 117

Electro-magnetic Induction

The tendency of electric currents to flow in a conductor when it is moved in a magnetic field so as to *"cut" lines of magnetic force* is known as electro-magnetic induction.

Faraday discovered that if he took a wire, joined its ends and moved it in front of a magneto, a current would be induced in the wire. The current is called the *induced current* and that part of the wire moved in the magnetic field, the *inductor*.

All dynamos of whatever from, are based upon this discovery made by Faraday in 1831, which in rule form is as follows:

Rule 25.—FARADAY'S DISCOVERY—*Electric currents are generated in conductors by moving them in a magnetic field, so as to cut magnetic lines of force.*

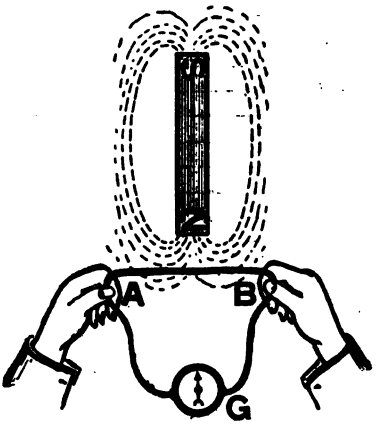


FIG. 7,518.—***Faraday's discovery:*** If a loop of wire be connected to a galvanometer and a section of the wire AB, be moved through a magnetic field as shown, the galvanometer will be deflected indicating that an electrice current is generated when *a conductor is moved in a magnetic field so as to cut lines of force.* A thorough understanding of the term *cut lines of force* is highly important.

NOTE.—***Michael Faraday,*** born 1791, died 1867. He was an English scientist, famous for his discoveries in chemistry, electricity and magnetism. He first produced the rotation of the magnetic needle around the electric current (1821) based upon Oersted's discovery of electro-magnetism in 1820; he discovered electro-magnetic induction (1831), a principle upon which is founded the development of dynamo machinery; specific inductive capacity (1838); magnetic polarization of light (1845); diamagnetism (1846). He was a brilliant experimenter, and contributed greatly to the knowledge upon which is based present day practice of electricity.

It is very important to understand the meaning of the term "*cut lines of force*":

A conductor, forming part of an electric circuit, **cuts** *lines of force when it moves across a magnetic field in such manner as to alter the number of magnetic lines of force which are embraced by the circuit;* the term is fully illustrated in the accompanying figures.

The proper name for a "conductor" which moves across a magnetic field is an *inductor.*

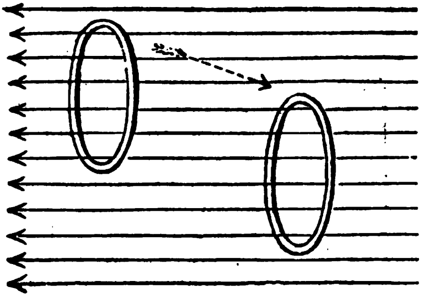


FIG. 7,519.—***Electromagnetic induction 1:*** In order to induce a current by electromagnetic induction, an inductor must be so moved through a magnetic field *that the number of lines of force passing through it (that is, embraced) are altered.* If a coil be given a simple motion of translation in a uniform magnetic field as indicated in the figure, no current will be induced *because the number of lines of force passing through it are not changed,* that is, during the movement as many lines are lost as are gained.

Laws of Electro-Magnetic Induction.—The principles of electro-magnetic induction are set forth in the following laws:

Rule 26.—FARADAY'S DISCOVERY—*To induce a current in a circuit, there must be a relative motion between the circuit and a magnetic field, of such a kind as to alter the number of magnetic lines embraced in the circuit.*

Rule 27.—*The voltage induced in a circuit is proportional to the rate of increase or decrease in the number of magnetic lines embraced by the circuit.*

Rule 28.—*When a straight wire cuts* 100,000,000 *lines of force at right angles per second, an electric pressure of one volt is induced.*

***Rule 29.**—By joining in series a number of inductors or coils moving in a magnetic field, the electric pressure in the separate parts are added together.*

Example.—If a coil of wire of 50 turns cut 100,000 lines in $^{1}/_{100}$ of a second, what will be the induced voltage?

The number of lines cut per second per turn of the coil is

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

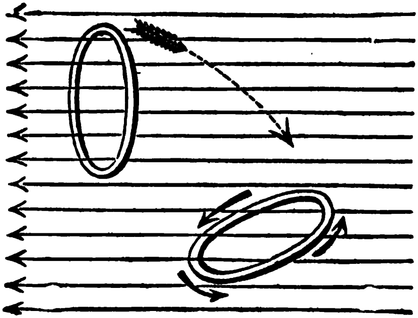


FIG. 7,520.—***Electromagnetic induction 2:*** If a coil be given a motion of rotation from any point within its own plane so that it passes through a uniform magnetic field, a current will be induced in the coil *because the number of lines of force passing through it is altered.*

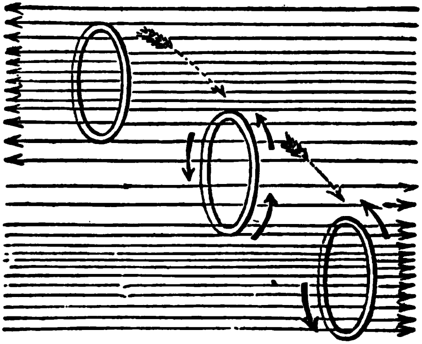


FIG. 7,521.—***Electromagnetic induction 3:*** If a coil be given a simple motion of translation in a non-uniform or variable magnetic field, a current will be induced in the coil, whether the motion be from the dense to the less dense region of the field or the reverse, *because the number of lines of force passing through the coil is altered.*

The total number of lines cut by the coil of 50 turns is

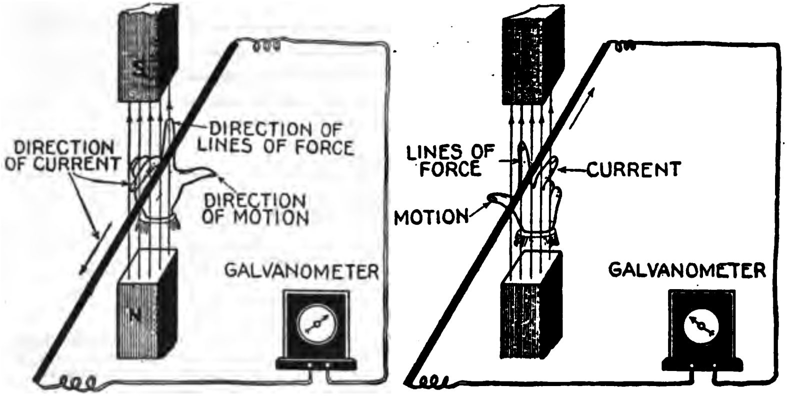
$$10,000,000 \times 50 = 500,000,000$$

which will induce a pressure of

$$500,000,000 \div 10^8 = 5 \text{ volts}$$

***Rule 30.**—A decrease in the number of magnetic lines which pass through a circuit induces a current around the circuit in the positive direction.*

The term positive direction is understood to be the direction along which a free N pole would tend to move.



FIGS. 7,522 and 7,523.—Fleming's rule for direction of induced current. *Extend the thumb, fore finger and middle finger of the right hand so that each will be at right angles to the other two. Place the hand in such position that the thumb will point in the direction in which the conductor moves, the fore finger in the direction of the lines of force* (*N to S*), *then will the middle finger point in the direction in which the induced current flows.* This is a very useful rule and the author recommends that it be thoroughly understood.

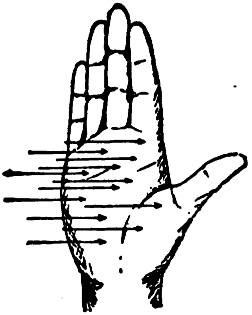


FIG. 7,524.—The palm rule for direction of induced current: *If the palm of the right hand be held against the direction of the lines of force, the thumb in the direction of the motion, then the fingers will point in the direction of the induced current.*

Rule 31.—An increase in the number of magnetic lines which pass through a circuit induces a current in the negative direction around the circuit.

Rule 32.—The approach and recession of a conductor from a magnet pole will yield currents alternating in direction.

Since the strength of the field depends on the proximity to the pole, the approach and recession of a conductor involve an *increase* and *decrease* in the rate of cutting of magnetic lines, hence a reversal of current.

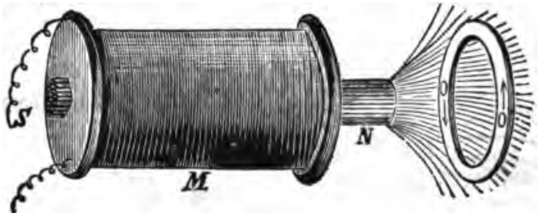


FIG. 7,525.—Experiment I illustrating Lenz's law. If a copper ring be held in front of an ordinary electro-magnet, and the current circulating through the coil of the magnet be in such a direction as to magnetize the core as indicated by the letters S,N, then as the current increases in the coil more and more of the lines of force proceeding from N, pass through the ring OO, from left to right. While the field is thus increasing current will be induced in the copper ring in the direction indicated by the arrows, such currents tending to set up a field that would pass through the ring from right to left, and would therefore *retard* the growth of the field due to the electro-magnet M.

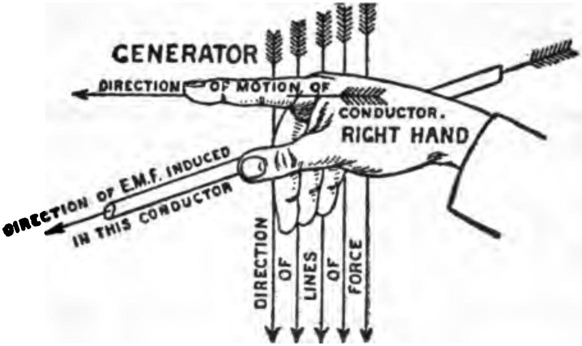


FIG. 7,526.—A rule for direction of induced current which, in some cases, is more conveniently applied than Fleming's rule: *Hold the thumb, fore finger and remaining fingers of the right hand at right angles to each other; place the hand in such position that the fore finger points in the direction of motion of the conductor, the three fingers in the direction of the lines of force, then will the thumb point in the direction of the induced current.*

***Rule 33.**—The more rapid the motion, the higher will be the induced magnetic force.*

Rule 34.—LENZ LAW—*The direction of the induced current is always such that its magnetic field* **opposes** *the motion which produces it.*

Hence, because of this opposition, power must be expended to operate a dynamo.

Self-Induction.—This term signifies *the property of an electric current by virtue of which it tends to resist any change of value.*

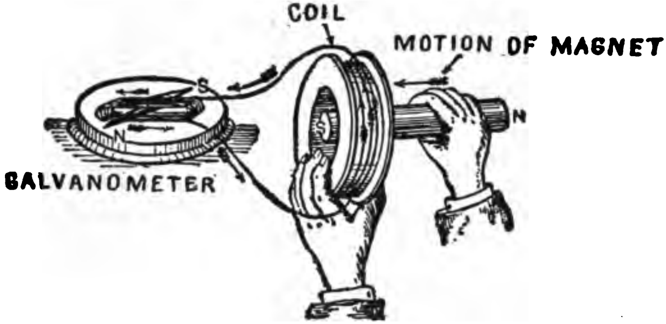


FIG. 7,527.—Experiment illustrating Lentz' law. In order to produce the induced current energy must be expended in bringing the magnet to the coil and in taking it away. This is just what happens in producing an electric current with a dynamo—*it takes power to drive the machine.*

Self-induction is sometimes spoken of as *electromagnetic inertia*, and is analogous to the mechanical inertia of matter.

Ques.—Why do sparks sometimes appear at the brushes of a dynamo?

Ans.—Because of self-induction when the brushes are not properly adjusted.

Mutual Induction.—This is a particular case of electromagnetic induction in which the magnetic field producing an electric pressure in a circuit is due to the current in a neighboring circuit.

CHAPTER 118

Dynamos

A dynamo, or so-called "generator" converts mechanical energy into electrical energy by means of electromagnetic induction.*

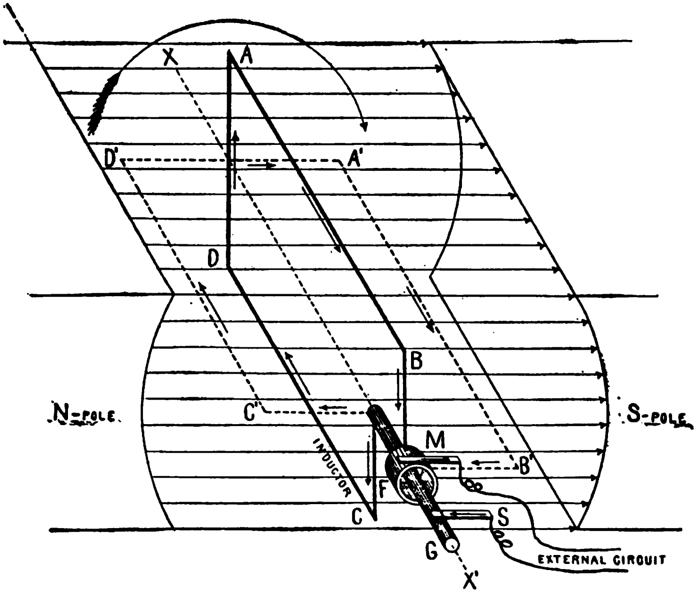


FIG. 7,528.—Simple elementary alternator. ***Its parts are*** a single conducting loop, A,B,C,D, placed between the poles of a permanent magnet, and having its ends connected with a ring F, and shaft G, upon which bear brushes M and S, connected with the external circuit. When the loop is rotated clockwise the induced current will flow in the direction indicated by the arrows during the first half of the revolution.

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*NOTE.—The author objects to the term "generator" because the machine does not generate electricity but simply pumps it from a low to a high pressure, similar to the operation of a pump in pumping water. Hence a dynamo is an electric pump.

The three essential parts of a dynamo are: *the field* magnets which provide the magnetic field; 2, *the armature*, containing the conducting loops (winding) which are arranged to rotate in the field and which cut the magnetic lines of force, and 3, *the commutator*, which takes off the current generated in the armature, converting it from alternating current to direct current.

Operation.—*The current generated by a loop rotating in a magnetic field is alternating;* that is, it flows in one direction

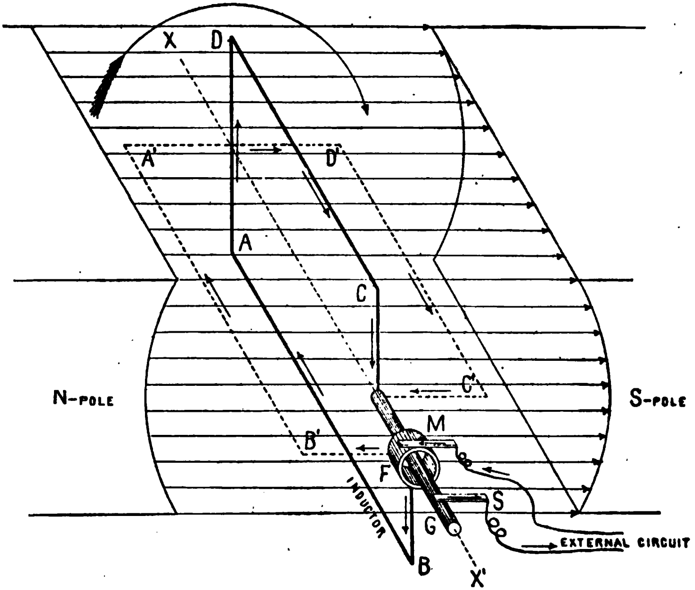
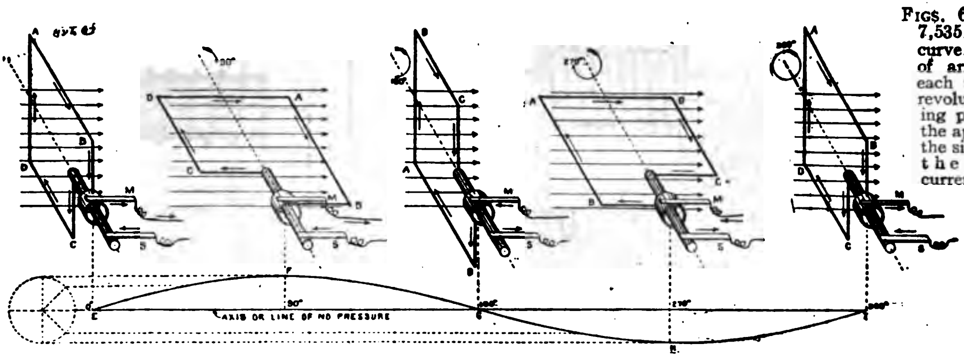
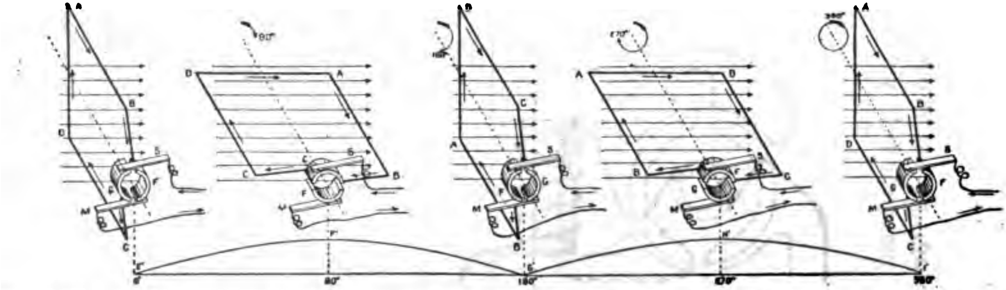


FIG. 7,529.—Simple elementary alternator, showing reversal of current when the loop has made one half revolution from the position of fig. 7,528. It should be noted that A B, for instance, which has been moving *downward* during the first half of the revolution (fig. 7,528), moves *upward* during the second half (fig. 7,529); hence, the current during the latter interval flows in the opposite direction.

doing one-half revolution, and in the other doing the second half. Hence, to understand how a dynamo works, first consider the elementary alternator in figs. 7,528 and 7,529, which delivers alternating current as shown in figs. 7,530 to 7,535.



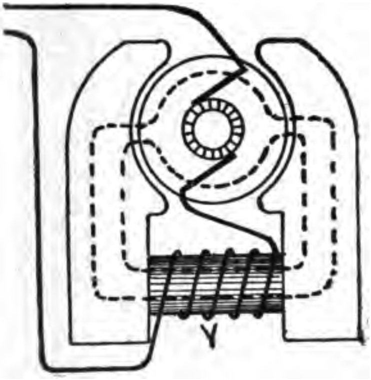
FIGS. 6,530 to 7,535.—The sine curve, with view of armature for each 90° of the revolution, showing progressively the application of the sine curve to the alternating current cycle.

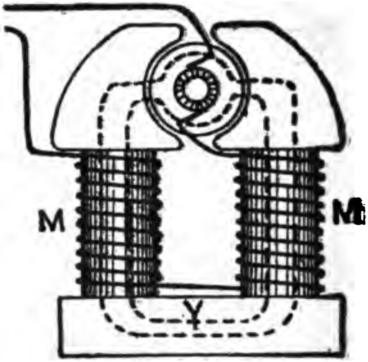


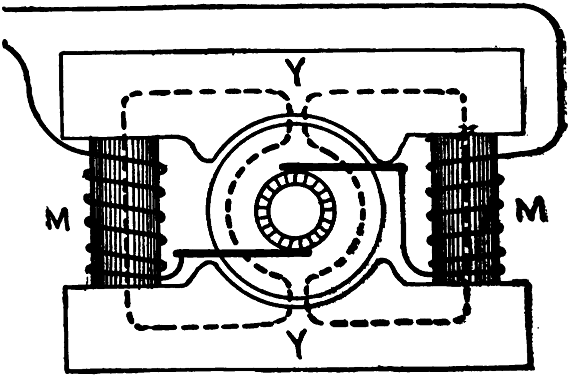
FIGS. 7,536 to 7,541.—Commutation of the current. These figures show how a dynamo transforms alternating into the so called direct current. During the first half of the revolution the current flows in the direction A B, out through segment F, of the commutator and brush M, returning through brush S and segment G, figs. 7,536 and 7,537. At the beginning of the second half of the revolution, fig. 7,538, the current in the armature reverses and flows around the loop in the direction B A. At this instant the brushes M and S, pass the gaps between the commutator segments, thus reversing contact with the segments, and causing the current in the external circuit to remain in the same direction.

Now once a dynamo must deliver *direct current*, a commutator or device for converting alternating to direct current is necessary. This device consists of a series of copper bars or segments arranged side by side and insulated from each other. The way it works is shown in figs. 7,536 to 7,541.

Field Magnets.—The object of the field magnets is to produce an intense magnetic field within which the armature revolves.







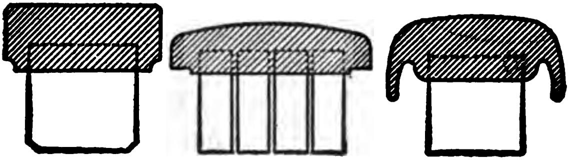
FIGS. 7,542 to 7,544.—Various field magnets; fig. 7,542, salient pole, bipolar field magnet with single coil wound around the yoke; Fig. 7,543, salient pole, bipolar field magnet with two coils wound around the cores. 1, fig. 7,544, consequent pole, bipolar field magnet with two coils on the cores. This is known as the "Manchester" type in which the cores are connected at the ends by two yokes—so named from its original place of manufacture at Manchester, England.

For this, ***permanent magnets*** are used in magnetos and ***electro-magnets*** in dynamos.

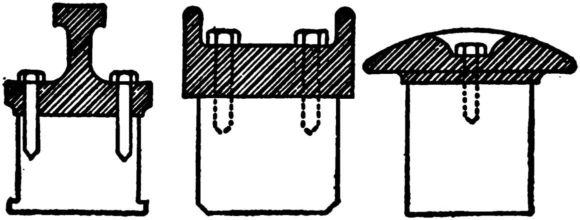
A field magnet consists of: 1, yoke; 2, cores; 3, pole pieces; 4 coils. Various types of field magnets are shown in figs. 7,542 to 7,544. One method of securing the coils in position is shown in fig. 7,568.

The materials generally used for magnets are wrought iron for the cores, copper for the winding, and cast iron for the yokes.

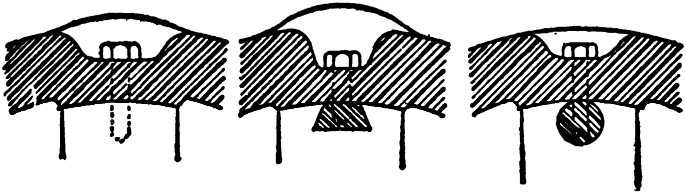
The pole faces are made larger than the coils in order to reduce the reluctance of the "air gap" or space between the pole face and armature. The projecting sides of the pole face are called *horns*. Machines are said to be



FIGS. 7,545 to 7,547.—Various sections of cast iron yoke. In form, these yokes may be either circular or segmental.



FIGS. 7,548 to 7,550.—Various sections of cast steel yoke. The ribs shown in figs. 7,548 and 7,549 are provided to secure stiffness.



FIGS. 7,551 to 7,553.—Some methods of attaching detachable cores. The core seat is machined to receive the core, it being necessary to secure good contact in order to avoid a large increase in the reluctance of the magnetic circuit.

bi-polar when they have two poles, and *multi-polar*, when there are more than two poles.

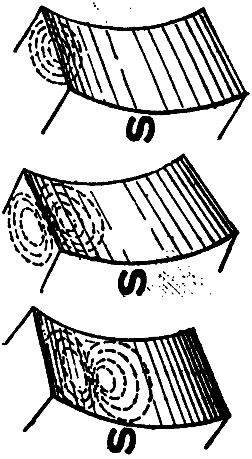
Eddy Currents; Laminated Fields.—The field magnet cores and pole pieces, as well as the armature of a dynamo are specially subject to *eddy currents*.

Eddy currents are induced electric currents occurring when a solid metallic mass is rotated in a magnetic field.

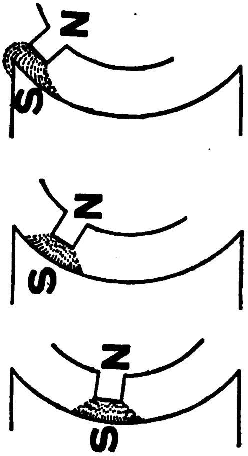
These currents consume a large amount of energy and often occasion harmful rise in temperature. This loss may be almost entirely avoided by laminating the pole piece, or both pole piece and core.

A laminated pole is one built up of layers of iron sheet, stamped from sheet metal and insulated.

In best construction these laminated pole pieces are cast welded into the frame or yoke to reduce the reluctance of the magnetic circuit.



FIGS. 7,554 to 7,556.—Alteration of magnetic field due to movement of mass of iron in the armature. *If the masses of iron in the armature be so disposed that as it rotates, the distribution of the lines of force in the narrow field between the armature and the pole piece is being continually altered, then, even though the total amount of magnetism of the field magnet remain unchanged, eddy currents will be set up in the pole piece and will heat it.*

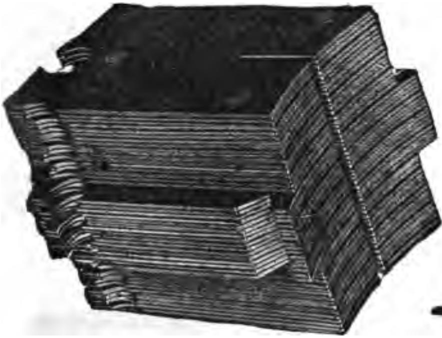


FIGS. 7,557 to 7,559.—Eddy currents induced in pole pieces by movement of masses of iron. These diagrams correspond to those of figs. 7,554 to 7,556. The strongest current flows between the vortices and is situated just below the projecting tooth, where the magnetism is most intense; it moves onward following the tooth.

The Magnetizing Coils. The object of these is ***to provide the number of ampere turns of excitation required to produce the required magnetic flux through the armature.***

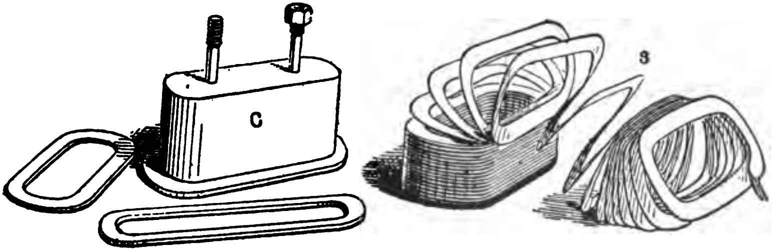
The coils may be *spool* or *former* wound. The spools upon which coils are wound are usually insulated with several layers of paper preparations.

Where pole pieces are simply extensions of the cores without enlargement, the coils can be slipped over the ends, but some kind of clamping device is necessary to hold them in place.



FIGS. 7,560.—Fort Wayne laminated pole piece before being cast welded into frame. ***In construction,*** the above core and pole piece is made up of sheets of annealed steel of two different widths assembled together to form proper size and shape. The minute spacing between these laminations and the slight oxidation on each surface is sufficient to reduce considerably the eddy currents. By cast welding the pole piece into the frame, a low reluctance is secured.

FIGS. 7,561.—Method of winding magnet spool so that the two ends of the coil will come to the outside.



FIGS. 7,562 to 7,565.—Core and edge strip winding for shunt field coils of large multipolar dynamo. S, copper strip; C, core. ***The winding consists of*** a copper strap S, carefully insulated and placed edgewise on the core C, in a single layer of winding. With this arrangement, the space occupied by insulation is reduced to a minimum.

Coils are generally united in series so that the same magnetizing current may flow through all of them. The coils should be so connected that they produce alternate north and south poles.

Heating.—Dissipation of the heat generated in the magnetizing coils takes place in three ways: by induction, radiation, and connection. In large multipolar machines the metal in the pole cores and frames are more efficient in carrying off heat than the external surface of the coil.

Figs. 7,566 and 7,567.—Square and hexagonal order of "bedding." The term bedding is an expression used to indicate the relation between the cross sectional area of the winding when wound square, as in fig. 7,566, and when wound in some other way, as in fig. 7,567. In the square order of bedding, the degree of bedding equals zero.

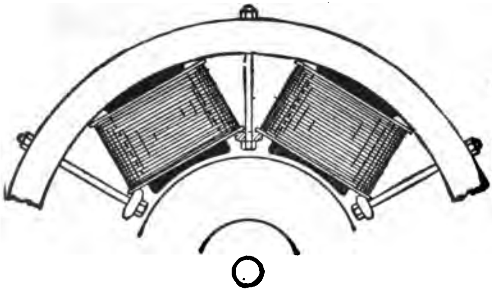


Fig. 7,568.—Method of securing coils in position when the pole pieces are simply extensions of the core without enlargement.

Fig. 7,569.—Fort Wayne compound wound rectangular ventilated spool field coil.

Ventilation.—Sometimes provision is made for ventilation of the field magnet coils as shown in fig. 7,569.

The Armature.—This, by definition, is *a collection of* ***inductors*** (***erroneously called conductors***) *mounted on a shaft and arranged to rotate in a magnetic field with provision for collecting the currents induced in the inductors.*

The inductors consist of coils of insulated wire.

There are three kinds of armature: 1, ring; 2, ***drum***, and 3, disc. Of these, the drum armature is the prevailing type; it requires less wire and magnetizing current for a given output because the inductors of a ring armature which lie on the inner side of the iron ring, being screened from practically all the lines of force, do not produce any current.

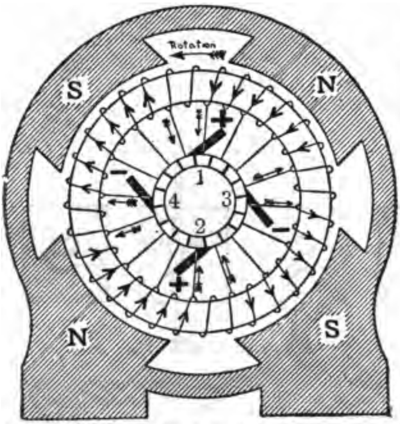


FIG. 7,570.—***Ring*** armature of four pole dynamo showing winding connections and direction of the induced currents.

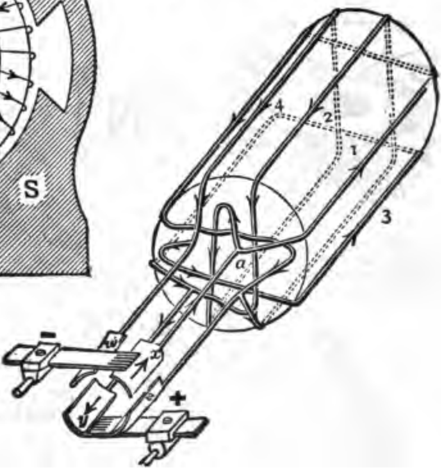
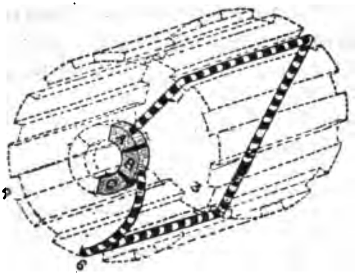


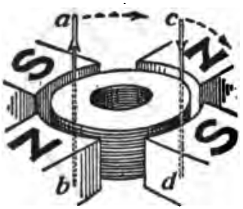
FIG. 7,571.—Elementary four coil ***drum*** armature showing winding, connections and current conditions. Starting from the part *a*, and following the winding around without reference at first to the commutator, it will be found that the rectangular turns of the wire form a closed circuit, and are electrically in series with one another in the order of the numbers marked on them. With respect to the connections to the four segments *w,x,s*, of the commutator it will be found that at two of these *x* and *y*, the pressures in the windings are both directed from, or both directed *toward* the junction with the connecting wire. At the other two segments, *s* and *w*, one pressure is toward the junction and the other directed from it. If, therefore, the brushes be placed on *x* and *y* they will supply current to an external circuit, *s* and *w*, for the moment being the segments.



In the drum armature only the end connectors are inactive.

The inductors of disc armatures move in a plane, perpendicular to the direction of the lines of force, about an axis parallel to them. They were introduced in an effort to avoid the losses due to eddy currents and hysteresis present in the other types of armature, but because of difficulty in making them durable their inherent advantages failed to justify the existence of the type.

Fig. 7,572.—Skeleton view of wooden armature core showing in position the first coil of the winding indicated in the table below.



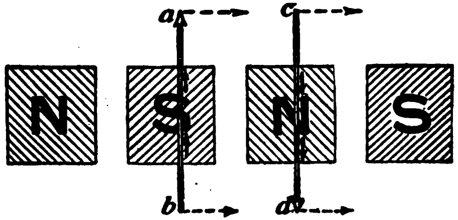
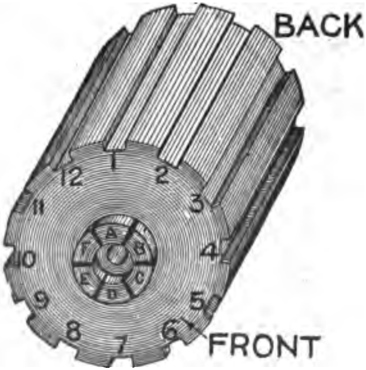
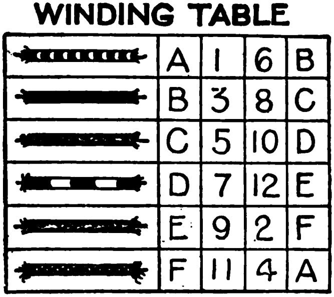


Fig. 7,573.—Partial sketch of a four pole machine laid on its side. If the observer imagine himself placed at the center, and the panorama of the four poles to be then laid out flat, the developed view thus obtained would appear as in fig. 7,574.

Fig. 7,574.—Developed view of the four pole field shown in perspective in fig. 7,573.





WINDING TABLE

	A	1	6	B
	B	3	8	C
	C	5	10	D
	D	7	12	E
	E	9	2	F
	F	11	4	A

Figs. 7,575 and 7,576.—Wooden armature core and winding table for practice in armature winding. By using strings of different colors to represent the various coils, the path of each coil is easily traced when the winding is completed.

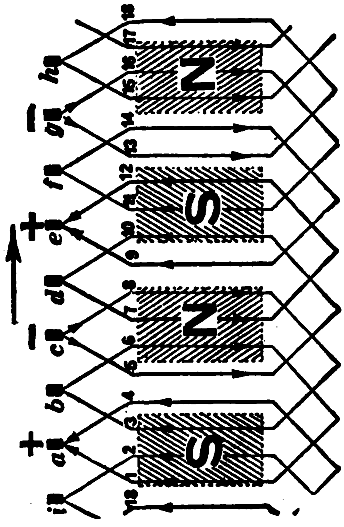


FIG. 7,577.—Developed view of a typical lap winding. From the figure it is seen that at the back of the armature each inductor is united to one five places further on, that is, 1 to 6, 3 to 8, etc., and at the front end of the winding, after having made one "element," as for example *d-7-12-e*, then forms a second element *e-9-14-f* which "laps" over the first, and so on all around until the winding returns on itself.

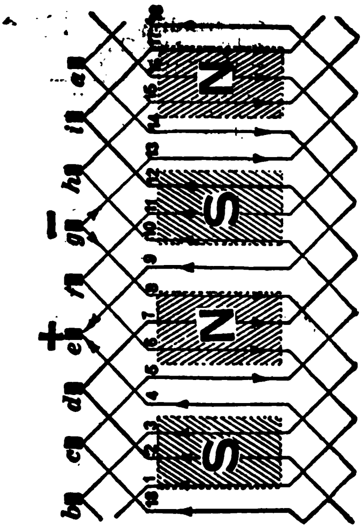


FIG. 7,578.—Developed view of a typical wave winding. This winding, instead of lapping back toward the commutator segment from whence it came, as in lap winding, turns the other way. For instance *d-7-12* does not return directly to *e*, but goes on to *i*, whence another element *i-17-4-e* continues in a sort of zigzag wave.

Armature Windings.—There are two distinct methods employed in winding armatures known as: 1, *parallel or lap winding*, and, 2, *series or* ***wave*** *winding*.

A ***lap*** *winding is one in which the ends of the coils come back to adjacent segments of the commutator; the coils of such a winding lap over each other.*

A ***wave*** *winding is one in which the coil ends diverge and go to segments widely separated, the winding to a certain extent resembling a wave*

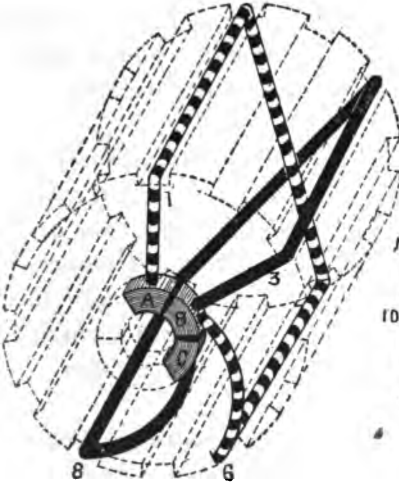
Directions for the order of winding are usually given in the form of a table. Thus, tables for the *lap*, and *wave* windings of figs. 7,580 and 7 583, are as follows:

Lap winding

A — 1 — 6 — B
B — 3 — 8 — C
C — 5 — 10 — D
D — 7 — 2 — E
E — 9 — 4 — F

Wave winding

A — 1 — 4 — C
B — 3 — 6 — D
C — 5 — 8 — E
D — 7 — 10 — A
E — 9 — 2 — B



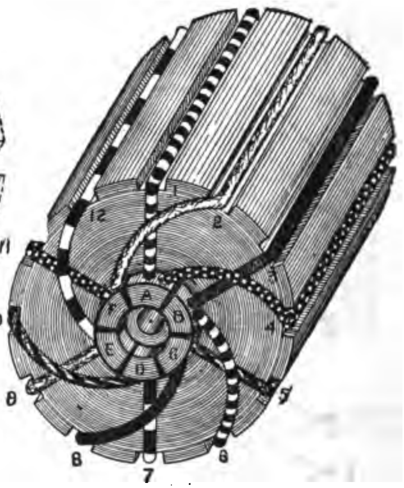


FIG. 7,579.—Skeleton view of wooden armature core showing in position the first two coils of the winding indicated in the above table for *lap winding*.

FIG. 7 580.—View of completed winding as indicated in the table above. Thus the path of the first coil, according to the table is A—1—6—B which means that the coil begins at segment A, of the commutator, rises to slot 1, and proceeds through the slot to the back of the drum; thence across the back to slot 6, through the slot and ending at segment B. The other coils are wound in similar order as indicated in the table.

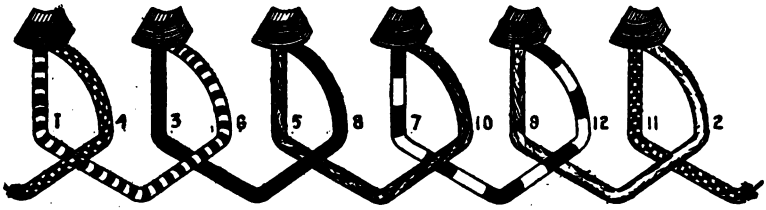
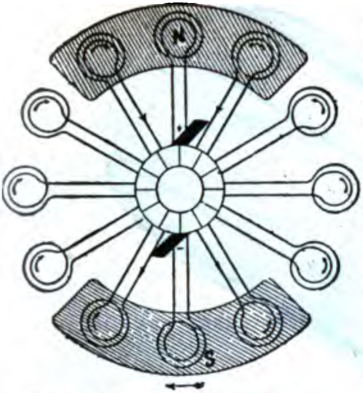


FIG. 7,581.—Developed view of the winding shown above in perspective in fig. 7,580.

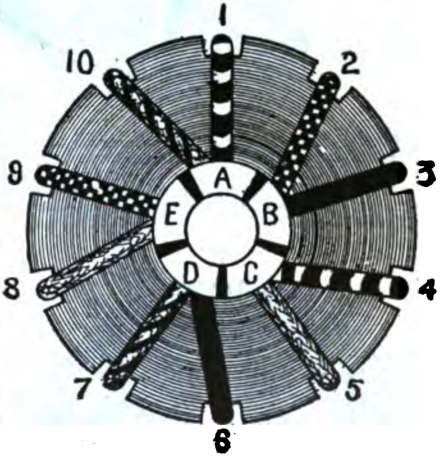


IG. 7,582.—**Disc** armature of Niaudet. It is equivalent to a ring armature, having the coils turned through an angle of 90° so that all the coils lie in a plane perpendicular to the axis of rotation.

Of course in larger machines many more inductors are used than in the tables here given. The *back pitch* is the number of spaces or teeth between the two inductors of a coil; front pitch means commutator pitch. Single winding consisting of one set of coils is called *simplex* as distinguished from a multiplex winding which consists of *two or more independent sets of coils.*

Instead of independent commutators for the several windings, they are combined into one having two or more sets of segments interplaced round the circumference. ultiplex windings reduce the ndency to sparking because the division of the current and so because adjacent commuttor bars belong to different indings.

Windings are said to be *right* or *ft* handed according as they rogress clockwise or counter ockwise, as in figs. 7,590 and ,591.



IG. 7,583.—Five coil wave winding for a four pole machine. In this winding only two brushes are used, there being only two paths trough the armature.

IG. 7,584.—Developed view of tbe five coil wave winding shown in fig. 7,583.

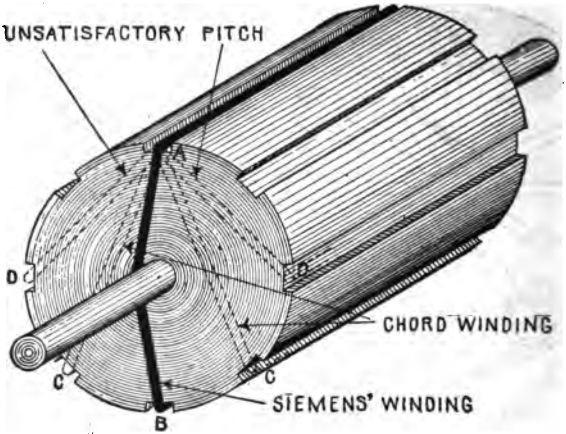


FIG. 7,585.—Distinction between ***Siemens winding*** and ***chord winding***. In cases where the front and back pitches are so taken that the average pitch differs considerably from the value obtained by dividing the number of inductors by the number of poles, the arrangement is called a chord winding. In this method each coil is laid on the drum so as to cover an arc of the armature surface nearly equal to the angular pitch of the poles; it is sometimes called ***short pitch winding***.

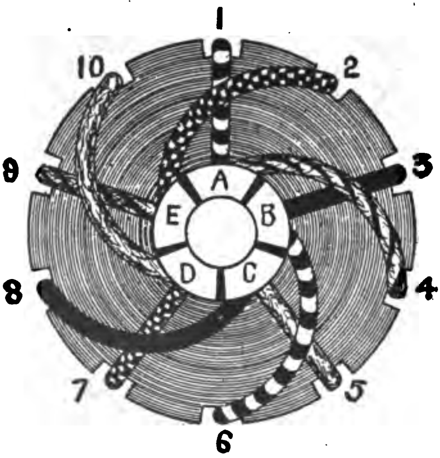


FIG. 7,586.—Lap winding for bipolar machine, with uneven number of coil; in this case the rear connectors may be made directly across a diameter as shown.

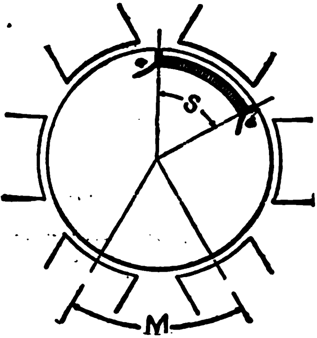
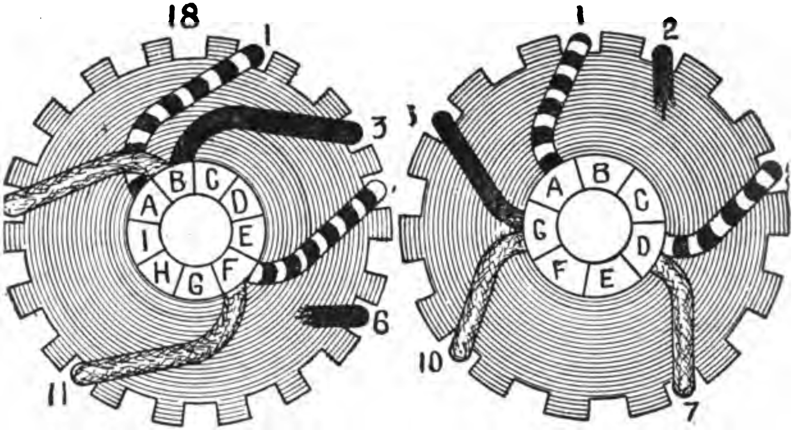
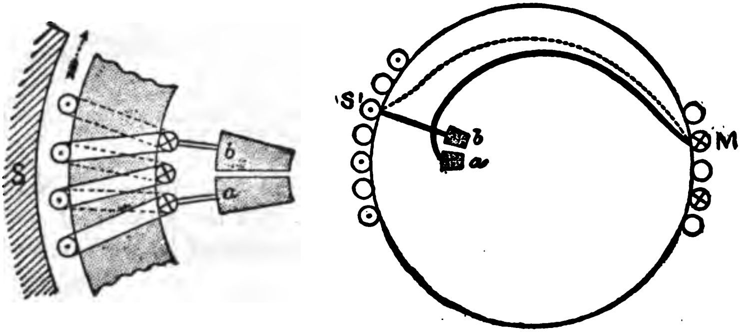


FIG. 7,587.—End view of drum armature of a multipolar machine showing one coil in position to illustrate the ***angular pitch*** or spread of drum coils.



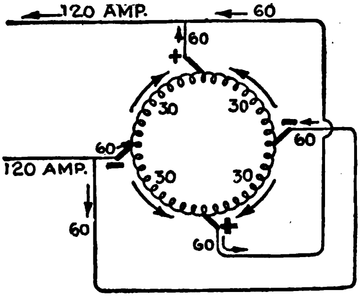
Figs. 7,588 and 7,589.—**Progressive** and **retrogressive** wave windings. *If the front and back pitches of a wave winding be such that in tracing the course of the winding through as many coils as there are pairs of poles, a segment is reached in advance of the one from which the start was made, the winding is said to be progressive, as in fig. 7,588. If the pitches be such that in tracing the winding through as many coils as there are pairs of poles, the first segment of the commutator is not encountered or passed over, the winding is said to be* ***retrogressive****, as in fig. 7,589.*



Figs. 7,590 and 7,591.—Right and left hand windings. These consist respectively of turns which pass around the core in a right or left handed fashion. Thus in fig. 7,590 in passing around the circle clockwise from *a*, to *b*, the path of the winding is a right handed spiral. In fig. 7,591, which shows one coil of a drum armature, if *a*, be taken as the starting point, in going to *b*, *a*, must be connected by a spiral connector across the front end of the drum to one of the descending inductors such as M, from which at the back end another connector must join it to one of the ascending inductors, such as S where it is led to *b* thus making one right handed turn.

Number of Brushes Required.—For ***lap winding***, there will be *as many brushes as there are poles*, situated in regular order around the commutator and *at angular distances apart equal to the pole pitch*. For ***wave winding***, *only* ***two*** *brushes are required for any number of poles*, the angle between the two brushes being the same as the angle between any **N** and **S** pole.

Number of Armature Circuits.—For a simplex spirally wound ring, *the number of paths in parallel is equal to the number of poles*, and for a simplex series wound ring, *there will be two paths*. In the case of multiplex windings *the number of paths is equal to that of the simplex winding multiplied by the number of independent windings*.



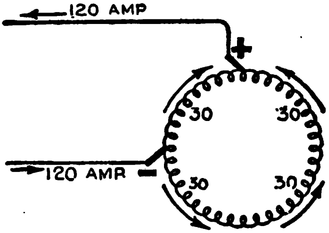
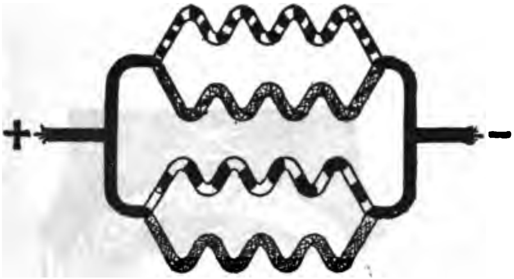


FIG. 7,592.—Distribution of armature currents in a four pole lap wound dynamo having four brushes and generating 120 amperes.

FIG. 7,593.—Showing effect of removing two of the brushes in fig. 7,592. If no spark difficulties occur in collecting the current with only two brushes, the arrangement will work satisfactorily, but the heat losses will be greater than with four brushes.

In large multipolar dynamos it is, as a rule, inadvisable to have more than 100 or 150 amperes in any one circuit, except in the case of special machines for electro-chemical work.

Equalizing Rings.—There are sometimes provided on parallel wound armatures *to counteract the effect of unbalancing*



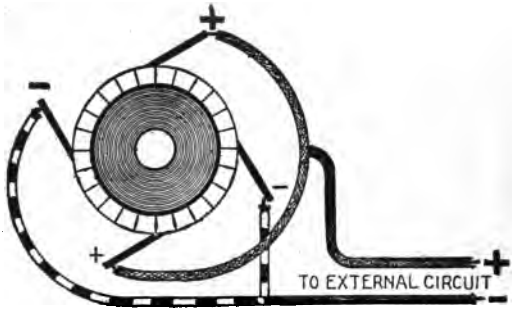


Fig. 7,594.—Diagram showing current distribution through armature of a four pole machine with like brushes connected. There are four paths in parallel, hence the induced voltage will equal that of one set of coils, and the current will be four times that flowing in one set of coils.

Fig. 7,595.—Brush connections for four pole dynamo. ***In a four pole machine,*** two separate currents can be obtained by omitting the parallel brush connections.

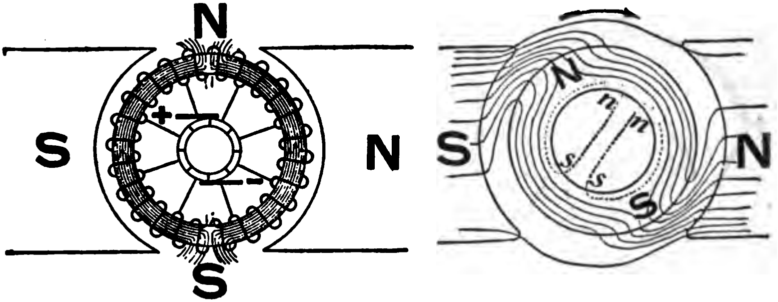
by which the current divides unequally among the several paths through the armature.

On multipolar machines any two or more points may be connected by equalizer rings that during the rotation are at nearly equal voltage.

Drum Winding Requirements.—The following points on drum winding are important:

1. **There cannot be an odd number of inductors.**
2. **Both the front and back pitches must be odd in simplex windings.**
3. **The average pitch should approximately be equal to the number of inductors divided by the number of poles.**

Field Distortion.—In the operation of a dynamo with load, the induced current flowing in the armature winding, converts the armature into an electro-magnet setting up a field across or at right angles to the field of the machine. This cross magnetization of the armature tends to distort the field produced by the



Figs. 7,596 and 7,597.—*Cross magnetization.* If the armature be at rest and a current be passed through it as indicated to represent the induced current, a north pole will be formed at the top and a south pole at the bottom of the armature as shown. Now *in operation,* the effect of this armature magnetization is to distort the field of the magnets giving a resultant or distorted field as in fig. 7,597. A drag or resistance to the rotation of the armature is caused by the attraction of the north and south poles on the armature and pole pieces respectively. Field distortion causes unsatisfactory operating and numerous attempts have been made to overcome this, as by: 1, various forms of pole piece; 2, lengthening the air gap; 3, slotting the pole pieces, and 4, using auxiliary poles.

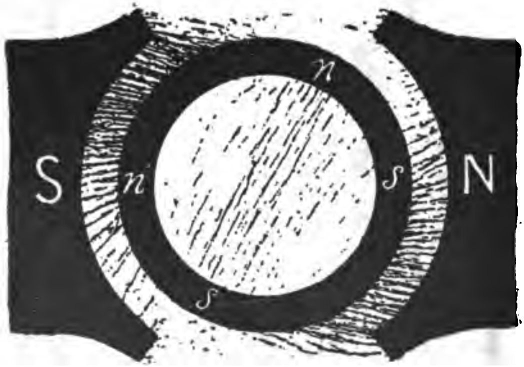
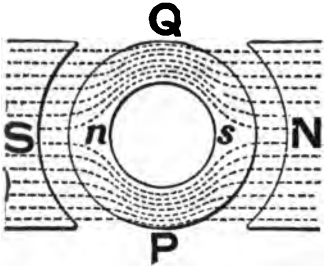


Fig. 7,598.—Actual distortion of field resulting from cross magnetization as shown by iron filings.



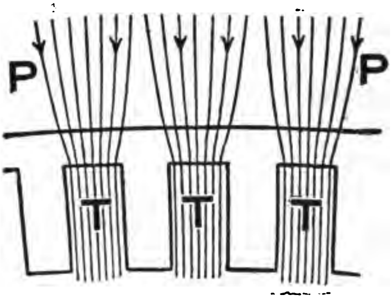
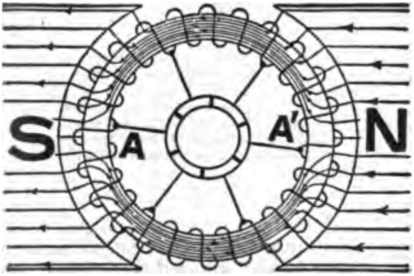


Fig. 7,599.—Magnetic hysteresis in armature core. Unlike poles are induced in the core opposite the poles of the field magnet. Since on account of the rotation of the core the induced poles are reversed a thousand or more times a minute, considerable energy is required to change the positions of the molecules of the iron for each reversal, resulting in the generation of heat at the expense of a portion of the energy required to drive the armature.

Fig. 7,600.—Effect of slotted armature. The teeth, as they sweep past the pole face, cause oscillations of the magnetic flux in the iron near the surface because the lines in the pole piece PP, tend to crowd toward the nearest teeth, and will be less dense opposite the slots. This fluctuation of the magnetic lines produces eddy currents in the pole faces unless laminated. The armature inductors, being screened from the field, are relieved of the drag which is taken by the teeth.



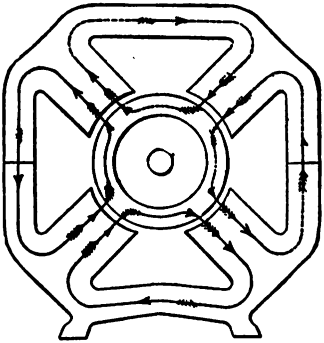


Fig. 7,601.—Distribution of magnetic lines through a ring armature. Since the lines follow the metal of the ring instead of penetrating the interior, no electric pressure is induced in that portion of the winding lying on the interior surface of the ring. There is, therefore, a large amount of dead wire or wire that is ineffective in inducing electric pressure; this is the chief objection to the ring type of armature.

Fig. 7,602.—Distribution of magnetic lines through solid drum armature of a four pole machin field magnets, the effect being known as *armature reaction*, as shown in figs. 7,597 and 7,598.

Magnetic Hysteresis in Armature Cores.—When an Armature rotates in a magnetic field, the armature coil *is subjected to opposite magnetic inductions which occur with great rapidity*, resulting in the generation of heat at the expense of a portion of the energy required to drive the armature

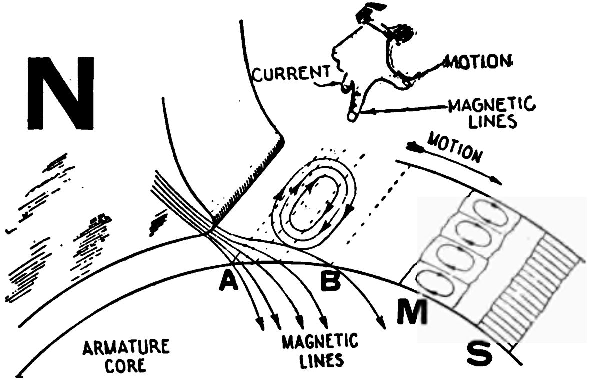


FIG. 7,603.—Foucault or "eddy" currents in solid armature core. Since the magnetic field is more dense at A, near the pole tip than at B, remote from the pole tip, the *rate* at which an element of the core in passing from A, to B, cuts magnetic lines is *altered*, hence eddy currents are set up as shown. To break up the path of these eddy currents the core is laminated or built up of thin steel stampings as indicated at S, which interposes resistance between each stamping, thus opposing the formation of these currents. If the laminations were few and thick as at M, currents would be set up in each lamination as indicated. *In practice* the thin metal discs at S, are usually about No. 18 gauge thick.

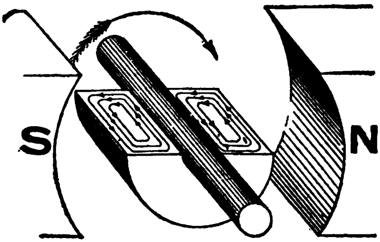
This loss of energy is due to the work required to change the position of the molecules of the iron, and takes place both in the process of magnetizing and demagnetizing; *the magnetism in each case lagging behind the force.*

Self-Induction in the Coils.—In an armature coil *the adjacent turns act inductively upon each other upon the principle of the mutual induction arising between two separate adjacent circuits*

This self-induction opposes a rapid rise or fall of the induced current, the effect being similar to the inertia of matter which prevents any instantaneous change in its motion. The self-induction is one of the factors which enters into brush adjustment requring additional lead to prevent sparking.

Eddy Currents in Armature Core.—Armature cores as well as field cores, are subject to eddy currents which consume considerable energy and often cause harmful rise of temperature.

To reduce eddy currents to a minimum, armature cores are **laminated.**



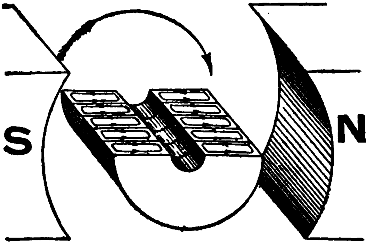
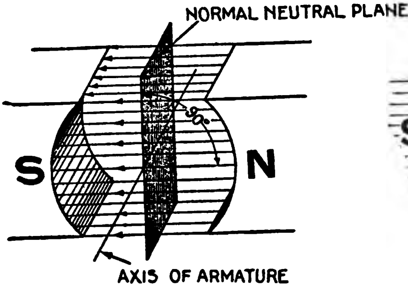


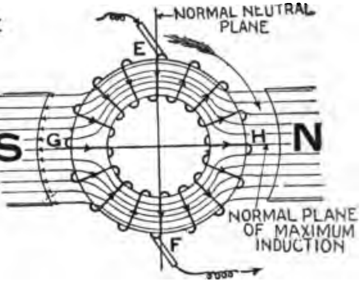
FIG. 7,604.—Eddy currents induced in a solid armature core. Eddy currents always occur when a solid metallic mass is rotated in a magnetic field, because the outer portion of the metal cuts more lines of force than the inner portion, hence the induced electric pressure not being uniform, tends to set up currents between the points of greatest and least pressure. Eddy currents consume a considerable amount of energy and often occasion harmful rise in temperature.

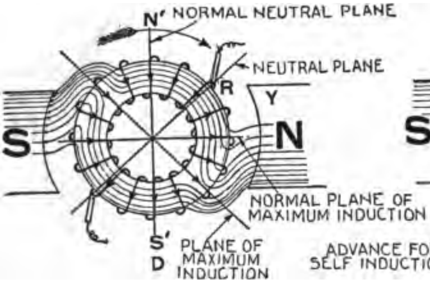
FIG. 7,605.—Armature core with a few laminations showing effect on eddy currents. In practice the core is made up of a great number of thin sheet metal discs, about No. 18 gauge, and introduces so much resistance between the discs that the formation of eddy currents is almost entirely prevented.

NOTE.—*Foucault or "eddy" currents* in armature core. When the construction of he armature core and inductors does not fulfil the necessary conditions required for the pre-ention of eddy currents, such as the laminations not being sufficiently insulated or numerous nough, a great heating of the whole of the armature results, which may even extend to the earings. There is no remedy for this defect other than the purchase of a new armature, or he entire reconstruction of the old. The fault may be detected by exciting the field magnets nd running the machine on open circuit, with the brushes raised off the commutator for some me, when the armature will be found to be excessively heated.

NOTE.—*Jean Bernard Leon Foucault,* born 1819, died 1868, was a French scientist nd inventor, noted for his optical researches and his investigations in connection with eddy urrents, these being called Foucault currents after him.







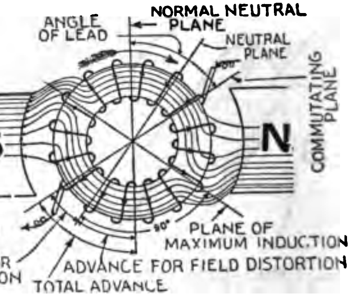
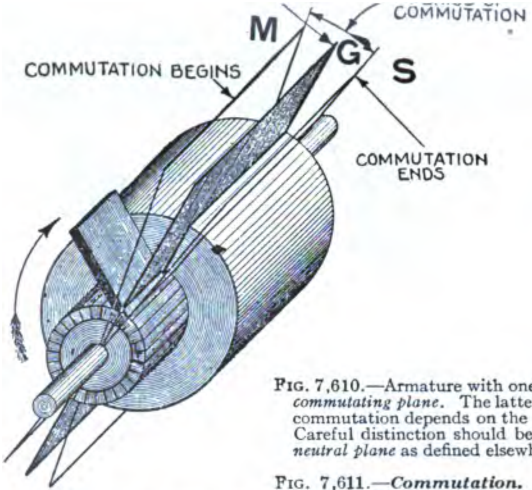


FIG. 7,606.—Normal neutral plane. This is a reference plane from which the lead is measured. As shown, the normal neutral plane lies at right angles to the lines of force of an undistorted field.

FIG. 7,607.—The proper position of the brushes, if there were no field distortion, self-induction in the armature coils would be in the normal neutral plane. In the actual dynamo these two disturbing effects are present which makes it necessary to advance the brushes as shown in figs. 7,608 and 7,609 to secure sparkless commutation.

FIG. 7,608.—Brush adjustment for ***field distortion.*** The effect of the latter is to twist the lines of force around in the direction of rotation, thus maximum induction takes place in an inclined plane. The brushes then must be advanced to the *neutral plane* which is at right angles to the plane of maximum induction. This gives the proper position of the brushes *neglecting self-induction*.

FIG. 7,609.—Brush adjustment for ***self-induction.*** By advancing the brushes beyond the neutral plane as shown, commutation takes place with the short circuited coil cutting the lines of force so as to induce a current in the opposite direction which opposes the continuance of current in the short circuited coil due to self-induction, brings it to rest and starts it in the opposite direction thus preventing sparking.



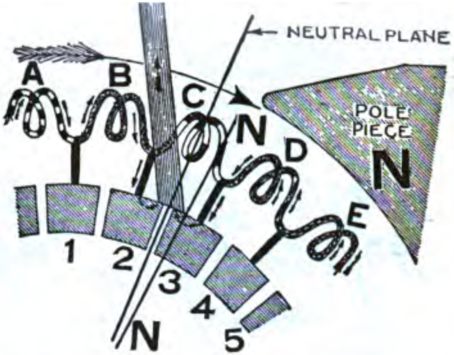
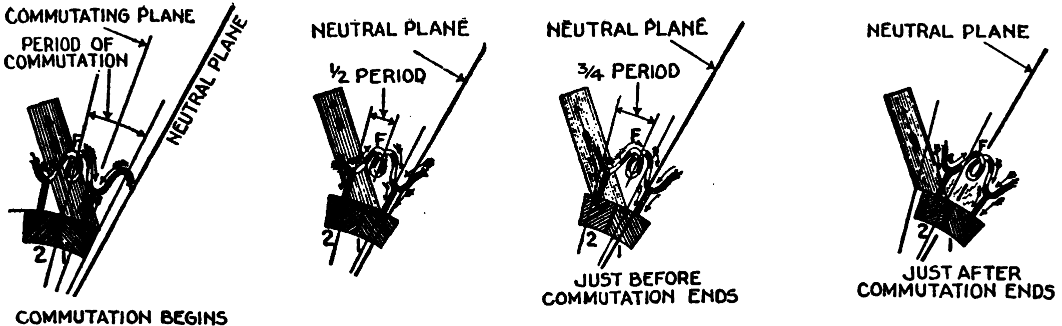
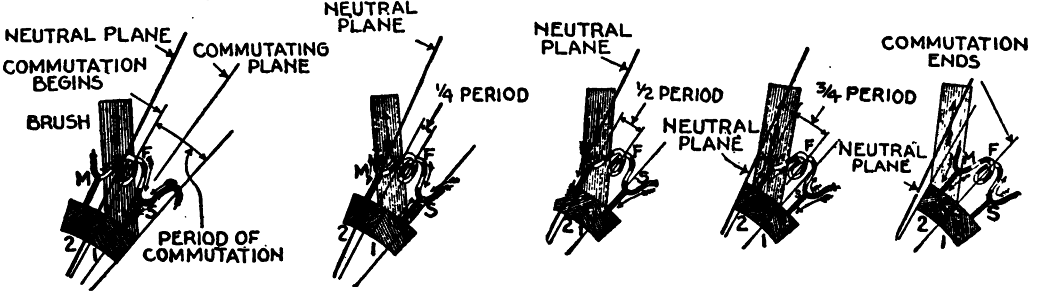


FIG. 7,610.—Armature with one brush in position to illustrate the *period of commutation* and *commutating plane*. The latter is called "commutating line" by some writers. The period of commutation depends on the thickness of the brush end in contact with the commutator. Careful distinction should be made between *commutating plane*, *neutral plane*, and *normal neutral plane* as defined elsewhere.

FIG. 7,611.—***Commutation.*** Here the coils A,B,C,D,E, are connected to commutator segments 1,2,3,4, and the positive brush is shown in contact with two segments 2 and 3, the brush being in the neutral position. Currents in the coils on each side of the neutral line flow to the brush through segments 2 and 3; the brush then is positive. Now, as the armature turns, the commutator segments come successively into contact with the brush. In the figure, segment 3, is just leaving the brush and 2, is beginning to pass under it, hence, for an instant the coil C, is short circuited. Previous to contact with sement 2, current flowed in coil C, in the same direction as in coil B. While the brush is in contact with segments 2 and 3, the current in C, is stopped and started again in the opposite direction. Similarly each coil of the armature as it passes the brush will be short circuited and have its current reversed. This is known as *commutation*.

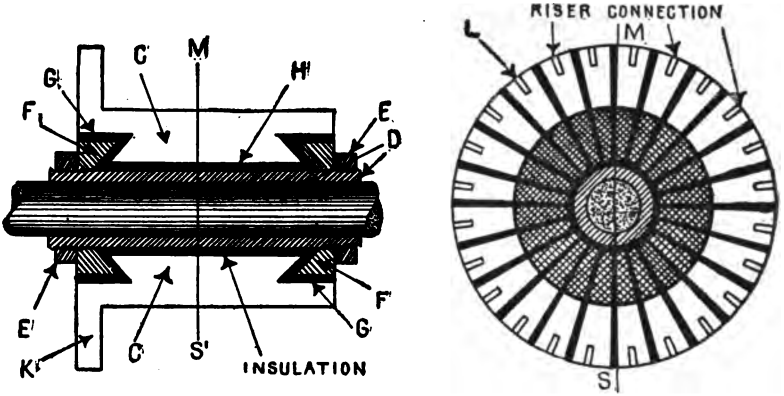
Commutation.—*This takes place during the brief interval in which any two segments of the commutator are bridged by the brush.*





Figs. 7,612 to 7,615.—Improper brush adjustment resulting in excessive sparking. When the brushes are not advanced far enough, commutation takes place before the short circuited coil reaches the neutral plane, hence, its motion is not changed with respect to the magnetic field so as to induce a reverse current till after commutation. There is then no opposing force, during commutation, to stop and reverse the current in the short circuited coil, and when the brush breaks contact with segment 1, as in fig. 7,615, the "*momentum*" of the current in coil F, causes it to jump the air gap from segment 1 to segment 2 and the brush, against the enormous resistance of the air, thus producing a spark whose intensity depends on the momentum of the current in coil F. Sparking, if allowed to continue, will injure the brushes and commutator segments.

Figs. 7,616 to 7,720.—How sparkless commutation is obtained by advancing the brushes beyond the neutral plane; commutation progressively shown.



SECTION ON LINE MS

SECTION ON LINE M'S''

FIGS. 7,621 and 7,622.—Side and end sectional views of commutator showing construction. The parts are: C, segments; D, tubular iron hub; E, end nuts; F, clamps; G, insulation· L, riser connection.

FIG. 7,616 to 7,620—*Text.*

FIG. 7,616.—Commutation begins; current flows up both sides of the armature, uniting at S and flowing to the brush through commutator segment 1 as indicated by the arrow.

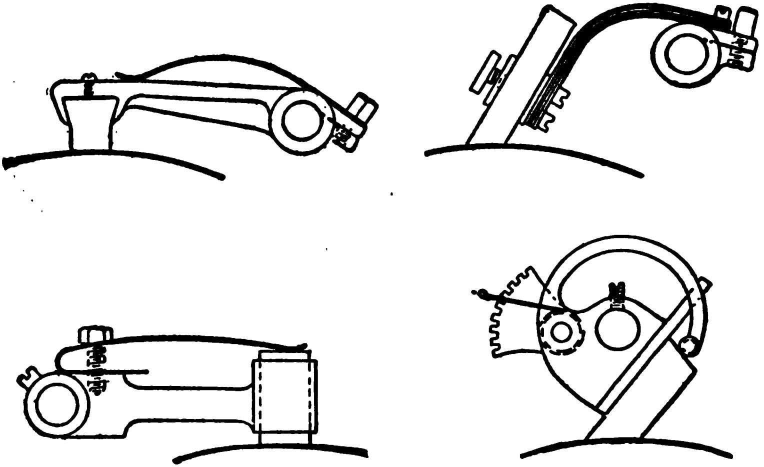
FIG. 7,617.—Segment 2 has come into contact with the brush and coil F, in which commutation is taking place, is now short circuited. The current now divides at M, part passing to the brush through segment 2, and part through coil F, and segment 1. Although coil F, is short circuited and having passed the neutral plane, is cutting the lines of force so as to induce a current in the opposite direction, it still continues to flow with unchanged direction against these opposing conditions. This is due to *self-induction* in the coil which resists any change just as the momentum of a heavy moving body, such as a train of cars, offers resistance to the action of the brakes in retarding and stopping its motion.

FIG. 7,618.—Segment 2 has moved further under the brush, and the opposition offered to the forward flow of the current in the short circuited coil F, by the reverse induction in the magnetic field to the right of the neutral plane has finally brought the current in F, to rest. The currents from each side of the armature now flow direct to the brush through their respective end segments 1 and 2.

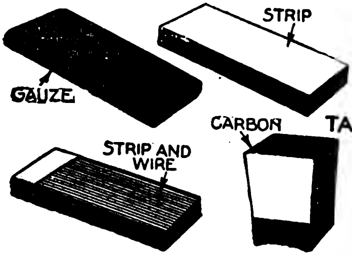
FIG. 7,619.—Segment 1 is now almost out of contact with the brush. A current has now been started in the coil F, in the reverse direction due to induction in the magnetic field to the right of the neutral plane; it flows to the brush through segment 2. The current has not yet reached its full strength in F, accordingly part of the current coming up from the right divides at S, and flows to the brush through segment 1.

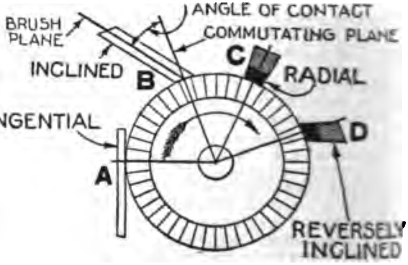
FIG. 7,620.—Completion of commutation in segments 1 and 2; the brush is now in full contact with segment 2, the current in coil F, has now reached its full value, hence the current flowing up from the right no longer divides at S, but flows through F, and segment 2 to the brush. If the current in F, had not reached its full value, at the instant segment 1 left contact with the brush, it could not immediately be made to flow at full speed any more than could a locomotive have its speed instantly changed. This, as previously explained, is due to self-induction in the coil or the so-called "inertia" of the current which opposes any sudden change in its rate of flow or direction. Accordingly that portion of the current which was flowing up from the right and passing off at S, to the brush through segment 1 as in fig. 7,619, would, when this path is suddenly cut off as in fig. 7,620, encounter enormous opposition in coil F. Hence, it would momentarily continue to flow through segment 1 and jump the air gap between this segment and the brush, resulting in a more or less intense spark depending on the current conditions in coil F.

The coil connecting with the two segments under the brush is thus short circuited. During commutation the current in the short circuited coil is brought to rest and started again in the reverse direction against the opposition offered by its so-called inertia, or effect produced by self-induction.



FIGS. 7,623 to 7,626.—Various types of brush holder. Fig. 7,623, arm or lever type; fig. 7,624, spring arm type; fig. 7,625, box type; fig. 7,626, reaction type.





FIGS. 7,627 to 7,630.—Various forms of brush. Fig. 7,627, gauze brush; fig. 7,628, laminated or strip brush; fig. 7,629, strip and wire brush as used on the early Edison machines; fig. 7,630, carbon brush. Carbon is preferred to copper for brushes on account of the reduction of sparking secured by its use.

FIG. 7,631.—Contact angle for the different types of brush. At A, is shown a brush with tangential contact, and at B, a so-called tangent brush; the latter is properly called an inclined brush. Sheet copper brushes are set tangentially as at A, and gauze brushes inclined as at B. Carbon brushes are placed radially as at C, when mounted in box holders, and inclined opposite to the direction of rotation when used with reaction holders.

different materials, such as copper or brass gauze, bundles of wire, carbon blocks, etc.

Copper brushes tend to tear and roughen the surface of the commutator while carbon brushes tend to keep the surface smooth. Copper brushes will carry from 150 to 200 amperes per sq. in. of contact surface; carbon brushes, from 40 to 70. Usual contact pressure 1¼ to 1½ lbs. per sq. in. Commutator rim velocities vary from about 1,500 to 2,500 feet per minute. The voltage drops for carbon brushes is about .8 to 1 volt at each contact.

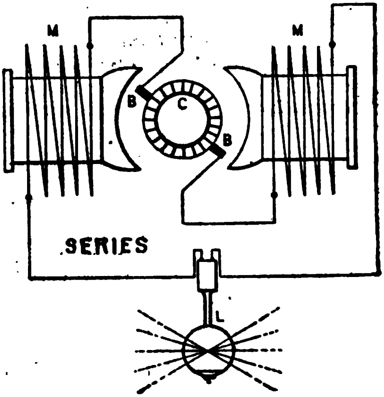


FIG. 7,632.—*Series* dynamo, used for series lighting, and as a booster for increasing the pressure on a feeder carrying current furnished by some other dynamo. The coils of the field magnet are in series with those of the armature and external circuit, and consists of a few turns of heavy wire. MM, field coils; BB, brushes; C, commutator; L, lamp. *Characteristics:* It furnishes current with increasing voltage as the load increases. If overloaded, the voltage will drop.

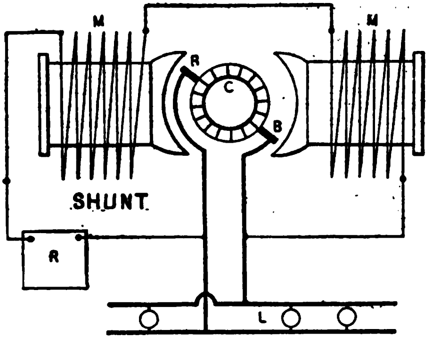


FIG. 7,633.—*Shunt dynamo,* used for parallel circuit incandescent lighting, and for mill and factory power. The coils of the field magnet form a shunt to the main circuit; they consist of many turns of fine wire and consequently absorb only a small fraction of the current induced in the armature. MM, field coils; BB, brushes; C, commutator; L, lamp circuit; R, field rheostat. *Characteristics:* It gives practically constant voltage for all loads within its range. If overloaded the voltage will drop and the machine cease to generate current.

Classes of Dynamo.—With respect to the field winding, dynamos may be divided into three important types: 1, series; 2, shunt, and 3, compound.

A **series dynamo** is one in which all the current produced flows through the field winding.

In a **shunt dynamo** only a portion of the total current passes through the field magnet.

A **compound dynamo** has a *series winding* around which the main current flows, and a *shunt winding* through which a fraction of the main current flows. These various windings are shown in the accompanying cuts.

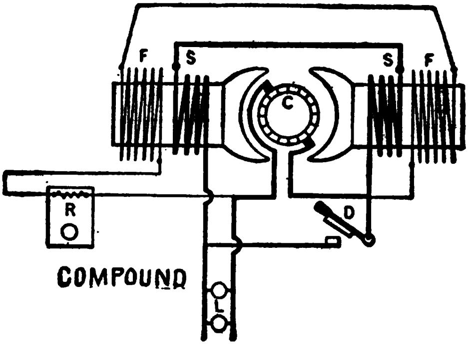


FIG. 7,634.—***Compound dynamo,*** used when better automatic regulation of voltage on constant pressure circuits is desired than is possible with the shunt machine, as for incandescent lighting or long lines. The compound dynamo is a combination of the series and shunt types, that is, the field magnet is excited by both series and shunt windings. SS, series winding; FF, shunt winding; R, shunt rheostat; C, commutator; L, external circuit; D, series cutout switch which permits dynamo to run as a simple shunt machine. *Characteristics:* The series coils strengthen the field as the load rises, and by varying the number of series turns, different results may be obtained. If the series coils be of many turns, the field magnets will be so strengthened as to cause the voltage to rise with increase of load. This is called *over compounding.*

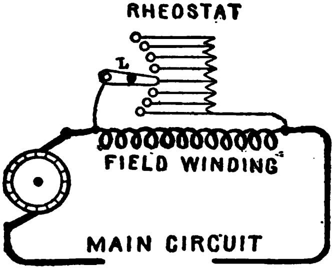
OPERATION

Starting Dynamo.—The different types of dynamos will require different treatment in starting, as follows:

Series Dynamo.—The extended circuit should be closed, otherwise a closed circuit will not be formed through the field magnets and the machine will not "build up." The term *build up* means the gradual increase of voltage to maximum.

Shunt Dynamo.—All switches controlling the external circuits should be opened, as the machine excites best when this is the case. If the machine be provided with a rheostat or hand regulator and resistance coils, these latter should all be cut out of circuit, or short circuited, until the machine excites, when they can be gradually cut in as the voltage rises.

When the machine is giving the correct voltage, as indicated by the volt meter or pilot lamp, the machine may be switched into connection with the external or working circuits.



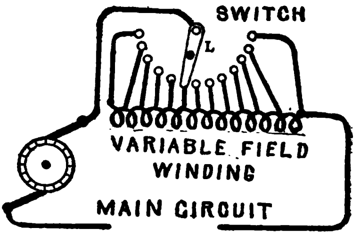


FIG. 7,635.—The two path method of regulating a series dynamo. The shunt current is regulated by the rheostat. In this way the field strength is easily regulated by switch L.

FIG. 7,636.—Regulation of series dynamo by variable field. A multi-point switch L is provided with connections to the field winding at various sections, thus permitting more or less of the field winding to be cut out to regulate its strength.

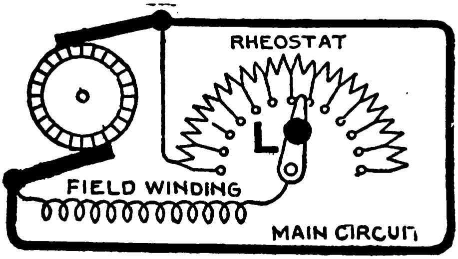
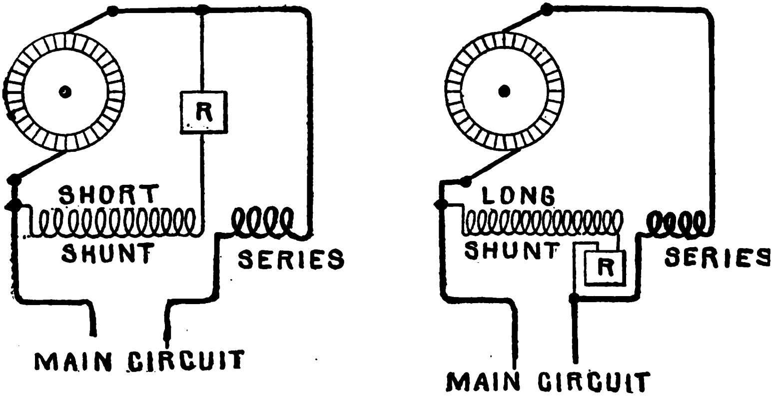


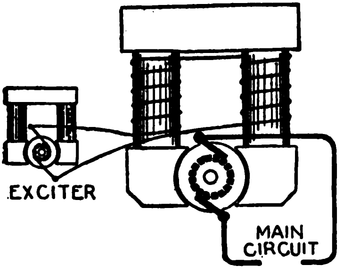
FIG. 7,637.—Regulation of shunt dynamo by method of varying the field strength with rheostat switch L.

If the machine be working on the same circuit with other machines, or with a storage battery, it is, of course, necessary to make the voltage of the machine equal to that on the line before connecting it in the circuit.

If the machine work alone, the switch may be closed either before or after the voltage comes up. The load will be thrown on suddenly if the switch be closed after the machine has built up its voltage, thus causing a strain on the belt, and possibly drawing water over the engine cylinder.



FIGS. 7,638 and 7,639.—Short and long shunt types of compound wound dynamos. The distinction between the two is that the ends of the short shunt connect direct with the brush terminals, while in the long shunt type, fig. 7,639, one end of the shunt connects with one brush terminal and the other with the terminal connecting the series winding with the external circuit. R, is the shunt field rheostat for regulating the current through the shunt.



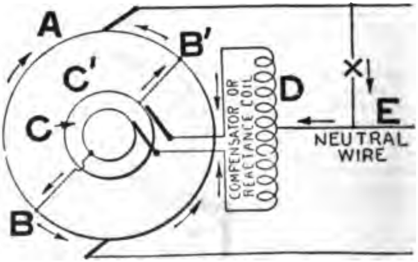


FIG. 7,640.—Separately excited-dynamo. This method of field excitation is seldom used except for alternators; it is, however, to be found occasionally in street railway power houses, the shunt fields of all the dynamos being separately excited by one dynamo. ***Characteristics:*** With the exception of armature reaction, the magnetism in its field and therefore the total voltage of the machine is independent of variations in the load.

FIG. 7,641.—Dobrowolski three wire dynamo used for three wire system without balancer. The armature A, is tapped at two points, B and B′, and connected to slip rings CC′. A compensator or reactance coil D, between the two halves of which there is minimum magnetic leakage, is connected to C and C′, by brushes, and has its middle point tapped and connected to the neutral wire E. ***Characteristic:*** The machine is capable of feeding unbalanced loads without serious disturbance of the pressure on either side of the system. Evidently, from the symmetry of the arrangement, the center point of the coil must always be approximately midway in pressure between that of the brushes, and hence any unbalanced current will return into the armature, dividing equally between the two halves of the coil.

Again, if the switch be closed before the voltage of the machine has come up, the load is picked up gradually, but the machine may be slow or may even refuse to pick up at all. Failure to pick up may be due to: 1, too little external resistance; 2, improper brush adjustment; 3, loss of residual magnetism; 4, wrong field connections, etc.

Compound Dynamo.—Cut in all field resistance and bring machine up to speed; cut out field resistance until voltage of dynamo equals or is a trifle above that of bus bar; throw on the load.

Coupling of Dynamos.—For very large and variable loads two or more dyamos are used, the number coupled together at any time depending on the current demand; then the output of one can be added to that of another, so that the dynamos actually at work at any moment can be operated as nearly as possible at full load.

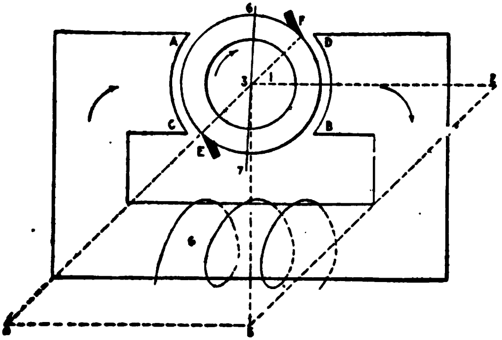


FIG. 7,642.—Diagram illustrating forces acting on a dynamo armature. *In the figure* the normal field magneto-motive force is in the direction of the line 1,2, produced by the field circuit G, if there were no current in the armature. But as soon as the armature current flows, it produces the opposing force 3,4, which must be combined with 1,2 to give the resulting force to produce magnetism and hence voltage. The resultant 1,5, if 3,4 be large enough, does not differ much from the original force 1,2. Or, expressed in a more physical way, the brushes E,F, rest on the commutator and all the turns embraced by twice the angle 6,3, F, oppose the flow of flux through the armature core as well as all the turns embraced by twice the angle, 7,3,E. The remaining turns distort the flux, making the pole corners at A and B, denser, and at C and D, rarer. So that all the effect is to kill an increase of flux, or voltage. This cross magnetism tends also to decrease the flow of flux, for the extra ampere turns required to force the flux through the dense pole tips are greater than the decreased ampere turns relieved by the reduction of flux at the other pole tips; this follows, since iron as it increases in magnetic density requires ampere turns greater in proportion than the increase of flux.

In coupling dynamos in series, the current capacity of the plant is kept at a constant value, while the output is increased in proportion to the pressures of the machines in circuit.

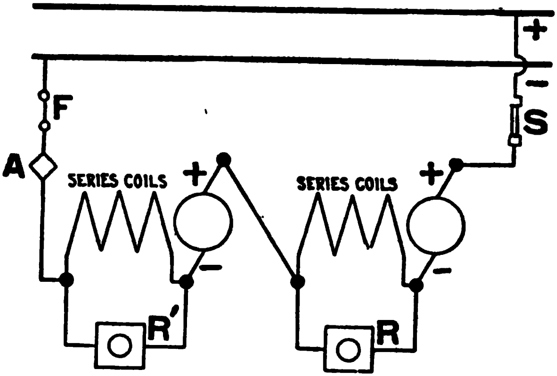


FIG. 7,643.—*Series dynamos in series.* The positive terminal of one dynamo is connected to the negative terminal of the other, and the two outer terminals are connected directly to the two main conductors or bus bars through the ammeter A, fuse F, and switch S. If it be desired to regulate the pressure and putput of the machines, variable resistances, or hand regulators R, R^1, may be arranged as shunts to the series coils as shown, so as to divert a portion or the whole of the current therefrom.

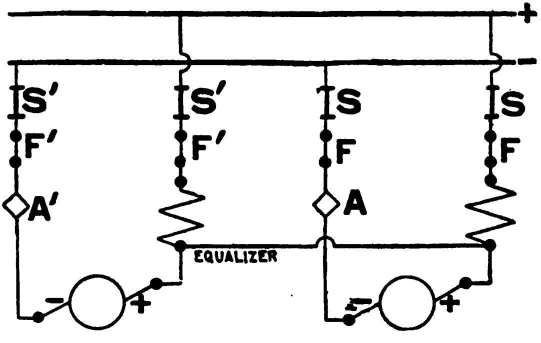


FIG. 7,644.—*Series dynamos in parallel.* The ends of the series coils are connected where they join on to the armature circuit by a third connection called the *equalizer* which prevents the tendency in series dynamos to reverse, that is, the fields in the dynamos being maintained constant or to vary equally, the tendency for the firemen of one dynamo to fall below that of the others is diminished. AA′, ammeters; FF′, fuses; SS′ switches. Series dynamos are very seldom connected in parallel because of the difficulty of regulating the voltage.

When connected in parallel, the pressures of all the machines are kept at a constant value, while the output of the plant is increased in proportion to the current capacities of the machines in circuit.

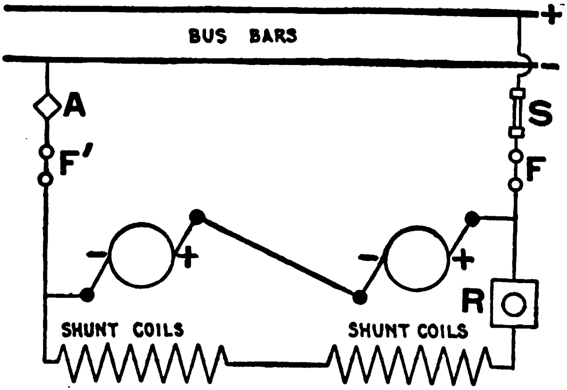


FIG. 7,645.—*Shunt dynamos in series.* The positive terminal of one machine is joined to the negative of the other, and the two outer terminals connected through the ammeter A, fuses FF′, and switch S, to the two main conductors or "omnibus bars." The ends of the shunt coils may be connected to the terminals of their respective machines, or they may be connected in series as shown.

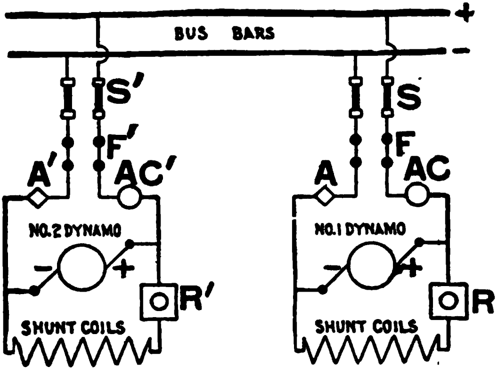


FIG. 7,646.—*Shunt dynamos in parallel.* The terminals are connected in parallel to the bus bars through the double pole switches SS, and fuses F,F′. Ammeters AA′, are inserted, and automatic cutouts AC, AC′, are sometimes provided. Both the shunt coils are connected in series and a field rheostat R, provided. Sometimes the shunt coils are connected to the terminals of each machine with individual field rheostats but the former method is better.

Uncoupling of Dynamos in Parallel.—The load of a compound dynamo, as in the case of a shunt machine, is first reduced to a few amperes, either by easing down the engine, or by cutting resistance into the shunt circuit by means of the hand regulator, and then opening the switch.

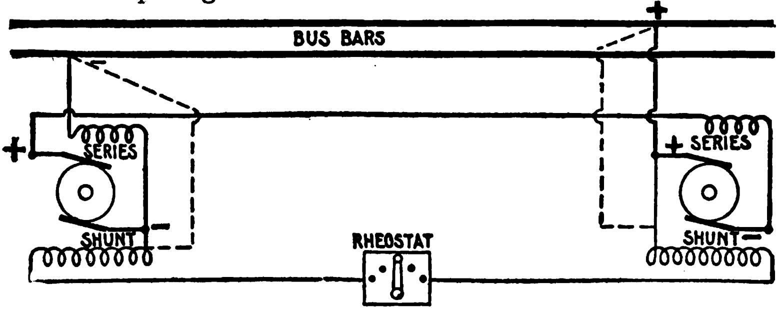


FIG. 7,647.—*Compound dynamos in series. Short shunt* connection. The dotted lines indicate the changes necessary for *long shunt* connection.

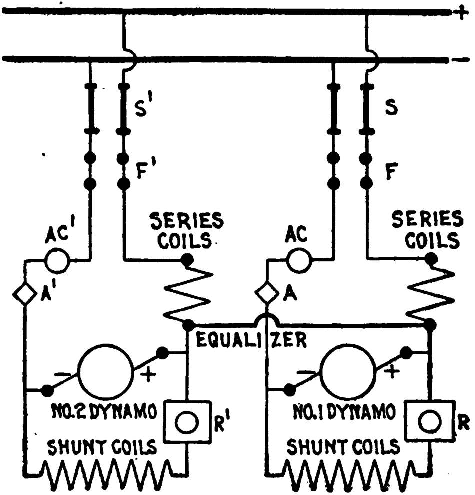


FIG. 7,648.—*Compound dynamos in parallel.* The equalizer for the series coils is necessary for satisfactory operation as in series dynamos. S,S′, switches; F,F′, fuses; A,A′, ammeters; AC, AC′, automatic cutouts; V, voltmeter; R,R′, shunt field rheostats.

Previous to this, however, it is advisable to increase the voltage at the bus bars to a slight extent, as while slowing down the engine the load upon the outgoing dynamo is transferred to the other dynamo armatures, and the current in their series coils not being increased in proportion, the voltage at the bus bars is consequently reduced somewhat.

Attention While Running.—An important item is the adjustment of brushes, because if this be neglected, the machine may spark badly which will necessitate frequent refiling of the commutator and brushes to secure good contact. The best lead for brushes can be found by rotating the rocker.

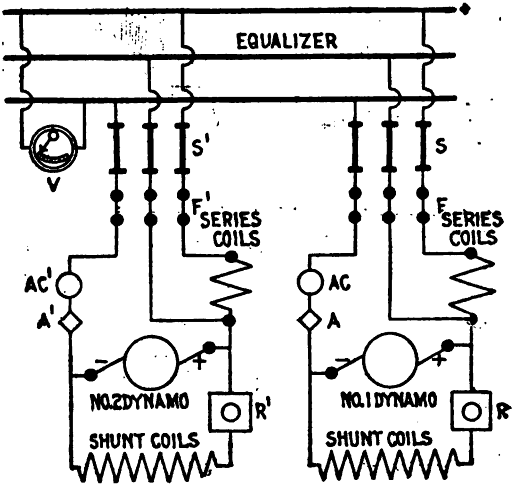
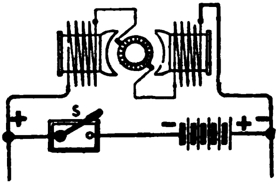


FIG. 7,649.—Diagram showing another and better method of coupling compound dynamos in parallel. With this arrangement the idle machines are completely disconnected from those at work. The same reference letters are common in both diagrams. S, S', are switches; F, F' fuses; A, A', ammeters, which indicate the total amount of current generated by each of the machines; AC, AC', automatic switches, arranged for automatically switching out a machine in the event of the pressure at its terminals being reduced through any cause; R,R', are hand regulators, inserted in the shunt circuits of each of the machines, by means of which the pressures of the individual machines may be varied and the load upon each adjusted. The pressure at the bus bars is given by the volt meter V, one terminal of which is connected to each of the bars; a second volt meter may be used, to give the pressure of any individual machine, by connecting "volt meter keys" to the terminals of each of the machines, or a separate volt meter may be used for each individual machine. The only essentia ldifference between figs. 7,644 and 7,449 is, that in fig. 7,644 the equalizer is connected direct to the positive brushes of all the dynamos, while in fig. 7,449 the equalizer is brought up to the switch board and arranged between the two bus bars, a switch being fitted for disconnecting it from the circuit when the machine to which it is connected is not working.

Stopping a Dynamo.—First reduce load gradually by slowing down engine, and do not open main switch until machine is supplying little or no current.

This reduces sparking at switch contact and prevents engine racing. When volt meter almost indicates zero raise brushes to prevent damage in case engine makes a backward movement (especially a gas engine) before coming to rest. *Caution*, if brushes be raised while there is much voltage the insulation of machine may be damaged, and with large shunt machines operator is liable to receive a severe shock.



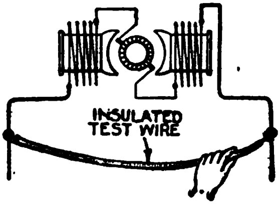


Fig. 7,650.—Method of overcoming insufficient residual magnetism. When connected as shown and circuit completed by switch S, the voltage of the battery will be added to any small voltage generated in the armature. When the machine is started, the combined voltages will probably be able to send sufficient current through the shunt to excite the machine. As the voltage rises and the strength of the current in the shunt windings increases, cut out battery by opening switch S.

Fig. 7,651.—Method of testing for break by short circuiting the terminals of the machine. If the external circuit test out apparently all right, and there be no defective contacts in any part of the machine, and all short circuiting switches, etc., be cut out of circuit, the machine still refusing to excite, short circuiting the terminals of the machine should be tried. This should be done very cautiously, especially in case of a high tension machine. It is advisable to have, if possible, only a portion of the load in circuit, and the short circuit should be effected as shown in the figure. The short circuit may be made by momentarily bridging across the two terminals of the machine with a single piece of wire. As this, however, is liable to burn the terminals, a better plan is to fix a short piece of scrap wire in one terminal, and then with another piece of insulated wire make momentary contacts with the other terminal and the short piece of wire. If the machine excite, it will be at once evident by the arc which occurs between the two pieces of wire.

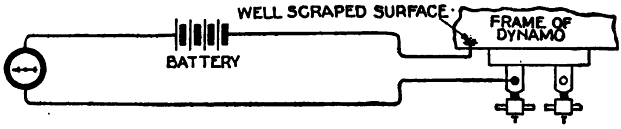
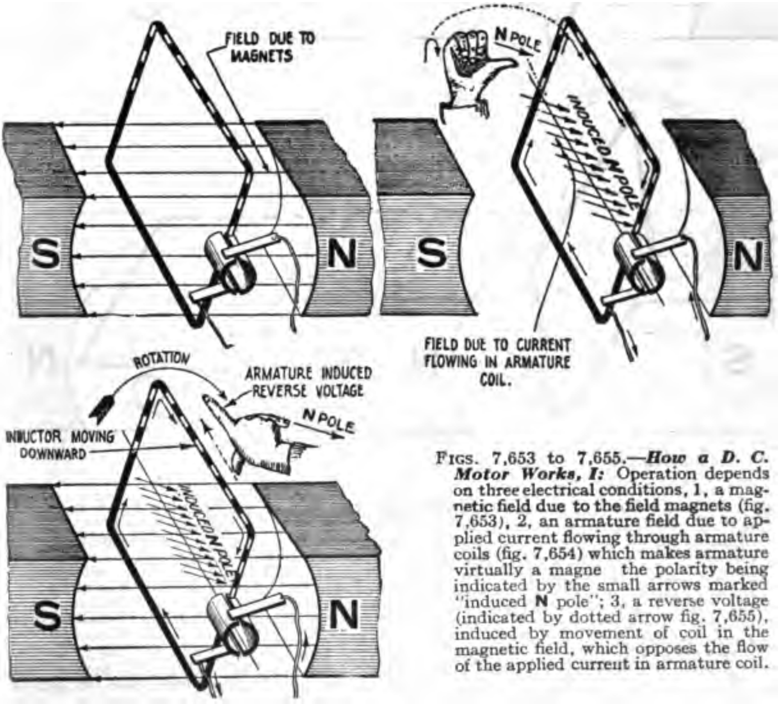


Fig. 7,652.—Method of testing dynamo for short circuits. T, T, are terminals under test. *In testing*, of a deflection of the needle be produced when the galvanometer terminal is in contact with either, the terminals are in contact with the frame, and they should then be removed, and the fault repaired by additional insulation or by reinsulating.

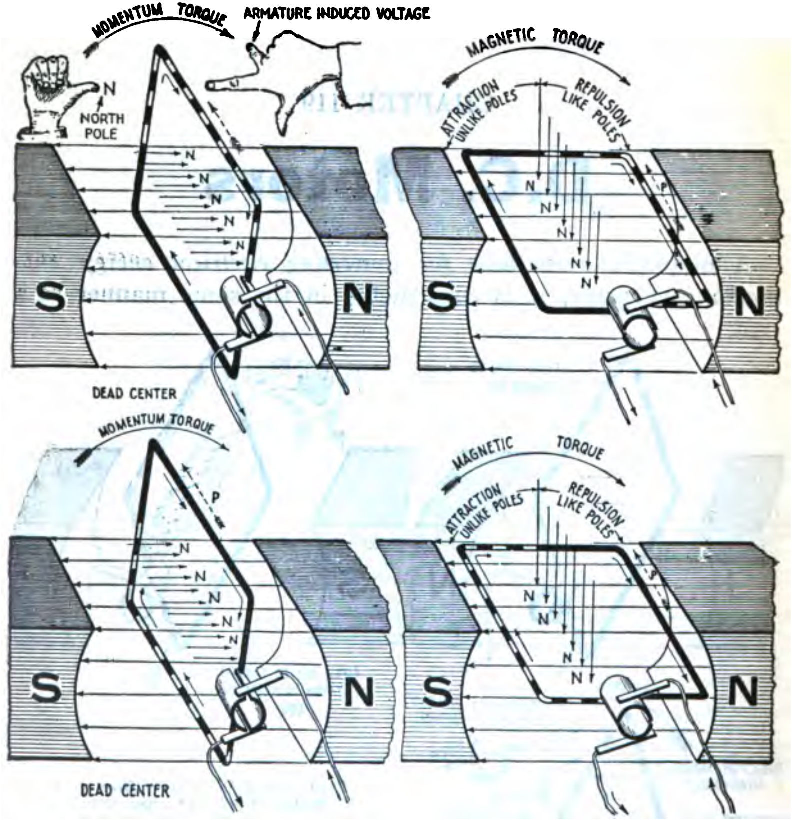
CHAPTER 119

D.C. Motors

A motor is *a machine for converting electrical energy into mechanical energy;* it is constructed in the same manner as a



Figs. 7,653 to 7,655.—*How a D. C. Motor Works, I:* Operation depends on three electrical conditions, 1, a magnetic field due to the field magnets (fig. 7,653), 2, an armature field due to applied current flowing through armature coils (fig. 7,654) which makes armature virtually a magnet the polarity being indicated by the small arrows marked "induced **N** pole"; 3, a reverse voltage (indicated by dotted arrow fig. 7,655), induced by movement of coil in the magnetic field, which opposes the flow of the applied current in armature coil.

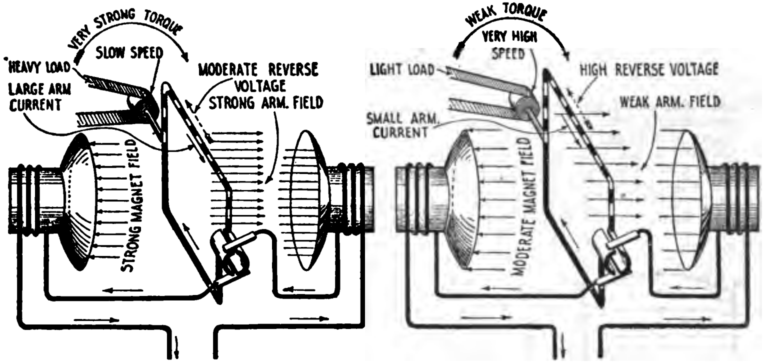


FIGS. 7,656 to 7,659.—***How a D.C. Motor Works, II:*** Cycle of operation: Fig. 7,656, beginning of revolution, armature and magnet poles in opposite directions and hence *they* ("like" poles) ***oppose each other***. This is the dead center position as there is no magnetic tendency to rotate armature, since magnetic lines of magnets and armature are parallel, but ***momentum*** of the armature (assured to be rotating) carries it past this dead center (just as a steam engine passes its dead center), when a clockwise torque is produced by the opposition of like poles. Fig. 7,657, ¼ revolution position; armature poles at right angles or midway between magnet poles; here the torque is due to ***the equal turning forces of repulsion of like poles and attraction of unlike poles***. Fig. 7,658, ½ revolution position; at this instant ***the armature polarity is reversed*** by the reversal of current flowing in the armature coil due to brushes passing to opposite segment of commutator; the magnetic lines being parallel, give a second dead center ***with like poles repelling each other*** similar as in fig. 7,656, ***momentum carrying the armature past the dead center***. Fig. 7,659, ¾ revolution position, armature poles ***again*** at right dynamo. As with dynamos, there are three general types of motors:

1. Series; 2. Shunt; 3. Compound.

Their characteristics are given below.

Series Motor.—It is inherently a variable speed motor starting with very powerful torque. On very light load the speed becomes dangerously high, hence it should be used only where the load is never entirely removed or where close attention is maintained. *Should never be used with a belt,* but always by coupling chain or gear. Used chiefly for hoists, cranes, street railways, and fans.



FIGS. 7,660 and 7,661.—*How a D. C. Motor Works, III: Series motor with variable load.* Since the same current passes through both the armature and field coils *the strength of the magnet field varies with that of the armature field.* Now if a heavy load cause the motor to slow down as in fig. 7,660, the reverse voltage will be reduced and a large current will flow through both armature and magnets producing a very strong toruqe to carry the load. Again, if the load be reduced, as in fig. 7,661, the motor will speed up and increase the reverse voltage which by cutting down the current will weaken both the armature and magnet fields until equilibrium with the load is established.

Shunt Motor.—The speed is practically constant. It will not start heavy loads, and is best adopted to constant loads such as pumps, fans, etc.

Compound Motor.—Since this motor is a combination of the shunt and series types, it partakes of the properties of both. The series winding gives it strong torque at starting (though not as strong as in the series

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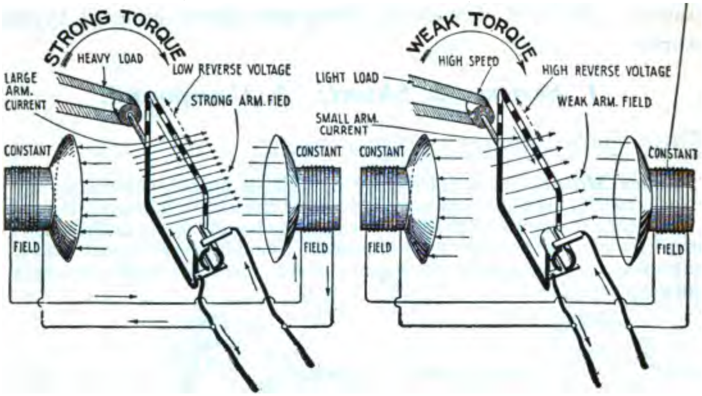
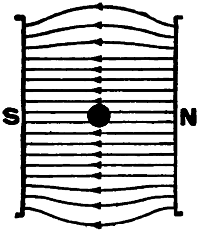
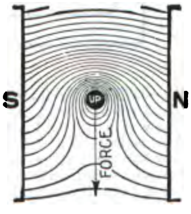
FIGS. 7,656 to 7,659.—*Text continued.*
angles or midway between magnet poles; here, (as in fig. 7,657) the torque is due to the equal *turning forces of **repulsion** of like poles* and ***attraction** of unlike poles.* Now at all times the rotation of the armature induces an electric pressure in the coil in a direction opposite to the current applied to the armature as indicated by the dotted arrow, called the ***reverse voltage***; which tends to reduce the current applied to armature.



FIGS. 7,662 and 7,663.—***How a D. C. Motor Works, IV: Shunt motor with variable load. The strength of the magnet field remain constant while that of the armature field varies.*** Now if a heavy load cause the motor to slow down as in fig. 7,662, the reverse voltage will be reduced allowing more current to flow through the armature which increases the torque till equilibrium is established between torque and load. Again, if the load be reduced, the motor will speed up, and since the field strength remains constant (instead of being reduced as in the series motor) this acceleration is quickly checked by the rapid rise of reverse voltage, there being very little difference in speed for either heavy or light load.





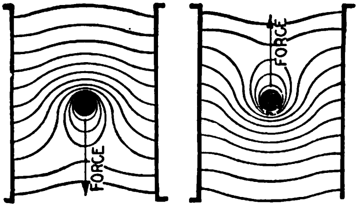


FIG. 7,664.—Conductor. lying in a magnetic field and carrying no current; the field is not distorted whether the conductor be at rest or in motion.

FIG. 7,665.—Conductor carrying a current in a magnetic field. The current flowing in the conductor sets up a magnetic field which distorts the original field as shown, making the magnetic lines denser on one side and less dense on the other. This results in a force upon the wire, which, in the case of a dynamo (fig. 7,665) opposes its movement, and which forms the *propelling drag* in the case of a motor (fig. 7,666).

FIGS. 7,666 and 7,667.—Action of the magnetic force in a dynamo and motor. In the first instance, according to Lenz' law, the direction of the current induced in the wire is such as to oppose the motion producing it. In the operation of a motor, the current supplied in flowing through the armature winding distorts the field and thus produces rotation. In the figures, the direction of the force is clearly indicated by remembering that the distorted lines of force act like rubber bands tending to straighten and shorten themselves.

motor), while the presence of the shunt winding prevents excessive speed. The speed is practically constant under all loads within the capacity of the machine.

A compound motor should be used in preference to a shunt motor where frequent starting and reversing are necessary. For severe mill service, the winding is heavily compounded (called *over-compounded*), having only enough shunt winding to limit the light load speed. At heavy loads such motors act virtually as series motors.

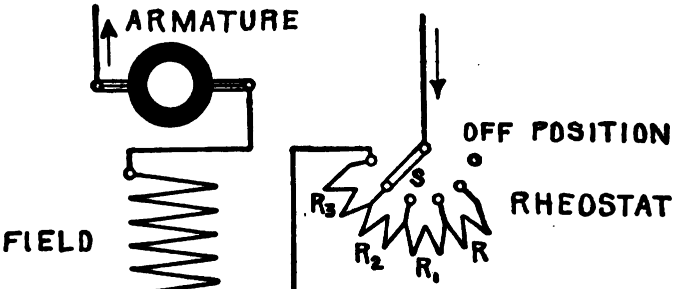


FIG. 7,668.—Series motor connections. ***To start*** the motor, the circuit is completed through a variable resistance or rheostat by moving the switch S, so that the resistance R,R_1,R_2,R_3, are gradually cut out of the circuit. ***To stop,*** the switch S, is moved back to its "off" position.

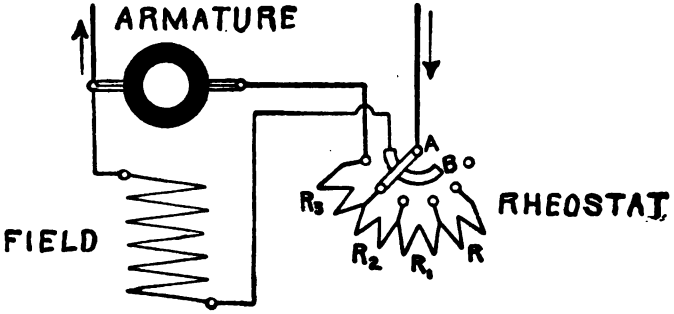
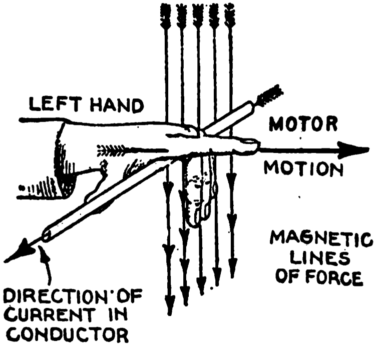


FIG. 7,669.—Shunt motor connections. ***In starting, unless the field magnets be put in the circuit first,*** the armature, at rest because of its low resistance would probably burn out. ***To start,*** the switch is closed, and the rheostat lever pushed over so as to make contact with A and B, thus *first* exciting the magnets. On further movement of the lever, the rheostat resistance R,R_1,R_2,R_3, etc., are gradually cut out as the speed increases, until finally all the resistance coils are cut out. ***To stop,*** the lever is brought back to its original position.

A series motor has usually only two terminals coming out from the case, whereas a shunt machine has three or four; three, by bringing together one armature and one field terminal inside of machine, if the the direction of rotation be fixed



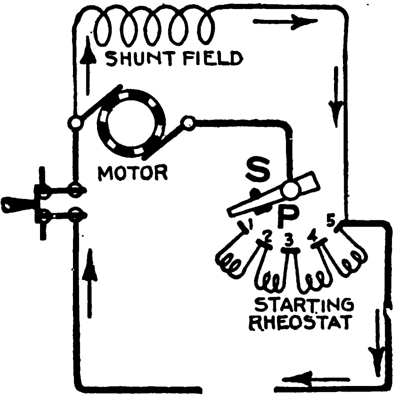
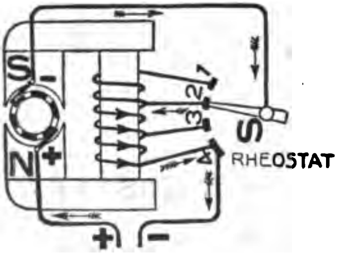


FIG. 7,670.—The "left hand rule" for direction of motion in motors. *Place the left hand,* as shown, *so that the thumb points in the direction of the current, the 3rd, 4th and 5th fingers in the direction of the lines of force, then will the 2nd or forefinger, at right angles to the others, point in the direction in which the conductor is urged.*

FIG. 7,671 —Speed regulation of shunt motor by inserting variable resistance in the armature circuit.



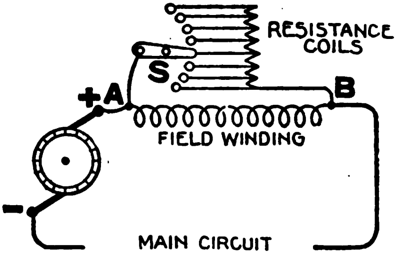


FIG. 7,672.—Speed regulation of series motor by cutting out sections of the field winding. By moving the lever S, downward the current will flow through one or more sections of the field winding, thus decreasing or increasing the ampere turns and thereby providing means of regulation.

FIG. 7,673.—Speed regulation of series motor by two path method. The current passing from A, to B, divides between the magnet coils and the rheostat coils; the higher the resistance of the rheostat the less current passes through it, and the more through the magnet coils, hence the stronger the field magnet.

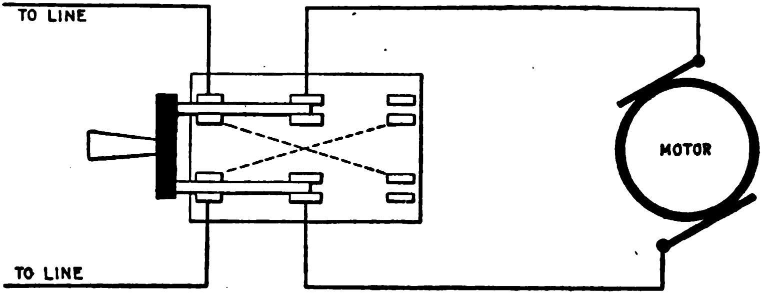
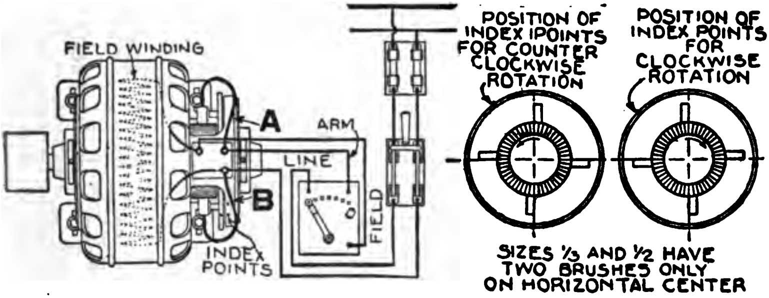
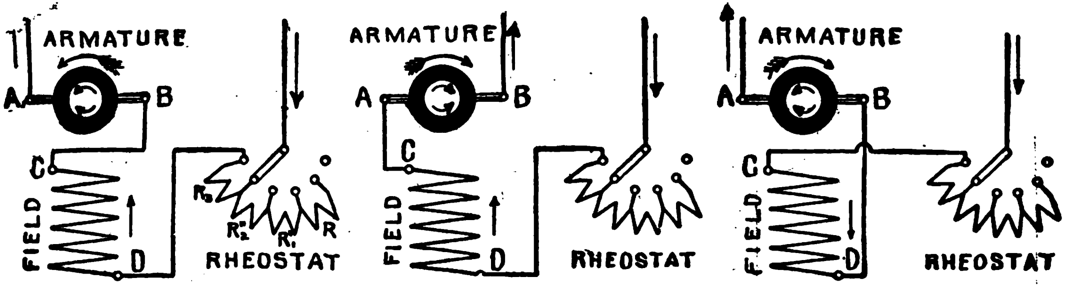


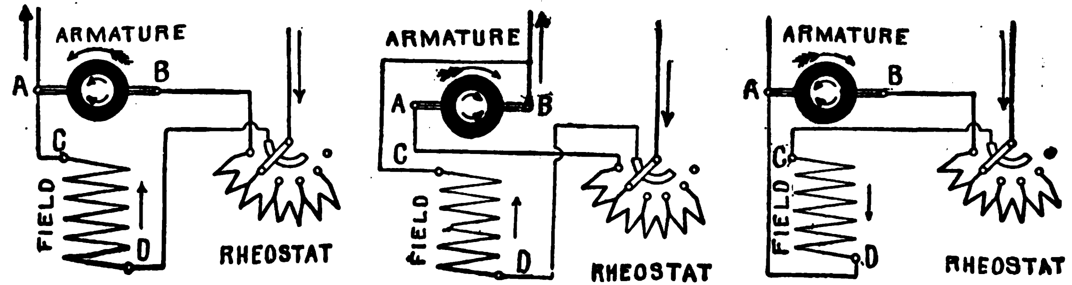
FIG. 7,674.—Motor reversing switch. A motor is reversed *by changing the direction of current in either the armature or field coils.* It is preferable to reverse armature current.



FIGS. 7,675 to 7,677.—Holter-Cabot shunt wound motor; diagrams showing connections and positions of index point for forward and reverse rotation. ***To reverse,*** interchange leads A and B, and shift brush ring as shown. ***Before starting,*** see that armature revolves freely, fill bearings with oil and inspect oil rings. ***Starting,*** 1, see that rheostat lever is on off contact, 2, close main switch, 3, gradually cut out starting resistance with rheostat lever. ***If motor do not start,*** trouble may be due to *a*, wrong connections; *b*, too great load on the motor; *c*, the motor brushes not in proper position; *d*, an open circuit of some kind; *e*, a short circuit of some kind. In case of trouble make sure that fields are magnetized. To do this, close main switch, put rheostat on front contact and place a screw driver or other piece of iron against pole piece. A heavy pull will result on iron if fields be magnetized. ***Stopping.*** Open main switch and lever of rheostat (if automatic) will after a brief interval fly back to first contact. ***Running temperature.*** If motor feel too hot to the hand, test by placing thermometer for 10 minutes against frame covering with a cloth or piece of waste. The temperature should not be over 75° Fahr. above that of the surrounding air. ***Oiling.*** Use good "dynamo oil"; if in dirty place draw off and refill every two or three months. ***Care of motor.*** The motor must be kept clean. If the commutator become rough, smooth it up with No. 00 sand paper moistened with oil. When fitting new brushes or changing them, always sand paper them down until they fit the commutator perfectly, by passing to and fro beneath the brush a strip of sand paper, having the rough side toward the brush. Brushes must *always* be renewed before the metal of the holder comes in contact with the commutator. Don't use anything on commutator except good mineral machine oil, or kerosene, and this only in very small quantities applied with a cloth having no lint or threads.



FIGS. 7,678 to 7,680.—Reversing the direction of rotation of a series motor. Fig. 7,678 shows the connections for counter clockwise rotation. The motor may be reversed: *1*, by allowing the current to flow in its original direction (from D. to C) in the field magnet coils, and altering the direction of the armature current by changing the two connections on the brushes A, and B, thus connecting C, to A, and B, to the return wires as in fig. 7,679; or *2*, by leaving the direction of the current in the armature in its original direction, and reversing that of the field current, as in fig. 7,680. If the wires leading to the rheostat and motor directly were reversed there would be no reversal of the motor, because by so doing, both the armature and field magnet currents would be reversed.



FIGS. 7,681 to 7,683.—Reversing the direction of rotation of a shunt motor. Fig. 7,681 shows the connections for counter clockwise rotation. The motor may be reversed: *1*, by allowing the current to flow in its original direction through the field magnet coils (from D, to C), and reversing its direction through the armature (from A to B) as in fig. 7,682; or *2*, by allowing the armature current to flow in its original direction (from B, to A), and reversing the current through the field coils (from C, to D), as in fig. 7,683.

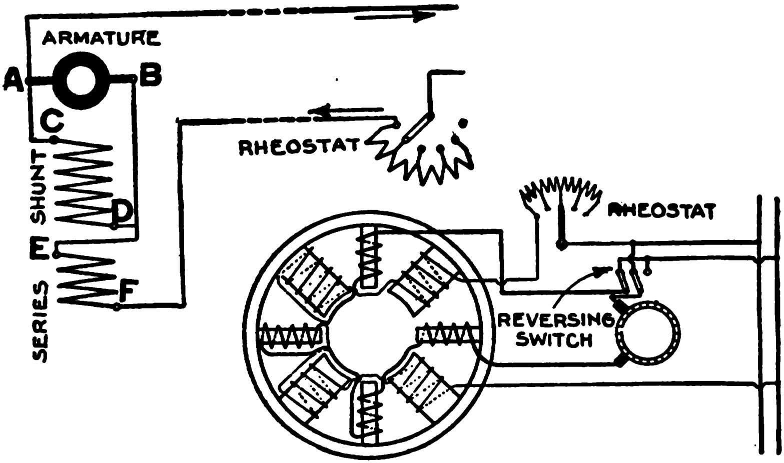


Fig. 7,684.—**Compound motor connections for starting from a distant point.**

Fig. 7,685.—***Interpole* motor. The object of the interpole winding is *to assist in the reversal of the current under the brushes to prevent sparking.***

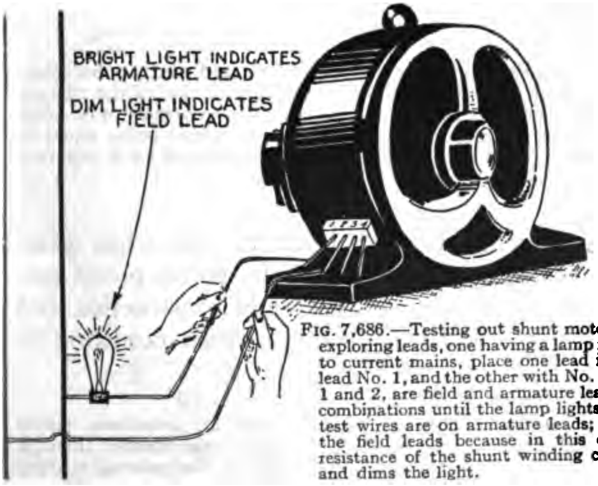


Fig. 7,686.—Testing out shunt motor circuits. With two exploring leads, one having a lamp in series and connected to current mains, place one lead in contact with motor lead No. 1, and the other with No. 2. If lamp do not burn 1 and 2, are field and armature leads. Now try different combinations until the lamp lights. If it burn brightly, test wires are on armature leads; if dimly, they are on the field leads because in this case the considerable resistance of the shunt winding cuts down the current and dims the light.

CHAPTER 120

Alternators

An alternator is *a machine for producing alternating current.* There are many types of alternator and these may be classified

1. With respect to the current as

   a. Single phase
   b. Two phase
   c. Three phase

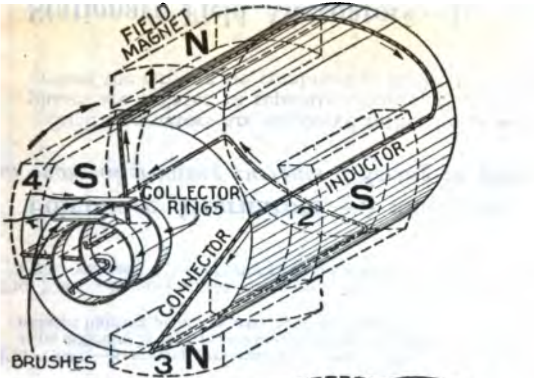
2. With respect to construction, as

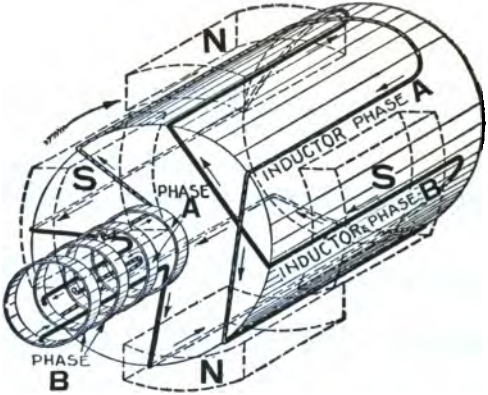
   a. Stationary field
   b. Revolving field
   c. Inductor

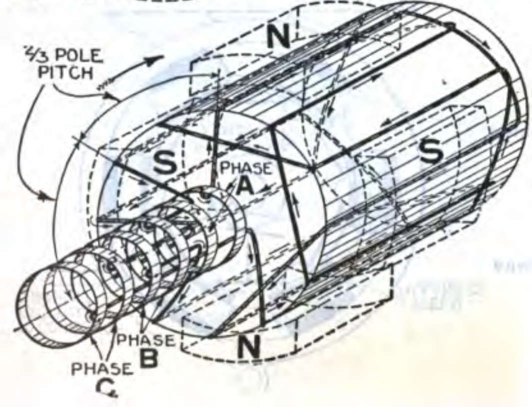
Alternators are usually multipolar, having north and south poles alternating around the field. The number of changes of direction of the current per revolution is the same as the number of coils in the armature or poles in the field, the armature coils in simple current machines being equal in number to the poles. The field magnets are often excited by a separate generator.

Single Phase Alternators.—As a general rule, when alternators are employed for lighting circuits, the single phase machines are preferable, as they are simpler in construction and do not generate the unbalancing voltages often occurring in polyphase work.

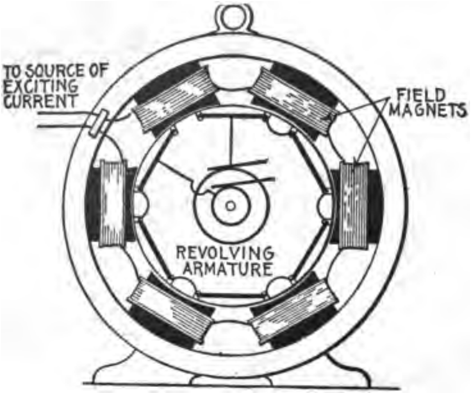
A single phase alternator consists essentially of an armature, single phase winding, field magnets and two collector rings and brushes through which the current generated in the armature passes to the external circuit.







FIGS. 7,687 to 7,689.—Elementary four pole alternators; fig. 7,687, one phase; fig. 7,688, two phase; fig. 7,689, three phase. Each winding consists of *one inductor per pole per phase*, the inductor of each phase being connected by *connectors*, to the *collector rings*. The poles being alternate N and S, there will be two cycles of the current per phase per revolution of the armature. Applying Fleming's rule for induced currents, the direction of the current induced in the inductors is easily found as indicated by the arrows. The field magnets are excited by coils supplied with direct current, usually furnished from an external source; for simplicity this is not shown. The magnets may be considered as of the permanent type.



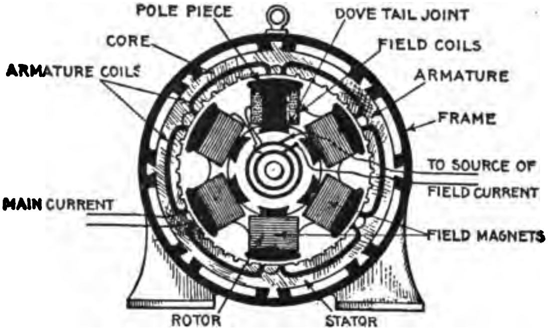


Fig. 7,690.—Revolving armature alternator. These are suitable for machines generating current at comparatively low pressure, as no difficulty is experienced in collecting such current. Revolving armature alternators are also suitable for small power plants, isolated lighting plants, where medium or small size machines are required.

Fig. 7,691.—Revolving field alternator. For medium and large machines ***the advantages are:*** 1, superior insulation permitting higher voltages; 2, no collector rings for armature current; 3, armature terminals may be enclosed.

Polyphase Alternators.—A multi- or polyphase alternator is *one which delivers two or more alternating currents differing in phase by a definite amount.*

Such alternators are employed rather for power purposes than for lighting; for lighting purposes the phases are isolated in separate circuits, that is, each is used as a single phase current. For driving motors the circuits are combined to facilitate starting.

Stationary Field Alternators.—In this type ***the armature*** *revolves while the field* *magnets are attached to the circular frame*, similar to dynamo construction. The machine may be single or polyphase and is used where the pressure and current are moderate.

Stationary Armature Alternators.—In this type *the field revolves while the armature is attached to the circular frame.*

Since ***motion** is purely a **relative matter*** it makes no difference whether the armature or field revolves.

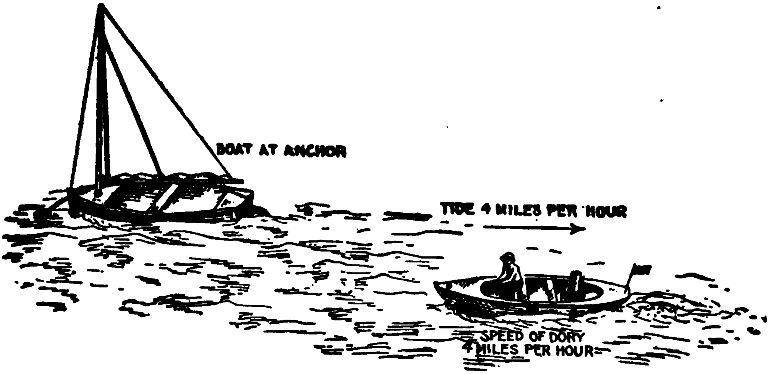
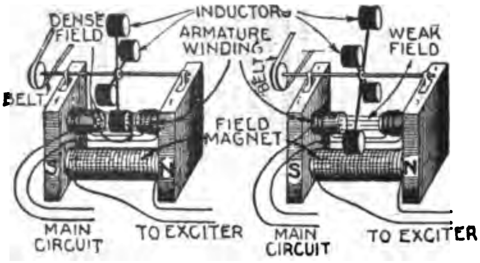


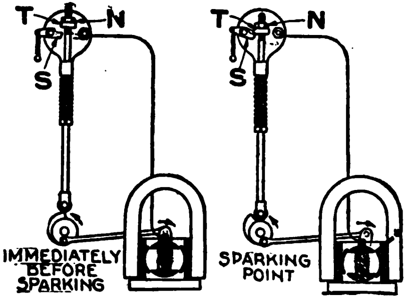
FIG. 7,692.—Marine view, showing that *motion is purely a relative matter*. In order that there may be motion something must be regarded as being stationary. ***The small dory*** running at a speed of four miles per hour against the current is *moving* at that velocity *relative* to the current, yet is at a standstill relative to the cat boat. In this instance both cat boat and dory are moving with respect to the water if the latter be regarded as stationary. Again if the earth be regarded as being stationary, the two boats are at rest and the water is moving relative to the earth. Hence, it makes no electrical difference if an alternator be constructed so that the armature revolve (regarding the earth as stationary) as in fig. 7,690, or the field magnets revolve as in fig. 7,691.

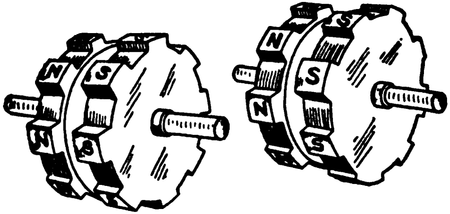
The advantage of making the armature stationary and letting the field revolve, is that in the case of large size machines, the difficulty of taking off currents of high amperage or high voltage from collector rings is avoided.

The terms *stator* and *rotor* are usually applied to the armature and field magnets with respect to which is stationary and which moves.

Inductor Alternator.—In this class, *both armature and field magnets are stationary*, a current being induced in the armature







FIGS. 7,693 to 7,696.—Elementary inductor alternator (figs. 7,693 and 7,694) and its application to low tension or make and break ignition. ***In construction*** inductors consisting of iron discs are arranged on a shaft to rotate through the air gaps of the magnetic poles, resulting in a variable (undulating) flux which induces a current in the winding. ***For ignition work*** it has the advantage of a stationary winding which avoids the use of brushes to collect the current. Figs. 7,695 and 7,696 show an oscillating inductor low tension ignition magneto. The inductor is rotated to and fro by means of a link, one end of which is attached to the inductor crank, and the other to the igniter cam, as shown. Two views are shown: immediately before and after sparking. S, is the grounded electrode of the igniter; T, an adjustable hammer which is secured in position by a lock nut N.

FIGS. 7,697 and 7,698.—Homopolar and heteropolar "inductors." Homopolar inductors have their N and S poles opposite each other, while in the heteropolar type, they are "staggered" as shown.

winding by the action of a so-called inductor or mass of iron moving through the magnetic field so as to periodically vary its instensity

A peculiarity of this type is that the current does not reverse, hence the total number of armature turns (for given magnetic flux) necessary to produce a given pressure is twice that required in an alternator having an alternating flux through its armature windings.

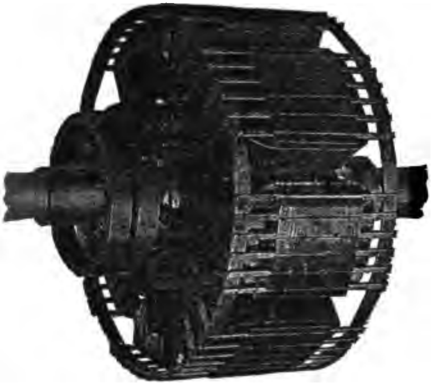
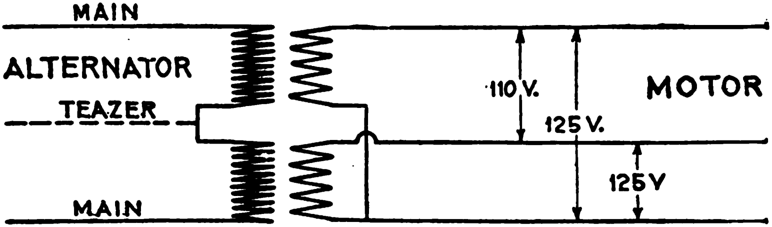
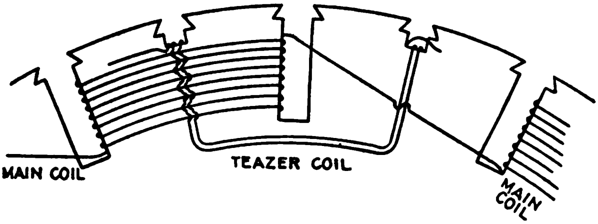


FIG. 7,699.—Westinghouse field with amortisseur or "damper" winding for 75 kva. and larger belted alternators, which prevents hunting and reduces eddy currents in the pole pieces. The copper bars of the amortisseur cage winding are arranged in partially closed slots in the pole pieces.

Hunting or Singing.—Hunting is a term applied to the state of two parallel connected alternators running out of step, or not synchronously, that is, "see sawing."

When two machines are operated in parallel with "peaked" current wave it is difficult to keep them in step. Any difference in the phase relation which is set up by the alternation will cause a local or synchronizing





FIGS. 7,700 and 7,701.—Monocyclic diagrams showing transformer connections and alternator armature winding. In fig. 7,700, the main coils are wound on every other tooth, and the *teaser* coils are placed in quadrature with them, as shown.

current to flow between the two machines and at times it becomes so great that they must be disconnected. This trouble is avoided by the use of *dampers* and *amortisseur* windings. The latter are often erroneously called *squirrel cage* windings.

Monocyclic Alternators.—These are *single phase machines provided with an additional coil, called a* **teaser coil,** *wound in two phase relationship with and connected to the center of the main single phase coil.*

The monocyclic alternator is provided with three collector rings; two for the single phase coil, and one for the free end of the *teaser coil.*

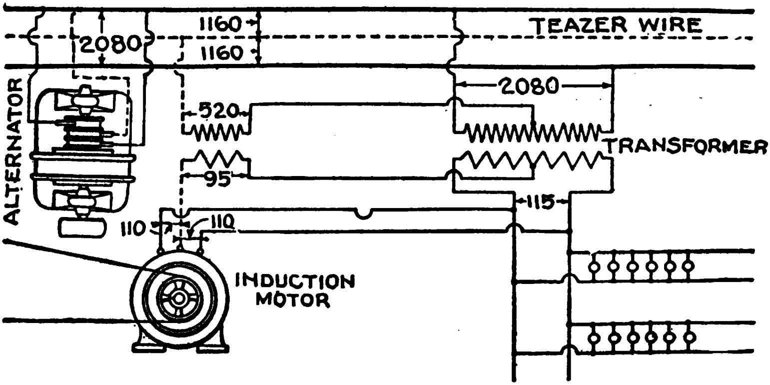


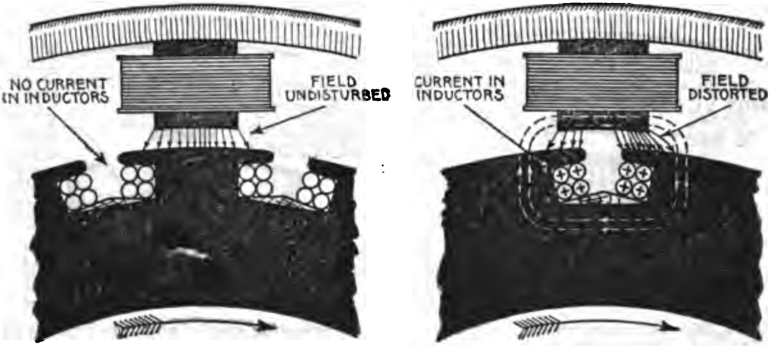
Fig. 7,702.—Diagram of monocyclic system showing connections. The monocyclic system is a single phase system primarily intended for the distribution of lights with an incidental load of motors. The lighting load is entirely connected to one single phase circuit, and the motors are started and operated from this circuit with the assistance of the teazer wire. The teaser coil to which this wire is connected generates a pressure in quadrature with that of the main coil. This pressure is combined with the main pressure of the alternator by transformers, so as to give suitable phase relations for operating induction motors.

By this arrangement ordinary single phase incandescent lighting can be accomplished by means of a single pair of wires taken from the single phase coil.

Where three phase motors have to be operated, however, a third wire, called the *power wire*, which is usually smaller than the main single phase wires, is carried to the point at which the motor is located, and by the use of two suitably connected transformers three phase currents are obtained from the combined single phase and power wires for operating the motors. This type of alternator was designed prior to the introduction of the polyphase systems, to overcome the difficulty of starting encountered in the operation of single phase alternators as motors.

Armature Reaction.—Every conductor carrying a current **creates** *a magnetic field around itself, whether it be embedded in iron or lie in air.*

Armature inductors, therefore, create magnetic fluxes around themselves, and these fluxes will, in part, interfere with the main flux from the poles of the field magnet, tending: 1, to *distort*, or 2, to *weaken* the field. Armature reaction is especially marked in slotted armatures.



FIGS. 7,703 and 7,704.—Section of armature and field showing *distorting effect* of armature reaction on the field. When a coil is opposite a pole as in fig. 7,703, no current is flowing (assuming no self-induction) and the field is undisturbed, but, as the inductors pass under a pole face as in fig. 7,704, current is induced in them, and lines of force are set up as indicated by the dotted lines. This distorts the main field so that the lines of force are crowded toward the forward part of the pole face as shown.

Magnetic Leakage.—In the design of alternators *the drop of voltage on an inductive load is mainly dependent upon the magnetic leakages, primary and secondary.*

They increase with the load, and, what is of more importance, they increase with the fall of the power factor of the circuit on which they may be working. This is one reason why certain types of alternator, though satisfactory on a lighting circuit, have proved themselves unsatisfactory when applied to a load consisting chiefly of motors.

In general, to keep the leakage small, the pole cores should be short, and of minimum surface, the pole shoes should not have too wide a span nor be too thick, nor present needless corners, and the axial length of the pole face and of the armature core should not be too great in proportion to the diameter of the working face.

Field Excitation.—The fields of alternators *require a separate source of direct current for their excitation*, and this current should be preferably automatically controlled.

In the case of alternators that are not self-exciting, the dynamo which generates the field current is called the *exciter*.

A self-excited alternator has, in addition to the main winding, another winding connected to a commutator for furnishing direct field exciting current.

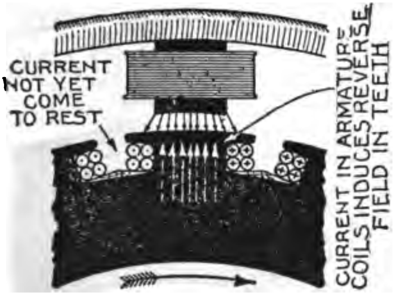


Fig. 7,705.—Section of armature and field showing ***weakening effect*** of armature reaction in the field. Self induction being present (as it almost always is), the current lags more or less behind the pressure, so that when the coil is in the position of zero induction, as shown, the current has not yet come to rest. Accordingly, lines of force (indicated by the dotted lines) are set up by the current flowing through the coils which are in opposition to the field, thus weakening the latter. The dots and crosses in inductor sections, have their usual significance in defining the direction of current, representing respectively the heads and tails of arrows.

Fig. 7,706.—Section of armature and field showing ***strenghtening effect*** of armature reaction when the current leads the pressure. If the circuit contain an excess of capacity the current will lead the pressure, so that when the coil is in the position of zero induction, as shown, the current will have come to rest and reversed. Accordingly, lines of force (indicated by the dotted lines (are set up by the current flowing through the coil and which are in the same direction as the lines of force of the field, thus strenghtening the latter.

Figs. 7,707 and 7,708.—Diagram showing respectively the character of stray field between adjacent straight poles, and between adjacent poles with shoes.

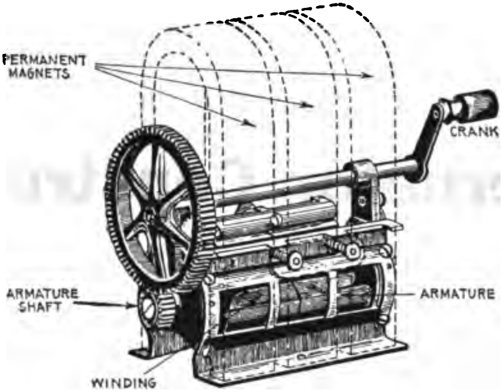


Fig. 7,709.—Connecticut *permanent magnet self-excited* magneto. This type of magneto was formerly used extensively to generate current for operation of telephone call bells. At present the principal use of magnetos is for gas engine ignition.

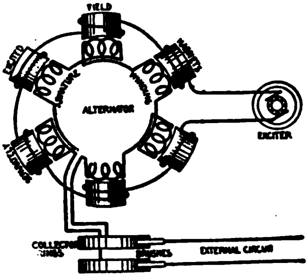


Fig. 7,710.—Diagram of separately excited alternator. The field winding is supplied with direct current, usually at 125 volts pressure by a small dynamo called the "exciter." The latter may be driven by independent power, or by belt connection with the main shaft, and in some cases the exciter is directly connected to the alternator shaft.

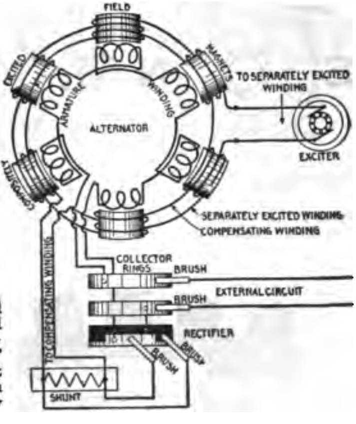
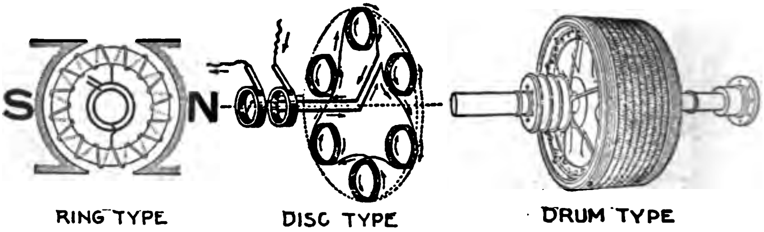


Fig. 7,711.—Diagram of compositely excited alternator. The current for exciting the field magnets is obtained, partly from an exciter and partly from the windings of the alternator, being transformed into direct current by the rectifier. The connections are as shown. ***In operation,*** the separately excited coils set up the magnetism necessary for the generation of the voltage at no load. The main current coming from the armature is shunted, part going through the shunts and the remainder around the compensating winding, furnishing the additional magnetism necessary to supply the voltage to overcome the armature impedance.

CHAPTER 121

Alternator Construction

The construction of alternators follows much the same lines as dynamos, especially in the case of machines of the revolving armature type. Usually, however, more poles are provided than on direct current machines, in order to obtain the required frequency without being driven at excessive speed.



Figs. 7,712 to 7,714.—Various armatures. Fig. 7,712, ring; fig. 7,713, disc; fig. 7,714, drum; —the prevailing type.

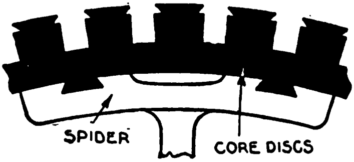


Fig. 7,715.—Large *revolving* armature construction with segmental discs *dovetailed to spider*.

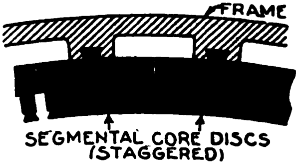
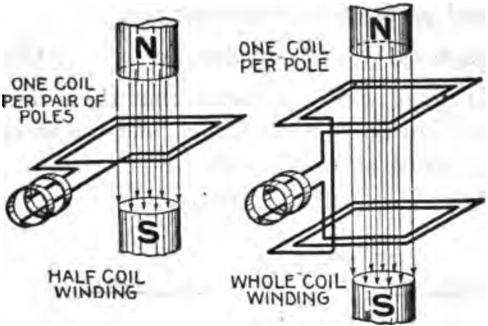


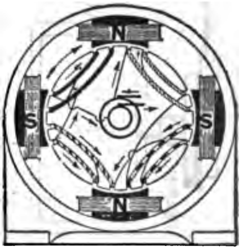
Fig. 7,716.—Large *stationary* armature construction with segmental discs *dovetailed to frame*. In both revolving and stationary armatures, the joints are staggered in building up the core, that is, they are overlapped so as not to unduly increase the reluctance of the magnetic circuit. Dovetail joints obviate the use of through bolts which, if not insulated are liable to give rise to eddy currents by short circuiting the discs.



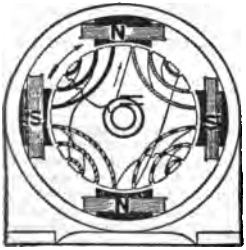
Figs. 7,717 and 7,718.—Elementary bipolar alternators with *half coil* and *whole coil* windings. In a half coil winding there is one coil per phase *per pair of poles*; in a whole coil winding there is one coil per phase *per pole*.

CONCENTRATED HALF COIL WINDING

CONCENTRATED WHOLE COIL WINDING



PARTIALLY DISTRIBUTED WINDING



FULLY DISTRIBUTED WINDING

Figs. 7,719 and 7,720.—Concentrated windings. A concentrated winding is one in which the armature has only *one tooth per phase per pole*, that is, the number of teeth equals the number of poles. A concentrated winding of the half coil type has only one side of a coil in each slot as in fig. 7,719. In the whole coil variety, each slot contains neighboring sides of adjacent coils, as in fig. 7,720.

Fig. 7,721.—Partially distributed winding. Each coil unit is here divided into two concentric coils of different dimensions and connected in series, as shown in detail in the figure. This being a "whole coil" winding the several units are so connected that the winding of adjacent units proceeds in opposite directions, that is, one coil is wound clockwise, and the next counter clockwise, etc., so that the induced currents flow in a common direction as indicated by the arrows for the position shown.

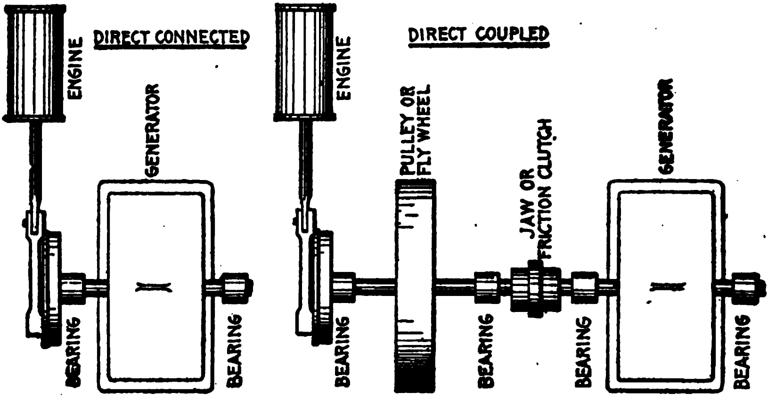
Fig. 7,722.—Fully distributed winding. Each coil consists of so many sub-coils that the winding occupies the entire surface of the armature core; that is, there are no extensive spaces unoccupied, the spacing being uniform as shown.

The essential parts of an alternator are:

1. Field magnets; 2. Armature; 3. Collector rings;

and in actual construction, in order that these necessary parts may be retained in proper co-relation, and the machine operate properly there must also be included:

4. Frame; 5. Bed plate; 6. Pulley.



FIGS. 7,723 and 7,724.—Diagram showing the distinction between *direct connected* and *direct coupled* units. In a **direct connected** unit, fig. 7,723, the engine and generator are permanently connected on one shaft, there being one bed plate upon which both are mounted. An engine and generator are said to be **direct coupled** when each is independent, as in fig. 7,724, being connected solely by a jaw or friction clutch or equivalent at times when it is desired to run the generator. At other times the generator may be disconnected and the engine run to supply power for other purposes.

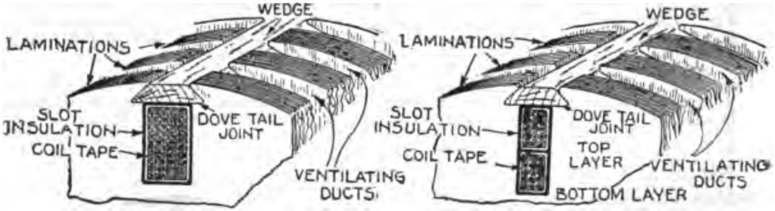
NOTE.—***Belt or Chain Driven Alternators.***—The mode in which power is transmitted to an alternator for the generation of current is governed chiefly by conditions met with where the machine is to be installed. In many small power stations and isolated plants the use of a belt drive is unavoidable. In some cases the prime mover is already installed and cannot be conveniently arranged for direct connection, in others the advantage to be gained by an increase in speed more than compensates for the loss involved in belt transmission. There are many places where belted machines may be used advantageously and economically. Where there is sufficient room between pulley centers, a belt is a satisfactory medium for power transmission, and one that is largely used. It is important that there be liberal distance between centers, especially in the case of generators or motors belted to a medium or slow speed engine, because, owing to the high speed of rotation of the electric machines, there is considerable difference in their pulley diameters and the drive pulley diameter; hence, if they were close together, the arc of contact of the belt with the smaller pulley would be appreciably reduced, thus diminishing the tractive power of the belt.

Field Magnets.—Alternators *are built with three kinds of electro-magnets*, classed according to the manner in which they are excited, the machines being known as:

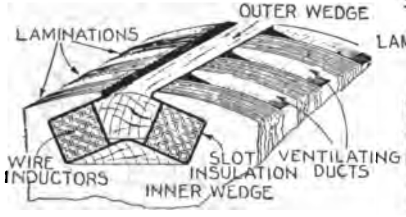
1. Self-excited; 2. Separately excited; 3. Compositely excited.

The two principal types of field magnet are the stationary, and the revolving.

In construction of stationary magnets, laminated pole pieces are used, each pole being made up of a number of steel stampings riveted together and bolted or preferably cast into the frame of the machine. The field coils are machine wound and carefully insulated. After winding they are taped to protect them from mechanical injury. Each coil is then dipped in an insulating compound and afterwards baked to render it impervious to moisture.



Figs. 7,725 and 7,726.—Single and double layer multi-wire inductors and methods of placing them on the core. Here the term layer means unit, in fact each unit is made up of several "layers" of wires.



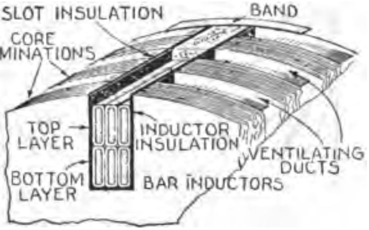
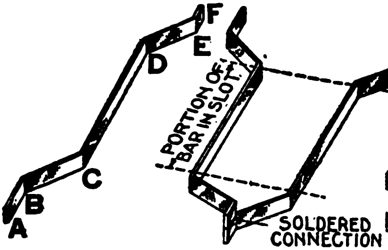
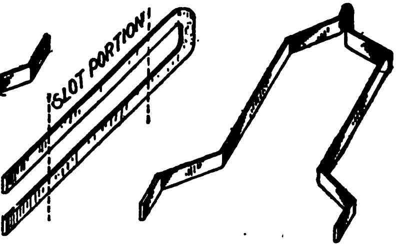


Fig. 7,727.—Two coil slot for whole coil winding. ***In assembling*** the winding, the inner wedge is first placed in position and then the slot lined with the insulating material. This usually consists of alternate layers of mica and pressboard. The coils composed of several turns of wire or copper strip are wound in place, and after covering with a layer of insulation, the outer wedge is pushed in place to retain the inductors in position.

Fig. 7,728.—Slot for two layer bar winding. Bar inductors, on account of the shape of their ends, must be placed in the slots from the top, because the bent ends do not admit of pushing them in. Straight slots are therefore necessary, the inductors being held in placed by wooden strips and tie bands as shown.

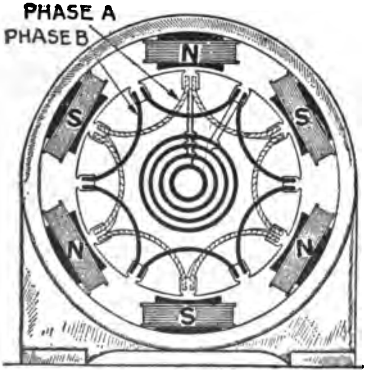
The entire structure or rotor of a revolving field consists of a shaft, hub or spider, laminated field magnets and slip rings. The insulated *slip rings* mounted on the shaft receive direct current for the revolving magnet, as distinguished from *collector rings* which collect the alternating current.





FIGS. 7,729 and 7,730.—Bent bar inductor and method of connection with soldered joint. Fig. 7,729 shows one bar and shape of bent ends. The portion from C, to D, is placed in the slot; B, to C, and D, to E, bent or connector sections; A, to B, and E, to F, ends bent parallel to slot for soldering. Fig. 7,730 shows two bar inductors connected.

FIGS. 7,731 and 7,732.—Method of avoiding a soldered joint at one end of a bar inductor by using a bar of twice the length shown in fig. 7,729, and bending it into a long U form, as in fig. 7,731, after which it is spread out forming two inductors, as in fig. 7,732.



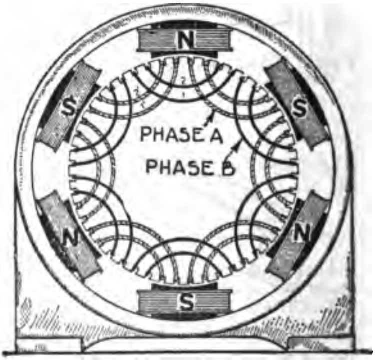


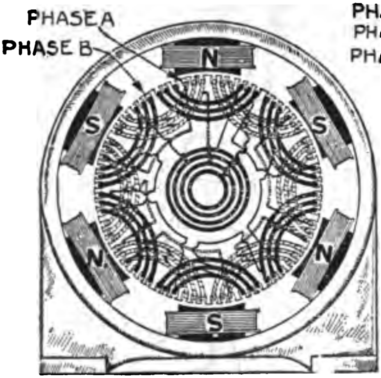
FIG. 7,733.—Two phase concentrated whole coil winding. The total number of slots is twice the number of poles, or one slot per pole per phase. It comprises two windings spaced 90 polar degrees as shown. The two circuits are independent, the windings terminating at the four collector rings.

FIG. 7,734.—Two phase winding in two slots per pole per phase. This stamping distributes the coils of each phase into two sections as A and B. The coils are of the "whole" type and with six poles the total number of slots is 4 × 6 = 24, uniformly spaced as shown.

Armatures.—In construction *these are similar to dynamo armatures*.

They are in most cases simpler than direct current armatures due to the smaller number of coils, absence of commutator with its multi-connections, etc.

Alternator armatures may be classified in several ways:



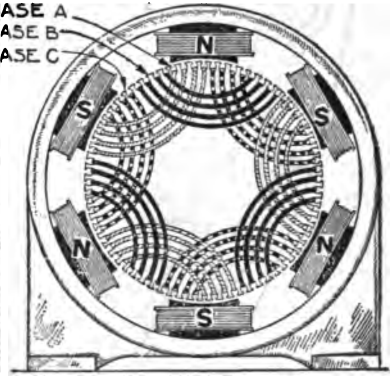


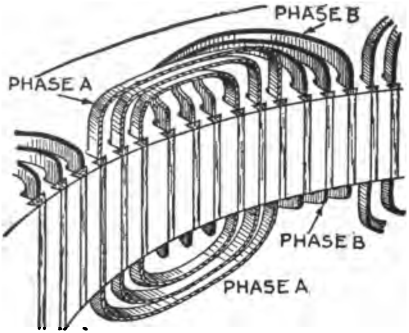
FIG. 7,735.—Two phase winding in three slots per pole per phase. The coils of each phase are of the partially distributed type, each coil being made up of three sections as shown. The direction of winding is alternately reversed.

FIG. 7,736.—Three phase winding with distributed coils—wound in four slots per pole per phase; diagram showing placement of the coils.

1. With respect to operation, as
   - *a*. Revolving;
   - *b*. Stationary.
2. With respect to the core, as
   - *a*. Ring;
   - *b*. Disc;
   - *c*. Drum.
3. With respect to the core surface, as
   - *a*. Smooth;
   - *b*. Slotted.

Both types of class 1 are in general use, whereas, in classes 2 and 3, the drum, and slotted core forms are the prevailing types.

Alternator Windings.—These are usually described *in terms of the number of slots per phase per pole*.



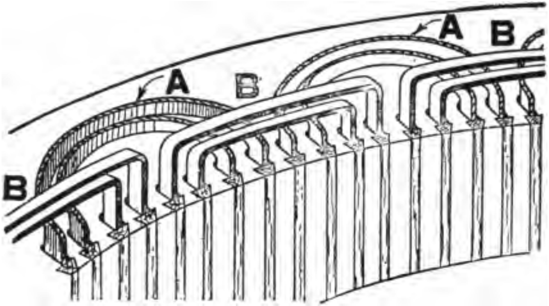
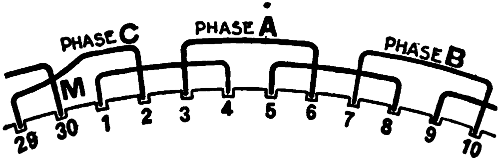


Fig. 7,737.—Section of two phase winding showing shaping of the coil ends. Every other coil is flat, while the alternates have their ends bent up as shown. With respect to the shaping of the coil ends, it is called a *two range winding*.

Fig. 7,738.—Treatment of coil ends in two phase, two range windings. In this arrangement *straight out* B and *bent up* A, coils are used which are placed on the armature as is clearly shown in the illustration.



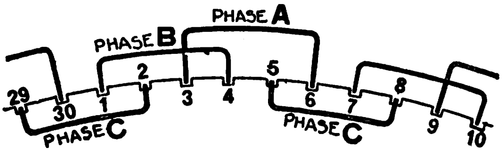
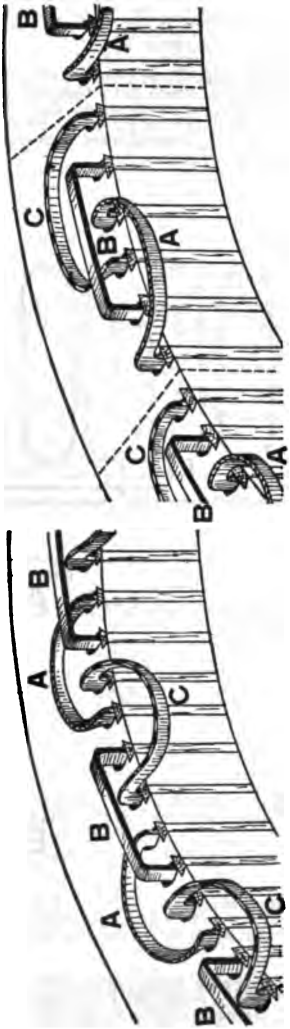


Fig. 7,739.—Three phase, 10 pole, 30 slot winding in two ranges. In this winding perfect symmetry occurs after every four poles. Accordingly in the case of an odd number of pairs of pole, one of the coils must necessarily be a skew going from the inner to the outer range as at M.

Fig. 7,740.—Three phase 10 pole 30 slot winding in three ranges. The coils of each phase are alike, those of the A phase being all in the straight out range, those in the B phase, in a bent up range, and those in the C phase in a bent down range.



FIGS. 7,741 and 7,742.—Treatment of coil ends in three phase, three range windings. Fig. 7,741, inadmissible arrangement in which the field magnet cannot be withdrawn; fig. 7,742, admissible arrangement in which the armature segments can be divided. This enables the top half of armature to be removed by disconnection without unwinding any coil.

For instance, if the armature of a 20 pole three phase machine have 300 slots, it has 15 slots per pole or 5 slots per each phase per pole, and will be described as a five slot winding. Therefore, in order to trace the connections of a winding, it is necessary to consider the number of slots per pole for any one phase on one of the following assumptions: 1, that each slot holds one inductor; 2, that there is one side of a coil in each slot; and 3, that one side of a coil is subdivided so as to permit of its distribution in two or more adjacent slots.

The voltage depends upon ***the number*** *of inductors in a slot.*

The breadth coefficient and wave form are influenced by the number of slots per pole, and not by the number of inductors within the slots.

Alternator windings may be classed with respect to the

1. Form of the armature, as
   - *a.* Revolving;
   - *b.* Stationary.

2. Mode of progression, as
   - *a.* Lap winding;
   - *b.* Wave winding.

3. Relation between poles and coils, as
   - *a.* Half coil winding;
   - *b.* Whole coil winding.

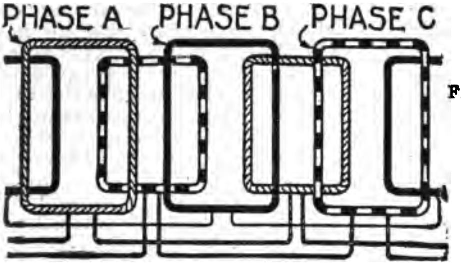
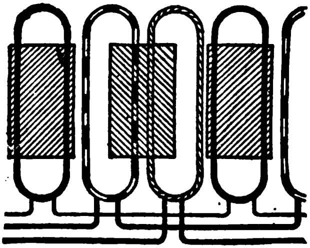
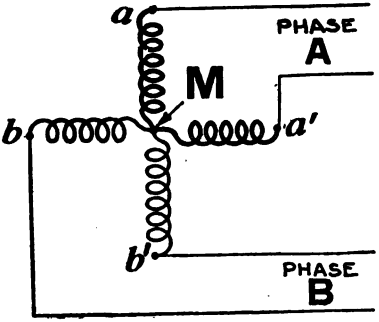


FIG. 7,743.—Three phase winding with half coils, which permit arranging of the ends in two ranges as shown. There is *one slot per phase per pole*, that is, total nmubers of slots = 3 × number of poles.

FIG. 7,744.—Three phase winding with short coils. The use of short coils as here shown, in which the coil breadth = ⅔ pole pitch, avoids the necessity of overlapping.





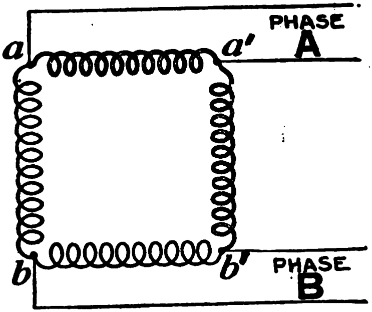
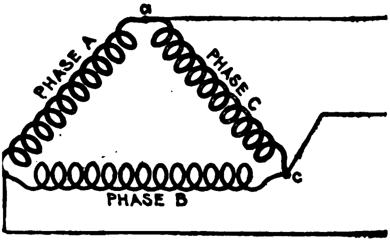
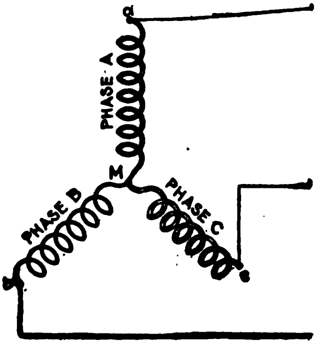


FIG. 7,745.—Two phase *star grouping* diagram. ***In connecting,*** the middle point of each of the two phases are united to a common junction M, and the four ends are brought out to four terminals, *a,a',b,b'*, as shown, or in revolving armatures to four slip rings. This grouping is equivalent to a four phase system.

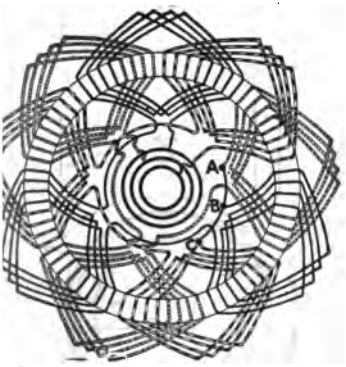
FIG. 7,746.—Two phase *mesh grouping* diagram. ***In connecting,*** the two phases are divided into two parts, and the four parts are connected up in cyclic order, the end of one to the beginning of the next, so as to form a square the four corners of which are connected to the four terminals *a,b,a',b'*, as shown or in the case of revolving armatures, to four slip rings.

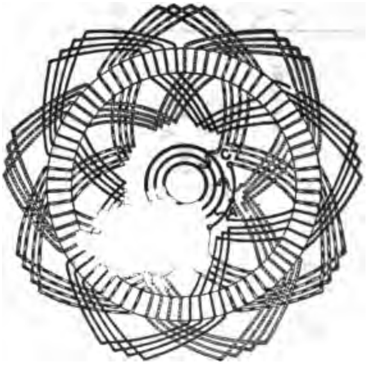


. 7,747.—Three phase *mesh grouping* diagram. n *connecting,* the three circuits are joined to rm a triangle and leads to terminals attached at he junctions *a,b,c,* or in revolving armatures to hree slip rings.



. 7,748.—Three phase *star grouping* diagram. *In connecting,* one end of each of the hree circuits is brought to a common junction M, usually insulated, and the three other ends re connected to three terminals—*a,b,c,* as shown, or in revolving armatures to three slip ngs.





. 7,749.—Radial diagram of three phase *lap winding* with *star connection.* The bar with onnections at A,B,C, comprises the star point or common terminal.

. 7,750.—Radial diagram of three phases *wave winding* with *star connection.* *To find* he proper ends (A,B,C,) to connect to the common terminal: Assume that the inductor pposite the middle of a pole is carrying the maximum current, and mark its direction by an rrow. Then the current in the inductors on either side of and adjacent to it will be in the ame direction. As the maximum current must be *coming from* the common terminal, the nd toward which the arrow points must be connected to one of the rings, while the other end connected to the common terminal. The current in the two adjacent inductors evidently ust be flowing into the common terminal, hence the ends toward which the arrows point ust be connected to the common terminal, while their other ends are connected to the emaining two rings.

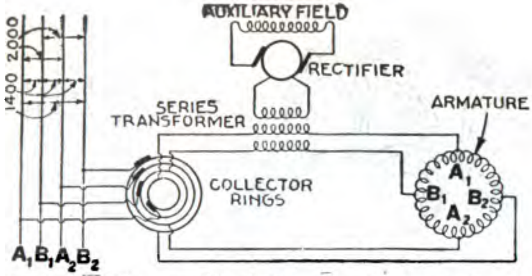


FIG. 7,751.—Diagram of Westinghouse two phase composite wound alternator, showing connections between two phase armature and a single phase rectified and composite field winding. The arrangement makes use of a series transformer, mounted on the spokes of the armature. By means of this series transformer the voltage delivered to the rectifying commutator and the fields is much less than that generated by the machine.

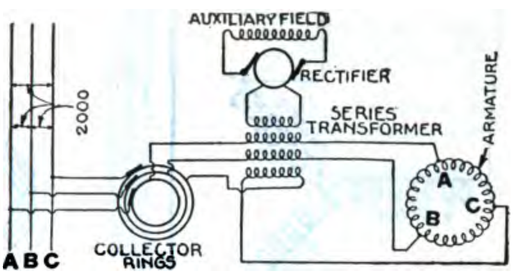
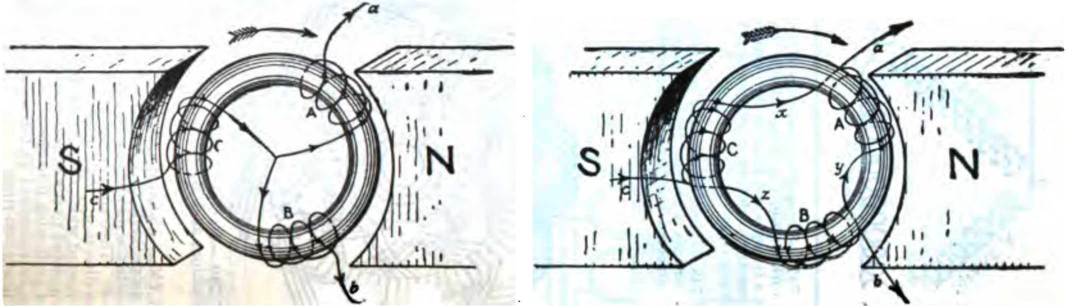


FIG. 7,752.—Diagram of Westinghouse three phase composite wound alternator. The armature inductors are of the closed coil or delta connected type, but are tapped at three points per pair or poles to the three collector rings. All three connections between the armature coils and the collector rings run through primary circuits of the series transformer within the armature, these three primaries each giving their own effect upon the secondary.



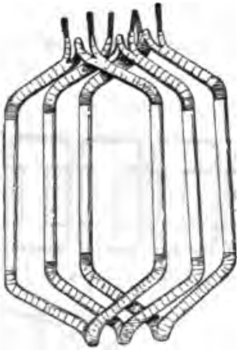
FIGS. 7,753 and 7,754.—Gramme ring amatures showing three phase star and mesh connections, respectively, with direction of currents in the coils. In the figures, the coils A,B.C, are spaced at equidistant positions on the ring core.

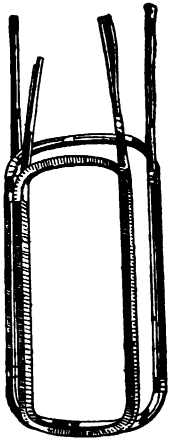
4. Number of slots, as

a. Concentrated or uni-coil winding;

b. Distributed or multi-coil winding.

Partially distributed:
Fully distributed.





Figs. 7,755 to 7,757.—Separate coils, and section of Allis-Chalmers alternator with coils in place.

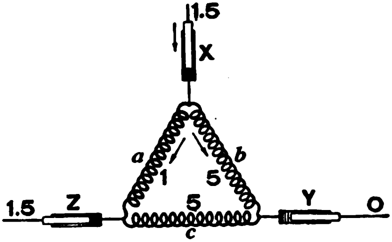


Fig. 7,.758—Diagram showing determination of path and value of current flowing in delta connected armature. The total watts is equal to √3 multiplied by the product of the line current and the line voltage. The delta connection gives a lower line voltage than the star connection for the pressure generated per phase, and cuts down the current in the inductors; since the inductors, on this account, may be reduced in size, the delta connection is adapted to machines of large current output.

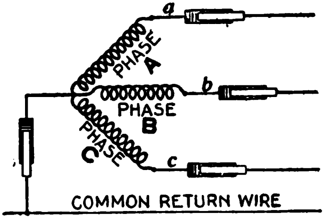


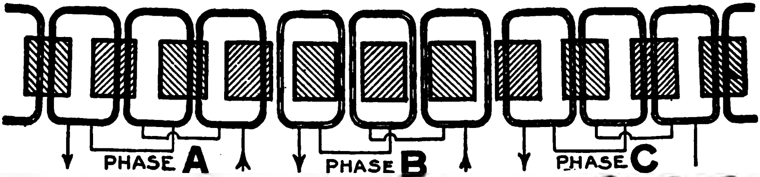
Fig. 7,759.—Diagram of Y connection with a common return wire. When the three lines leading from *a*,*b* and *c*, are equal in resistance and reactance, or in other words when the system is *balanced*, the currents of the three phases are equal and are 120° apart in phase (each current lagging behind its pressure by the same amount as the others) and their sum is at each instant equal to zero. In this case the resultant current being equal to zero there is no need of a common return wire. However, in some cases, where power is distributed from transformers or three wire systems, the different branches are liable to become unbalanced. Under such circumstances the common return wire is sometimes used, being made large enough to take care of the maximum unbalancing that may occur in operation. The return wire is used sometimes on alternators that furnish current mostly for lighting work.

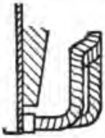
5. Form of the inductors, as
   - *a.* Wire winding;
   - *b.* Strap winding;
   - *c.* Bar winding.

6. Coils per phase per pole, as
   - *a.* One slot winding;
   - *b.* Two slot winding; etc.

7. Kind of current delivered, as
   - *a.* Single phase winding;
   - *b.* Two phase winding;
   - *c.* Three phase winding.

8. Shape of coil ends, as
   - *a.* Single range;
   - *b.* Two range; etc.





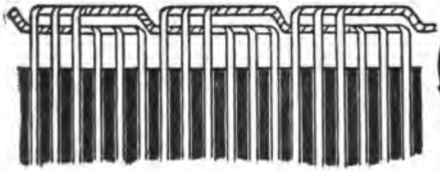


FIG. 7760.—Creeping winding of three coils subtending four poles.

FIGS. 7,761, 7,762 and 7,764.—Views of a section of skew coil winding; so called on account of the skew shape given to the coil ends in order that all the coils may be of one shape.

FIG. 7,763.—Diagram showing chain winding. In this method of winding, the coils are all similar with long and short sides. It obviates the extra cost of making coils of several different shapes. The diagram represents a winding for one slot per pole per phase.

FIG. 7,765.—Diagram showing a spiral coil. This type of coil is one in which each successive turn lies entirely within the previous turn, starting with the outermost turn of the coil. The successive turns of a spiral coil are thus not of the same size, and are not over-lapping as in a "lap" coil.

In addition to these there are a number of miscellaneous windings such as

a. Chain or basket winding;
b. Skew coil winding;
c. Fed-in winding;
d. Imbricated winding;
e. Mummified winding;
f. Spiral winding;
g. Shuttle winding;
h. Creeping winding;
i. Turbine alternator winding.

All these various windings are shown in the accompanying cuts.

Arrangement of Phases.—In polyphase alternators *the separate windings of the various phases may be grouped in two ways*, as 1, ***star or* Y** *connection, or* 2, ***mesh or delta*** *connection.*

The star connection is sometimes called a Y connection on account of its resemblance to that letter; the mesh connection is sometimes called a *delta* connection owing to its resemblance to the Greek letter Δ. In star grouping the point where the phases join is called the *star point.* In a three phase ***star connected alternator*** the voltage between any two collector rings is equal to *the voltage generated per phase multiplied by* $\sqrt{3}$ *or 1.732.* The total output is equal to the sum of the output of each of the three phases. When working on a non-inductive load, the total output of a star connected alternator is equal to $\sqrt{3}$ multiplied by the product of the line current and line voltage.

In a three phase ***delta connected*** alternator, the line current is equal to the *current in each phase multiplied by* $\sqrt{3}$; the total output with non-inductive load is equal to $\sqrt{3}$ *multiplied by the product of the line current and line voltage.* Star connection gives a higher line voltage than the delta connection for the same pressure generated per phase, hence it is suited for machines of high voltage and moderate current.

Delta connection gives a lower line voltage than the star connection for the pressure generated per phase, and cuts down the current in the inductors; since the inductors, on this account, may be reduced in size, the delta connection is adapted to machines of large current output.

CHAPTER 122

A. C. Motors

The fact that many central stations furnish only alternating current has caused manufacturers to perfect many types of *a.c.* motors to meet the needs of all classes of industrial devices. The multiplicity of types thus produced may be classed as:

1. SYNCHRONOUS MOTORS
2. ASYNCHRONOUS MOTORS
    - *a.* **Induction motors**
    - *b.* **Commutator motors** { *series;* *compensated;* *shunt;* **repulsion.**

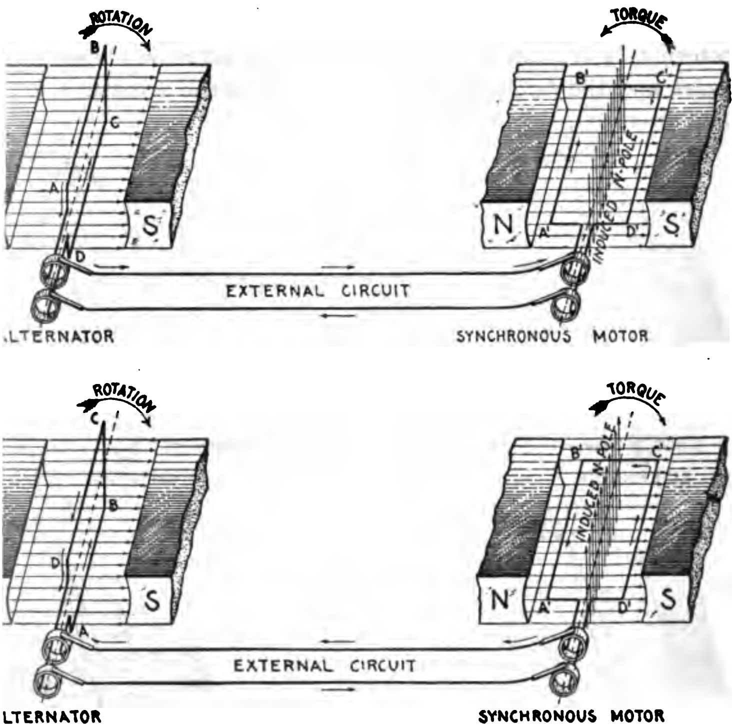
1. Synchronous Motors

The term "synchronous" means *in unison*, that is, *in step*. A so-called synchronous motor, then, as generally defined, *is one which rotates in unison or in step with the phase of the alternating current which operates it.*

Strictly speaking, however, it should be noted that this condition of operation is only approximately realized as will be later shown.

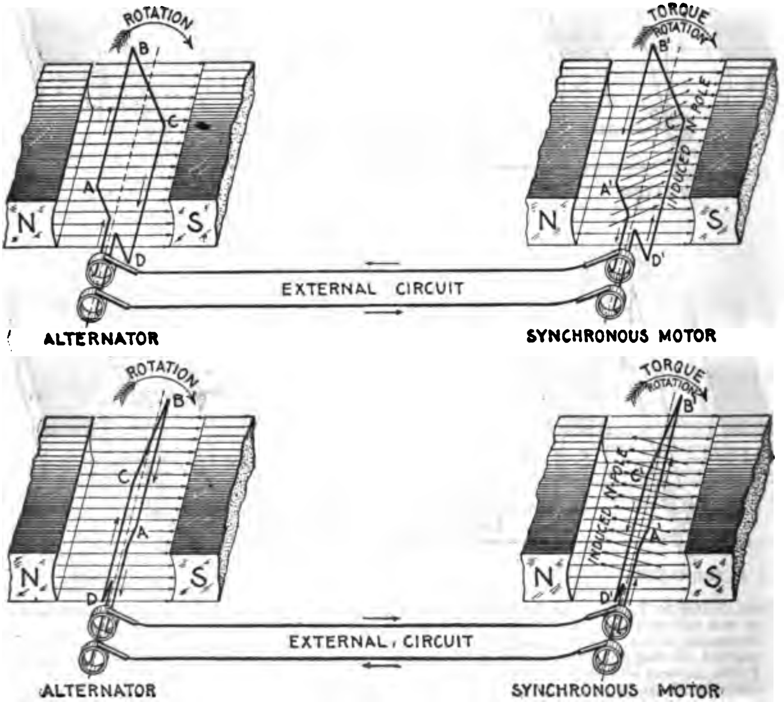
In construction, synchronous motors are almost identical with the corresponding alternator and consists essentially of, 1, *an armature*, and 2, *a field*, either of which may revolve.

The field is separately excited with direct current. In operation, when the field is thus excited and alternating current is



. 7,766 to 7,769.—Synchronous motor principles: *I. A single phase synchronous motor not self-starting.* The figures show an elementary alternator and an elementary syn-onous motor, the construction of each being identical as shown. If the alternator be rted, during the first half of a revolution, beginning at the initial position ABCD, fig. '66, current will flow in the direction indicated by the arrows, passing through the external cuit and armature of the motor, fig. 7,767, inducing magnetic poles in the latter as shown the vertical arrows. These poles are attracted by unlike poles of the field magnets, which id to turn the motor armature in a counter-clockwise direction. Now, ***before the torque is set up has time to overcome the inertia of the motor armature and cause it to rotate,*** *alternator armature has completed the half revolution,* and beginning the second half of revolution, as in fig. 7,768, *the current is reversed* and consequently *the induced magnetic les in the motor armature are reversed also.* This tends to rotate the armature in the reverse ection, as in fig. 7,769. *These reversals of current occur with such frequency that the force* ***es not act long enough in either direction to overcome the inertia of the armature;*** *sequently it remains at rest,* or to be exact, ***it vibrates.*** Hence, a single phase synchronous tor must be started by some external force and brought up to a speed that gives the same quency as the alternator before it will operate. A single phase synchronous motor, then, not self-starting, which is one of its disadvantages; the reason it will operate after being eeded up to synchronism with the alternator and then connected in the circuit is explained figs. 7,770 to 7,773.

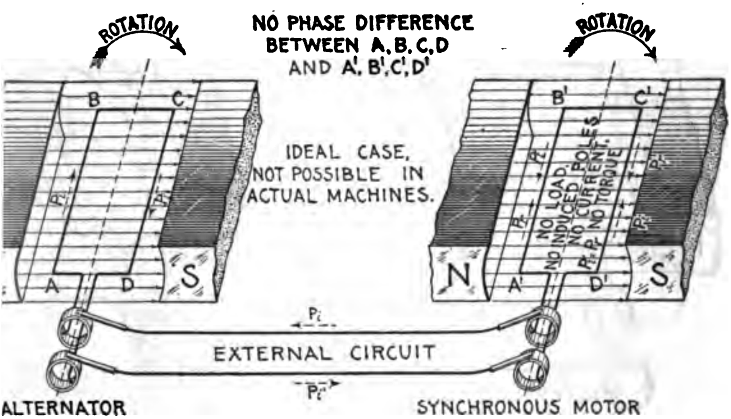
applied to the armature of a single phase motor, it will produce alternately N, and S, poles, the reaction between these *induced* poles and the *field* poles tending to rotate the armature first in one direction, then in the other.



Figs. 7,770 to 7,773.—*Synchronous motor principles: II. The condition necessary for synchronous motor operation is that the motor be speeded up until it rotates in synchronism, that is, in step with the alternator.* In figs. 7,770 and 7,771, assuming synchronism, the arrows indicate the direction of the current for the armature position shown. The current flowing through the motor armature induces magnetic poles which are attracted by the field poles, thus producing a torque in the direction in which the armature is rotating. After the alternator coil passes the vertical position, the current reverses as in fig. 7,772, and the current flows through the motor armature in the opposite direction, thus reversing the induced poles as in fig. 7,773. *This brings like poles near each other, and since the motor coil has rotated beyond the vertical position the repelling action of the like poles, and also the attraction of unlike poles, produces a torque acting in the direction in which the motor is rotating.* Hence, when the two armatures move synchronously, the torque produced by the action of the induced poles upon the field poles is always in the direction in which the motor is running, and accordingly, tends to keep it in operation.

Because of the very rapid reversals in direction of the torque thus set up, re is not sufficient time **to overcome the inertia of the armature** *ore the current reverses and produces a torque in the opposite direction, ce, the armature remains stationary or, strictly speaking,* **it vibrates.**

Now if the motor armature be first brought up to a speed correspond- g in frequency to that of the alternator before connecting the motor the circuit, the armature will continue revolving at the same frequency the alternator.

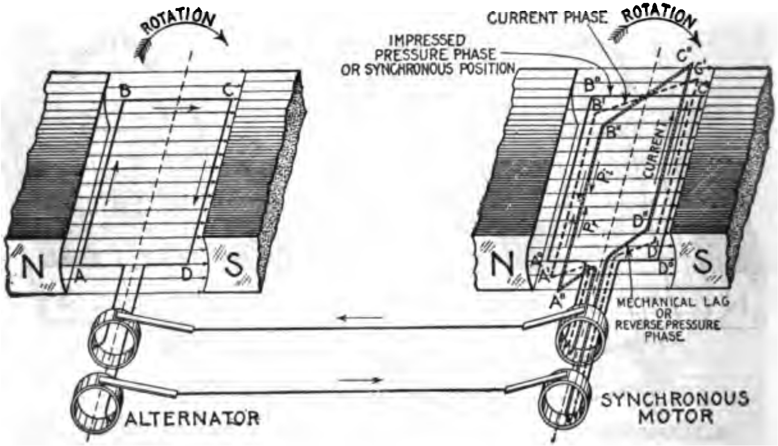


7,774 and 7,775.—***Synchronous motor principles: III.*** *The current which flows ugh the armature of a synchronous motor is that due to the* ***effective pressure.*** Since the tor rotates in a magnetic field, a pressure is induced in its armature in a direction opposite that induced in the armature of the alternator, and called the *reverse pressure,* as disguished from the pressure generated by the alternator called the *impressed pressure. any instant; the pressure available to cause current to flow through the two armatures, called* ***effective pressure,*** *is equal to the difference between the pressure generated by the alternator* ***impressed pressure*** *and the* ***reverse pressure*** *induced in the motor.* Now if the motor perfectly free to turn, that is, without load or friction, the reverse pressure will equal impressed pressure and no current will flow. This is the case of real synchronous opera- n, that is, not only is the frequency of motor and alternator the same, but the coils rotate hout phase difference. In figs. 7,774 and 7,775, the impressed and reverse pressures represented by the dotted arrows *Pi* and *Pr*, respectively. Since in this case these op- sing pressures are equal, the resultant or effective pressure is zero; hence there is no cur- t. *In actual machines this condition is impossible,* because even if the motors have no rnal load, there is always more or less friction present; hence, in operation there must more or less current flowing through the motor armature to induce magnetic poles so as produce sufficient torque to carry the load. The action of the motor in automatically justing the effective pressure to suit the load is explained in figs. 7,776 and 7,777.

The armature continues revolving, because, **at synchronous speed,** *e field flux and armature current are always in the same relative position,* roducing a torque which alwavs pulls the armature around in the same irection.

A polyphase synchronous motor is self starting, because, before the current has died out in the coils of one phase, it is increasing in those of the other phase or phases, so that there is always some turning effort exerted on the armature.

The speed of a synchronous motor is that at which it would have to

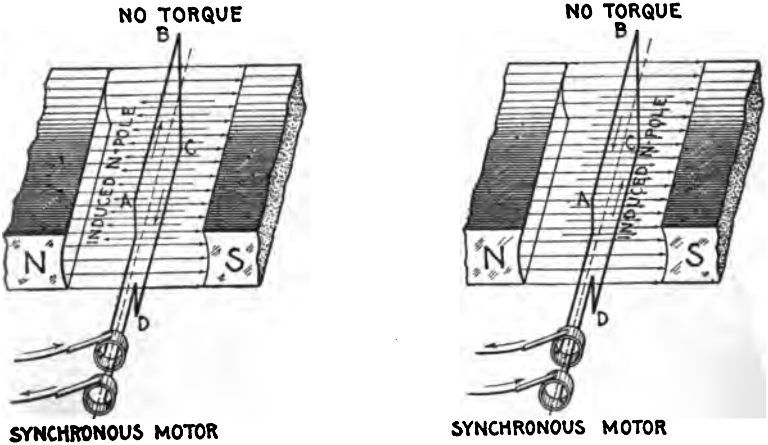


FIGS. 7,776 and 7,777.—Synchronous motor principles: *IV—A synchronous motor adjusts itself to changes of load by changing the phase difference between current and pressure.* If there be no load and no friction, the motor when speeded up and connected in the circuit, will run in true synchronism with the alternator, that is, at any instant, the coils ABCD, and A°B°C°D°, will be in parallel planes. When this condition obtains, no current will flow and no torque will be required (as explained in figs. 7,774 and 7,775). If a load be put on the motor, the effect will be to cause A°B°C°D°, to lag behind the alternator coil to some position A″B″C″D″, and current to flow. The reverse pressure will lag behind the impressed pressure equally with the coil, and the current which has now started will ordinarily take an intermediate phase so that it is *behind the impressed pressure but in advance of the reverse pressure.* These phase relations may be represented in the figure by the armature positions shown, viz.: 1, the synchronous position A°B°C°D°, representing the impressed pressure; 2, the intermediate position A′B′C′D′, the current; 3, the actual position A″B″C″D″, (corresponding to mechanical lag), the reverse pressure. From the figure it will be seen that the current phase represented by A′B′C′D′, is in advance of the reverse pressure phase represented by A″B″C″D″. Hence, by ***armature reaction, the current leading the reverse pressure weakens the motor field and reduces the reverse pressure,*** thus establishing equilibrium between current and load. As the load is increased, the mechanical lag of the alternator coil becomes greater and likewise the current lead with respect to the reverse pressure, which intensifies the armature reaction and allows more current to flow. In this way equilibrium is maintained for variations in load within the limits of zero and 90° mechanical lag. The effect of armature reaction on motors is just the reverse to its effect on alternators, which results in marked automatic adjustment between the machines especially when a single motor is operated from an alternator of about the same size. In other words, the current which weakens or strengthens the motor field, strengthens or weakens respectively the alternator field as the load is varied.

run, if driven as an alternator, to deliver the number of cycles which is given by the supply alternator.

Any synchronous motor if supplied with motive power can be converted without any change to an alternator or any alternator can be run as a synchronous motor if supplied with an alternating current of the same voltage and phase values.

Synchronous motors are used principally for power factor corrections, such as in a plant, where a large inductive load is used such as arc lamps, transformers, and motors, which reduces the power factors so much, that it causes trouble at the power house.

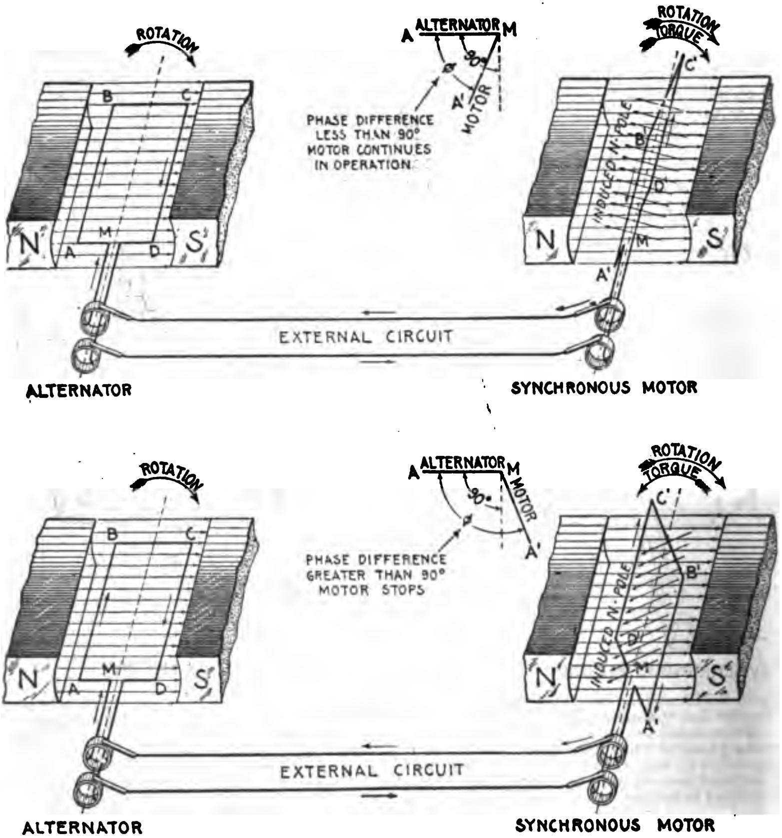


FIGS. 7,778 and 7,779.—***Synchronous motor principles: VI.*** *A single phase synchronous motor has "dead centers," just the same as a one cylinder steam engine.* Two diagrams of the motor are here shown illustrating the effect of the current in both directions. When the plane of the coil is perpendicular to the field, the poles induced in the armature are parallel to field for either direction of the current; that is, the field lines of force and the induced lines of force acting in parallel or opposite directions, no turning effect is produced, just as in analogy when an engine is on the dead center, the piston rod (field line of force) and connecing rod (induced line of force) being in a straight line, the force exerted by the steam on the piston produces no torque.

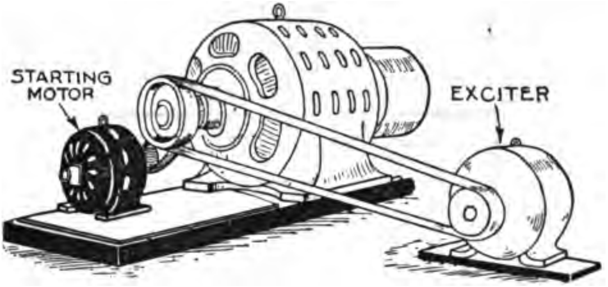
Synchronous motors produce a leading power factor which thereby helps to increase the power factor to unity.

There are two types of synchronous motors, classed with respect to the method of starting:

1. Auxiliary motor type;
2. Self-starting type.



Figs. 7,780 to 7,785.—Synchronous motor principles. ***VII.*** ***An essential condition for synchronous motor operation is that the mechanical lag be less than*** 90°. Figs. 7,780 to 7,782 represent the conditions which prevail when the lag of the motor armature A'B'C'D' is anything less than 90°. As shown, the lag is almost 90°. The direction of the current and induced poles are indicated by the arrows. *The inclination of the motor coil is such that* ***the repulsion of like poles*** *produces a torque* ***in the direction of rotation,*** thus tending to keep motor in operation. Now, in figs. 7,783 to 7,785, for the same position of the alternator coil ABCD, *if the lag be greater than* 90°, *the inclination of the motor coil* A'B'C'D' *is such that at this instant* ***the repulsion of like poles*** *produces a torque in a direction* ***opposite*** *to that of* ***the rotation,*** *thus* ***tending to stop the motor.*** In actual operation this quickly brings the motor to rest, having the same effect as a strong brake in overcoming the momentum of a revolving wheel.



G. 7,786.—***Auxiliary starting*** **type synchronous motor, showing exciter and starting induction motor.**

The usual type of synchronous motor is started by means of an auxiliary induction motor, whose shaft is connected to the synchronous motor shaft by means of a silent chain. The teeth on gears of starting motor shaft and of synchronous motor shaft are so selected that when the auxiliary motor has attained full speed the synchronous motor runs slightly above synchronous speed. The starting motor switch is then opened and the synchronous motor is allowed to coast down to synchronous speed, which is indicated by lamps or synchroscope.

The synchronous motor line switch is then closed at the proper instant. The size of the auxiliary starting induction motor depends upon the friction

FIG. 7,787.—Rotor field of General Electric 360 horse power ***self-starting*** **type synchronous motor, showing the amortisseur or squirrel cage starting winding in the pole faces. The synchronous motor can use a high resistance squirrel cage inding because when operating in synchronism, there is practically no loss in the inding.**

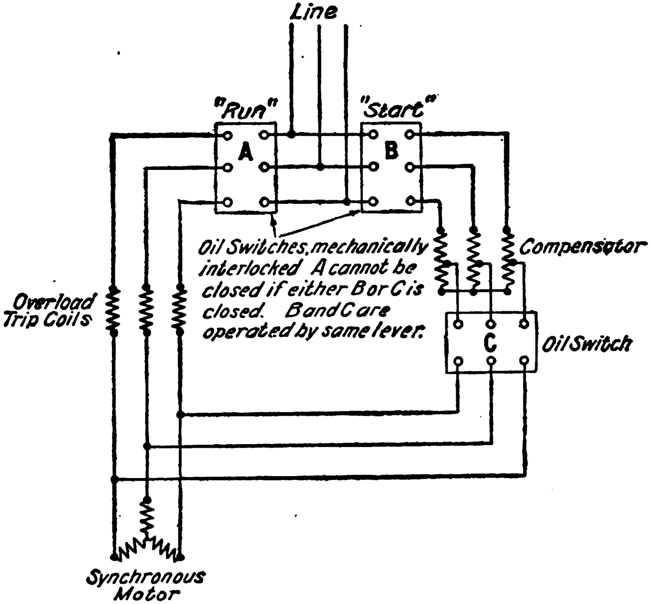


FIG. 7,788.—Starting connections for self-starting synchronous motor. ***In starting:*** 1, Open field switch completely if the excitation voltage be 125 volts; If the excitation voltage of the motor be higher than 125 volts, the field switch should not be opened completely but left in the clips connected to the discharge resistance. This prevents any high induced voltage across the collector rings. ***Exception:*** If the motor be part of a motor generator set (other than a frequency converter set) the field switch should be left in the clips connected to the discharge resistance irrespective of the degree of field excitation. Note that frequency degree converter sets should be started in accordance with the general rule given above; 2, Throw compensator lever to "start" position. (If oil switches be used, close the switch marked "start.") 3. After the motor has reached constant speed close the field switch; the field rheostat having been previously adjusted to give a field current corresponding approximately to no load, normal voltage, with machine running as a generator. 4. Throw compensator lever quickly to the "run" position. (If oil switches be used, open the switch marked "start," and after this, as quickly as possible, close the switch marked "run.") ***Cautions:*** 1. Do not touch collector rings or brushes when the motor is being started. An induced pressure of about 2,000 volts exists across the rings at the moment of starting. This voltage decreases as the motor speeds up, reaching zero at full speed. 2. The motor should be started on the lowest tap of the compensator that will start it promptly and bring it to full speed in about one minute. If two or three minutes are consumed in coming to full speed, there is danger of burning the squirrel cage winding. *Special cases.* There are a few instances where requirements of torque and line current, or perhaps a demand for a high excitation voltage (which involves a high induced voltage at starting) make it necessary to modify the procedure in starting. ***Closing running switch before synchronizing.*** There are rare cases where severe requirements of "pull-in" torque make it necessary to close the running switch, throwing on full line pressure before the field switch is closed. That is operation 3 above should follow 4. ***Closing field current through resistance.*** There are two occasions for closing the field circuit through a resistance as part of the starting procedure. In one case the object is to increase the torque near full speed; in the other, to prevent high induced pressure across the collector rings at starting. With the proper value of resistance across the collector rings the torque near full speed is increased. A change frictional load of the synchronous motor and the synchronous motor load. In some instances this may require an excessively large auxiliary motor, which makes its cost prohibitive.

This type of synchronous motor may be used successfully where reliable attendance is at hand, quickness of start is not important, and sufficient floor space is available.

The self-starting type is provided with a squirrel cage winding on the rotor which serves as an induction motor secondary winding during starting.

The motor is started by means of applying a reduced voltage directly to the armature winding by means of an auto transformer with taps brought out for different starting voltages.

The voltage is applied to the motor by means of an auto starter switch which acts as a combined starting and line switch.

On account of the fact that during the starting a dangerous voltage would be induced in the field winding if the field circuit were left open, it is necessary to short circuit the field. In cases where individual exciters are used, the motor field is left connected across the exciter armature while starting.

When the motor is excited from an exciting bus, a double throw field switch is provided for short circuiting the field while starting. The field rheostat is included in the circuit with the field winding, during starting, and to limit the current which would otherwise decease the starting torque.

A synchronous motor is desirable for large powers where starting under

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FIG. 7,788.—*Continued*

from this resistance in either direction will decrease tne torque. At starting, however, any value of resistance will decrease the torque which the motor would develop with collector rings open. Hence, when a motor at the time it is purchased is required to pull into synchronism a large percentage of normal load, or when conditions arise in service where the "pull-in" torque requirements prove to be greater than were anticipated, the above scheme is sometimes resorted to. An accurate and convenient way of determining the proper resistance is to bring the motor to constant speed at full line voltage with the load it has to pull into synchronism; then by means of a water box connected across the collector rings, determine the resistance which will increase the speed to the highest value. This will be the proper resistance. The field discharge resistance in such case is increased to the proper value and capacity for this added service. Here, the switching procedure is only slightly modified. When the motor is running on the last tap, or on the line, as the case may be,—that is, when in the standard case, the next operation would be to close the field switch—close the field switch on the first point thereby throwing the resistance across the field. A moment later say 5 or 10 seconds, close the field switch entirely. On a given machine, the higher the excitation voltage for which the field winding is designed, the higher the induced voltage across the collector rings at starting. Motors which are designed for normal excitation voltages higher than 125 volts, or those which form part of motor generator sets other than frequency converter sets, should have the field winding short circuited through the discharge resistance at starting. This will prevent the high induced voltage across the collector rings. It is standard practice to make all discharge resistances for synchronous motors of ample capacity for this service.

load is not necessary. Its power factor may be controlled by varying the field strength. The power factor can be made unity and further, the current can be made to lead the pressure.

A synchronous motor is frequently connected in a circuit solely to improve the power factor. In such cases it is often called a "condenser motor" for the reason that its action is similar to that of a condenser.

The stationary armature type is adapted to high voltages because of the absence of slip rings in the armature circuit.

The disadvantages of a synchronous motor are that it requires an auxiliary power for starting, and will stop if, for any reason, the synchronism be destroyed; collector rings and brushes are required. For some purposes synchronous motors are not desirable, as for driving shafts in small workshops having no other power available for starting, and in cases where frequent starting, or a strong torque at starting is necessary. A synchronous motor has a tendency to *hunt* and requires intelligent attention; also an exciting current which must be supplied from an external source.

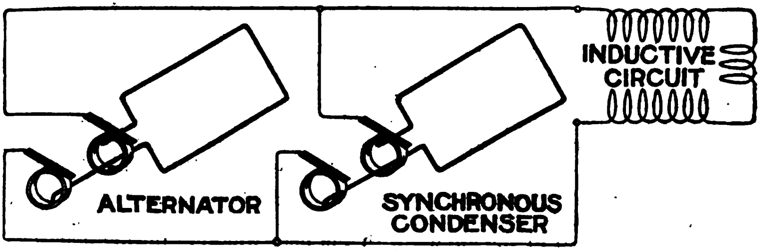

Fig. 7,789.—Diagram illustrating the use of a synchronous motor as a condenser. If a synchronous motor be sufficiently excited the current will lead. Hence, if it be connected across an inductive circuit as in the figure and the field be over excited it will compensate for the lagging current in the main, thus increasing the power factor. If the motor be sufficiently over excited the power factor may be made unity, the minimum current being thus obtained that will suffice to transmit the power in the main circuit. A synchronous motor used in this way is called a *rotary condenser* or *synchronous compensator*. This is especially useful on long lines containing transformers and induction motors.

Hunting of Synchronous Motors.—Since a synchronous motor runs practically in step with the alternator supplying it with current when they both have the same number of poles, or some multiple of the ratio of the number of poles on each machine, it will take an increasing current from the line as its speed drops behind the alternator, but will supply current to the line as a generator if for any reason the speed of the alternator should drop behind that of the motor, or the current wave lag behind, which produces the same effect, and due to additional self-induction or inductance produced by starting up or overloading some other motor or rotary converter in the circuit.

When the motor is first taking current, then giving current back to the line, and this action is continued periodically, the motor is said to be *hunting*.

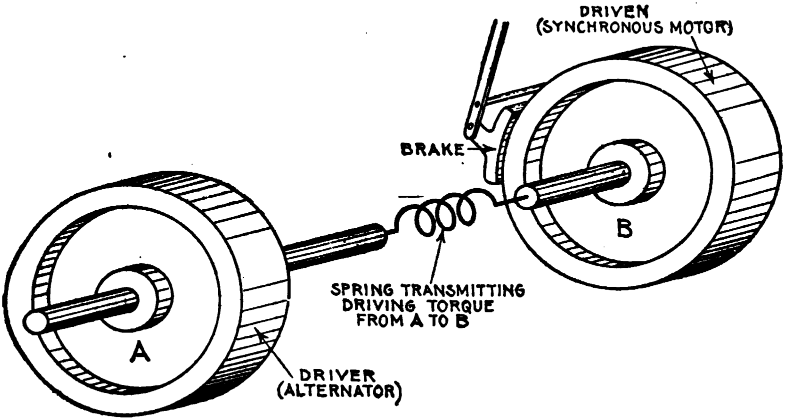

FIG. 7,790.—Mechanical analogy illustrating "hunting." The figure represents two fly wheels connected by a spring susceptible to tortion in either direction of rotation. If the wheels A, and B, be rotating at the same speed and a brake be applied, say to B, its speed will diminish and the spring will coil up, and if fairly flexible, more than the necessary amount to balance the load imposed by the brake; because when the position of proper torque is reached, B, is still rotating slightly slower than A, and an additional torque is required to overcome the inertia of B, and bring its speed up to synchronism with A. Now before the spring stops coiling up the wheels must be rotating at the same speed. When this occurs the spring has reached a position of too great torque, and therefore exerting more turning force on B, than is necessary to drive it against the brake. Accordingly B, is accelerated and the spring uncoils. The velocity of B, thus oscillates above and below that of A, when a load is put on and taken off. Owing to friction, the oscillations gradually die out and the second wheel takes up a steady speed. A, similar action takes place in a synchronous motor when the load is varied.

The *term surging* is used to describe the current fluctuations produced by hunting. The accompanying series of illustrations of synchronous motor principles, show in a very simple way how a synchronous motor works.

2. *Asynchronous Motors*

a. Induction Motors

*An induction motor consists essentially of an armature and a field magnet, there being, in the simplest and most usual types, no electrical connection between these two parts.**

There are two general types of induction motor:

1. Single phase;
2. Polyphase.

The operation of an induction motor depends on the production of a magnetic field by passing an alternating current through field magnets.

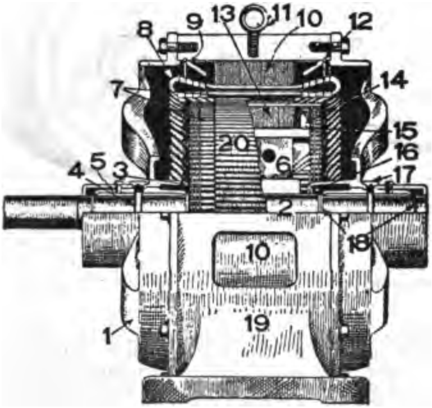

Fig. 7,791.—Sectional view showing parts of Reliance polyphase induction motor. A special feature of the squirrel cage armature construction is the multiplicity of short circuiting rings. The holes in the rings are bored slightly smaller than the diameter of the copper rods, and the force fit gives good contact. The rings having been forced in place are dip soldered in an alloy of tin of high melting point. The motor parts are: 1, end yoke; 2, shaft; 3, armature short circuiting rings; 4, oil ring; 5, self-aligning bearing bushing; 6, spider; 7, armature bars; 8, field coils; 9, field lamination end plate; 10, field laminations; 11, eye bolt; 12, stator locking key; 13, armature laminations; 14, armature lamination end plate; 15, armature locking key; 16 dust cap; 17 oil well cover; 18 oil throws; 19, field frame; 20, squirrel cage armature.

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*NOTE.—The author prefers the terms armature and field magnet, instead of "primary," "secondary," "stator," "rotor," etc., as used by other writers, the armature being the part in which currents are induced and the field magnet (or magnets) that part furnishing the field in which the induction takes place.

The character of this field is either **oscillating** *or* **rotating**, *according, as single or* **polyphase** *current is respectively used.*

Since a single phase motor must start with a rotating field and come up to speed before the oscillating field can be employed, a knowledge then of the production of a rotating field is necessary to understand the action of the single phase motor at starting, hence the polyphase motor will be explained first.

Polyphase Induction Motor.—The construction of an induction motor is very simple. It consists of only two parts, *an armature and field magnets.*

There is no electrical connection between these parts, hence such motors are adapted for use in places where special precautions against fire are necessary. The operation of a polyphase induction motor depends on:

1. *The production of a rotating field;*

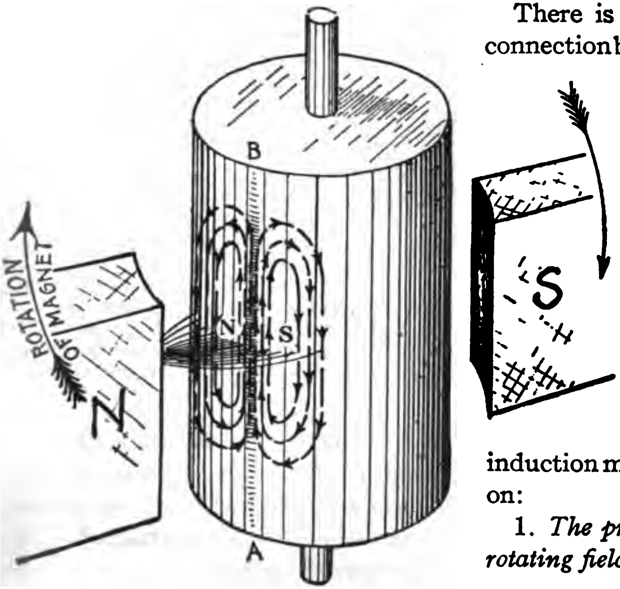


FIG. 7,792.—Elementary induction motor consisting of a copper cylinder and rotating magnet *illustrating the principle of operation of an induction motor* as explained in the accompanying text. ***In operation,*** the speed of the copper cylinder armature depends upon the load; it must always turn *slower* than the magnet, in order that its elements may cut magnetic lines and induce poles to produce the necessary torque to balance the load. The difference in speed of the magnet and cylinder is called the *slip*. Evidently the greater the load, the greater is the slip required to induce poles of sufficient strength to maintain equilibrium. The figure is drawn somewhat distorted, so that both eddies are visible.

2. *Induction of current in the armature;*
3. *Reaction between the revolving field and the induced currents.*

In practice the *rotating field* is produced without any movement of the mechanical parts of the electro-magnets, but for simplicity in explaining the principle of operation, the rotating magnetic field may be supposed to be produced by a pair of magnetic poles placed at opposite sides of the armature and revolved around it as in fig. 7,792, which shows an elementary induction motor.

The armature here consists of a copper cylinder.

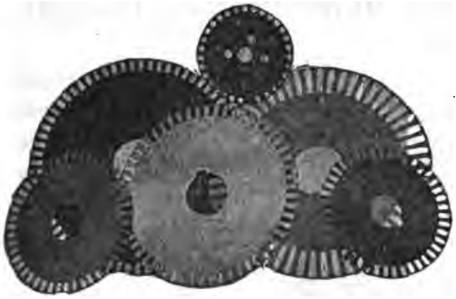


Fig. 7,793.—Mechanical Appliance Co. solid core discs as used on small and medium size induction motors.

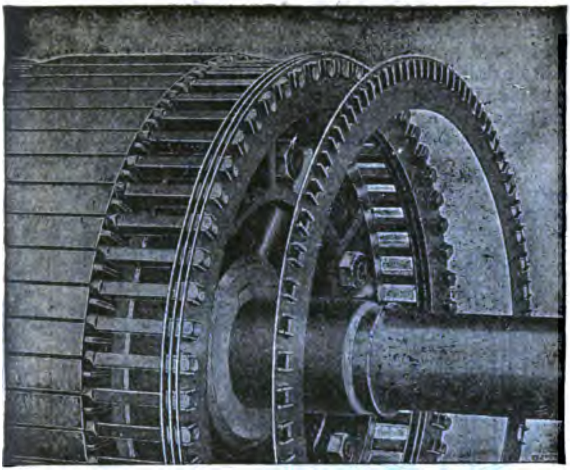
Now, for instance in starting, the cylinder being at rest any element or section of the surface as the shaded area AB, will, as it comes into the magnetic field of the rotating magnet, cut magnetic lines of force inducing a current therein, whose direction is easily determined by applying Fleming's rule.

Since the field is not uniform, but gradually weakens, as shown, on either side of the shaded area (which is just passing the center), the pressure induced on either side will be less than that induced in the shaded area AB, giving rise to eddy currents as shown. These eddy currents induce poles as indicated at the centers of the whorls, the polarity being determined by applying the right hand rule for polarity of solenoids, as given on page 3,409-49.

By inspection of fig. 7,792, it is seen that *the induced pole toward which the magnet is moving is of the same polarity as the magnet; therefore it is* **repelled,** *while the induced pole from which the magnet is receding, being of opposite polarity, is* **attracted.** *A torque is thus produced tending to rotate the cylinder.*

It must be evident that this torque is greatest when the cylinder is at rest, because the magnetic lines are cut by any element on the cylindrical surface at the maximum rate.

Moreover, as the cylinder is set in motion and brought up to speed, the torque is gradually reduced, because the rate with which the magnetic lines are cut is gradually reduced.



The essential condition of operation of an induction motor is that the armature, or part in which currents are induced, ***must** rotate at a speed slower than that of the rotating magnetic field.*

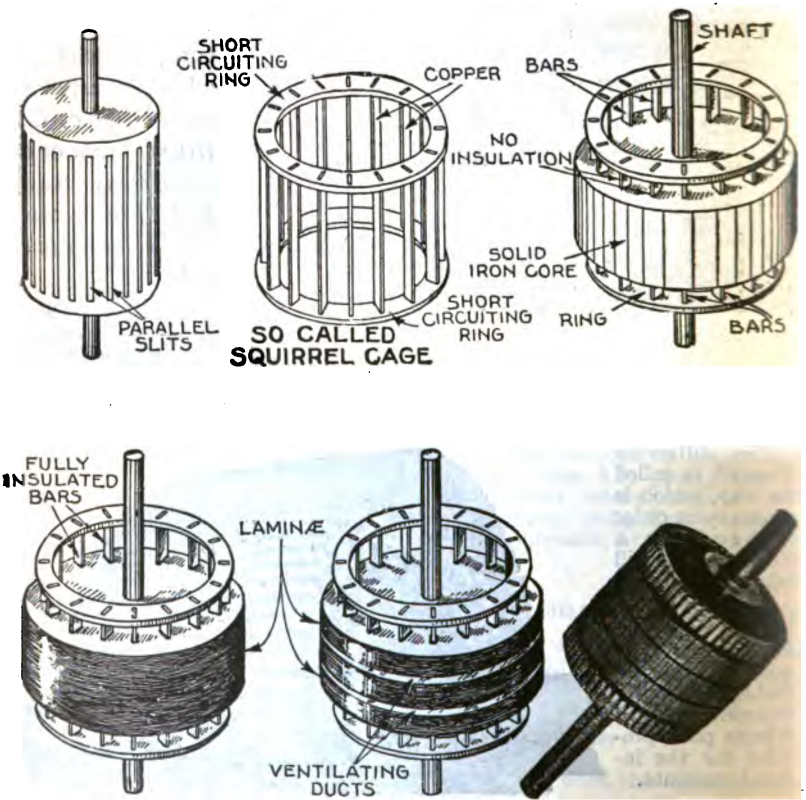
Fig. 7,794.—General Electric soldered form of end ring construction on squirrel cage armatures. The armature inductors or copper bars laid in the core slots are short circuited by these end rings, which are also made of copper. For the smaller sizes, the rings are thin but of considerable radial depth and are held apart by spacing washers. They have rectangular holes punched near their outer peripheries through which the bars pass. Lips are formed on the rings, as shown to which the bars are soldered.

This difference of speed is called the *slip*, which is necessary in order to produce a torque that will balance the load.

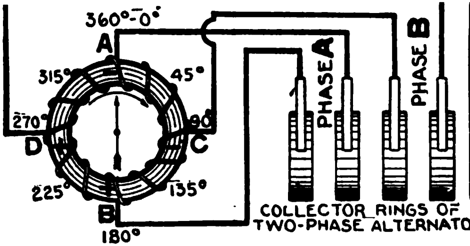
The copper cylinder armature shown in fig. 7,792 would not be desirable in practice because there is no definite path provided for the induced currents.

Fig. 7,795.—General Electric welded form of end ring construction on squirrel cage armatures Space limitations make it difficult to provide parallel soldered rings of sufficient area for large motors; hence, on such machines welding is resorted to, as shown. The ring in welded construction is placed beneath the bars at each end of the armature. Short radial bars are welded to the edges of these rings and to the inductors or squirrel cage bars, thereby making good electrical contact.

Obviously, a better result is obtained if the downward returning currents of the eddies are led into some path where they will return across a field of opposite polarity from that across which they ascended, as in such case, the turning effect will be doubled. Such modification was made by cutting a number of parallel slits in the copper cylinder, leaving at each end an uninterrupted *ring* of metal as in fig. 7,797. Later a built up construction (fig. 7,797) was embedded in a solid mass of iron as in fig. 7,798.



FIGS. 7,796 to 7,801.—Development of the squirrel cage armature. **Fig. 7,796, slotted copper** cylinder; fig. 7,797, so called squirrel cage; fig. 7,798, squirrel cage embedded **in solid** iron core; fig. 7,799, squirrel cage with insulated bars, laminated core; fig. 7,800, **squirrel cage** with insulated bars, laminated core with ventilating ducts; **fig. 7,801, modern squirrel cage armature.**



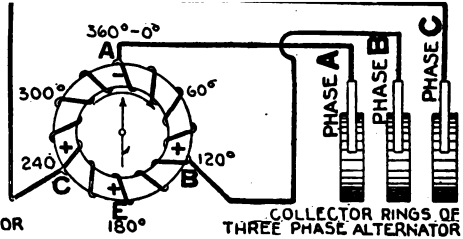


FIG. 7,802.—Production of a rotary magnetic field by two phase current. If only one current *a*, entered the ring at A, and the direction of the winding be suitable, a negative pole (—) will be produced at A, and a positive pole (+) at B, so that a magnetic needle pivoted in the center of the ring would tend to point vertically upward toward A. Now suppose that at this instant, corresponding to the beginning of an alternating current cycle, a second current *b*, differing in phase from the first by 90 degrees, be allowed to enter the ring at C. As shown, when the pressure of the current *a*, is at its maximum, that of the current *b*, is at its minimum; therefore, even a two phase current, at the beginning of the cycle, the needle will point toward A. As the cycle continues, however, the strength of *a*, will diminish and that of *b*, increase, thus shifting the induced pole toward C, until *b*, attains its maximum and *a*, falls to its minimum at 90° or the end of the first quarter of the cycle, when the needle will point toward C. At 90°, the phase *a*, current reverses in direction and produces a negative pole at B, and as its strength increases from 90° to the 180° point of the cycle, and that of phase *b* diminishes, the resultant negative pole is shifted past C, toward B, until *a*, attains its maximum and *b*, falls to its minimum at 180°, and the needle points in the direction of B. At the 180° point of the cycle, *b*, reverses in direction and produces a negative pole at D, and as the fluctuation of the pressure of the two currents during the second half of the cycle, from 180° to 360°, bear the same relation to each other as during the first half, the resultant poles of the rotating magnetic field thus produced carry the needle around in continuous rotation so long as the two phase current traverses the windings of the ring.

FIG. 7,803.—Production of a rotary magnetic field by three phase current. At the instant when the current *a*, flowing in at A, is at its maximum, two currents *b* and *c*, each one-half the value of *a*, will flow out B and C, thus producing a negative pole at A, and a positive pole at B, and at C. The resultant of the latter will be a positive pole at E, and consequently, the magnetic needle will point towards A. As the cycle advances, however, the mutual relations of the fluctuations of the pressures of the three currents, and the time of their reversals of direction will be such, that when a maximum current is flowing at any one of the points A, B, and C, two currents each of one-half the value of the entering current will flow out of the other two points, and when two currents are entering at any two points, a current of maximum value will flow out of the other point. This action will produce one complete rotation of the magnetic field during each cycle of the current.

A solid cylinder of iron will of course serve as an armature, as it is magnetically excellent; but the high specific resistance of iron prevents the flow of induced currents taking place sufficiently copiously; hence a solid cylinder of iron is improved by surrounding it with a mantle of copper, or by a squirrel cage of copper bars (like fig. 7,801), or by embedding rods of copper (short circuited together at their ends with rings) in holes just beneath its surface. However, since all eddy currents that circle round, as those sketched in fig. 7,792, are not so efficient in their mechanical effect as currents confined to proper paths, and as they consume power and spend it in heating effects, the core was then constructed with laminations lightly insulated from each other, and further the squirrel cage copper bar inductors were fully insulated from contact with the core. Tunnel slots were later replaced by designs with open tops.

Slip.—This is a vital factor in the operation of an induction motor since *there must be slip in order that the armature inductors shall cut magnetic lines* to **induce** (hence the name **"induction"** motor) currents therein so as to create a driving torque.

The slip usually varies from about 2 to 5% of synchronous speed depending upon the size, that is, the armature turns from about 2 to 5% *slower* than the rotating magnetic field. There is ordinarily very little slip because due to the very low resistance of the armature, very little pressure is required to produce current therein of sufficient strength to give the required torque.

The revolutions of the rotating field per minute or synchronous speed is determined by the following formula:

$$\text{synchronous speed} = \frac{2 \times \text{frequency}}{\text{number of poles}} \times 60$$

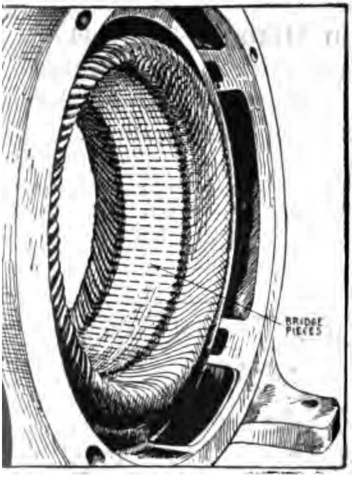
The following table gives the synchronous speed for various frequencies and different numbers of poles:

Frequency	R.P.M. of the rotating magnetic field, when number of poles is						Frequency	R.P.M. of the rotating magnetic field, when number of poles is					
	2	6	10	16	20	24		2	6	10	16	20	24
25	1,500	500	300	188	150	125	100	6,000	2,000	1,200	750	600	500
60	3,600	1,200	720	450	360	300	120	7,200	2,400	1,440	900	720	600
80	4,800	1,600	960	600	480	400	125	7,500	2,500	1,500	938	750	625

Rotating Magnetic Field.—It should be understood that the term *rotating field* does not signify that the magnets revolve (as in fig. 7,792), the expression merely refers to the magnetic lines of force set up by the field magnets without regard to whether the latter be the stationary or rotating member.

A rotating field then may be defined as *the resultant magnetic field produced by a system of coils symmetrically placed and supplied with polyphase currents.*

A rotating magnetic field may be produced either by



1. Two phase currents as in fig. 7,802, or by

2. Three phase currents as in fig. 7,803.

The Field Magnets.—The construction of the field magnets, which, when energized with alternating current produce the rotating magnetic field, is in many respects identical with the armature construction of revolving field alternators.

. 7,804.—Field construction of Crocker Wheeler induction motor with *magnetic bridge.* teel bridges are inserted in the grooves where the coils are placed, to protect them from irt and mechanical injury, and at the same time to provide a path for the magnetic flux which as a nearer uniform reluctance, thereby insuring a better distribution of the flux in the air ap and at the same time retaining open slot construction from which the coils can be readily emoved.

he field magnets con-
t essentially of: 1,
ke or frame; 2, la-
næ, or core stamp-
s; 3, winding. The
ke and laminæ are
every way similar
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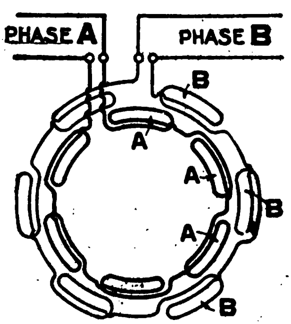
revolving field al-
nators.

. 7,805.—Western Electric core construction and method of winding field of skeleton frame duction motor. The coils are wound on forms to give them exact shape and dimensions reuired. They are pressed into hot moulds to remove any irregularities and then the coils are pregnated with hot cement, to bind the layers together in their permanent shape. The ortion of the coil which fits into the slot is wrapped with varnished cloth and a layer of dry pe is wound over the entire coil. The coils are then impregnated with an insulating comound and baked, the process being repeated six times. Coils for 1,100 and 2,200 volt motors ave an extra covering of insulation and double the amount of impregnating and baking.

Field Windings for Induction Motors.—The field windings of induction motors are almost always made to produce more than two poles in order that the speed may not be unreasonably high. This will be seen from the following:

If P, be the number of *pairs* of poles per phase, *f*, the frequency, and N, the number of revolutions of the rotating field per minute, then

$$N = \frac{60 \times f}{P}$$



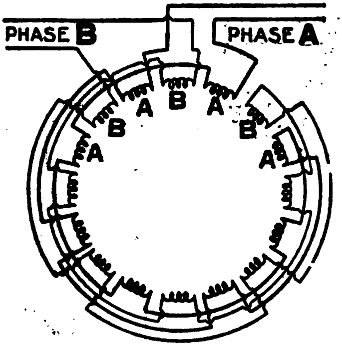


FIG. 7,806.—Diagram of two phase, six pole field winding. There are six coils in each phase as shown. The coils of each phase are connected in series, adjacent coils being joined in opposite senses, thus, for each phase, first one coil is wound clockwise, and the next counter clockwise.

FIG. 7,807 —Diagram of two phase, eight pole field winding. The winding is divided into 16 groups (equal to the product of the number of poles multiplied by the number of phases). Each group such as at A, comprises a number of coils in series, each coil being located in a separate pair of slots, the end of one being connected to the beginning of the next. When the currents are in the same direction, the currents circulate in the same direction in two adjacent groups, a pole then with this arrangement being formed by two groups, both phases contributing to the formation of the pole. After ½ cycle when the current in each phase reverses, the pole advances the angular distance, covered by two groups; hence the field completes one revolution in eight alternations of current.

Thus for a frequency of 100 and one pair of poles, N = 60 × 100 ÷ 1 = 6,000. By increasing the number of pairs of poles to 10, the frequency remaining the same, N = 60 × 100 ÷ 10 = 600. Hence, in design, by increasing the number of pairs of poles the speed of the motor is reduced.

An objection to very high speed of the rotating field is the increased difficulty of starting. Hence, in practice there are a multiplicity of field poles, and in some cases low frequency current is used to reduce the speed of the rotating field. Where the current is used both for power and lighting, low frequency is objectionable because of the resulting "flicker" in the lamps which is perceptible.

In general the field core slots contain a distributed winding of substantially the same character as the armature winding of a revolving field polyphase alternator.

The poles are formed *by properly connecting the groups of coils* and not by windings concentrated at certain points on salient or separately projecting masses of iron, as in direct current machines.

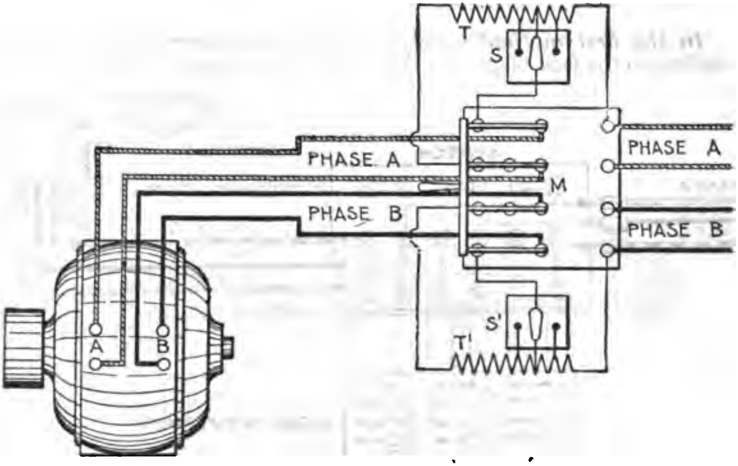


FIG. 7,808.—Westinghouse auto-transformer or compensator. ***It consists of*** two auto tranformers T and T', each having only a single winding for both primary and secondary which are tapped at certain points by switches, thus dividing the winding into a number of loops, so that one of several voltages may be applied for starting, and the starting torque thus adjusted to the work that has to be performed. At the highest points tapped by the switches S and S', the full pressure, and at the lowest points, the lowest pressure, is applied to the motor by the operation of the main switch M. This switch has four blades and three positions. When thrown to the left as indicated, it connects the auto-transformers T and T', across the circuits A and B, respectively, so that the pressure across the transformer coils, as determined by the position of the switches S and S', is applied to the motor circuits A and B. The intermediate position of the switch M, interrupts both circuits. ***To start the motor,*** switch M, is thrown to the left and a reduced pressure applied; after the motor has started and come up to speed the switch M, is thrown to the right, thus cutting out the transformer and connecting the motor directly to the circuit.

In grouping the coils, three phase windings are usually Y connected. In some cases Y grouping is used for starting and △ grouping for running.

Starting of Induction Motors.—Because of the very low resistance of the armature, the machine, unless of very small size, would probably be destroyed by the heat generated before it could come up to speed. Accordingly some form of starting device is necessary. There are several methods of starting, as with:

1. Resistances in the field;
2. Auto-transformer or compensator:
3. Resistance in armature.

In the first method variable resistances are inserted in the circuits leading to the field magnets and mechanically arranged so that the resistances are varied simultaneously for each phase in equal amounts. These starting resistances are enclosed in a box similar to a direct current motor rheostat.

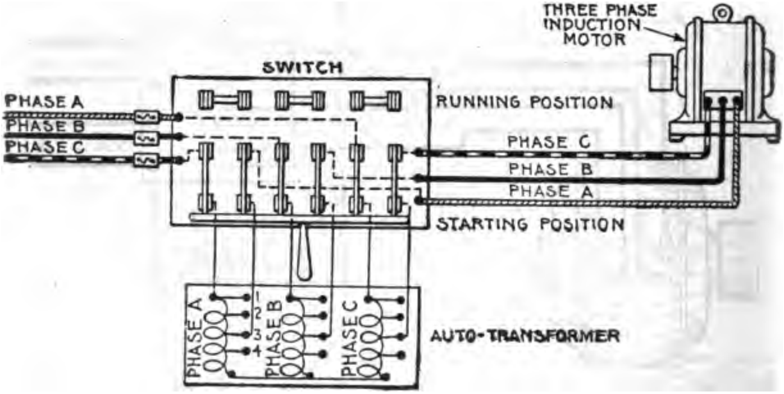


Fig. 7,809.—Auto-transformer or compensator connections for three phase induction motor. ***In operation,*** when the double throw switch is thrown over to starting position, the current for each phase of the motor flows through an auto-transformer, which consists of a choking coil for each phase, arranged so that the current may be made to pass through any portion of it (as 1,2,3) to reduce the voltage to the proper amount for starting. After the motor has come up to speed on the reduced voltage, the switch is thrown over to running position, thus supplying the full line voltage to the motor. ***In actual construction*** fuses are usually connected, so that they will be in circuit in the running position, but not in the starting position, where they might be blown by the large starting current.

An objection to this method is that it is less efficient than the use of variable inductances.

In the second method, variable inductances or auto-transformers are inserted in the field magnet circuits.

In the third method, variable resistances are inserted in the armature circuit, and according to the location of these resistances, the machine is classed as an internal resistance motor, or an external resistance (slip ring) motor.

Internal Resistance Induction Motors.—The armature of this type of induction motor differs from the squirrel cage variety in that the winding is not short circuited through copper rings, but, in starting, is short circuited through a resistance mounted directly on the shaft in the interior of the armature.

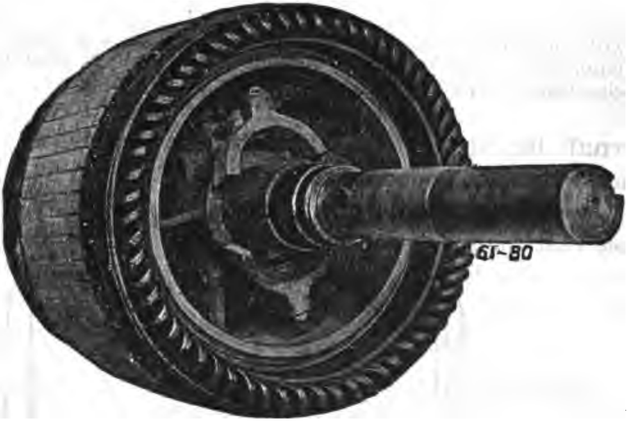


FIG. 7,810.—View of armature interior of Wagner poplyphase induction motor with wound armature, showing the centrifugal device which at the proper speed short circuits all the coils, transforming the motor to the squirrel cage type. The winding is connected with a vertical "commutator" so called. Inside the armature are two governor weights, which are thrown outward by the centrifugal force when the machine reaches the proper speed thus pushing a solid copper ring (which encircles the shaft) into contact with the inner ends of the "commutator" bars, in this way completely short circuiting the armature winding.

When the motor is thrown in circuit, a very low starting current is drawn from the line due to the added resistance in the armature. As the motor comes up to speed, this resistance is gradually cut out, and at full speed the motor operates as a squirrel cage motor, with short circuited winding.

The starting resistance is gradually cut out by operating a lever which engages a collar free to slide horizontally on the shaft. The collar moves

FIG. 7,811.—Richmond slip ring motor.

over the internal resistance grids (located within the armature spider), thus gradually reducing their value until they are cut out.

This arrangement is suitable for small motors, but is objectionable on large motors because of the considerable heat produced.

The initial rush of current when a squirrel cage motor is thrown on the line is more or less objectionable and there are central stations which allow only resistance type of induction motor to be used on their lines.

As with the internal resistance motor, the armature winding of a slip ring motor is not short circuited through copper rings in starting, but through a resistance, which in this case is located externally.

External Resistance or Slip Ring Motors.—In large machines, and those which must run at variable speed, such as is required in the operations of cranes, hoists, dredges, etc., it is advisable that the regulating resistances be placed externally to

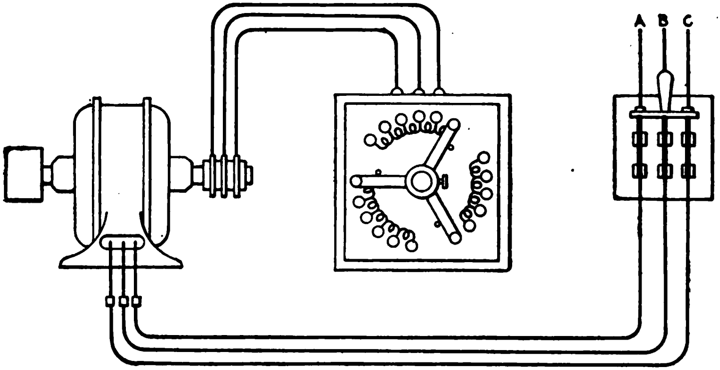


FIG. 7,812.—External resistance or slip ring induction motor connections. The squirrel cage armature winding is not short circuited by copper end rings, but connected in Y grouping and the three free ends connected to three slip rings, leads going from the brushes to three external resistances, arranged as triplex rheostat having three arms rigidly connected as shown, so that the three resistances may be varied simultaneously and in equal amounts.

the motor. Motors having this feature are commercially known as **slip ring motors,** because *connections are made between the external resistances and the armature inductors by means of slip rings.*

The armature winding is connected in Y grouping and the free ends connected to the slip rings, leads going from the brushes to the variable resistances as in fig. 7,812.

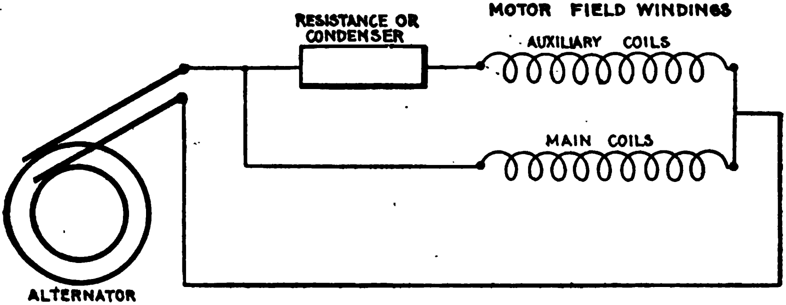
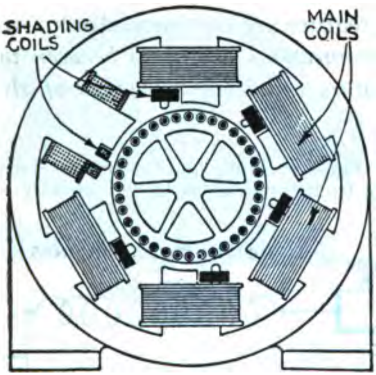


FIG. 7,813.—Simplified diagram showing the principle of phase splitting for starting single phase induction motors. *By the use* of an auxiliary set of coils connected in parallel with the main coils and having in series a resistance or condenser as shown, the single phase current delivered by the alternator is "split" into two phases, which are employed to produce a rotating field on which the motor is started.

SINGLE PHASE INDUCTION MOTORS

On account of the growing practice of central stations of supplying their lighting service through single phase distribution and permitting the use of moderate size single phase motors on the lighting circuit and also because of the simplicity of single phase systems, the general utility of single phase motors of small and medium sizes, is constantly being enlarged.



A single phase motor consists essentially of an *armature and field magnet having a single phase winding and also some phase splitting arrangement for starting*.

The phase splitting device is necessary because the nature of the field produced by a single phase current is such that it will not start the motor. By splitting the phase, a field is set up normal to the axis of the armature, and nearly 90° displaced in phase from the field in that axis. This cross field produces the useful torque.

FIG. 7,814.—Single phase fan motor with *shading coils* for starting. *In addition* to the main field coils, one tip of each pole piece is surrounded by a short circuited coil of wire or frame of copper, as indicated in the figure. This coil, or copper frame, is called a *shading coil* and it causes a phase difference between the pulsating flux that emanates from the main portion of each polar projection and the pulsating flux which emanates from the pole tip, thus introducing a two phase action on the armature which is sufficiently pronounced to start the motor.

Phase Splitting.—With single phase current, splitting the phase will produce a rotating field to start on, which after the motor has come up to speed, may be cut out and the motor will then operate on the oscillating field. Splitting the phase may be accomplished by:

1. Auxiliary coils and condenser or resistance as in fig. 7,813, or by

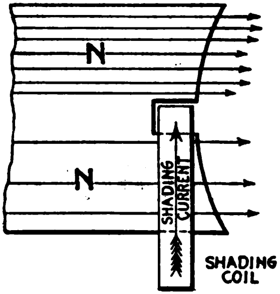


FIG. 7,815.—Diagram showing action of shading coil in alternating current motor. The extremities of these pole pieces are divided into two branches, one of which a copper ring called a *shading coil* is placed as shown, while the other is left *unshaded*. The action of the shading coils is as follows: Consider the field poles to be energized by single phase current, and assume the current to be flowing in a direction to make a north pole at the top. Consider the poles to be just at the point of forming. Lines of force will tend to pass downward through the shading coil and the remainder of the pole. Any change of lines within the shading coil generates a pressure which causes to flow through the coil a current of a value depending on the pressure and always in a direction to oppose the change of lines. The field flux is, therefore, partly shifted to the free portion of the pole, while the accumulation of lines through the shading coil is retarded.

2. Shading coils as in fig. 7,814.

These methods being described under the illustrations.

The method of starting by splitting the phase does not give a strong starting torque which is an inherent defect of single phase motors. To overcome this, on some motors an automatic centrifugal clutch as shown in figs. 7,816 and 7,817 is provided, which allows the armature to turn free on the shaft until it accelerates almost to running speed.

Figs. 7,816 and 7,817.—General Electric dissembled clutch as used on clutch type, single phase (KS) induction motor. ***In starting,*** the armature revolves freely on the shaft until approximately 75 per cent. of normal rated speed is reached. The load is then picked up by the automatic action of a centrifugal clutch, which rigidly engages an outer shell, keyed directly to the shaft. The brass friction band of the clutch is permanently keyed to the pulley end of the armature.

b. COMMUTATOR MOTORS

Machines of this class are similar in general construction to direct current motors They have a closed coil winding, which is connected to a commutator.

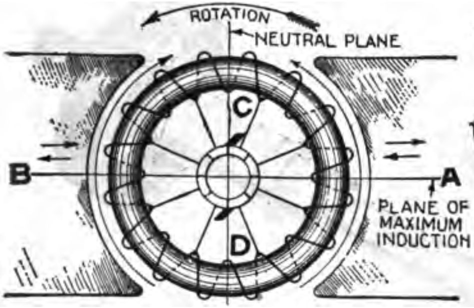
There are several types of commutator motor, namely:

1. Series 2. Shunt 3. Compensated 4. Repulsion.

Commutator motors are similar in construction to direct current motors, because if the mains leading to a direct current motor be reversed, the direction of rotation remains the same, because the currents through both the field magnets and armature are reversed. It must follow then that an alternating current applied to a direct current motor would cause rotation of the armature.

There are some modifications that must be made for commutator motors to overcome the sparking due to local armature currents.

Series Motors.—This is the simplest of the commutator motors; it is identical with the series *d.c.* motor, except that all



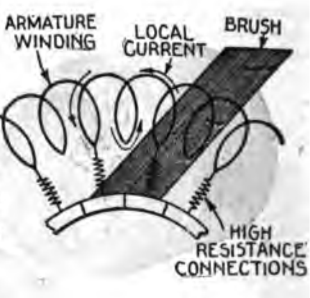


FIG. 7,818.—Diagram of ring armature in alternating current field illustrating commutator motor principles. When a closed coil rotates in an *a.c.* field, there are several different pressures set up as follows: 1. ***The transformer pressure induced in the armature by the alternating flux from the field magnets.*** Evidently the variable flux passing through armature coil is least at the plane AB, because at this point the coils are inclined very acutely to the flux, and greatest at the plane CD, where the coils are perpendicular to the flux. Accordingly, the transformer pressure induced in the armature winding is least at AB, and greatest at CD. The transformer pressure acts in the same direction as the generated pressure as indicated by the long arrows and gives rise to what may be called *local armature currents*. 2. ***The generated pressure induced in the armature by the cutting of the flux when the armature rotates.*** This is minimum at the neutral plane CD, and maximum at AB. It tends to cause current to flow up each half of the armature from D, to C, producing poles at these points. 3. ***The self induction pressure induced in both the field and armature by self-induction.*** This pressure being opposite in direction to the impressed pressure, it must be evident that in the operation of an alternating current commutator motor, the impressed pressure must overcome not only the generated pressure but also the self-induction pressure. Hence, as compared to an equivalent direct current motor, the applied voltage must be greater than in the direct current machine, to produce an equal current.

FIG. 7,819.—Section of ring armature showing high resistance connectors and ***local armature current.*** These currents produced by the transformer pressure occur in those coils undergoing commutation. They are large, because the maximum transformer action occurs in them, that is, in the coils short circuited by the brushes. Local armature currents cause sparking because of the sudden interruption of the large volume of current, and also because the flux set up by the local currents being in opposition to the field flux, tends to weaken the field just when and where its greatest strength is required for commutation. These local currents may be from 5 to 15 times the strength of the normal armature current, and they depend upon the number of turns of the short circuited coils, their resistance and the frequency. Local currents may be reduced: 1, by reducing the number of turns of the short circuited coils, that is, providing a greater number of commutator bars; 2, reducing the frequency; and 3, increasing the resistance of the short circuited coil current either by means of high resistance connectors, or by high resitance brushes.

the iron in the magnetic circuit is laminated and sometimes a neutralizing winding is employed. The characteristics of the series motor are similar to the *d.c.* series motor, the torque being maximum at starting and decreasing as the speed increases. These motors are especially adapted to railway service.

Neutralized Series Motor.—To overcome excessive induction of the armature, most single phase series motors are provided with a neutralizing winding.

The neutralizing coil is wound upon the frame 90 magnetic degrees or half a pole pitch from the field winding and arranged to carry a current equal in magnetic pressure and opposite in phase to the current in the armature.

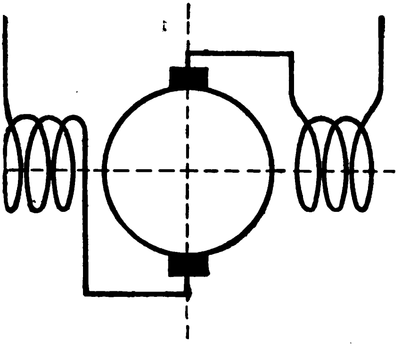


FIG. 7,820.—Diagram of single phase series commutator motor. It is practically the same as the series direct current motor, with the exception that all the metal of the magnetic circuit must be laminated.

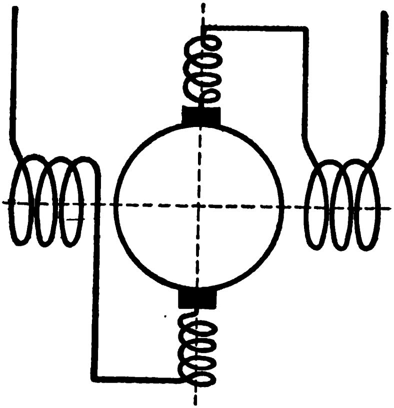
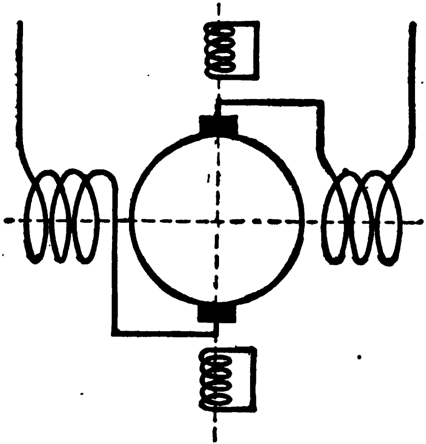


FIG. 7,821.—Diagram of neutralized series motor; *conductive method.* In the simple series motor, there will be a distortion of the flux as in the direct current motor. As the distorting magnetic pressure is in phase with that of the magnets, the distortion of the flux will be a fixed effect. If the poles be definite as in direct current machines, this distortion may not seriously affect the running of the motor, but with a magnetizing system like that universally adopted in induction motors the flux will be shifted as a whole in the direction of the distortion, which will produce the same effect as if in the former case the brushes had been shifted forward, whereas for good commutation they should have been shifted backward. As in direct current machines, this distortion is undesirable since it is not conducive to sparkless working, and also reduces to a more or less extent the torque exerted by the motor. The simplest remedy is to provide *neutralizing coils* displaced 90 magnetic degrees to the main field coils as shown. The neutralizing current is obtained by the method of connecting the neutralizing coils in series in the main circuit.



The current through the neutralizing winding may be obtained, either 1. conductively; or 2. inductively, as shown respectively in figs. 7,821 and 7,822.

Shunt Motors.—The simple shunt motor has inherently many properties which render it unsuitable for practical use, and accordingly is of little importance.

FIG. 7,822.—Diagram of neutralized series motor; ***inductive method.*** Although the conductive method of neutralization is employed in nearly all machines, it is possible merely to short circuit the neutralizing winding upon itself, instead of connecting it in series with the armature circuit. In this case the flux due to the armature circuit cannot be eliminated altogether, as sufficient flux must always remain to produce enough pressure to balance that due to the residual impedance of the neutralizing coil. It would be a mistake to infer, however, that on this account this method of neutralization is less effective than the conductive one, since the residual flux simply serves to transfer to the armature circuit a drop in pressure precisely equivalent to that due to the resistance and local self-induction of the neutralizing coil in the conductive method.

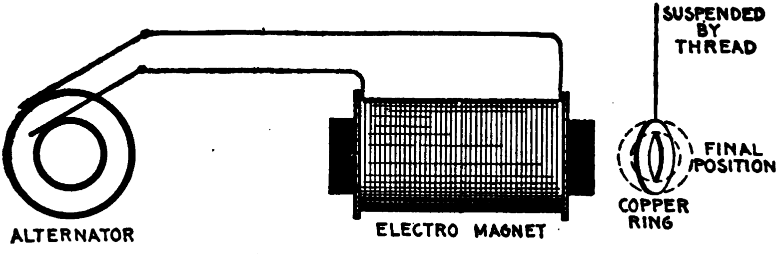


FIG. 7,823.—Effect of alternating field on copper ring. *If a copper ring be suspended in an alternating field so that the plane of the ring is oblique to the lines of force, it will turn until its plane is parallel to the lines of force*, that is, to the position in which it does not encircle any lines of force. ***The explanation*** is that when the ring (or closed coil) is suspended in an alternating field so that lines of force pass through it, an alternating pressure will be induced in the coil which will be 90° later in phase than the inducing flux, and since every coil contains some inductance, the resulting current will lag more or less with respect to the pressure induced in the coil. The cosine of this phase relation becomes a negative quantity which means that the coil is *repelled* by the field. *It is only when the ring is in an oblique position that it tends to turn*. If it be placed with its plane directly at right angles to the direction of the magnetic lines, it will not turn; if ever so little displaced to the right or left, it will turn until its plane is parallel to the lines. The largest torque will be obtained, when the lag of the current in the ring is 45°.

Owing to the many turns of the field winding there is large inductance in the shunt field circuit.

The phase difference between the field and armature currents and the corresponding relation between the respective fluxes results in a weak torque.

Repulsion Motors.—The operation of repulsion motors as described by Elihu Thomson, depends on the fact that *a copper ring or closed coil when placed in an alternating magnetic field tends either to move out of the field, that is, it is* **repelled** *by the field (hence the name* **repulsion motor***), or to return so as to set itself edgewise to the magnetic lines.*

The production of the torque which turns the ring may be explained by saying that *the current induced in the ring produces a cross field, which, being out of phase with and inclined to the field impressed by the primary alternating current, causes a rotary field, and this in turn, reacting on the conductor, a turning moment results.*

Thomson took an ordinary *d.c.* armature and preserved the obliquity of the active coil by the brushes and commutator and obtained continuous rotation, but since an open coil armature was used the torque developed was due to only one coil at a time. This was later remedied by the use of a closed coil armature and to stop sparking, compensating brushes and high resistance connectors were used. There are several types of commutator motor.

A simple repulsion motor consists essentially of an armature, commutator and field magnets. The armature is wound exactly like a direct current armature, and the windings are connected to a commutator.

The carbon brushes which rest on this commutator are not connected to the outside line, however, but are all connected together through heavy short circuiting connectors. The brushes are placed about 60° or 70° from the neutral axis. The field is wound exactly like that of the usual induction motor.

Repulsion Induction Motor has a governor mounted on the armature which short circuits the windings, after the motor has been started. The motor then runs as a squirrel cage induction motor. As a rule the brushes are lifted off the commutator when the armature is short circuited, so as to prolong their life.

This is a very successful motor, but it is of course more costly than the simple squirrel cage motor used on two and three-phase circuits.

A compensated repulsion motor consists essentially of a simple repulsion motor in which there are two independent sets of brushes, one set being short circuited, while the other set is in series with the field magnet winding, as in the series alternating current motor.

The two sets of brushes are called the *energy* or main short circuiting brushes, and the *compensating* brushes. The armature possesses at starting most of the apparent reactance of the motor, and the effect of speed is to decrease such apparent reactance, the latter becoming zero at either positive or negative synchronism, and negative at higher speeds in either direction.

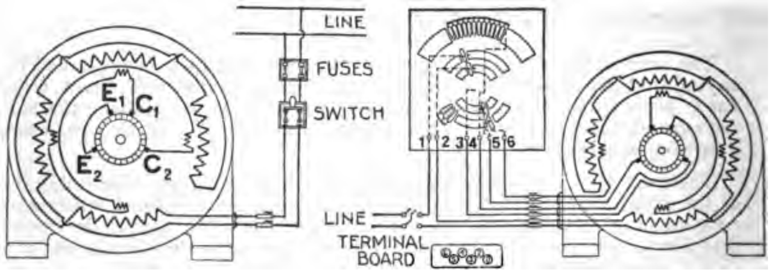


Fig. 7,824.—Diagram of connection of Sprague single phase compensated repulsion motor To reverse direction of rotation interchange leads C_1 and C_2 and slightly shift the brush holder yoke. Brushes E_1 and E_2 are permanently short circuited. This diagram of connections applies also to fig. 7,825.

Fig. 7,825.—Diagram of connections of Sprague variable speed single phase compensated repulsion motor and controller. The controller is designed to give speed reduction and speed increase as resistance or reactance is inserted in the energy and compensating circuits. With the exception of the leads brought out from the circuits, the constant speed and variable speed motors are identical. The standard controller gives approximately 2 : 1 speed variation.

At starting the field is practically non-inductive, the effect of speed being to introduce a spurious resistance which increases directly with the speed, and becomes negative when the speed is reversed.

Compensated repulsion motors are especially adapted for light railroad service and when thus employed a series transformer is used in the field circuit. The usual frequencies employed are 25, 40, and 60, the preferred frequency being 40.

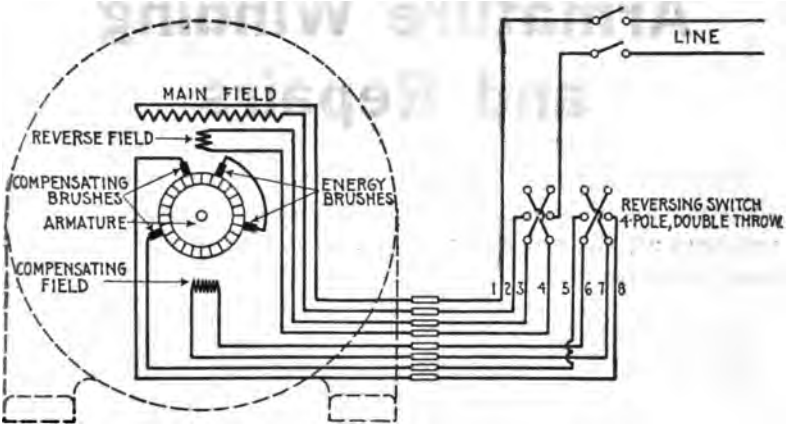


FIG. 7,826.—Diagram of connections of Sprague reversing type of single phase compensated repulsion motor. As shown, there is a special reverse field winding having terminals for connection to a four pole double throw switch.

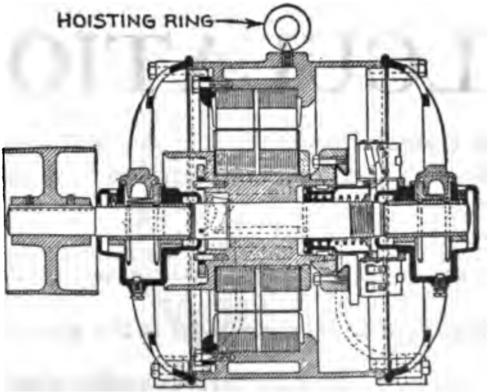


FIG. 7,827.—Sectional view of Century single phase repulsion induction motor.

CHAPTER 123

Armature Winding and Repairs

When a repair man is called upon to rewind or reconnect an armature for different operating conditions he must solve such problems as, the order of winding, what size wire to use, how many turns per slot, etc.

Of course, if the winding of the armature to be repaired has not been removed, these difficulties are not encountered, but in the absence of the winding there is nothing to indicate the size of wire, number of turns, etc.

1.

CALCULATIONS

Armature Calculations.—In the design of a dynamo or motor, it is usual to first design the armature and make the other parts fit around it.

Accurate design, is a matter of both calculation and experiment because many of the factors involved cannot be determined by calculation alone.

The principal item to be considered is the size of the wire.

In order to deliver a certain current, the number of poles, etc., being fixed, a certain size wire must be used. As must be evident, the heating

FIG. 7,828.—Fairbanks standard type TR machine disassembled.

of the wire is what governs the size. For a given current the smaller the wire the greater the heating.

Example in Design.—Determine size of wire, number of turns, etc., for an 8×8 in. armature, for a flux of 30,000 lines per sq. in., 110 volts, 1,200 *r.p.m.*, 5 horse power.

Cross sectional area of armature = 8×8 = 64 sq. ins.

Total flux through armature = 30,000 × 64 = 1,920,000 lines.

Now, since it requires 10^8 or 100,000,000 lines of force cut per second to generate one volt, for the given 110 volts, the required rate of cutting is

TABLE I.—3 sq. ins.

Capacity of Wires at various depths of winding, 3 sq. in. radiating surface per watt

(*According to Horstmann and Tousley*)

B. & S. Gauge.	Diameter bare.	Resistance per foot 140° F.	Diameter D. C. C.	Amperes at different depths of winding layers.						Number of wires per inch.	I^2
				1	2	3	4	5	6		
4	.2043	.000283	.224	56.28	39.74	32.42	28.12	25.15	22.97	4.45	3166
5	.1819	.000357	.200	47.30	33.46	27.33	23.66	21.16	19.31	5.00	2240
6	.1620	.000450	.180	40.00	28.28	23.08	20.00	17.88	16.34	5.5	1600
7	.1418	.000567	.158	33.40	23.60	19.28	16.67	14.93	13.68	6.3	1114
8	.1285	.000715	.144	28.85	20.04	16.37	14.17	12.68	11.57	7.0	805
9	.1144	.000902	.130	24.00	16.97	13.85	12.00	10.72	9.74	7.7	576
10	.1019	.001137	.117	20.27	14.31	11.70	10.14	9.05	8.24	8.6	411
11	.0907	.001436	.106	17.19	12.12	9.69	8.60	7.68	7.00	9.6	295
12	.0808	.00181	.093	14.31	10.09	8.24	7.14	6.40	5.83	10.7	205
13	.0719	.00228	.084	12.12	8.54	7.00	6.08	5.38	4.89	11.9	147
14	.0640	.00288	.075	10.19	7.21	5.91	5.09	4.58	4.12	13.8	104
15	.0570	.00362	.067	8.60	6.08	4.95	4.30	3.87	3.50	15.0	74
16	.0508	.00458	.059	7.14	5.04	4.12	3.57	3.19	2.91	17.0	51
17	.0452	.00575	.053	6.08	4.30	3.5	3.04	2.64	2.47	19.0	37
18	.0403	.00727	.048	5.09	3.60	2.94	2.54	2.28	2.08	21.0	26
19	.0358	.00916	.044	4.36	3.08	2.52	2.18	1.97	1.78	22.7	19
20	.0319	.01153	.040	3.74	2.64	2.16	1.87	1.67	1.52	25.0	14
21	.0284	.01454	.036	3.14	2.22	1.81	1.57	1.39	1.28	28.0	9.9
22	.0253	.01845	.033	2.66	1.87	1.54	1.33	1.19	1.09	30.8	7.1
23	.0225	.0231	.030	2.28	1.61	1.30	1.14	1.01	.94	33.3	5.2
24	.0201	.0295	.028	1.94	1.37	1.14	.97	.86	.80	35.7	3.8
25	.0179	.0365	.026	1.70	1.18	.98	.85	.80	.74	38.4	2.9
26	.0159	.0461	.024	1.41	1.00	.82	.71	.63	.57	42.0	2.0
27	.0142	.0608	.022	1.18	.78	.68	.59	.52	.47	45.5	1.4
28	.0126	.0744	.021	1.04	.72	.60	.52	.47	.42	48.0	1.1
29	.0112	.0925	.020	.92	.65	.52	.46	42	.38	50.0	.86
30	.0100	.1181	.019	.77	.54	.44	.38	.35	.31	56.0	.61

$$\frac{\text{required rate of cutting}}{\text{total flux}} = \frac{11{,}000{,}000{,}000}{1{,}920{,}000} = 5{,}728 \text{ lines per sec.}$$

The number of inductors (wires) necessary to place on the armature to cut 5,728 lines per second will depend on the speed, thus

$$\text{number of inductors} = \frac{\text{total lines per wire per sec.}}{\text{revolutions per second}} = \frac{5{,}728}{\frac{1}{60}\text{ of }1{,}200} = 286$$

For five horse power, at 110 volts

$$\text{watts} = 746 \times 5 = 3{,}730;\quad \text{amperes} = \frac{3{,}730}{110} = 34$$

Since there are two paths through the armature in parallel,

$$\text{amperes per circuit} = 34 \div 2 = 17$$

The size wire to be used is based upon a certain radiating surface per unit of energy consumed. The greater this radiating surface, the less will be the heating. The amount of ratiating surface allowed in armatures varies from 1 sq. in. per watt to 3 sq. ins. About 1.75 will insure a cool operating armature. In the accompanying tables, the current capacity is given for 3 sq. in. and for 1 sq. in. per watt. An inspection of the tables will show that the capacity of wires depends also upon the kind of winding—whether single layer or more than one layer—because radiation is more effective in carrying off the heat with outside wires than with those embedded under an outer layer of wires.

Now, since the diameter of the core is 8 ins.

$$\text{its circumference} = 8 \times 3.1416 = 25 \text{ ins.}$$

and the number of inductors per inch of circumference is

$$\text{for single layer winding } 286 \div 25 = 11.4$$

$$\text{for double layer winding } \tfrac{1}{2} \text{ of } 286 \div 25 = 5.7$$

Allowing 3 sq. ins. radiating surface per watt, the size of inductor required to carry 17 amperes is (from Table I, page 3,972-612).

for single layer winding, No. 11, B. & S. gauge

for double layer winding, No. 9 B. & S. gauge

Example.—With the armature of the previous example running at same speed and same flux conditions what is the maximum capacity that could be obtained with a two layer winding of larger size wire and same number of inductors? As calculated, the number of inductors per inch of core circumference is 5.7, hence, for table I, for 5.5 inductors per inch a No. 6 wire may be used, and for a two layer winding it may carry 28.28 amperes. Now since there are two paths in parallel through the armature

TABLE II.—1 sq. in.

Capacity of Wires at various depths of winding, 1 sq. in. radiating surface per watt
(*According to Horstmann and Tousley*)

B. & S. Gauge.	Diameter bare.	Resistance per foot 140° F.	Diameter D. C. C.	Amperes at different depths of winding layers.						Number turns per inch	I^2
				1	2	3	4	5	6		
4	.2043	.000283	.224	97.36	68.75	55.88	48.64	43.30	39.73	4.45	9498
5	.1819	.000357	.200	81.82	57.88	47.27	40.87	36.60	33.40	5.00	6720
6	.1620	.000450	.180	69.20	48.92	39.92	34.60	30.93	28.28	5.5	4800
7	.1418	.000567	.158	57.78	40.82	33.35	28.91	25.86	23.60	6.3	3344
8	.1285	.000715	.144	49.04	34.66	28.37	24.57	21.97	20.07	7.0	2416
9	.1144	.000902	.130	41.52	29.37	24.00	20.76	18.60	16.97	7.7	1728
10	.1019	.001137	.117	35.06	24.81	20.27	17.54	15.71	14.35	8.6	1233
11	.0907	.001436	.106	29.74	21.02	17.17	14.86	13.30	12.12	9.6	885
12	.0808	.00181	.093	24.79	17.52	14.31	12.40	11.09	10.09	10.7	615
13	.0719	.00228	.084	21.00	14.86	12.12	10.50	9.38	8.54	11.9	441
14	.0640	.00288	.075	17.66	12.49	10.19	8.83	7.88	7.21	13.3	312
15	.0570	.00362	.067	14.89	10.53	8.60	7.44	6.66	6.08	15.0	222
16	.0508	.00458	.059	12.40	8.77	7.21	6.20	5.56	5.09	17.0	154
17	.0452	.00575	.053	10.53	7.44	6.08	5.26	4.71	4.30	19.0	111
18	.0403	.00727	.048	8.88	6.28	5.12	4.44	3.97	3.63	21.0	79
19	.0358	.00916	.044	7.54	5.34	4.35	3.76	3.37	3.08	22.7	57
20	.0319	.01153	.040	6.49	4.58	3.74	3.24	2.89	2.64	25.0	42
21	.0284	.01454	.036	5.38	3.80	3.11	2.68	2.40	2.19	28.0	29
22	.0253	.01845	.033	4.58	3.24	2.64	2.28	2.04	1.87	30.3	21
23	.0225	.0231	.030	4.00	2.82	2.30	2.00	1.78	1.64	33.3	16
24	.0201	.0295	.028	3.37	2.38	1.94	1.67	1.51	1.37	35.7	11.4
25	.0179	.0365	.026	2.93	2.07	1.67	1.44	1.30	1.18	38.4	8.6
26	.0159	.0461	.024	2.49	1.76	1.44	1.22	1.09	1.00	42.0	6.2
27	.0142	.0603	.022	2.07	1.44	1.18	1.04	.94	.84	45.5	4.3
28	.0126	.0744	.021	1.78	1.26	1.04	.89	.78	.71	48.0	3.2
29	.0112	.0925	.020	1.61	1.14	.94	.79	.71	.65	50.0	2.6
30	.0100	.1181	.018	1.34	.95	.78	.64	.60	.55	56.0	1.8

$$\text{total current} = 2 \times 28.28 = 56.6 \text{ amperes}$$

and capacity at 110 volts, or

$$\text{watts} = 56.6 \times 110 = 6{,}226$$

Such 1 horse power = 746 watts,

$$\text{capacity} = 6{,}226 \div 746 = 8.4 \text{ horse power}$$

In the case of slotted armatures, which is the prevailing type, a considerable portion of the circumference is taken up with the teeth that cannot be used for the winding, hence it is necessary to allow for this in figuring the number of inductors per inch of circumference.

FIG. 7,829.—**Fairbanks Morse type TR machine armature construction.** ***The armature core*** **is built up of thin sheet steel laminations with notches in the circumference, which, when the discs are placed together, form grooves or slots to receive the armature coils. With specially designed tools these notches are so accurately spaced that no filing of the slots is required. The armature cores for the Nos. 23, 24, 25, 26, 27, 28 and 29, machines are mounted on a cast iron spider, which also carries the commutator, making the two parts entirely self-contained, and with this construction, it is possible to remove the armature shaft, without disturbing the core, commutator or windings.**

To calculate the size wire for a slotted armature a single slot should be considered, and the wire chosen if possible with reference as to how it will fit in the slot, that is, the size should be such as to fill the slot with the least amount of waste space. In design, the approximate width of the slot is obtained by ***multiplying the diameter of the wire over insulation by the number of turns per layer***, and the depth of slot obtained by ***multiplying the number of layers by 86***.

To find the number of inductors per slot when the speed and flux are fixed the following formula may be used:

$$\text{inductors per slot} = \frac{10^8 \times \text{volts}}{\text{flux} \times \text{slots} \times \text{rev. per sec.}} \quad \text{..............} (1)$$

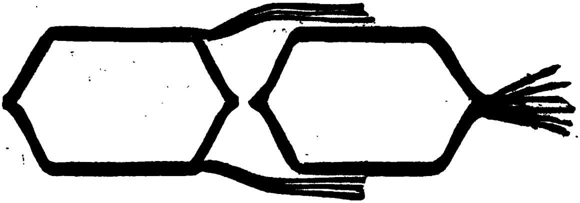
Example.—How many inductors per slot are required, to generate 110 volts, with a total flux of 1,920,000 lines, 24 slots and 1,200 revolutions per minute?

10^8 = 100,000,000 and 1,200 rev. per minute = 1,200 ÷ 60 = 20 rev. per sec. Substituting in (1)

$$\text{inductors per slot} = \frac{100{,}000{,}000 \times 110}{1{,}920{,}000 \times 24 \times 20} = 11.9 \text{ say } 12$$

Example.—If the slots of a 24 slot armature be ½ in. wide and there are 12 inductors per slot arranged as a three layer single coil winding, what is the maximum size wire that can be used, and current capacity for a four pole machine? If flux be provided to generate 110 volts what horse power will be developed?

Table 3 relation between slot sizes and various practical arrangements of standard double cotton wires B. & S. guage. Allowance is made in the slot widths for ⅛ in. total insulation besides the cotton wrapping on the wire, when there is only one coil per slot.



FIGS. 7,830 and 7,831.—Fairbanks Morse wire wound armature coils of type TR machine. ***In construction,*** the coils are form wound and are thoroughly insulated and baked before assembling in the slots. Material of great mechanical strength as well as high insulating value is used, and the coils are subjected to repeated dippings in insulating compound and to repeated bakings, thus thoroughly driving out all moisture and making a coil which is practically water proof and which will withstand rough handling. These coils when completed, are placed in the slots, where they are retained by bands on the three smaller sizes and by hardwood wedges on the larger sizes. Cores of all sizes are provided with ventilating spaces, running from the surface to the central opening of the core, so that air is drawn through the core and blown out over the windings by the revolution of the armature.

For each additional coil per slot, ⅛ in. of extra insulation is allowed. In slot depths, .17 in. beside the cotton on the wire is provided.

In the example since there are 12 inductors per slot and the winding is in 3 layers

number of wires abreast = 12 ÷ 3 = 4

Referring to the table it will be found that a slot .49 in. wide will accommodate four No. 10 inductors abreast. Allowing 3 sq. in. radiation per watt, the carrying capacity (from table No. 1) for a 3 layer winding of No. 10 wire is 11.7 amperes.

Since the number of paths is equal to the number of poles

total current output = 11.7 × 4 = 47 amperes

At 110 volts

$$\text{watts} = 47 \times 110 = 5{,}170, \text{ and}$$
$$\text{horse power} = 5{,}170 \div 746$$

After having determined the size of wire, number of turns per coil, the drop or loss of voltage due to the resistance of the winding should be determined to see if this loss be within limit.

Example.—If the average length per turn of the coils in the armature of the previous example be 2 ft., what is the drop or loss of voltage in the armature?

Since the winding is of the single coil type each coil will occupy two slots, hence

$$\text{total number of coils} = 24 \div 2 = 12$$

For 12 turns per coil,

$$\text{length of each coil} = 12 \times 2 = 24 \text{ ft.}$$

Now, since the machine has 4 poles, there are 4 paths in parallel, hence, only ¼ of the coils or 3 coils need be considered in determining the drop. Accordingly,

$$\text{length of 3 coils} = 24 \times 3 = 72 \text{ ft.}$$

According to table 1 (page 3,972-612), the resistance of No. 10 wire at 140° Fahr. is .001137 ohm per foot, hence

$$\text{resistance of 3 coils} = 72 \times .001137 = .08 \text{ ohms}$$

According to Ohms law

$$\text{current} = \frac{\text{volts}}{\text{ohms}} \text{ or volts} = \text{current} \times \text{ohms}$$

NOTE.—*To find the speed* when the volts, flux, and number of inductors are fixed use this formula:

$$\text{rev. per sec.} = \frac{100{,}000{,}000 \times \text{volts}}{\text{flux} \times \text{number of slots} \times \text{inductors per slot}}$$

NOTE.—*To find the strength of field* when the volts, inductors and speed are fixed, use the formula:

$$\text{flux} = \frac{100{,}000{,}000 \text{ volts}}{\text{inductors per slot} \times \text{number of slots} \times \text{rev. per sec.}}$$

NOTE.—*To find the volts* when the inductors, flux, and speed are fixed use the formula:

$$\text{volts} = \frac{\text{flux} \times \text{inductors per slot} \times \text{number of slots} \times \text{rev. per sec.}}{100{,}000{,}000}$$

Substituting in the expression for volts,

volts or "drop" = 11.7 × .08 = .94 volt

which may be considered within satisfactory limit.

Magnet Calculations.—In figuring field magnets, the unit ampere turn is frequently employed and is defined as *the magnetic force due to a current of one ampere flowing through one turn of a magnet winding* numerically it is equal to the *product of one turn multiplied by one ampere.*

Thus, one ampere flowing through 10 turns, gives 1 × 10 = 10 ampere turns. Again, 10 amperes flowing through 10 turns gives 10 × 10 = 100 ampere turns. Having fixed the voltage and size of wire it makes no difference in the magnetic effect how many turns are contained in the winding, that is, for a given voltage and size of wire *the ampere turns remain the same regardless of the number of turns in the winding.*

FIG. 7,832.—Fairbanks Morse field coils of type TR machine. *In construction,* the coils are wound upon iron forms, each layer treated with insulating compound. Afterward they are removed from the forms and baked hard and dry and finally wrapped with insulating materials and finished with black insulating enamel.

Thus, if 10 amperes flow through 10 turns of the winding the result is 10 × 10 = 100 ampere turns. Now, if the number of turns be doubled, the resistance of the winding will be doubled which will cut down the current one half, that is, 5 amperes × 20 turns = 100 ampere turns. Of course, this is not strictly true where the magnet is made up of more than one layer, because the diameter of an outer turn being greater than that of an inner turn, its length and resistance is greater, the resulting effect being to slightly decrease the ampere turns as each layer is added. The reason then for increasing the number of turns in a magnet winding is *to cut down the current sufficently to prevent overheating of the winding.*

Example.—If the winding on a spool 8 ins. in diameter be one inch thick, what is the average diameter of the turns?

The diameter of the inner layer turns are 8 ins., and the outer layer turns 8 + 2 = 10 turns, hence,

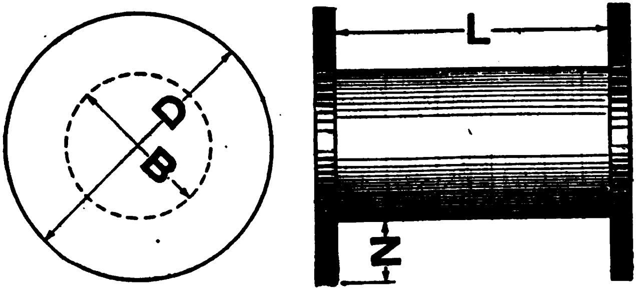
$$\text{average diameter of the turns} = \tfrac{1}{2}\,(8 + 10) = 9 \text{ ins.}$$

Example.—If the magnet of the previous example contain 500 turns, what is the length of the winding?

The average diameter of the turns, as obtained, being 9 ins.,

$$\text{length of winding} = \frac{9 \times 3.1416 \times 500}{12} = 1{,}178 \text{ ft.}$$

Example.—If a winding one inch deep be placed on an 8 in. spool, what is the smallest size wire that will give 10,000 ampere turns with 110 volts?



Figs. 7,833 and 7,834.—Magnet spool with essential dimensions necessary for calculation. ***Formulæ:*** $d = \sqrt{(L \times N) + T}$; $L \times N = d^2 \times T$; $l = (D^2 - B^2)L = k$; $W = (D^2 - B^2)L \times c$; $R = (D^2 - B^2)\ L \times a$; $rs = D \times 3.14 \times L$. In the formulæ, d = diam. of wire over insulation; l = length of wire on spool; T = number of turns; r = resistance of one foot of wire; rs = radiating surface; B = diam. of core and insulation; D = diam. over outside of completed winding; L = length of winding spaces on spool; N = depth of winding core to outside; W = weight of wire; a, c, k, constants whose values are given on next page. All dimensions in inches.

$$\text{Average diameter of turns} = \tfrac{1}{2}\,(8 + 10) = 9 \text{ ins.}$$

$$\text{length of average turn} = \frac{9 \times 3.1416}{12} = 2.36 \text{ ft.}$$

The sectional area of the smallest wire (in circular mils) is obtained from the formula

$$^{*}\text{area wire} = \frac{12 \times \text{length average turn in feet} \times \text{ampere turns}}{\text{volts}} \quad \ldots\ldots\ (1)$$

Substituting

$$\text{area wire} = \frac{12 \times 2.36 \times 10{,}000}{110} = 2{,}575 \text{ circular mils}$$

nearest size wire from table is No. 16 B. & S. gauge.

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*NOTE.—In the formula, 12 is the resistance of 1 mil foot of copper at 130° Fahr.

Having determined the minimum size of wire, the next step is to find how many turns must be placed on the spool to prevent undue heating.

The watts lost by the current heating the winding *is equal to the square of the current multiplied by the resistance*, that is

watts lost = amperes² × ohms.

In proportioning the winding for depth and length, the deph of the winding must be such that there will be from 1 to 2 sq. ins. of surface per watt. With 1 sq. in. per watt, the magnet in operation will be "hot," and with 2 sq. ins., "warm."

Table of Constants

B & S. Gauge.	k Constant for Length.			c Constant for Weight.			a Constant for Resistance.		
	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk
20	40.9	50.4	56.7	.137	.162	.177	.415	.512	.576
21	50.4	64.1	72.7				.638	.812	.920
22	60.2	78.0	88.7				.97	1.257	1.445
23	68.8	89.7	104.7				1.387	1.82	2.08
24	83.6	113.5	135.	.1115	.149	.169	2.14	2.91	3.46
25	97.2	135.	163.				3.14	4.36	5.27
26	114.	163.	202.				4.65	6.65	8.24
27	135.	202.	255.				6.94	11.75	13.1
28	148.	226.	291.	.0845	.122	.148	9.60	14.62	18.82
29	182.	291.	387.				14.85	23.7	31.6
30	201.	334.	454.				20.7	34.4	46.8
31	226.	387.	542.				29.36	50.25	70.4
32	255.	454.	655.	.0667	.1045	.132	41.8	74.4	107.2
33	291.	542.	812.				60.33	114.5	168.
34	334.	655.	1023.				87.1	170.5	266.5
35	354.	712.	1140.				116.2	234.	374.8
36	387	811.	1340	.0492	.0825	.1115	160.	335.5	555.
37	422.	897.	1582.				220.5	468.	806.
38	457.	1023.	1825.				308.	674.	1192.
39	496.	1170.	2165.				412.	972.	1795.
40	532.	1300.	2525.	.038	.0615	.0833	557.	1360.	2645.

Example.—How much radiating surface (neglecting the ends) on a magnet whose outside dimensions are 9 ins. diameter, 6 ins. long

area outer cylindrical surface = 9 × 3.1416 × 6 = 188½ sq. ins.

Example.—An 8 in. spool is to be wound with No. 16 wire to a depth of 1 in., which, as calculated in a previous example, is the smallest size wire that will give a required 10,000 ampere turns with 110 volts. How many turns of wire must be wound on the spool to prevent undue heating?

For winding magnets what is known as ***magnet wire*** is used, the wire generally having a single cotton covered insulation.

By reference to the accompanying table the number of turns per linear

TABLE III—*Properties of Insulated Wires*

(*According to Houstmann and Tousley*)

B. & S.	Single silk		Double silk		Dble. cotton		Resistance	I^2 3 sq. in. per watt. Cool	I^2 2 sq. in. per watt. Warm	I^2 1 sq. in. per watt. Hot
	Turns per inch	Radiating Surface	Turns per inch	Radiating Surface	Turns per inch	Radiating Surface				
40	193	.016	143	.022	90	.035	.273	.027	.04	.08
39	181	.017	133	.024	87	.047	.216	.036	.055	.11
38	169	.018	126	.025	84	.037	.172	.046	.07	.14
37	156	.020	119	.026	81	.039	.136	.070	.10	.20
36	143	.022	111	.028	77	.041	.108	.086	.13	.26
35	131	.024	104	.030	73	.043	.075	.13	.20	.40
34	120	.026	97	.032	69	.045	.068	.15	.23	.46
33	111	.028	91	.035	66	.047	.054	.22	.32	.64
32	101	.031	83	.038	63	.050	.043	.29	.44	.88
31	91	.034	77	.041	59	.053	.034	.37	.56	1.12
30	83	.038	71	.044	55	.056	.027	.54	.81	1.62
29	76	.041	67	.047	53	.059	.022	.72	1.07	2.14
28	68	.046	60	.052	48	.065	.017	1.0	1.5	3.00
27	63	.050	55	.056	45	.069	.014	1.3	2.0	4.00
26	56	.055	50	.062	41	.075	.011	1.9	2.8	5.60
25	50	.062	46	.069	38	.081	.0084	2.7	4.1	8.2
24	45	.069	42	.075	35	.088	.0070	3.5	5.3	10.6
23	41	.077	37	.083	32	.095	.0053	5.2	7.8	15.6
22	36	.086	34	.092	30	.104	.0042	7.3	11.0	22.
21	33	.094	31	.101	28	.113	.0034	10.	15.0	30.
20	29	.106	27	.113	25	.126	.0026	14.	21.	42.
19	26	.119	25	.126	22	.138	.0021	20.	30.	60.
18	24	.132	22	.138	21	.151	.0017	27.	40.	80.
17	21	.148	20	.154	19	.166	.0013	39.	59.	118.
16	19	.166	18	.173	17	.185	.0011	52.	78.	156.
15			16	.191	15	.204	.00083	70.	105.	210.
14			15	.213	14	.226	.00066	107.	161.	322.
13			13	.238	12	.251	.00053	149.	224.	448.
12			12	.267	11	.279	.00042	217.	325.	650.
11			11	.298	10	.311	.00033	301.	451.	902.
10			9.5	.329	9.1	.342	.00026	421.	632.	1264.
9			8.4	.370	8.1	.383	.00021	587.	880.	1760.
8			7.5	.414	7.3	.428	.00016	842.	1262.	2524.
7			6.9	.455	6.8	.468	.00013	1167.	1750.	3500.
6			6.0	.521	5.8	.534	.00010	1680.	2521.	5042.

inch or per sq. in. of cross sectional area. Considering a portion of the winding covering an inch length of spool, 1 in. deep, the sectional area of this portion is 1 sq. in. Referring to the table of magnet wire, No. 16 wire single covered, will wind 306 turns per sq. in., that is, per inch length of spool. The length of the average turn being 2.36 ft. (as calculated in a previous example)

$$\text{length of winding per inch of spool} = 306 \times 2.36 = 722 \text{ ft.}$$

and from table its resistance being 6.39 ohms per 1,000 ft.

$$\text{resistance of winding per inch of spool} = \frac{722}{1{,}000} \text{ of } 6.39 = 4.6 \text{ ohms}$$

The outside diameter of the winding being 10 ins.,

$$\text{radiating surface per inch of spool} = 10 \times 3.1416 = 31.4 \text{ sq. ins.}$$

Now, from any electric circuit, the energy lost by heating the wire, or

$$\text{watts} = \text{amperes} \times \text{ohms} \ldots\ldots\ldots\ldots (1)$$

but by Ohm's law

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}$$

Substituting this value for amperes in equation (1)

$$\text{watts} = \frac{\text{volts}^2}{\text{ohms}^2} \times \text{ohms} = \frac{\text{volts}^2}{\text{ohms}}$$

And if the coil be designed for "warm" working by allowing 2 sq. in. radiating surface per watt, then it must be so proportioned that

$$\text{radiating surface} = 2 \times \text{watts} = 2 \times \frac{\text{volts}^2}{\text{ohms}} \ldots\ldots\ldots\ldots (2)$$

In order to determine the length of the coil, first find what resistance would be necessary if the winding were to consist of only the one inch portion just considered. To do this, solve equation (2) for resistance, thus

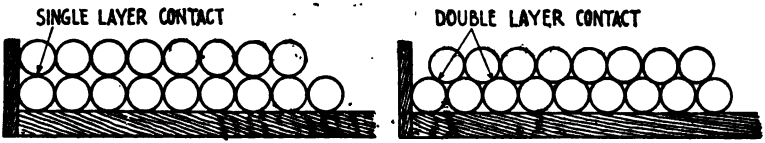
$$\text{ohms} = \frac{2 \times \text{volts}}{\text{radiating surface}} \ldots\ldots\ldots\ldots (3)$$

This will give a resistance much greater than the 4.6 ohms as calculated for that portion of the winding, hence, the spool length of the winding must be increased until the resistance of the winding has a value as obtained by equation (3). Thus substituting in equation 110 volts, and 31.4 sq. ins. radiating surface in equation (3), the necessary resistance of the winding for "warm" working, or

$$\text{ohms} = \frac{2 \times 110}{31.4} = 7$$

Accordingly, since the resistance of the winding is proportional to its length,

$$\text{length of winding} = 1 \text{ in.} \times \frac{7}{4.6} = 1.5 \text{ ins.}$$



FIGS. 7,835 and 7,836.—Square and hexagonal order of "bedding." The term, bedding is an expression used to indicate the relation between the cross sectional area of the winding when wound square, as in fig. 7,835, and where wound in some other way, as in fig. 7,837. In the square order of bedding, the degree of bedding equals zero.

NOTE.—***Number of armature slots.*** As a rule there are not less than ten slots per ole. In multiple machines there are at least three or four slots in the space between adjacent ole tips. The area per slot on machines above five horse power is approximately one sq. in. nd roughly the capacity of a slot of this area is about 1,000 ampere turns for machines designed o work on less than 500 volts.

NOTE.—***Number of commutator bars.*** This depends on the voltage between the ars. The number of bars may be a multiple of the number of slots. A large number of comutator bars improves the commutation but this advantage is offset by increased difficulties ncountered in construction.

NOTE.—***Current density in armature inductors.*** In determining the intensity of urrent much depends upon the provision for ventilation and operating conditions. *In general* 00 to 700 circular mils per ampere is safe. For short overloads or for operation in hot engine oms, 1,000 circular mils per ampere may be used.

NOTE.—***Magnetic densities.*** In small machines the ***density in the air gap*** is rarely ver 32,000 lines per sq. in.; in large machines the density may be as high as 60,000 lines per . in. ***Density in teeth*** is usually about 100,000 lines per sq. in., being somewhat less in very nall machines. ***Density in magnet core:*** cast iron may be worked up to about 40,000 or ,000 lines per sq. in.; wrought iron and cast steel being about 95,000 to 105,000 or more lines r sq. in. ***Density in yoke:*** for cast iron the density should be about 30,000 lines per sq. in.; r cast steel, about 75,000 lines, and for wrought iron forgings about 85,000 lines. ***Density armature core:*** this may be taken at from 85,000 to 90,000 lines per sq. in. for drum armares.

NOTE.—***Dynamo losses.*** These are the *mechanical loss* due to friction, and *electrical ses* in the core, field, and armature. ***Friction loss.*** This ranges from 3 to 5 % in respecely small and large machines of good design. ***Core loss.*** In well designed machines this ould not exceed 2% of the output at full load. ***Field loss.*** The portion of the electrical rgy generated in the armature which is lost in exciting the field magnets varies from 00 to 0% the total energy generated. ***Armature loss.*** This is usually termed the *copper* loss since due to the resistance of the winding; it is a very variable quantity and is equal to *the square he current multiplied by the resistance of a section of the winding between brushes.*

NOTE.—***Armature paths in wave and lap windings.*** A wave winding has but two hs through the armature, regardless of the number of poles; whereas a lap winding has as y paths as there are poles. This distinction is important in figuring the size of wire for the ding to carry the current without undue heating.

2. REPAIR SHOP METHODS

A. Rewinding

Dismantling.—When an armature is brought into the shop to be rewound, it must first be stripped of the old winding and re-insulated throughout. Before doing this the winding should be examined and a complete winding data sheet made out so that in rewinding, the workman will know what size wire to use, number of turns per slot, pitch of coil, and the numerous other items necessary to duplicate the former winding.

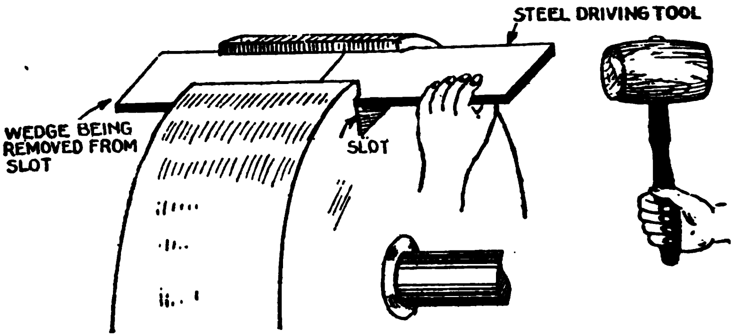


Fig. 7,837.—Operation of removing wedge from slot of armature by use of steel driving too

In dismantling, the first operation is to remove the banding wires, being careful if these be cut with a chisel not to dent the teeth.

Next, unsolder the commutator leads and remove slot wedges with a steel drive of the same size as the wedge. Now remove coils by raising the top sides for a distance of the throw, when the bottom side of each coil can be reached and the others taken out. Take out one coil as carefully as possible without disturbing its shape so that it will serve as a guide in forming the new coils. After all coils have been removed, the slots should be cleaned of the old insulation by burning with a torch and any burrs or rough places smoothed with a file.

Winding Methods.—The new coils are made to conform with the data taken in dismantling the old coils. In large repair shops coils are made either by winding on a mould, former, or shuttle.

Mould coils are wound by rotating the mould in a lathe. Former coils

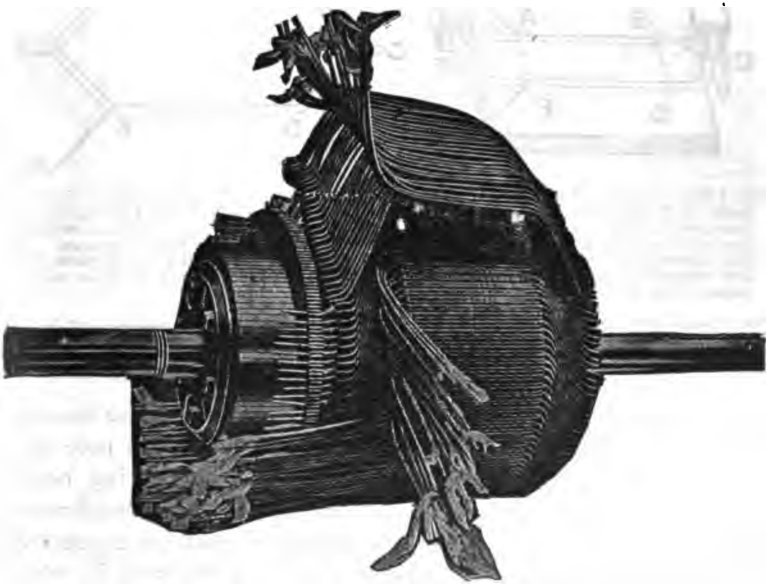
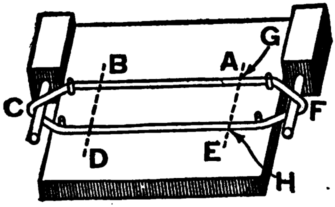


FIG. 7,838.—Holter-Cabot partially wound barrel wound armature showing arrangement of coils. The core is built up of thin discs of soft annealed steel, which are slotted to allow the wire to sink below the surface, this being sometimes called *iron clad construction*. The discs are held by end plates, clamped with through bolts. The coils are machine formed of round ribbon or bar copper depending on the size and purpose of the machine, being without joint except at the commutator. They lie in insulated troughs, the upper layers being insulated from the lower layers by fibre.

are made over stationary forms, using levers or mallets to force the coil to the proper shape. Shuttle coils are wound on a shuttle fastened in a lathe and then pulled on a coil puller to the required shape.

Commutator Connections.—Before winding, the commutator should be tested for grounds. In winding as each coil is put in its slot the sleeving on the ends of the lower leads should be fastened to the wire by friction tape and these leads inserted into the slits of the proper commutator bars.



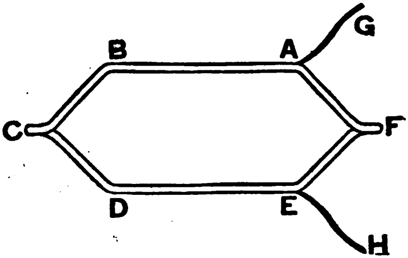
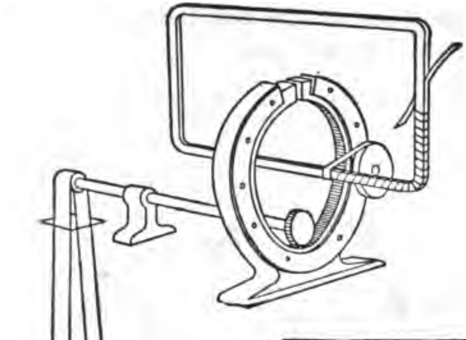


FIG. 7,839.—Method of winding "straight out" coils. There are several ways of making these coils. A former may be prepared, as shown in the figure, with a board having inserted four pins, and having attached two blocks at the ends carrying horizontal pins as shown. Around the several pins, the coil is wound to the required number of turns and taped. This coil differs from the evolute coil in that the two halves are of equal size, the parts which act respectively as upper and under inductor being of equal length. The coil as shown is suitable for wave winding.

FIG. 7,840.—Appearance of straight out coil after being opened out. ***In opening out*** the coil, the ends C and F, are put into a clamp and twisted at right angles to the plane of the coil. The letters correspond to the points indicated in fig. 7,839.

In connecting the first lead, the proper bar to use depends upon the location of the brushes with respect to the pole tips, thus: If brushes be midway between poles connecting beginning of coil to bar radially opposite inductor slot; when brushes are centered with poles, the connection should be made with bar 90 electrical degrees to right or left of the slot in which the beginning or bottom side of the coil is located.

In soldering care should be taken that molten solder do not fall or run down back of the commutator which would cause a short circuit. Never use an acid flux; a good preparation consists of a solution of rosin in alcohol.



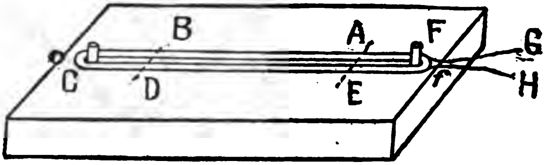


Fig. 7,841.—Armature coil taping machine. Numerous machines have been invented for taping armature coils. They consist essentially of a device which revolves a roll of tape around the coil, in such a direction that the tape is unwound from the roll and rewound on the coil. The speed at which the coil is fed through the machine will determine the overlapping of the tape.

Fig. 7,842.—Another and simpler method of winding a "straight out" coil. A board with only two pins is employed as shown; this plan, however, gives more trouble in the subsequent opening out of the coil.

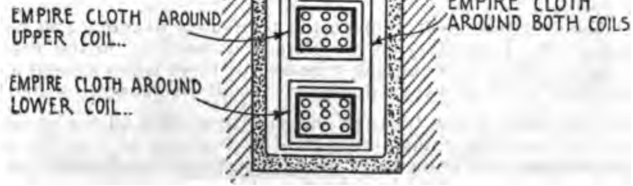


Fig. 7,843.—Method of insulating double layer winding in semi-closed slot.

Lighting Out Test.—The object of this test is to see if the leads have been connected to the proper bars.

In testing, use a lamp tester placing one terminal on a commutator bar and touch the top leads of several coils until the lamp lights. This locates the top side of the coil corresponding to the bottom side connected to the test lamp. If the lamp light on more than one lead it indicates a short circuit.

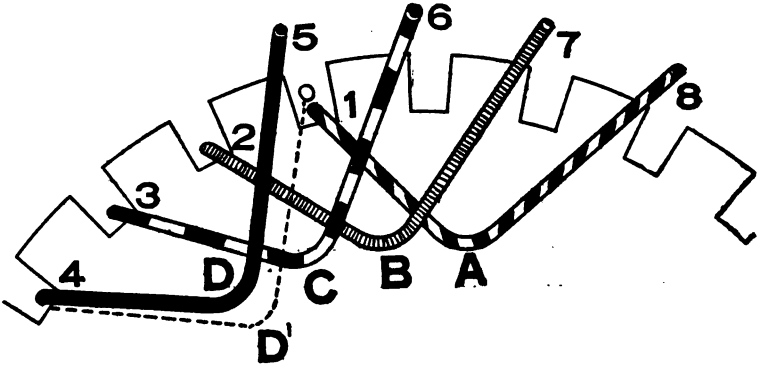


FIG. 7,844.—Method of placing two layer lap winding coils in armature slots. In a two layer winding one side of a coil will be at the bottom of a slot and the other at the top of another slot. To place coils in slot, put in the lower sides first as, 1, 2, 3, 4, of coils A, B, C, D, leaving the other side of each coil outside its slot. Evidently when enough coils to make up the inner layer have been placed this way, the upper layer side of the last coil so placed can be put into the slot. Thus, after lower layer side 4, of coil D, is put in the slot, the upper layer side 5, may be put in position on top of side 1 of coil A. Thus moving the last coil from point D to D′ indicated by the dotted line.

Banding.—Since heat causes the coil insulation to shrink, it is necessary to first put on a temporary banding to heat armature, mount in a lathe, and then wind on a temporary binding.

After the armature cools, remove the temporary banding, and put on a permanent one. In putting on the permanent banding, in the absence of a banding machine, pass banding wire two or three times around a round banding stick about 2 ins. in diameter and adjust tension by hand.

In starting, wind a few turns at one end, then wind all the groups continuously to avoid fastening the ends of each group as they are wound. The ends are fastened by means of narrow tin strips placed under the wires, bent back over the top and held by tin solder. Insert these strips about every 3 ins., while the wire is being wound on.

The end windings are secured by groups of wire wound on insulating boards.

The tension on banding wires should be from about 200 to 400 lbs., depending on the size of the wire.

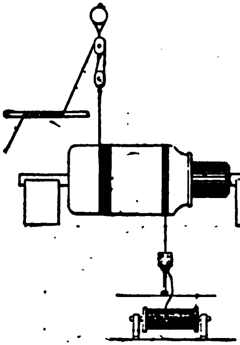


FIG. 7,845.—Method of binding armature winding. Complete appliances for handling armatures in making repairs are usually not available with most street railway companies, since they are so seldom required. When needed, therefore, some temporary contrivance must be resorted to for help in the dilemma. Should an armature burn out, some local concern that makes coils and rewinds armatures may be available to do the work; again, it will be necessary to send to the manufacturers for a man, as soon as coils can be made ready for the work. In no case should any but an experienced man be given charge of this work. But if there be any doubt as to whether the armature is really burnt out, let a competent man be the judge. When a large armature needs repairing, a pair of chain tongs can be used on some part of the shaft when putting in the coils, and a block and tackle, as shown, can be used, when putting on the band wires. Do not finish one band and then cut off the wire, but run it over for the next, etc. Then solder and trim off the wires.

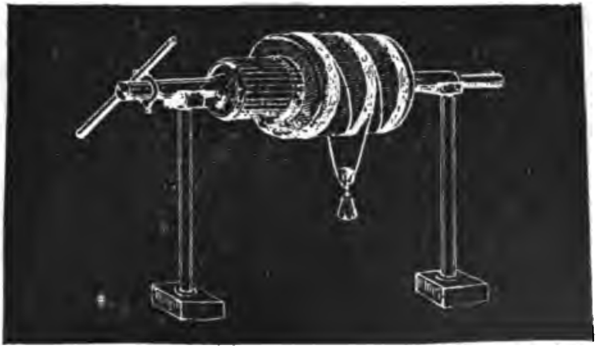


FIG. 7,843.—Method of securing tension in bending wire by use of weighted pulley.

B. COMMUTATOR REPAIRS

Grinding of Commutators.—When a new or reassembled armature has been in use some time, the shrinkage of the insulation causes the commutator bars to settle resulting in an uneven surface. This must be trued up by turning in a lathe when in very bad condition but otherwise a grinding tool, or simply an application of very fine sand paper No. 00 will do.

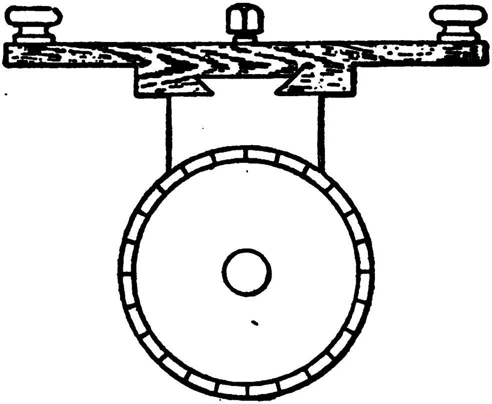


FIG. 7,847.—Method of smoothing commutator with a stone. The proper stone to use is made out of white sandstone similar to that used for grindstones, but a trifle softer. It is dovetailed into a holder, as shown in the illustration, and held in place by a set screw. When being used, one knob is grasped in one hand and the other knob in the other hand, the stone being moved back and forth along the length of the commutator. As the stone will become coated with copper at first, it must be cleaned frequently by means of coarse sand paper. The fine dust from the stone will get under the brushes and wear them to a very close fit. After using the stone, finish with fine sandpaper.

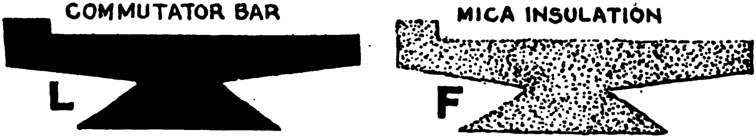
On small machines this may be applied by inserting under a brush, utilizing the brush tension to press the paper against the commutator, but on larger machines the brushes should be lifted to prevent the dust becoming imbedded in the brush contact surface, which tends to cause poor commutation.

High Mica.—This condition obtains after considerable wear and results in heating of the commutator bars due to arcing.

In severe cases the solder melts resulting in short circuits and open circuits due to leads becoming disconnected. To remedy this condition the mica must be under cut.

Undercutting of Mica.—The mica insulation between the commutator bars should be undercut from 1/32 to 1/16 in. below the surface of the bars.

In doing this be careful to avoid leaving thin slivers of mica next to the bars. Special motor driven saws are available for cutting the mica. Small commutators may be machine cut on a milling machine. Various hand tools also have been devised for cutting the mica.



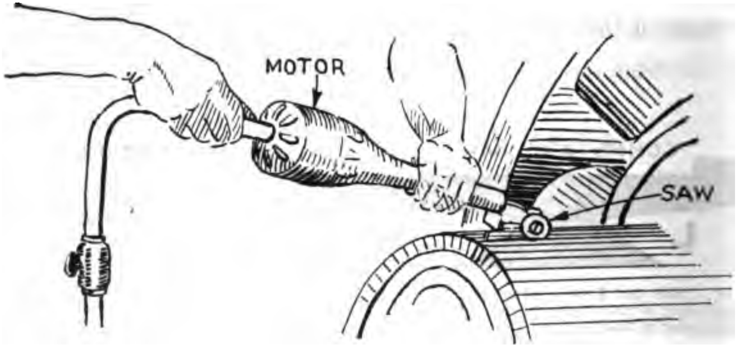
FIGS. 7,848 and 7,849.—Mica segment F, cut from sheet using bar L, as pattern. Such a segment is cut large at top and at ends so as to turn down evenly with copper bars when commutator is finally surfaced.

High and Low Commutator Bars.—When a commutator is hot the shellac in the mica being in a soft state will allow the bars to move more or less under centrifugal force due to rotation which is frequently the cause of high or low bars.

NOTE.—***Commutator Slotting.***—For slotting, a home made outfit is frequently used. A good cutting tool consists of a circular saw or miller ¾ to 1¼ in. in diameter with from 15 to 30 teeth. The thickness of the saw should be slightly greater than that of the mica, that is for mica .03 in. thick a .035 in. saw should be used. In this way the mica can be removed completely with no thin layers left at the sides. This saw may be mounted on the tool carriage of a lathe as here shown, and driven at from 1,200 to 1,800 *r.p.m.* by a belt from the line shaft or by a small motor mounted on the carriage. With a spacer of the same width as the commutator bars two saws may be used and the slotting operation be performed in half the time. Instead of the circular saw, a lathe tool ground to fit the slots may be used, by mounting it in the tool post and moving back and forth across the commutator by operating the carriage. It may also be mounted on a special stationary post and moved back and forth by a hand lever. These methods require a lathe which is not always available, and several types of machines avoiding this are in use.

To remedy this defect let machine run till hot, then take up on commutator ring, repeating the process several times if necessary. High or low bars can sometimes be re-aligned by respectively tapping down, or prying up and inserting underneath a narrow strip of mica.

Burn Outs.—This trouble which occurs between commutator bars is usually due to oil which collects dust, causing leakage of current from bar to bar with resulting carbonizing of the mica and finally a short circuit.



FIGS. 7,850.—Rotary hand tool for undercutting mica and method of using. The saw is mounted between two handles and adjustable shoes are provided on each side so that the depth of the slot may be gauged and kept uniform. The saw may be driven by a small stationary motor through a flexible shaft or by a compressed air drill. In this case the armature is simply placed on a pair of V supports and clamped to prevent it turning if necessary.

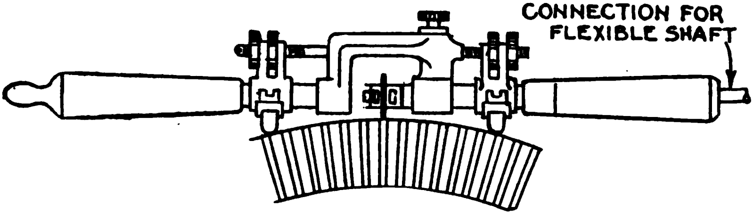
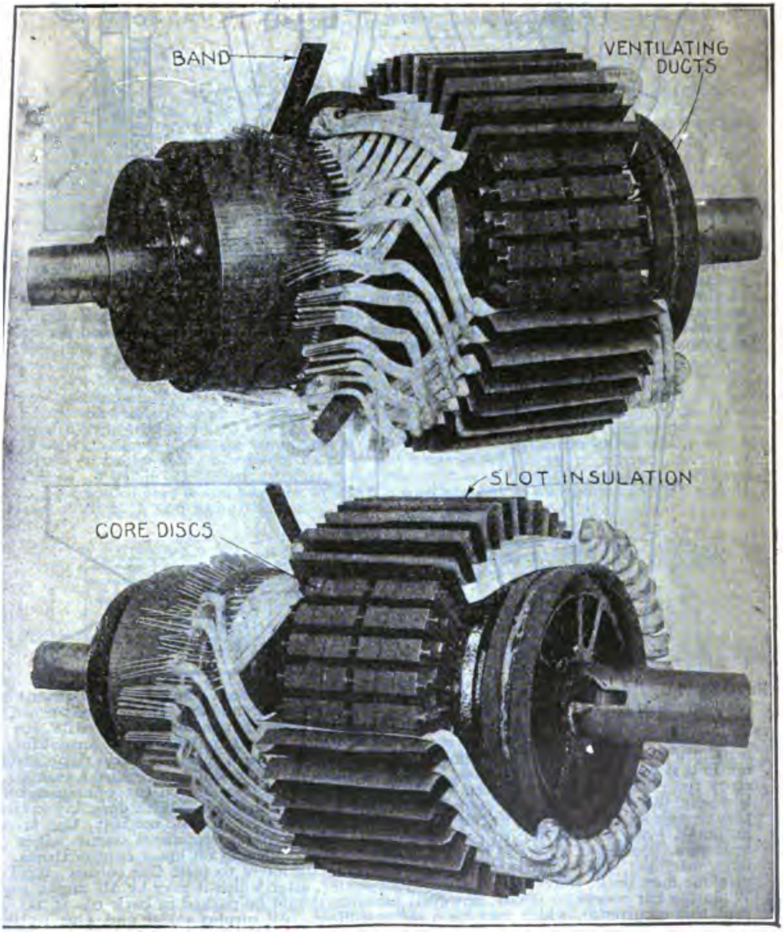
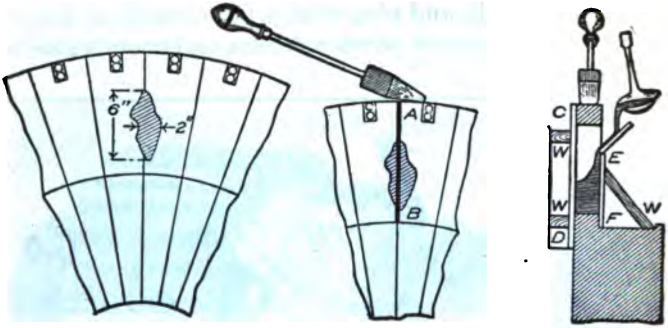


FIG. 7,851.—Motor driven mica cutting tool in which the cutting tool is mounted on a slide and moved back and forth by hand. The drive is through a flexible shaft as shown, or a belt may be used.

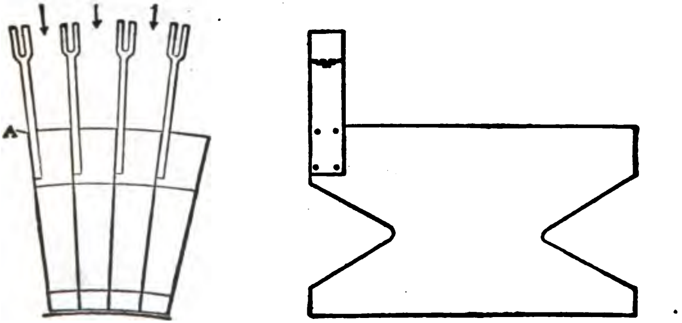
Plugging.—When the mica is not burned too deep, clean out the hole thoroughly and plug with a filling made of two parts of plaster of paris, one part powdered mica and enough glue to make a thick paste.



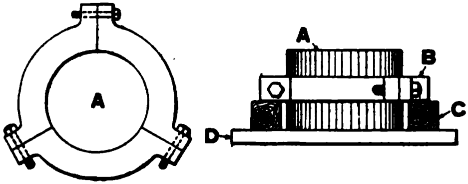
:s. 7,852 and 7,853.—Commutator and rear ends of General Electric Standard type R.C. vave wound armature using strap coils.



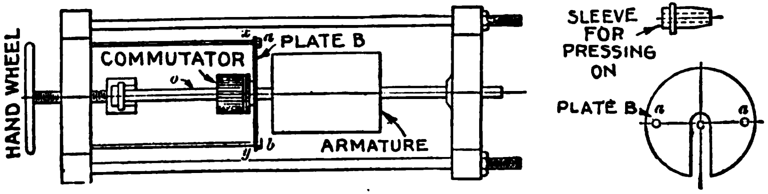
Figs. 7,854 to 7,856.—Method of repairing a large hole burned in two adjacent bars of a commutator. Fig 7,854 shows the hole. The first operation is to clean carefully and tin the surface of the hole. The two bars are then wedged apart and mica strips, A,B, fig. 7,855, of the requisite size and thickness forced in. The commutator must now be warmed up as much as possible by means of soldering irons, and strips of mica, C,D,E, F, fig. 7,856 placed at the front and back of the hole, being kept in position by pieces of wood W. Solder is poured into the hole from a ladle, using a rough mica funnel to guide it.



Figs. 7,857 and 7,858.—Method of repairing broken joint between commutator segment and lug. To repair such a break, push asbestos in between adjacent bars, so that heat from the torch will not affect them. Asbestos should also be worked in at the back if possible, for the purpose of keeping solder from places where it would cause trouble. Then unsolder the armature leads from the lug and remove the latter. Next, with specially made cape chisels, cut in a slot in the commutator bar for a new lug. Care and skill are required not to destroy the mica insulation between the segments. The slot should be cut one-quarter to three-eighths inch deep. The connector is then soldered in place. With care a satisfactory connection can be made in this way, which will last well. If it do not last, the trouble in almost every case is due to poor soldering. Short circuits sometimes occur after this operation, because of solder falling in at the back and lodging on lower connections. In large machines, the excessive current flowing is quite likely to melt this solder, and the machine may buck, throwing out the melted solder, after which it may be all right again. While the bar connector is out, however, asbestos should be packed in back of it to prevent this occurrence, which may be a serious affair. All surplus solder and the asbestos packing should be removed after the connection is finished, and the connections cleaned with compressed air. The armature should be turned over slowly, air being applied all the while.



FIGS. 7,859 and 7,860.—Ring or clamp for holding commutator bars together when assembling and method of using. The clamp should be slightly smaller than the diameter of the commutator. ***In using,*** wooden blocks C, may be used as distance pieces to align the clamp at the middle of the commutator. D is an iron face plate. The distance pieces C, and clamp B, are placed on the plate D, as shown, and the bars and mica segments stacked in a circular form within it. Be careful not to omit any of the mica segments, so that each bar is insulated. Carefully count the bars to be sure that the correct number are in position. Take several pieces of copper wire (about No. 9 B. & S. gauge) and remove the insulation. Place these around the commutator near the top and lower ends to act as band wires, and twist them tight. The clamp may then be removed, and the commutator straightened. Bring out the mica segments even with the surface of the bars by holding the fingers against the inside edge of the segments and tapping the bars on the outside with a small mallet. Place a square or steel scale on the face plate and tap the bars on the outside with a small mallet. Place the square of steel scale on the face plate and see that the bars line up perpendicularly with one edge of the square. If they do not, a gentle pressure one way or the other on the top end of the commutator with the palm of the hand will bring them in line. See that each bar and segment is down flat against the surface of the plate, since that end will be fastened to the face plate on the lathe facing off the ends of the bars. Tap each bar and segment down solid with a square ended punch, a little narrower than the thickness of the bar. When this has been done, the band wires can be drawn a little tighter and the surface of the commutator, where the clamp will fit, should be filed to remove any protruding mica, and present a smooth surface for the clamp. Replace each section of the clamp about the commutator again using the wooden blocks mentioned before. Draw the clamp tight, being sure to leave the same amount of space between each clamp section. A small gas burner, or some other source of heat should be handy, and the commutator placed over it and heated. When it is good and hot to the hand, tighten the clamp, allow it to cool, and again tighten.



FIGS. 7,861 to 7,863.—Press for forcing on and removing a commutator. Small commutators are pressed on to the shaft by a hand press. All of the larger commutators are pressed on by means of a power press. In the above figure is shown a hand press. The plate B, is used in removing old commutators. It is placed back of the commutator as at *x,y*, with the slot C, over the shaft. Bolts *a,b*, are passed through the holes in the plate and secured by nuts. The commutator can then be forced off the shaft. In pressing on a commutator, a sleeve is placed over the shaft at O, and against the commutator. The rear end of the shaft is secured so it will withstand the pressure, and the commutator is forced on. The power presses are built on the principle of a hydraulic press. In pressing on a commutator a piece of babbit metal or soft brass should be used against the end of the shaft. The shaft should be painted with white lead before having the commutator pressed on, in order to lubricate the shaft so that the commutator will press on easily. The wiper rings are pressed on after the commutator and then the armature is ready to be connected.

Dissembling Commutator for Repairs.—If a burned commutator bar or mica strip are to be removed for repairs, unloosen clamping ring bolts and mark ring so that it can be replaced in the same position.

Remove clamping ring and if the mica ring be stuck to commutator it should be heated to soften the shellac. After the ring is taken off it is easy to remove any of the bars. In replacing a bar the mica segment should be put in first, being careful to first see that there is no dust or solder lodged on the back of mica ring.

Tightening a Repaired Commutator.—When assembled put on clamp ring and screw up bolts. Bake in oven to drive out the shellac, let cool and again take up on ring bolts.

Repeat operation one or more times until there is no slack in the bolts.

B. RE-CONNECTING D.C. MACHINES

Repairmen are frequently called upon to make changes in a dynamo or motor such that the machine can be operated at a different voltage or speed, and sometimes to adopt a dynamo for use as a motor, etc.

Voltage Changes.—In making changes for motors or dynamos to operate on different voltages it should be noted that the speed of a motor varies directly with the voltage.

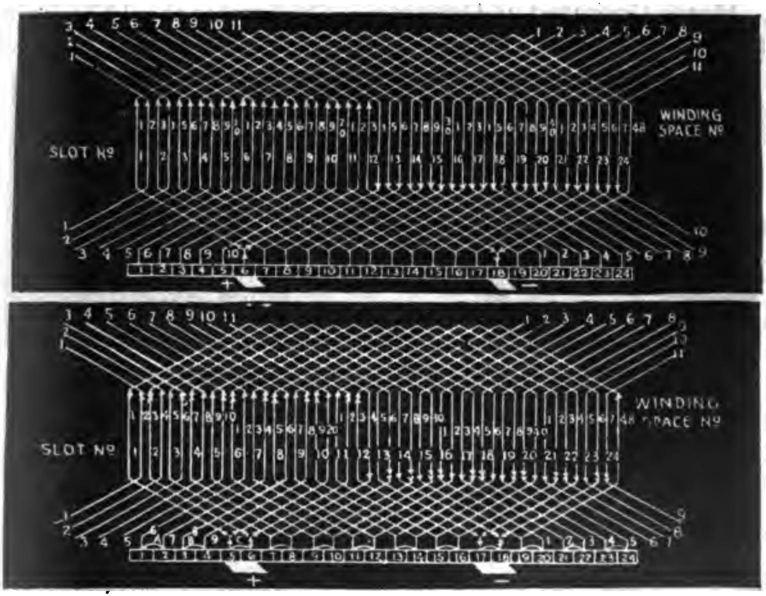
The variation of voltage affects the excitation of the fields, and after saturation is reached the speed only approximately varies with increase of voltage. Small speed changes may be effected by changing the width of the air gap.

Changes for Half Voltage Operation.—Arrange the shunt field coils in two groups and connect the groups in parallel.

With this arrangement evidently on half voltage circuit, the voltage per field coil will be the same, hence the flux will be the same but the speed will be only half what it was before the changes were made. To bring speed up to normal, place resistance in the shunt field and increase air gap as much as possible. The foregoing changes reduce the horse power one half.

Changes for Double Voltage Operation.—The field coils must be rewound in case with the shunt fields in series the smallest air gap cannot be used. Changing for double voltage, gives twice the horse power.

Armature Winding Changes for Voltage Changes.—



FIGS. 7,864 and 7,865.—A 240 volt, 24 slot lap winding and method of reconnecting or rewinding for 120 volts. When a *d.c.* armature is to be rewound or reconnected for a change in voltage *the number of turns in series between the brushes, will vary directly as the voltages*, and *the cross sectional area of the wire will vary inversely as the voltages*. To reduce the voltage from 240 to 120 and do the same amount of work, twice the current will be required and accordingly, twice the cross sectional area of wire. The winding may be reconnected so that two coils are in parallel and bridge the commutator bars in pairs as in fig. 7,865, or the machine may be rewound with a wire of double the cross sectional area.

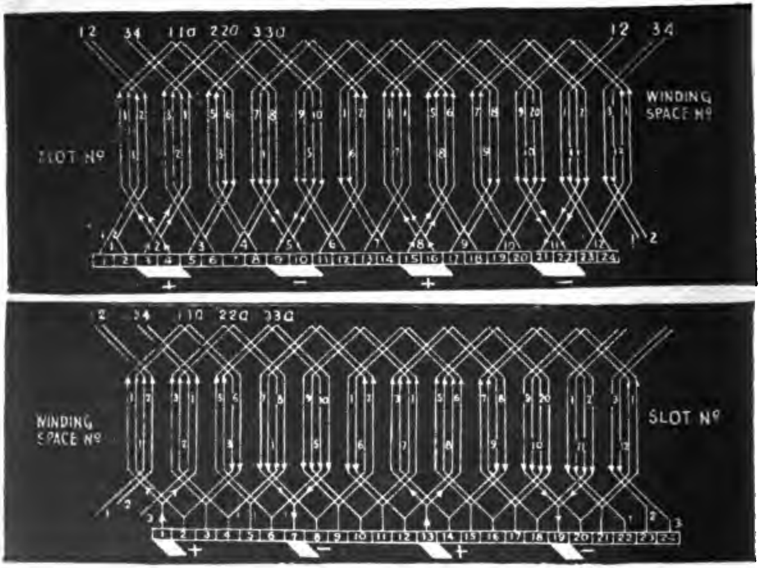
An armature can usually be adapted to a lower voltage either by reconnecting or by rewinding.

In making changes it should be noted that the sectional area of the wire for the coils and number of turns in series vary inversely as the old to the new voltage. In determining the form of coil and number of turns to be used in rewinding the slot space available must be considered.

Speed Changes.—By adjusting the air gap of a motor the speed may be varied from 10 to 15%. To increase speed, increase air gap; to reduce speed, reduce air gap.

Dynamo Operated as Motor.—Give backward lead to brushes for the correct rotation of the armature.

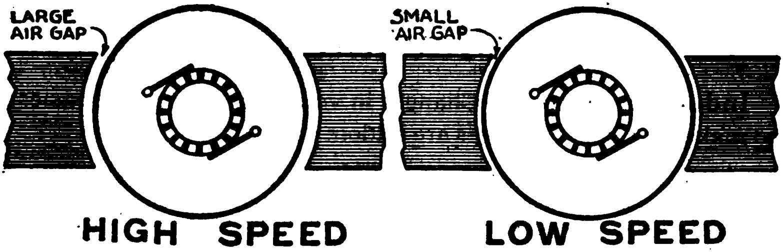
Motor Operated as Dynamo.—The brushes should be given forward lead and the air gap reduced to a minimum for equal or



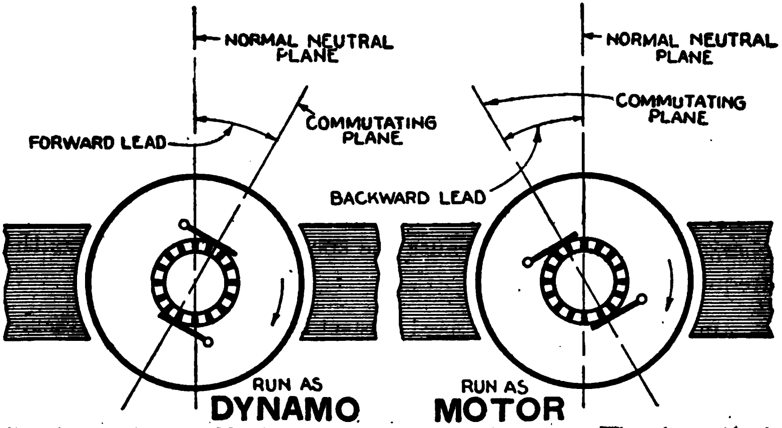
FIGS. 7,866 and 7,867.—Duplex lap winding for 120 volts, and method of reconnecting for 240 volts. On armatures having duplex windings there are usually twice as many commutator bars as there are slots and each of the two wires is connected to separate bars. The brush will however cover at least 1½ to 2 bars. To change from 120 to 240 volts, reconnect the winding so that adjacent pairs of coils will be in series as in fig. 7,867 instead of in parallel as in fig. 7,866, and reduce width of brushes to that of one commutator bar.

higher voltage, but for lower voltage the same air gap can usually be used.

Wrong Field Connections.—Sometimes due to error in the shop a new motor may have one or more magnets reversed, resulting in little or no torque. Trace out connections or test polarity of magnets by means of a compass.



FIGS. 7,868 and 7,869.—Method of changing the speed of a motor by adjusting the air gaps.



FIGS. 7,870 and 7,871.—Machine operated as dynamo and as motor. When the machine is operated as dynamo the brushes should be given *forward* (positive) *lead*, and when operated as a motor, *backward* (negative) lead.

Wrong Rotation.—In the case of a motor the direction may be changed by reversing the field connections.

If the field of a dynamo be reversed to change rotation, the magnetism induced by the winding will oppose the residual magnetism and the machine may not *build up*. Instead of reversing the field, reverse the armature leads. A multipolar machine can be reversed by reversing the brushes on the studs and then relocating them.

C. Reconnecting A. C. Machines

Induction Motors.—Changes in voltage alone are the easiest to make, but phase changes are seldom advisable.

In making changes the repair man should first examine the winding and note throw and connection of coils, number of turns in coil, size of wire, etc., so that he can get an idea of the possibilities of the machine.

Voltage Changes.—Nearly all commercial motors are arranged so that they can be reconnected for two voltages.

To make these changes, the polar groups are connected in series for the higher voltage and in parallel for the lower voltage.

In changing to higher voltages it should be noted that motors as manufactured are provided with insulation good for 500 volts or for 2,500 volts. The capacity of the insulation should accordingly be considered and no change be made beyond the capacity of the insulation.

Frequency Changes.—For the same number of poles a change in frequency will cause the speed to vary directly as the frequency.

In order to maintain the speed constant in making a frequency change, the voltage on the motor should be varied in the same proportion as the frequency is changed.

Phase Changes.—The change most frequently desired is from two to three phases, or from three to two phases.

For the same voltage there should be about 25% more total turns in a two phase winding than in a three phase winding, hence, unless the voltage be reduced a three phase motor connected for two phase will overheat.

A two phase motor has too many coils for three phase operation, hence, in this case, about $^1/_5$ of the total coils might be dead ended to secure the proper voltage on the other coils. In doing this the dead coils should be distributed as symmetrically as possible.

Reversing Polyphase Induction Motors.—For a two phase four wire machine, interchange the connections of the two leads on either phase.

For a two phase three wire motor, interchange the two outside leads.

For a three phase machine, interchange the connections of any two leads.

Method of Soldering Wires to Lugs.—The *Code* requires that all stranded wire above No. 8 B. & S. gauge shall be soldered to all terminal lugs or terminal connectors. The following is the approved method:

First coat the lug with laundry soap; this is to prevent surplus solder sticking to outside surface of lug, making an unsightly job. Next, fill lug with soldering paste, and hold lug in flame of a gasoline torch, when soldering paste begins to bubble, put a little solder in the lug; this will melt very easily as the lug is now heated to the proper temperature.

Skin or remove insulation of wire, and clean same with file until it shows the copper to be bright. Coat end of wire with paste in flame of torch; when paste bubbles, insert wire into lug, which contains melted solder, remove flame of torch from lug and do not move the arms until the solder has set; a quick method is to apply wet rag to lug to cool solder. Now, take pliers and try to twist off lug from wire. This is a test to prove if wire be securely soldered to lug. If lug come off wire, this indicates that it has not been properly soldered. Next clean off soap and polish lug; tape up any bare spaces on wire.

The following points should be remembered:

Use plenty of paste.

Wire to be soldered must be as hot as the solder.

Wire and interior of lug must at all times be clean.

Do not use cutting pliers to hold lug in flame as this softens the cutters and thereby ruins the pliers.

Use a good solder having a good combination of lead and tin; 50-50 recommended or 60-40 is the standard for electrical work.

If solder do not hold in lug, this is due to poor solder, dirt in lug—dirty wire. Remedy: fill lug with paste melt solder in lug, dump out solder, then repeat as described and it will be found that the lug will hold.

TROUBLES

Failure to Excite.—In starting a dynamo it should be remembered that shunt and compound machines require an appreciable time to build up, hence, it is best not to be too hasty in hunting for faults.

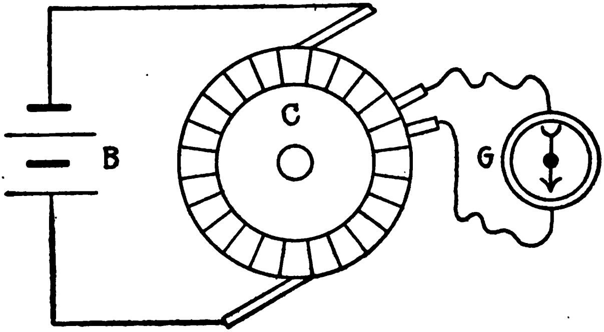


FIG. 7,872.—Method of locating short circuited armature coil. Connect apparatus as shown; pass 20 to 100 amperes from a battery or another dynamo. Now having previously well cleaned commutator, measure voltage between adjacent segment all around. A zero reading will indicate a short circuit, which may be permanent or intermittent; when intermittent it may be carried by wire coming into contact due to centrifugal force developed while armature is rotating.

The principal causes which prevent a dynamo building up are:

1. Brushes not properly adjusted;
2. Defective contacts;
3. Incorrect adjustment of regulators;

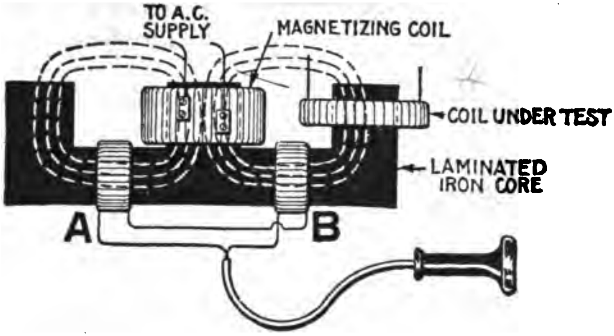
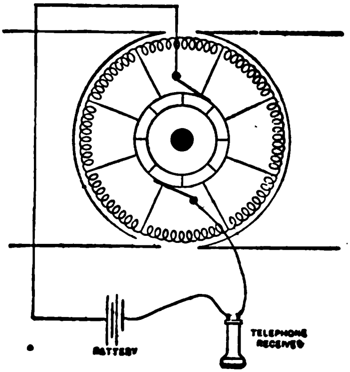


Fig. 7,873.—Field coil testing with telephone receiver. In the method here shown, a telephone receiver is connected in series with two symmetrically placed coils A and B. Very little sound will be heard when the flux through the two coils AB is the same; but if a short circuited coil is being tested, the fluxes through the coils A, B will not be equal and a noise can be heard in the receiver.



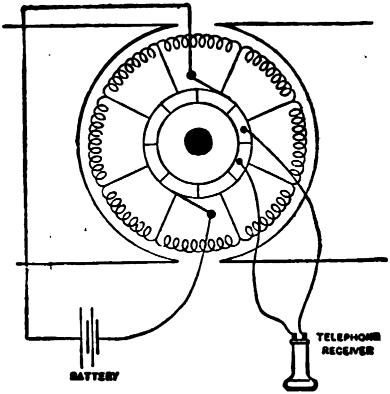


Fig. 7,874.—Test for break in armature lead. Connect apparatus as shown and clean commutator. Rotate armature slowly; telephone receiver "clicks" as brush makes contact with each good segment; a faulty segment gives no response. Note:—Brushes must not cover more than a single segment.

Fig. 7,875.—Bar to bar test for open circuit. In coil or short circuit in one coil or between segments. If, in testing as in fig. 206, on rotating the armature completely around, the receiver indicate no break in the leads, connect battery as here shown, and touch the connections from the receiver to two adjacent bars, working from bar to bar. The clicking should be substantially the same between any two commutator bars; if the clicking suddenly rise in tone between two bars, it indicates a high resistance in the coil or a break (open circuit).

4. Speed too low;
5. Insufficient residual magnetism;
6. Open circuits;
7. Short circuits;
   a. In external circuits;
   b. In dynamo.
8. Wrong connections;
9. Reversed field magnetism

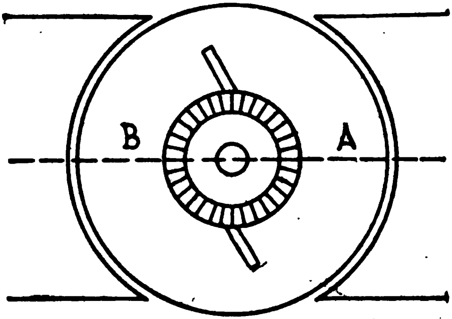


FIG. 7,876.—Method of locating short circuits between adjacent armature coils. Excite fields with coils in parallel. It will now require considerable force to rotate the armature, and then it will move quite slowly, except at one position. When this position has been found, mark the armature at points in the center of the pole pieces at points A and B and at both ends of the armature. The "cross" or "short" circuit is nearly always found on the commutator end in the last half of the winding, where the wires pass down through the first half terminals. This applies to an unequal winding. In armatures where the windings are equal, it is as liable to occur at one point as at another.

Armature Faults.—The chief mishaps to which armatures are subject are:

1. Short circuits:
   In individual coils; between adjacent coils; through frame or core; between sections of armature; partial short circuits
2. Grounds;
3. Breaks in armature circuit.

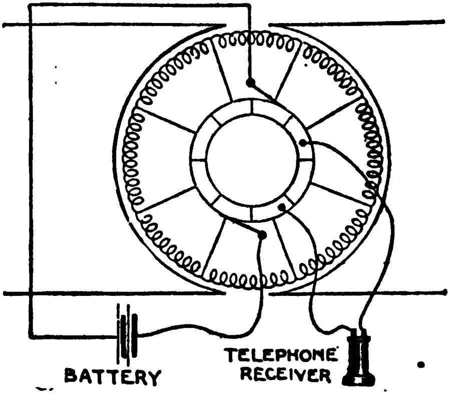


FIG. 7,877.—Alternate bar test for short circuit between sections. Where two adjacent commutator bars are in contact, or a coil between two segments becomes short circuited, the bar to bar test described in fig. 7,875 will detect the fault by the telephone receiver remaining silent. If a short circuit be found, receiver leads should straddle three commutator bars as shown. The normal click will then be twice that between two segments until the faulty coils are reached, when the clicking will be less. When this happens, test each coil for trouble and, if individually they be all right, the trouble is between the two. To test for a ground, place one terminal of the receiver on the shaft or frame of the machine, and the other on the commutator. If there be a click, it indicates a ground. Move the terminal about the commutator until the least clicking is heard and at or near that point will be found the contact. Grounds in field coils can be located in the same manner.

Commutator Troubles.—In badly designed or constructed dynamos, sparking occurs at all positions, no matter where the brushes are placed, and in such dynamos it is therefore impossible to prevent this no matter how well they are adjusted.

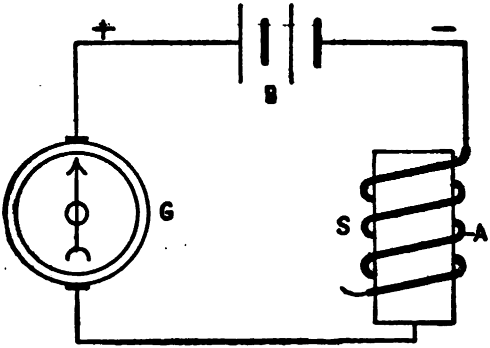


FIG. 7,878.—Method of locating short circuit between coils through armature coil. *Connect* as shown, then connect free terminal of galvanometer to shaft. If then some portion of the wire insulation be abraided or destroyed, as at A, the galvanometer needle will be deflected.

Sparks due to bad adjustment of brushes are generally of a bluish color; when produced by dirty or neglected state of commutator, the color is reddish and there is a spluttering or hissing sound. The chief causes of sparks are:

1. Bad adjustment of brushes;
2. Bad condition of brushes;
3. Bad condition of commutator;
4. Overload of dynamo;
5. Loose connections, terminals, etc.;
6. Breaks in armature circuit;
7. Short circuits in armature circuit;
8. Short circuits or breaks in field magnet circuit.

Heating.—When the machine heats, a common mistake is to suppose that any part found to be hot is the seat of the trouble.

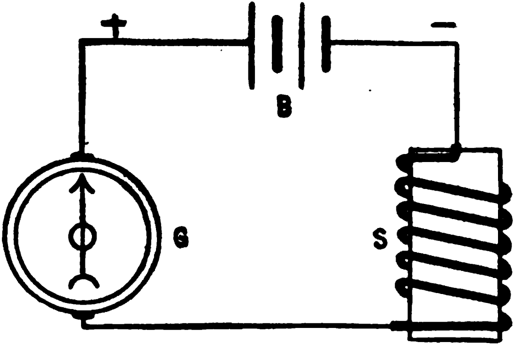
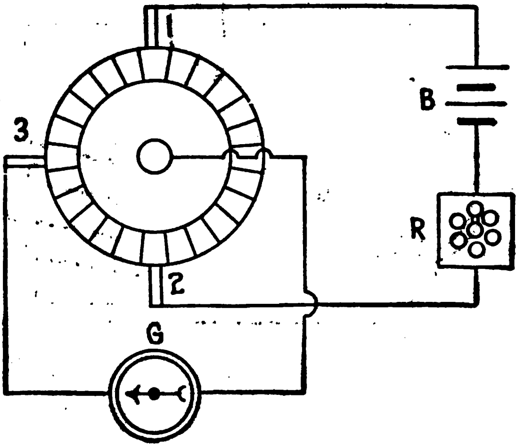
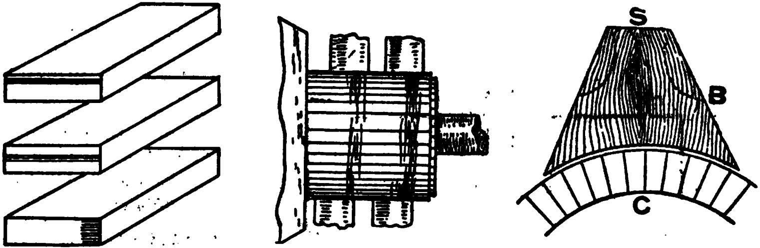


FIG. 7,879.—Method of testing for breaks. Connect as shown. Galvanometer deflection indicates that wire of coil S, being tested is unbroken. No deflection indicates a break or faulty terminal connection.



Hot bearings may cause the armature or commutator to heat, or vice versa. All parts of the machine should be tested to ascertain which is the hottest, since heat generated in one part is rapidly diffused. This is best done

FIG. 7,880.—Method of locating grounded armature coil. Connect as shown; assume a steady current to be flowing from battery through the armature; touch the commutator with brush 3, and a current will flow through the galvanometer. Slowly rotate the armature or the brush 3, until the galvanometer shows no deflection. The coil in contact with 3, will be found to be *grounded*. A rheostat may be inserted in series with the battery or dynamo circuit to regulate the strength of the current passing.



FIGS. 7,881 to 7,883.—Brushes making bad contact. A brush making a bad contact, as only at the shaded portion of figs. 7,881 and 7,882, will not allow the short circuited coil enough time to reverse, causing sparking and heating. The latter will also result from bad contact on account of the surface being too small for the current to be carried off. This form of bad contact is worse than that shown in fig. 7,883, where the area of contact surface only is lessened. If the brushes do not make good contact, they should be ground down.

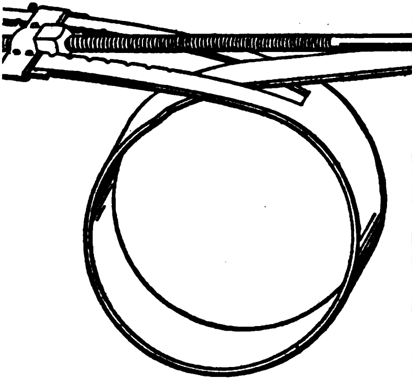
FIG. 7,884.—Rough and grooved commutator due to improper brush adjustment and failure to keep brushes in proper condition.

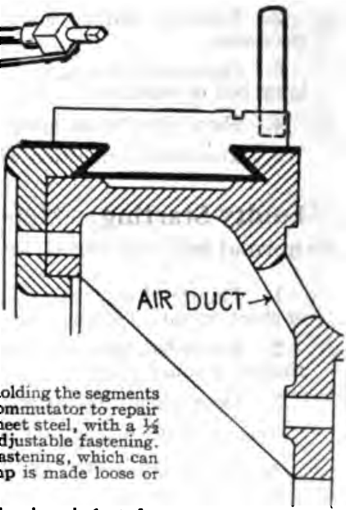
FIG. 7,885.—Sandpaper block. It is made to fit the surface of the commutator. At S, is a saw cut into which the ends are pushed after being wrapped around the block. The latter should be cut down on the dotted lines to form a handle. The dotted line extending to B, indicates the portion of the block cut away to afford a good grip. C, commutator.

starting with the machine cold; any serious trouble from ating isusually perceptible after a run of a few minutes at l speed with the field magnets excited.

Heating may be due to various electrical or mechanical causes, d it may occur in the different parts of the machine, as in:

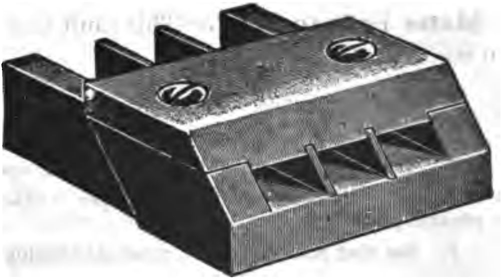
1. The connections;
2. The brushes and commutator;
3. The armature;
4. The field magnet;
5. The bearing.





G. 7,886.—Commutator clamp; a useful device for holding the segments firmly in position in taking out the end rings of the commutator to repair for internal grounds. It is made of 2 × ⅛ inch sheet steel, with a ½ inch screw. The illustration clearly shows the adjustable fastening. The notches fit around rivets on one side of each fastening, which can be moved by removing the two cotters. The clamp is made loose or taut by screwing the bolt in the nut.

G. 7,887.—Ventilated commutator; Sectional view showing air ducts for maintaining low temperature.



G. 7,888.—Jig for filing brushes to the correct level; used with copper brushes to fit them to the commutator.

1. Split Phase Motor Troubles

Speed Too Low.—This may be due to any of the following causes, which may be corrected by the remedies given.

1. Wrong voltage and frequency.
2. Overload reduce low on motor, replace with a larger motor is necessary.
3. Grounded starting and running windings. Test out with magneto lamp bell or voltmeter.
4. Short circuited or open winding in field current. Test out as above.
5. Too small connection wires. Increase size of wires.

Faulty Starting.—Motor starts, runs slowly, will not pick up to normal full load speed, and blows fuses, due to:

1. Failure of cut out to work properly. Test out cut out for grounds or short circuit. Oil pivots and springs, sand paper rough spots.
2. Grounded plate, test with lamp or magneto, one wire to each slip ring or contact plate.
3. Open circuit in starting or running winding.

Test out with magneto or lamp.

4. Grounded or short circuited starting or running winding.

Test out with magneto, Bell and battery or voltmeter.

Motor Fails to Start.—This fault is sometimes encountered. In such cases

1. Test line voltage with lamp.
2. Test fuses with lamp.
3. Trace out all connections for grounds, open or short circuit.
4. See if brushes be making proper contact with collector rings or contact plates.
5. See that rotor is free to rotate in bearings.

Motor Fails to Start and Hums Loudly.—This may be due to the starting winding being burnt out, open, or grounded.

If motor hum, this indicates that the main or running winding is not open; the motor may be started by rotating the armature by hand until it reaches its normal rated speed.

Sparking At the Brushes.—As the brushes of split phase motors are only used in starting, sparking may be due only to worn and loose brushes, or dirty slip rings.

Clean slip rings with a benzine soaked rag. Apply a little vaseline with the finger to each slip ring to prevent cutting by the brushes.

Heating of the Windings.—This may be due to any of the following causes:

1. Moisture in windings. Dry out in an oven.
2. Short circuit or ground. Test out with magneto, lamp, bell or voltmeter.
3. Overload. Reduce load or install a larger motor.
4. Too low line voltage. Check up with voltmeter.
5. Too high line voltage. Any voltage in excess of 5% on 220 volts, 10% on 110 volts should be reduced at this will cause the windings to hurn out.
6. Wrong frequency. A 40-cycle motor cannot be used on 60 cycle current as the rotor will not revolve in synchronism with the alternator.
7. Wrong voltage connections to motor.
8. Connection wires too small. This will cause a voltage drop.

Heating of the Rotor.—This is usually caused by overloading the motor or by broken soldered connections of end bars. Reduce load or solder broken connections.

2. Fractional Horse Power Motor Troubles

Motor Fails to Start.—Be sure that the wires connected to the motor terminals make good contact; that each of the brushes of the motor makes perfect contact with the commutator; that the connected load is not too great for the size of motor used.

Motor Hums Loudly and Refuses to Start.—The fault may be due to

1. Short circuited field windings.
2. Grounded connections, or cut out switch.

Test out individual windings with volt meter, holding one wire to frame, the other to each lead of field windings.

Test out cut out switch with magneto, one wire to shaft the other to each half of cut out plates.

Motor Runs Too Slow.—This fault may be due to

1. Burnt out, short circuited, or grounded winding.
2. Grounded cut out switch.
3. Cut out switch refuses to short circuit itself.

This may be due to corroded springs, dirty plates, dirt in springs and pivots.

Care of Compensators.—These should be inspected once a year and the oil changed. Use only oil as furnished with the compensator by the manufacturer, as this has been found to give the best results; any other grades of oil will cause a lot of unnecessary trouble.

If the contact fingers on the switch of the compensator be scortched or burnt they should be smoothed with a piece of sand paper, if they be too far burnt or worn, they should be replaced with new ones.

Tighten all springs on switch and no voltage release, so that contact fingers press firmly on all contact.

Oil all exterior moving parts of switch handle, also the no voltage release.

Grounding of Compensators.—The cases of all compensators should be grounded especially when installed on high voltage circuits, to insure safety to the operator if for any reason the current carrying parts should accidentally come in contact with the case.

A good contact is obtained by securing the ground wire under a screw or bolt on the compensator.

The ground wire should be run to a water pipe as required in the *Code*.

3. Compensator Troubles

Motor Fails to Start.—If the fuses and motor be in good condition, examine all contacts and see if contact fingers make contact.

Press with a screw driver all contacts and see if motor start. Trace out all leads from terminal block to contacts. Examine all transformer taps. In case of a burn out on one coil of a three phase compensator the coil may be cut out by a slight change in connections and the compensator used temporarily until a new set of coils can be obtained.

Compensator Hums.—This is due to an improper sealing surface of the no voltage release or loose laminations of the solenoid or transformer.

Tighten all screws on the no voltage release solenoid plunger and no voltage coil, also tighten screws on transformer.

No Voltage Release Fails.—If the voltage release fail to hold switch in running position, the fault may be due to:

1. Burnt out no voltage coil.

   Test with a magneto.

2. Wrong connections.
3. Latch of no voltage release stuck.

   This may be due to dirt or foreign object. Remove same.

4. Overload relay plunger stuck.

   This causes an open circuit in the no voltage release circuit. Inspect all relays, and try moving by hand, and note if they make contact.

CHAPTER 124

Power Stations

There are three general classes of power stations:

1. Central stations. 2. Sub-stations. 3. Isolated stations.
and these may be classed:

1. With respect to their function, as

a. Generating stations. *b*. Distributing stations. *c*. Converting stations.

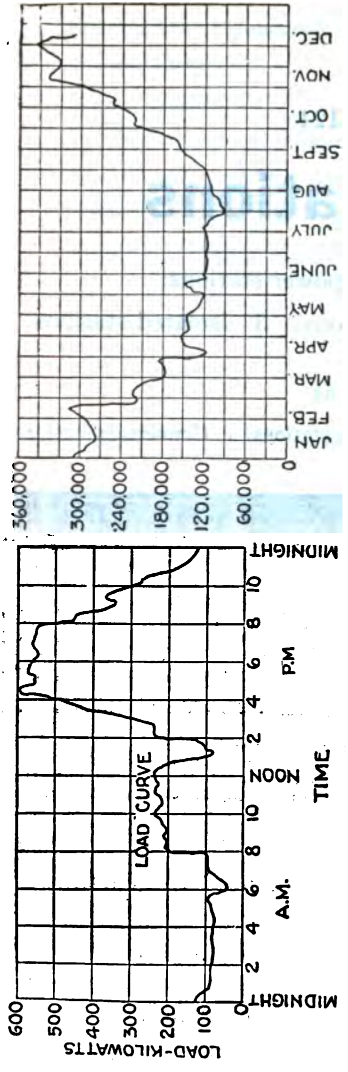
Fig. 7,889.—Example of central station located remote from the distributing center and furnishing alternating current at high pressure to a sub-station where the current is passed through step down transformers and suplied at moderate pressure to the distribution system. In some cases the sub-station contains also converters supplying direct current for battery charging, electro-plating, etc.

2. With respect to the form of power used to generate the current, as

a. Steam electric. *b*. Hydro-electric *c*. Gas electric.

3. With respect to the kind of current generated, as

a. Direct. *b*. Alternating. *c*. Direct and alternating



FIGS. 7,890 and 7,891—Power station load curves; fig. 7,890, load curve for one day; fig. 7,891, load curve for one year.

Location of Central Stations. — Usually they are located so that the average line drop is a minimum, this point of location being called the center of gravity of the system.

In practice this is rarely the best location because the price of land, difficulty of obtaining water, facilities for delivery of coal and removal of ashes, etc., may more than offset the minimum line losses and copper cost due to locating the station at the center of gravity of the system. There should be room for future extension of the plant.

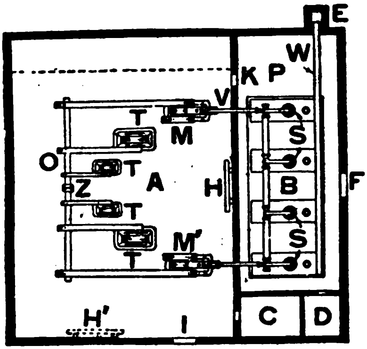
Choice of System.—The chief considerations in the design of a central station are *economy and capacity*.

When the current has to be transmitted long distances for either lighting or power purposes, economy is attainable only by reducing the weight of the copper conductors. This can be accomplished only by the use of the high voltage currents obtainable from alternators.

Again, where the consumers are located within a radius of two miles from the central station, thereby requiring a transmission voltage of 550 volts or less, dynamos may be employed with greater economy.

Alternating current possesses serious disadvantages for certain important applications.

For instance, in operating electric railways and for lighting it is often necessary to transmit direct current at 500 volts a distance of five or ten miles. In such cases, the excessive drop cannot be economically reduced by increasing the sizes of the line wire, while a sufficient increase of the voltage would cause serious variations under changes of load. Hence, it is common practice to employ some form of auxiliary dynamo or booster, which when connected in series with the feeder, automatically maintains the required pressure in the most remote districts so long as the main dynamos continue to furnish the normal or working voltage.



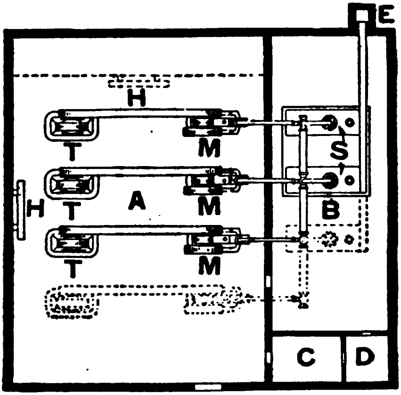


FIG. 7,892.—Floor plan of station having belted drive with countershaft A, engine and dynamo urn; B, boiler room; C, office; D, store room; E, chimney connected with the boilers by flue W; S, S, boilers; V, V, steam pipes; M, M, engine; O, countershaft; T, T, T, T, generators; H, switch board. A pulley may be mounted on the countershaft O, with a friction clutch. A jaw clutch may also be provided at Z, thus permitting the shaft O, to be divided into two sections. It is therefore possible by this arrangement to cause either of the engines to drive any one of the generators, or all of them, or both of the engines to drive all of the generators simultaneously.

FIG. 7,893.—Plan of electrical station with belt drive without counter shaft. The installation here represented consists of two boilers, S, etc., and three sets of engines and generators, T, M, etc. Sufficient allowance has been made in the plans, however, for future increase of business, as additional space has been provided for an extra engine and generator set, as indicated by the dotted lines. Other reference letters are the same as in fig. 7,892.

The advantage of a direct current installation in such cases over a similar plant supplying alternating current line is the fact that a storage battery may be used in connection with the former for taking up the fluctuations of the current, thereby permitting the dynamo to run with a less variable load, and consequently at higher efficiency.

Size of Plant.—Before any definite calculation can be made, or plans drawn, the engineer *must determine the probable load.*

This is usually ascertained in terms of the number and distances of lamps that will be required, by making a thorough canvass of the city or town, or that portion for which electrical energy is to be supplied. The probable load that the station is to carry when it begins operation, the nature of this load, and the probable rate of increase are matters upon which the design and construction chiefly depend.

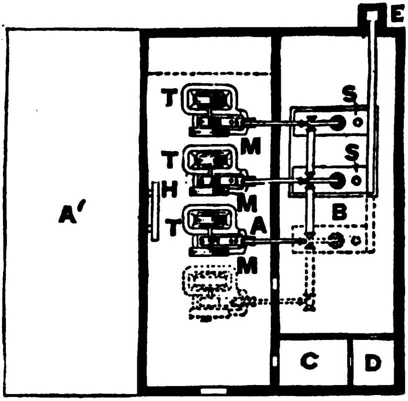


FIG. 7,894.—Plan of electrical station containing direct connected units. *As shown,* space is provided for an extra boiler and engine and generator set, as indicated by the dotted lines. Space also exists for a storage battery room if necessary, and the partition dividing this room from the engine and dynamo room is shown by a dotted lines.

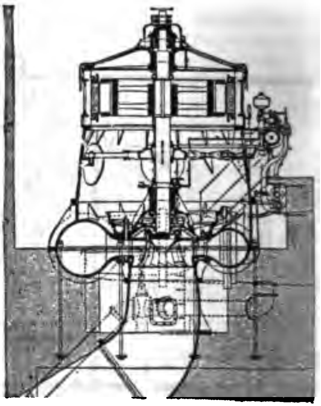


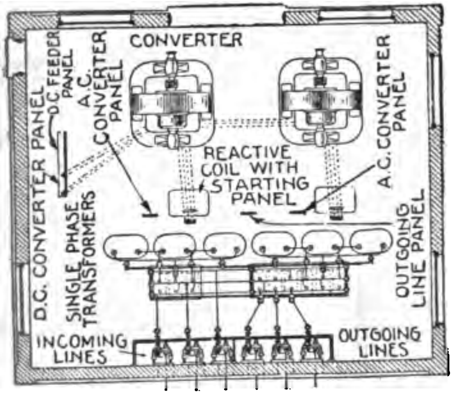
FIG. 7,895.—Sectional elevation of one of the 5,000 horse power vertical Pelton-Francis turbines directly connected to generator, as installed for the Schenectady Power Co.

General Arrangement.—In designing an electrical station, it is preferable that whatever rooms or divisions of the interior space are desired should determine the total outside dimensions of the plant in the original plans of the building than that these latter dimensions be fixed and the rooms, etc., be fitted in afterward.

The engines and generators will occupy the majority of the space, and these are usually placed in one large room; in some stations, however, they are located respectively in two adjacent rooms. The boilers are generally located in a room apart from the engines and generators.

FIG. 7,895.—Triumph dymano set with upright slide valve engine.

FIG. 7,896.—Murray alternating current direct connected unit with high speed Corliss engine and belt driven exciter, 50, 75 and 100 *kva*. alternator and 150 *r.p.m.* engine.

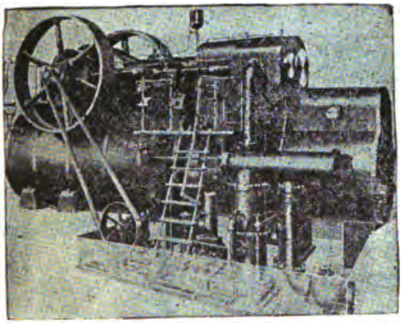


In general, the boilers should be near the engines to avoid loss of heat and pressure drop in steam pipe, and the condensers should be near the engines (especially in case of turbines) to avoid excess back pressure. The location of engines and boilers, and details of station construction are given in Chapter 39 on Installation.

FIG. 7,897.—Plan of small sub-station with single phase oil insulated self-cooling transformers and hand operated oil switches 11,000 or 13,200 volts, overhead high tension lines.

Isolated Plants.—The average type of isolated plant has enlarged from a small dynamo driven by a little slide valve engine located in an out of the way corner to direct connected generators and engines of hundreds and even thousands of horse power assembled in a large room specially adapted to the purpose.

Sub-Stations.—As usually defined, a sub-station is a building provided with apparatus for changing high pressure *a.c.* received from the central station into *d.c.* of the requisite pressure, which in the case of railways is 550 to 600 volts.



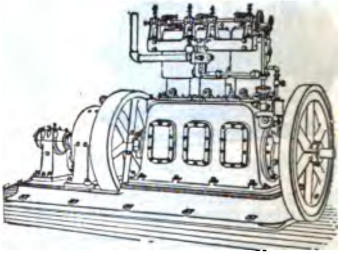


Fig. 7,898.—Buckeye-mobile, or self-contained unit consisting of compound condensing engine, boiler, superheater, reheater, feed and air pumps. It produces one horse power on 1½ lbs. of coal. Built in sizes from 75 to 600 horse power.

Fig. 7,899.—Westinghouse three cylinder gas engine, direct connected to dynamo, showing application of gas engine drive for small direct connected units.

Where traffic is heavy and the railway system of considerable distance, sub-stations are provided at intervals along the line, each receiving high pressure current from one large central station and converting it into moderate pressure *d.c.* for their districts.

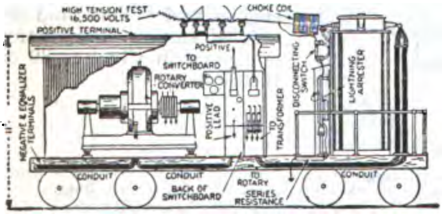


Fig. 7,900.—Portable (outdoor transformer type) sub-station. ***In railway service,*** direct current can be provided at any point on the system where there is track at the high pressure line. The direct current can be made available very quickly as its production involves only the transferring of the sub-station, and its connections to the high pressure line.

CHAPTER 125

Management

Broadly, the term *management* embraces: 1, selection; 2, location; 3, erection; 4, testing; 5, running; 6, care, and 7, repair.

The designer of the plant, specifies or "selects" the machines. An *erector* should install them, but usually this job is left to the man in charge who in most small and medium size plants is the chief steam engineer, who also must run, care for and repair the machines.

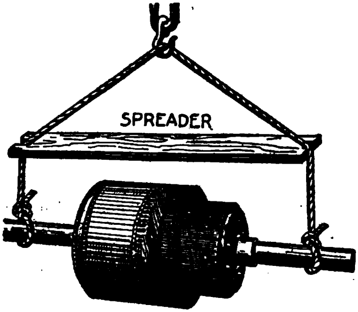


FIG. 7,901.—Method of moving armature to prevent injury to commutator or winding.

Selection.—To properly select a machine, such items as 1, type; 2, capacity; 3, efficiency, and 4, construction, should be considered.

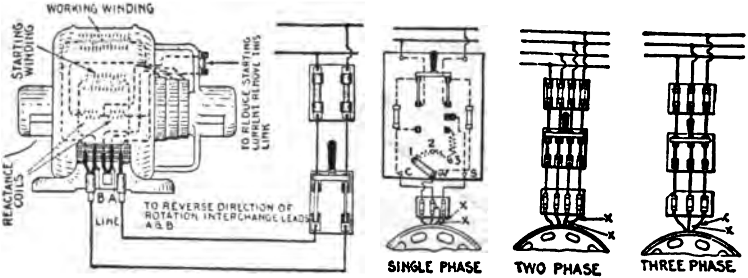
The type depends on the system in use.

In *a.c.* constant pressure transmission circuits, average voltage is 2,200 with transformer ratios of $^1/_{10}$ and $^1/_{20}$. Standard frequencies are 25 and 60.

In fixing the capacity of a machine, ***careful consideration should be given to the conditions of operation both present and future*** in order that the resultant efficiency may be maximum.

Installation.—Small parts may readily be placed in position, either by hand, by erecting temporary supports which may be moved from place to place as desired, or by rolling the parts along on the floor upon a piece of iron pipe.

Large and heavy parts necessitate the use of a crane. Special care



FIGS. 7,902 to 7,905.—Wiring diagram and starter connections for Holzer-Cabot *a.c.* motors. ***Single phase motors are started*** by first throwing the starting switch down into the starting position, and when the motor is up to speed, throwing it up into the running position. *Do not hold the switch in starting position over 10 seconds*. Starter for single phase motors above ½ H.P. are arranged with an adjusting link at the bottom of the panel. The link is shown in the position of least starting torque and current. Connect from W, to 2, or W to 3, for starting heavier loads. *Two or three phase* motors are started simply by closing the switch. ***To reverse*** the rotation interchange the leads marked XX. The single phase self-starting motor fig. 7,902 is provided with a link across two terminals on the upper right hand bracket at front of motor and this connection will start considerable overloads. Interchange leads A and B to reverse rotation.

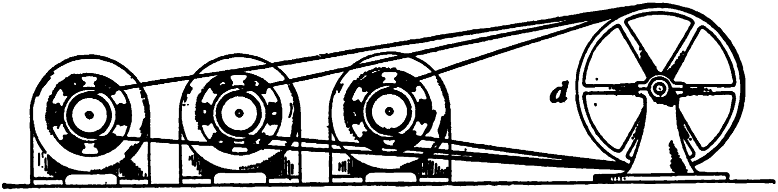
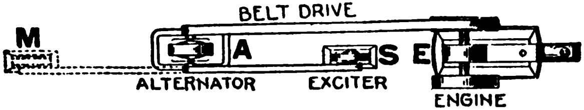


FIG. 7,906.—Tandem drive for economizing floor space.



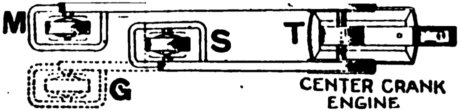


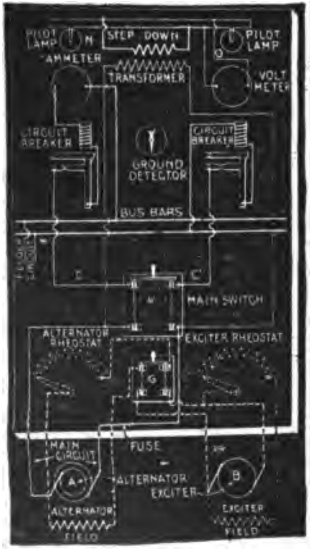
Fig. 7,907.—Separately excited belt driven alternator showing method of economizing floor space by locating exciter at S, instead of at M.

Fig. 7,908.—Double pulley drive for economizing floor space. If the generators thus belted were placed at M and G, yet still more floor space would be saved by having them occupy the positions indicated at M and S.

should be exercised in installing electric machines as the insulations of the windings are very easily injured. The prick of a pin or tack, a bruise, or a bending of the wires by resting their weight upon them or by their coming in contact with some hard substance, will often render a field coil or an armature useless.

Operation of Alternators.—The exciter must first be started. This is done in the same way as for any shunt dynamo.

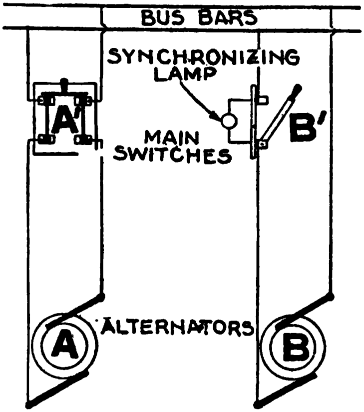
At first only a small current should be sent through the field winding of the alternator; then, if the exciter operate satisfactorily and the field magnetism of the alternator show up well, the load may gradually be thrown on until the normal current is carried, the same method of procedure being followed as in the similar case of a dynamo.



Fig, 7,909.—Switch board wiring for a single phase separately excited alternator. The direct current circuits are represented by dotted lines, and the alternating current circuit, by solid lines.

Synchronizing.—When it becomes necessary to run more than one alternator to carry the load, before they can be connected in parallel *they must be synchronized*; that is, the alternating cycles must be in step with each other, otherwise one machine will be short circuited through the other and serious results will follow.

In other words the speed, phase and voltage of each machine must be the same before connecting in parallel. Synchronizing is accomplished in several ways, as by dark, and brilliant lamp methods.



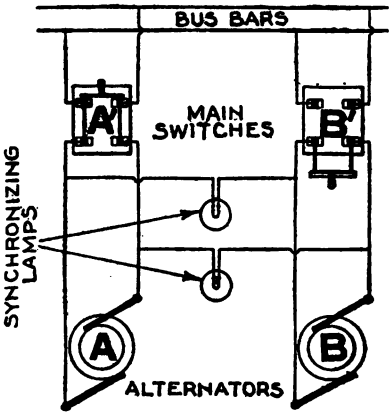


FIG. 7,910.—Synchronizing *one dark lamp method*. Assuming A, to be in operation, B, may be brought up to approximately the proper speed, and voltage. Then if B, be run a little slower or faster than A, the synchronizing lamp will glow for one moment and be dark the next. When the lamp remains dark the machines are in synchronism and switch may be thrown in.

FIG. 7,911.—Synchronizing two dark lamp method. When the machines are in phase there will be no difference of pressure between the left hand terminals or between the right hand terminals of the two machines. Hence, if the synchronizing lamps be connected as shown, both will be dark, and the switch may be thrown in connecting the machines in parallel.

Cutting Out Alternator.—To properly cut out an alternator: 1, reduce driving power until load has been transferred to the other alternators, adjusting field rheostats to obtain minimum current; 2, open main switch; 3, open field switch. Never open field switch before main switch.

Transformers.—The kind of efficiency of transformers the station master is interested in is the *all day efficiency**.

Mineral oil is used in oil cooled transformers. *It must be free from moisture.* To test, thrust a red hot iron rod in the oil; if it "crackle," moisture is present. The presence of moisture reduces the insulation value of the oil.

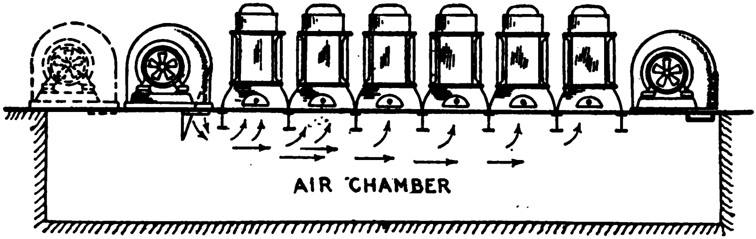
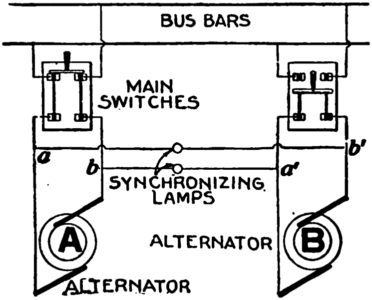


Fig. 7,912.—General arrangement of air blast transformers and blowers.



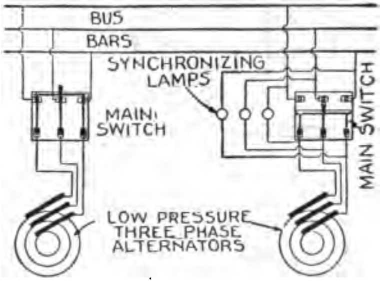


Fig. 7,913.—Synchronizing brilliant lamp method. When the voltages are equal and the machines in phase, the difference of pressure between *a*, and a given point is the same as that between *a'*, and the same point; this obtains for *b* and *b'*. Accordingly, a lamp connected across *a b'*, will burn with the same brilliancy as across *a' b;* the same holds for the other lamp. When the voltages are the same and the phase difference is 180° the lamps are dark, and as the phase difference is decreased, the lamps glow with increasing brightness until at synchronism they glow with maximum brilliancy. Hence the incoming alternator should be thrown in at the instant of maximum brilliancy.

Fig. 7,914.—Synchronizing three phase alternator, being an extension of the single phase method. Three lamps are only necessary to insure that the connections are properly made after which one lamp is all that is required.

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*NOTE.—***All day efficiency.*** This expression, as commonly met with in practice, denotes *the percentage that the amount of energy actually used by the consumer is of the total energy supplied to his transformer during 24 hours.*

Motor Generators.—These are frequently *used as boosters to raise or boost the voltage near the extremities of long distance, d.c. transmission lines.*

Dynamotors.—A dynamotor is a *combination dynamo and motor having both windings on one core.*

With this construction armature reaction due to the one winding is neutralized by the reaction caused by the other winding. There is,

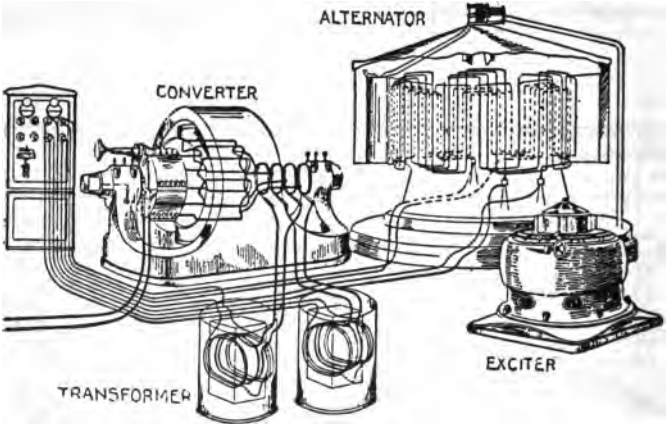


Fig. 7,915.—Wiring diagram of alternator, exciter, transformer and converter showing also switch board connections.

Figs. 7,916 to 7,918 —Converter connections. Fig. 7,916, double delta connection; 7,917, diametrical connection; 7,918, two circuit single phase connection.

consequently, little or no tendency for sparking to occur at the brushes, and they therefore need not be shifted on this account for different loads.

A dynamotor is connected at its motor end and started in the same manner as any shunt wound motor.

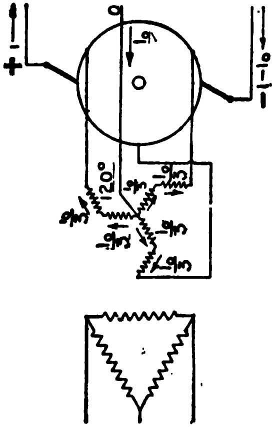


Fig. 7,919.—Wiring diagram for three wire synchronous converter with delta-Y connected step down transformer with the neutal brought out.

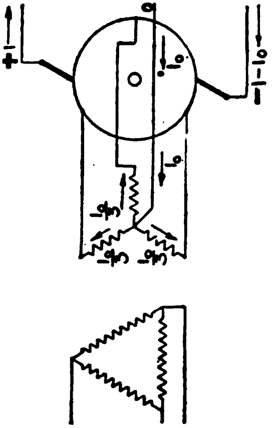


Fig. 7,920.—Wiring diagram of three wire synchronous converter with distributed Y secondary. This system avoids the flux distortion due to the unbalanced *d.c.* in the neutral.

Rotary Converters.—This type of machine is a *combination of an a.c. motor and a dynamo.*

It has practically become a fixture in all large electric railway systems and in other installations where heavy direct currents of constant pressure are required at a considerable distance from the generating plant.

When driven by *d.c.*, a rotary converter operates the same as a *d.c.* motor; when driven by *a.c.*, it operates the same as a synchronous motor. The commutator is the most troublesome part.

If it be found advisable to start the converter with *d.c.*, the same connections would be made between the source of the direct current and the armature terminals on the commutator side of the converter as would be the case were a direct current shunt motor of considerable size to be started; this naturally means that a starting rheostat and a circuit breaker will be introduced in the armature circuit.

A polyphase converter may be started with *a.c.* by applying the *a.c.* pressure directly to the collector rings while the armature is at rest.

The electrical difficulty experienced with rotary converters is the regulation of the *d.c.* voltage; the mechanical difficulty is hunting due to variations in frequency. Hunting is best prevented by the damping method.

Electrical Measuring Instruments.—Voltmeters in most common use have capacities of 5, 15, 75, 150, 300, 500 and 750 volts each, although in the measurement of very low resistances such as those of armatures, heavy cables, or bus bars, voltmeters having capacities as low as .02 volt are employed.

In operation if the hand of an instrument do not readily come to rest

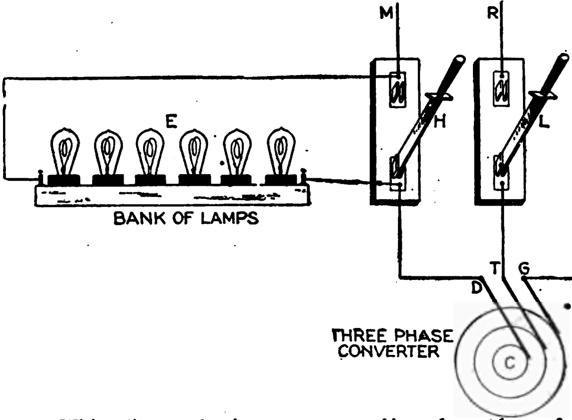
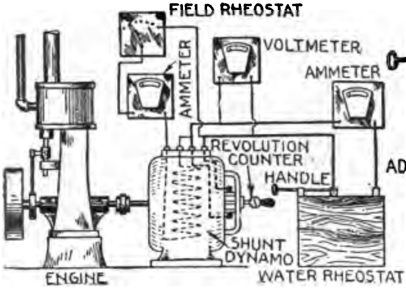


FIG. 7,921.—Wiring diagram showing arrangement of incandescent lamps for determining the proper phase relations in starting a rotary converter. The alternating current side of a three phase converter is shown at C. The three brushes, D, T and G pressing on its collector rings are joined in order to the three single pole switches H, L and B, which can be made to connect with the respective wires M, R, and V, of the alternating current supply circuit. Across one of the outside switches H, for example, a number of incandescent lamps are joined in series as indicated at E, while the three pole switch (not shown) in the main circuit, between the alternator and the single pole switches is open. If then the main switch just mentioned and the middle switch L, be both closed, and the armature of the alternator be brought up to normal speed by running it as a direct current motor, the lamps at E, will light up and darken in rapid succession; the lighting and darkening of the lamps will continue until, by a proper adjustment of the speed, the correct phase relations be established between the alternating current in the supply circuit and the alternating current developed in the armature of the converter. As this condition is approached, the intervals between the successive lighting up and darkening of the lamps will increase until they remain perfectly dark. There is then no difference of pressure between the supply circuit M,R,V, and the rotary converter armature circuit, so the source of the direct current may at that instant be disconnected from the machine, and the switches H and B, closed. If the change over has been accomplished before the phase relations of the two circuits differed, the converter will at once conform itself to the supply circuit and run thereon as a synchronous motor without further trouble.

gently tap it. Before connecting up instruments *it should be known that the pressure or current to be measured is within the range of the instrument otherwise the latter may be burnt out.*

Do not place instruments near conductors carrying large current and expect to get an accurate *a.c.* An *a.c.* voltmeter will work on a *d.c.* circuit, but a *d.c.* voltmeter will not work on an *a.c.* circuit.

The usual capacities of *a.c.* voltmeters are 3, 7.5, 10, 12, 15, 20, 60, 75, 120, 150, 300 and 600 volts but these capacities may be increased by the use of *multipliers*. Ammeters should be cut out of circuit except while taking reading to avoid error due to heating. To correct 3 or 4% error in voltmeter readings, straighten pointer, vary tension of spiral springs, renew jewel in bearings, alter value of the high resistance, etc.



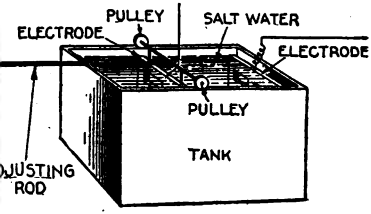


FIG. 7,922.—Dynamo test. During the test, one man should be assigned to the tachometer, another man to the water rheostat, and there should preferably be one man at each of the electrical measuring instruments. In order to enable the man at the tachometer to keep the speed constant, he should be in communication either directly or indirectly with the source of the driving power, and the man at the water rheostat should be in plain view of the man reading the ammeter so that the latter party may signal him for the proper adjustment of the rheostat in order that the desired increase of current be obtained for each set of readings.

FIG. 7,923.—Water rheostat. ***It consists essentially of*** a tank of suitable size containing salt water into which are placed two electrodes having means of adjustment of the distance separating them. The solution depends on the voltage. With current density of one ampere per sq. in., a water solution gives a drop of 2,500 to 3,000 volts per inch distance between the plates. Where high voltage is used, the water must be circulated through and from the tank by rubber hose allowing for 2,500 volts, a length of 15 to 20 feet of 1 inch hose to prevent grounding.

How to Test Dynamos.—The instruments needed are, voltmeter, ammeter, speed indicator, and the usual switches and rheostats, connected as in fig. 7,922.

In the case of a shunt machine, the speed should be made normal and the field rheostat adjusted until the voltmeter reading indicates the rated voltage of the machine at no load and readings taken.

The electrodes of the water rheostat should be adjusted for maximum resistance and main circuit closed, and a second set of readings taken. Several sets of readings are taken, with successive reductions of water rheostat resistance. The results are then plotted on coördinate paper.

To obtain the commercial efficiency the *input* and *output* must be found and compared for different loads, thus

$$\text{input in brake horse power} = \frac{2\pi L W R}{33{,}000} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

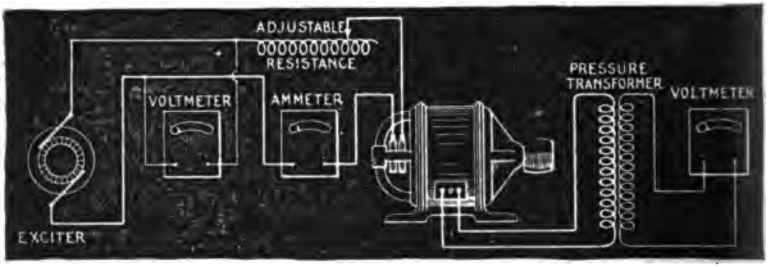


FIG. 7,924.—Test to obtain saturation curve of an alternator. *In testing* a series of observations of the voltage between the terminals of one of the phases, is made for different values, of the field current. If the machine be two phase or three phase, the volt meter may be connected to any one phase throughout a complete series of observations.

in which L = length of Prony brake lever; W = pounds pull at end of lever; R = revolutions per minute.

The output or electrical horse power for the same load is easily calculated from the formula

$$\text{output in electrical horse power} = \frac{\text{amperes} \times \text{volts}}{746} \quad \ldots\ldots\ldots (2)$$

After obtaining value for (1) and (2), the commercial efficiency for the load taken is obtained from the formula

$$\text{commercial efficiency} = \frac{\text{output}}{\text{input}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

CHAPTER 126

Motor Driven Tools

There is a constantly increasing demand for small portable motor driven tools which has resulted in a multiplicity of highly developed devices designed for numerous duties formerly performed by hand in machine and carpenter work, etc., such as drilling, grinding, buffing, screw driving, hammering, etc., the saving in labor accomplished by the use of these tools is very great.

FIG. 7,925.—Chicago "Little Giant" electric track-drills reaming joint holes on the tracks of the Pittsburgh Railways Co.

According to the kind of power used, motor driven tools may be classed as

1. Electric
2. Pneumatic.

Electric Drive.—The extensive demand for motor driven tools has resulted in many improvements in the design of the driving mechanism and they may be obtained suitable for almost any kind of electric current.

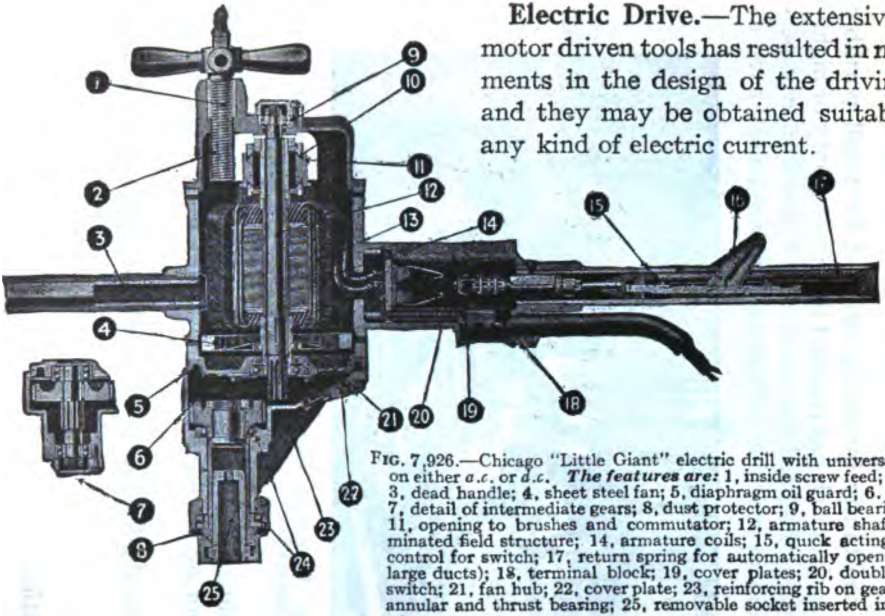


FIG. 7,926.—Chicago "Little Giant" electric drill with universal motor which runs on either *a.c.* or *d.c.* ***The features are:*** 1, inside screw feed; 2, protecting sheath; 3, dead handle; 4, sheet steel fan; 5, diaphragm oil guard; 6, grease compartment; 7, detail of intermediate gears; 8, dust protector; 9, ball bearing; 10, commutator; 11, opening to brushes and commutator; 12, armature shaft and pinion; 13, laminated field structure; 14, armature coils; 15, quick acting switch; 16, trigger control for switch; 17, return spring for automatically opening switch (used on large ducts); 18, terminal block; 19, cover plates; 20, double pole double break switch; 21, fan hub; 22, cover plate; 23, reinforcing rib on gear case; 24, combined annular and thrust bearing; 25, removable socket inserted in spindle.

The "Universal" motors will operate on either direct or alternating current, some being suitable for frequencies ranging from 20 to 125 cycles single phase, and for pressures ranging from 110 to 600 volts. The universal feature is of value to contractors or others who may have occasion to do work in various localities and find in some place only direct current available and in others only alternating current.

In addition to the universal line, tools may be obtained with motors designed for direct, or for alternating

FIG. 7,927.—Chicago "Little Giant" screw spike driver (for 110, 220 or 600 volt *d.c.*). It is a powerful electric rotary tool which operates in conjunction with a special circuit breaker designed to open the circuit when the spike is screwed home. It requires an operator and a helper to take care of the heavy torque developed at the instant of maximum effect when the head of the spike is forced against the base of the rail. At this instant the circuit breaker opens the circuit and the tool stops turning. On electric roads the circuit is taken from the trolley or third rail.

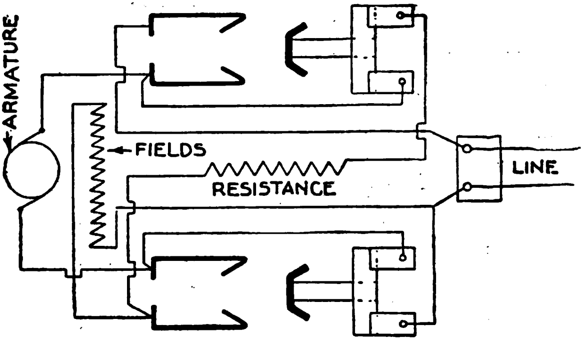


FIG. 7,928.—Osborn safety device for electric drills. *It consists of* a special switch with connections including a small armature resistance mounted directly on the switch case. When the operator's hand is removed from the trigger shown at the right of the cut, a spring opens the main circuit from the line, thereby cutting off the line current from the drill. Immediately after the line circuit is open, a circuit is made through the armature and field windings, causing the motor to become a generator, the armature being practically short circuited through the resistance. The load thus produced on the armature causes it to stop almost immediately, thus effectively destroying the torque or pull on the handles of the tool. The tool cannot become unmanageable, as upon releasing the switch the electric braking takes place, thus acting as a safety device for the operator.

current only. Some tools are designed for two and three phase alternating current. In these an induction motor is used, which possesses the advantage of having no commutator or brushes. The motor being of the short circuited type is practically impossible to burn out.

The two and three phase motors cannot be operated from a lamp socket connection, but must be connected to the three or four wires of a three phase, or two phase circuit as the case may be, a suitable cable being provided for this purpose.

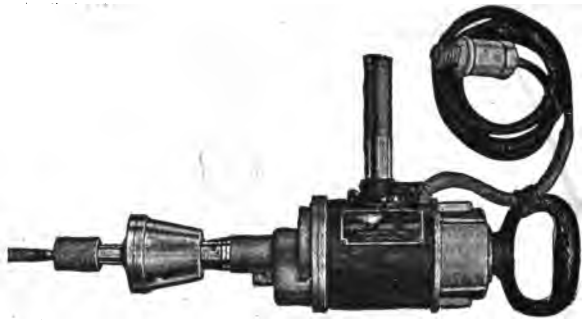


Fig. 7,929.—U. S. electric tool driver designed for driving wood screws. The large size tool may be used for driving large screws or tightening up nuts and bolts, using a socket wrench. ***In operation,*** when a screw has been driven as far as desired, the screw driver bit remains stationary, motor still revolves, this being accomplished by a friction clutch with spring release which forms a part of the tool.

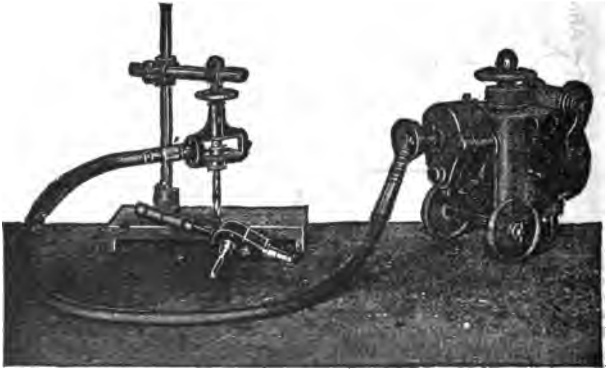
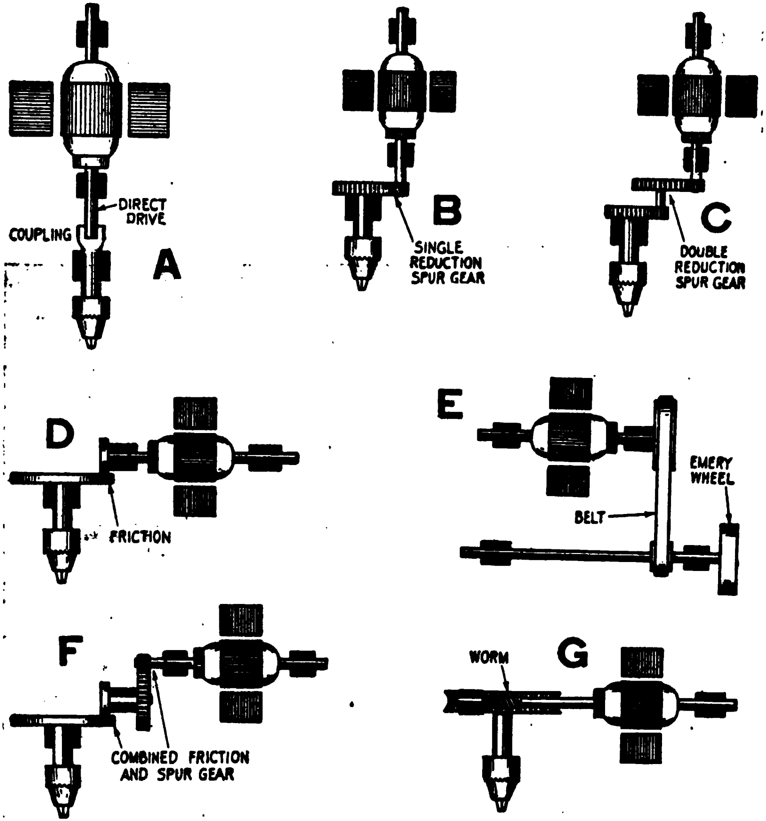


Fig. 7,930.—Stow combination of flexible shaft and enclosed multi-speed *d.c.* motor.

The Transmission.—The term transmission here means *the mechanism between the motor and the tool shaft through which the power is applied.* Its object is to "transmit" the power of the motor to the tool shaft altering if necessary the velocity of these parts in any desired ratio to properly perform the work.



Figs. 7,931 to 7,937.—Various electric rotary tool transmissions. **A,** direct drive; **B,** single reduction spur gear; **C,** double reduction spur gear; **D,** friction; **E,** belt; **F,** combined friction and spur gear; **G,** worm gear.

Fig. 7,938.—Electro electric ***direct drive*** drill adapted to light high speed work such as light wood drilling in preparation for screws, piano, cabinet and furniture work, also small holes in the softer metals. Speed 8,000 *r.p.m.*; universal motor for either *d.c.* or *a.c.*

As the speed of a motor or turbine must be very high to develop a given power, because of the weakness of the torque, it must be evident that some form of gearing is necessary between the motor or turbine and the tool shaft to slow down the speed of the latter so as to develop sufficient torque to perform the required operation, except in the case of very light duty operations, such as light duty drills.

Accordingly transmissions may be classed:

1. With respect to the relative movements of motor and tool shaft, as:

- *a* Direct drive
- *b* Single reduction
- *c* Double reduction
  - gears
  - belt
- *d* Worm
- *e* Friction
- Combined gear and friction.

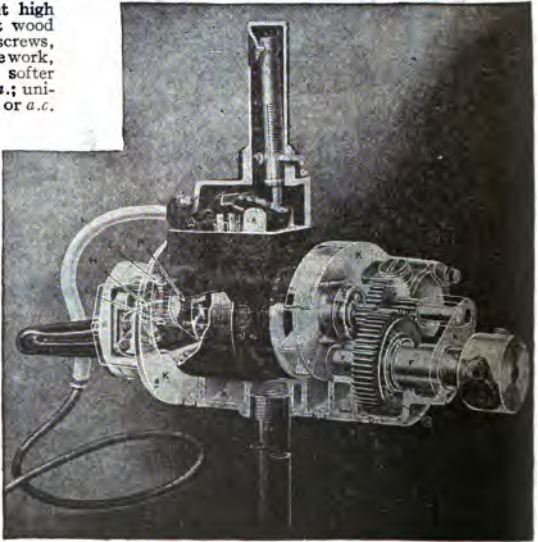
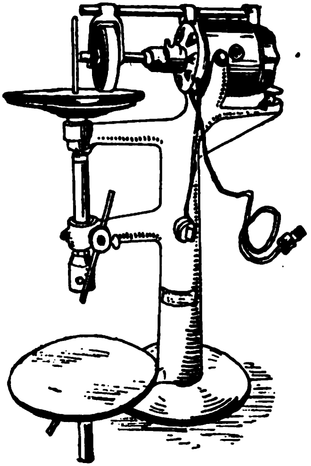


Fig. 7,939.—Van Dorn electric drill with double reduction spur gear transmission. ***The parts are:*** A, cable connection; B, switch; C, armature bearings; D, gear case; E, bearings; F, drive spindle; G, drive spindle thrust; H, brushes; I, commutator; J, motor; K, casing; L, side handle.



2. With respect to the direction of rotation, as:

- *a* Non-reversible
- *b* Reversible

The direct drive is suitable for light wood drilling, in preparation for screws, piano, cabinet and furniture work, also for drilling small holes in the softer metals.

A single or double reduction gear may be interposed between the driver and driven shafts according to the desired degree of speed reduction, adapting the machine respectively to medium or heavy duty work.

Fig. 7,940.—U. S. friction drive electric bench drill for drilling and light tapping.

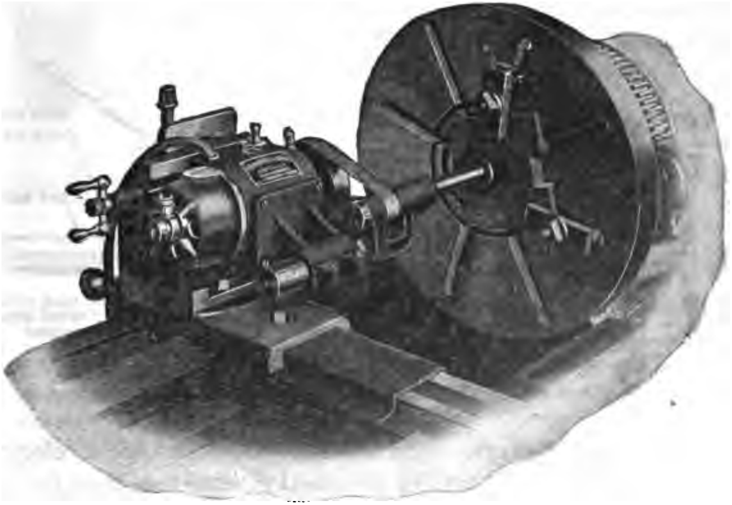


Fig. 7,941.—U. S. combination grinder on a lathe, set for *internal grinding operations.* The grinder can be raised, lowered or swivelled to any angle.

Where a very high degree of speed reduction is required, as in a combination of high speed motor and slow speed tool shaft, a worm gear transmission is desirable, however, with worm gearing the motor shaft and tool shaft must be at right angles to each other; this may or may not be objectionable, depending upon the service required.

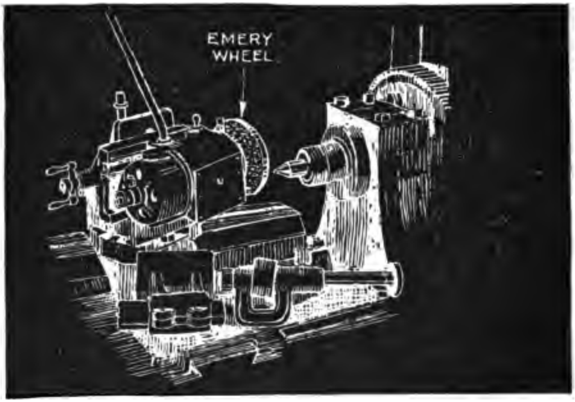


Fig. 7,942.—U. S. combination grinder with internal grinding attachment taken off and every wheel put on in place of pulley for ***external grinding operation.***

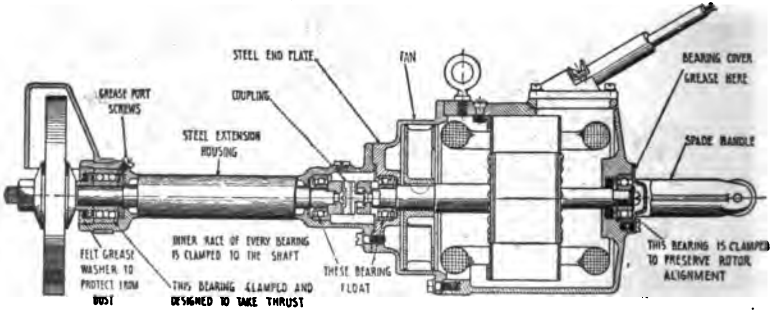


Fig. 7,943.—Van Dom direct drive electric grinder; sectional view showing construction.

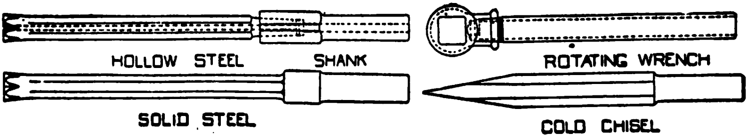
Drills and Grinders.—The present widespread use of electric tools is no less notable for the increased general use, than for the many important variations of applications.

FIG. 7,944.—Chicago "Little Giant" electric hammer drill with universal motor adapted to concrete and soft stone, also for light chipping of metals. *In operation,* the hammer blow which is delivered by a piston on the dull steel or chisel, is produced by pneumatic impact and is very effective. At the instant the blow is struck, the piston is running free of all mechanical parts, and hence no shock or vibration is transmitted to the electrical parts of the tool. There is a live air device for cleaning hole of powdered cuttings when drilling in downward direction.

Drills, formerly, were thought to be valuable only for drilling; grinders found little use outside of foundries. New uses for these tools are frequently being discovered, many effecting great economy in production, maintenance, or construction methods.

The use of a drill for screwing insulator holders into cross arms is a typical example. Notable among the varied applications of grinders is rail grinding on railroad track work.

Hammers.—There are many operations such as chipping, caulking, tube beating, light rivetting, etc., that can be performed by a motor driven hammer with considerable saving of labor.



FIGS. 7,945 to 7,948.—Steels for Chicago hammer drill.

These hammers can be obtained in various types, so designed that the blows delivered per minute range from a few hundred heavy blows to 3,000 or more light blows adapting them to all kinds of uses. An important feature in hammer designs, is a provision against it being overworked, that is, it is so constructed that the strength of blow is constant.

In the electric drive a simple magnetic cushion is interposed between the hammer element and the motor, which prevents excessive vibration and breakage.

FIG. 7,949.—Slow adjustable flexible grinder for use in foundries and steel working industries. The motor shaft combination is mounted on a truck making it easily transportable to any part of the shop, eliminating the necessity of taking the work to the tool, thus saving time and cutting cost. By means of the swivel suspension the work can be carried on over an extensive area.

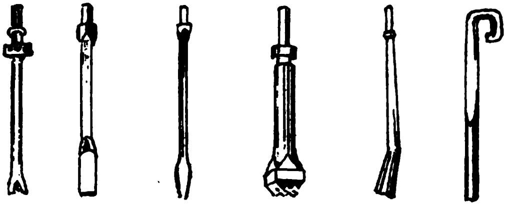
The pneumatic drive lends itself to hammers of the long stroke type which are well adapted to bridge, structural, and boiler rivetting being regularly designed for driving hot rivets of sizes ranging from ¼ to ⅞ in. in diameter.

Hammer Steels.—The efficiency of hammers is due to the number of blows struck per minute. These blows are comparatively light and the action in drilling is a crumbling or very minute chipping process.

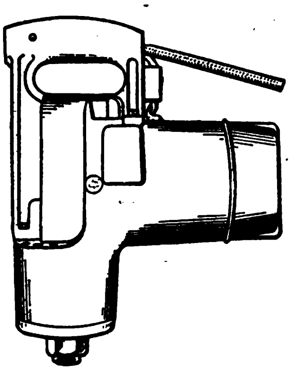
For this reason the type of drills selected depends largely on the nature of the material to be drilled.

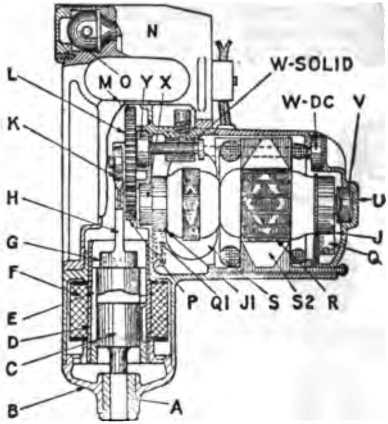
Star drills are recommended for ordinary drilling in concrete, ordinary brick, soft lime and Bedford stone.

Diamond drills used in hard rocks, granite, marble, vitrified brick and hard concrete. These are single point drills and may be used satisfactorily in places where the hammer does not drive the steel into the material so far that it is difficult to turn it. It is more difficult to drill a true hole with a diamond drill than with a star drill, unless care be taken to rotate the tool rather rapidly at the start, giving it a full ¾ swing.



FIGS. 7,950 to 7,955.—Various Electro hammer steels. Fig. 7,950, hollow drill; fig. 7,951, chisel; fig. 7,952, bull point; fig. 7,953, bush hammer; fig. 7,954, channelling tool; fig. 7,955, wrench.





Figs. 7,956 and 7,957.—Exterior and sectional views of Electro hammer. The control is by a switch mounted in the handle. A simple magnetic cushion is placed between the hammer element and motor to prevent excessive vibration and breakage. The strength of blow is constant.

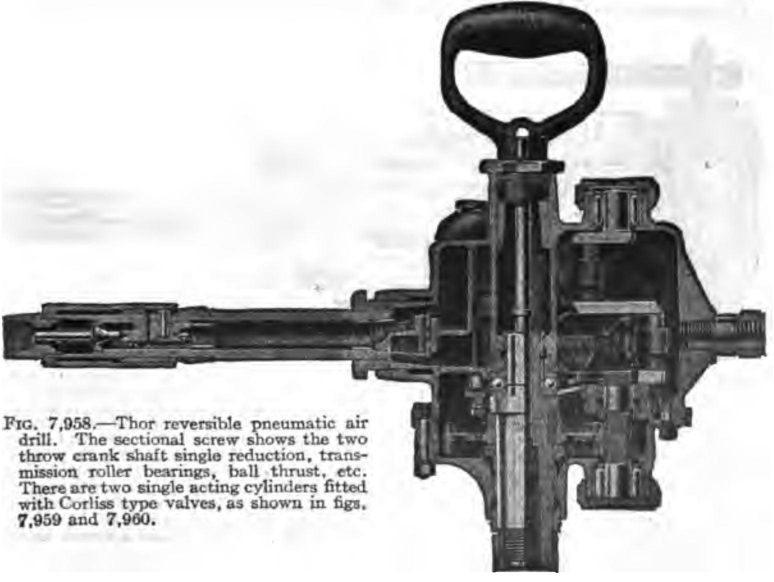
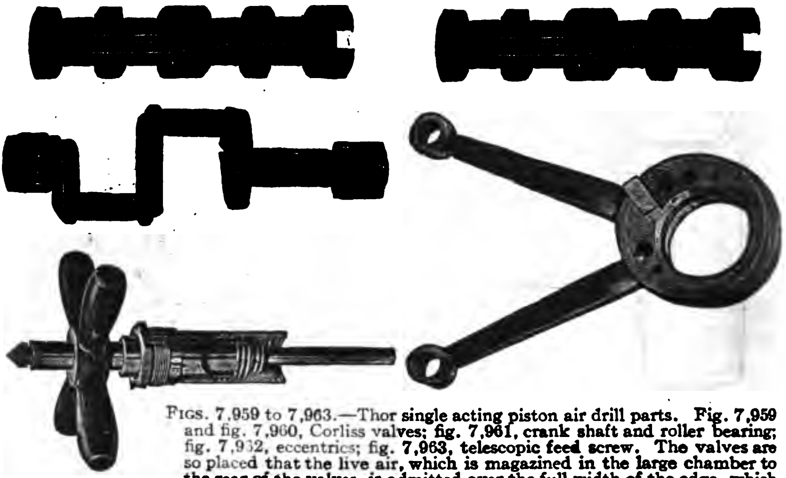


Fig. 7,958.—Thor reversible pneumatic air drill. The sectional screw shows the two throw crank shaft single reduction, transmission roller bearings, ball thrust, etc. There are two single acting cylinders fitted with Corliss type valves, as shown in figs. **7,959** and **7,960.**



FIGS. 7,959 to 7,963.—Thor single acting piston air drill parts. Fig. 7,959 and fig. 7,960, Corliss valves; fig. 7,961, crank shaft and roller bearing; fig. 7,962, eccentrics; fig. 7,963, telescopic feed screw. The valves are so placed that the live air, which is magazined in the large chamber to the rear of the valves, is admitted over the full width of the edge, which is a distance of but the thickness of the valve bushing and cylinder wall from the piston. The exhaust slots cut into the hollow valve allows the air to be exhausted into the atmosphere.

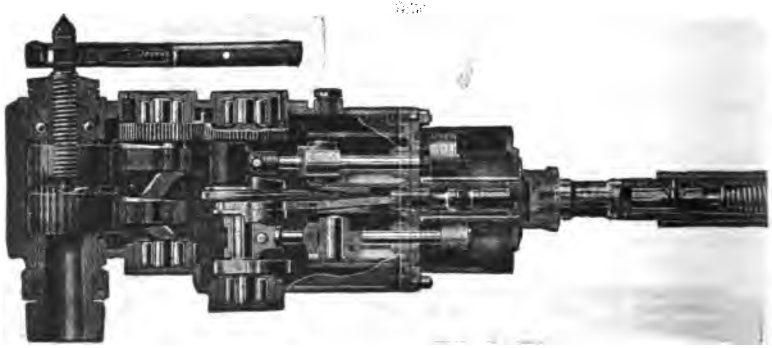


FIG. 7,964.—Thor close quarter double acting piston air drill, with piston valves. *In construction and operation:* There are two double acting cylinders, with valves located between the cylinders. Air is taken in centrally between the cylinders and there is as little clearance as possible. Geared to the crank shaft is another two throw crank diametrically opposed. This crank operates directly on two oscillating levers centered on the drill spindle proper and having the bearings around same. These levers are provided with pawls of practically the whole thickness of the lever. The pawls operate on ratchet teeth sunk in the spindle, the outer circumference, or point of teeth leaving ample slack for bearings of the levers. The motion of the drill spindle is continuous. The engine cranks are at an angle of 135° which allows the two pistons to pull together when the position of the levers requires the greatest power. The drill has a reversible ratchet feed and a poppet shuttle controls the speed and power.

Both star and diamond drills are made with square shanks to keep the cuttings loose in the hole and to prevent packing around the tool.

The relation of the square shank to the cutting size is important and has been established by a large amount of experience. The life of drill steels depends upon the material.

FIG. 7,965.—Thor *short stroke* pneumatic hammer for chipping, caulking and tube beading, etc. A feature is the valve mechanism. The valve block consists of two solid cylindrical parts. The exhaust passes below and above the valve.

In granite or vitrified brick frequently a drill dulls in from 2 to 5 ins. of drilling, while in soft stones the same steel will run over 60″ before it needs resharpening.

Drills of all types drill first upon the outside edges and when these edges become dull and rounded the drilling efficiency is rapidly lost.

Steels may be resharpened on a wheel, but after being touched up a few

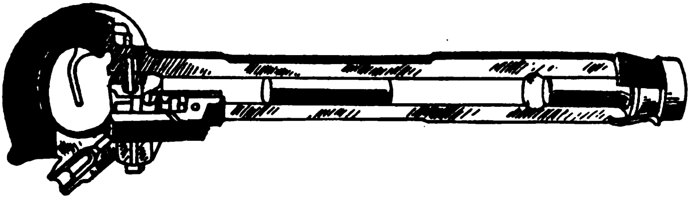


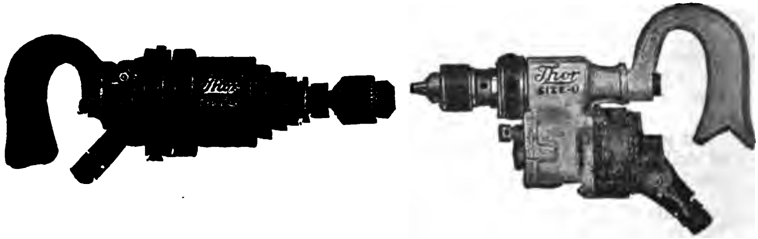
FIG. 7,966.—Thor *long stroke* pneumatic riveting hammer. The main valve lies parallel with the main bore, but is not directly operated with the air in the downward stroke. When the piston returns, it opens what is termed the auxiliary valve, the purpose of which is to admit a slight amount of air, which lightly starts the piston downward, and also supplies air for the power stroke. After short travel in the downward direction, the main valve opens and admits the full volume of air direct and very close to the piston. The piston, therefore, from a gentle start gets an extremely forceful and quick acting blow and quicker return, with practically no vibration. The throttle valve is arranged so that a light or heavy blow can be given.

times they lose their size. This is important where holes are being drilled for expansion bolts and the like. When the sizes are lost the steel may be redressed by a blacksmith and this redressing process may be repeated many times until the whole shank of the tool is used up.

Pneumatic Drive.—Compressed air is extensively employed as the power medium for motor driven tools. These tools are usually designed to operate on 80 lbs. air pressure. There are two general types of motor used:

1. Piston
2. Turbine.

They are made non-reversible or reversible, according to the requirements of the service for which they are intended.



FIGS. 7,967 and 7,968.—Thor reversible *turbine* air drills. Fig. 7,967, direct drive speed 220 *r.p.m.*, adapted to drilling in steel up to ¼ inch, and boring in wood up to ⅜ in. in diameter. These drills are intended for light drilling and are equipped with roller bearings. In the gear type two sets of drive gears are between the turbine shaft pinion and spindle. The air chamber encircles the turbine, the air jets passing through the wall in diametrically opposed position have no tendency to side or end pressure. The air is cut off by pushing trigger to neutral point, and by throwing it over the neutral point the air is reversed and quickly stops spindle.

The piston or reciprocation drills have two cylinders and cranks at right angles, thus avoiding dead centers.

The turbine drive is inherently suitable for high speed work as it turns at a high rate without appreciable vibration; hence it is adapted to light duty service, as for insulated light drilling, and when sufficiently geared down heavy duty work may be performed.

On account of the free running qualities of all the parts, the spindle would continue to turn over for a long time after the pressure is cut off, but by momentarily reversing a reversible machine the moving parts are quickly brought to rest.

CHAPTER 127

Ignition

It is a good plan before tinkering for ignition (or carburetor) troubles ***to see** if there be any gasoline in the tank, and if the cock in the pipe between the tank and carbureter be turned on.*

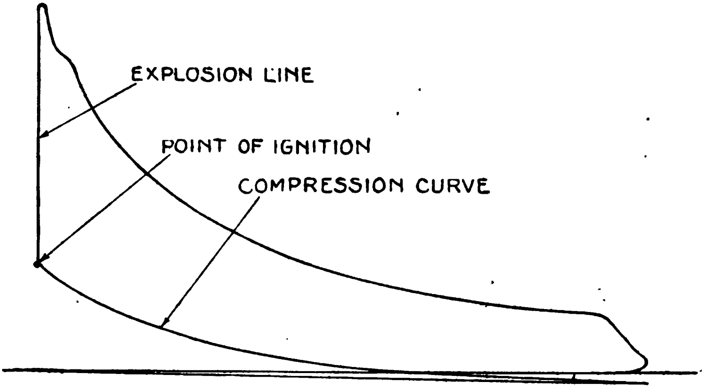
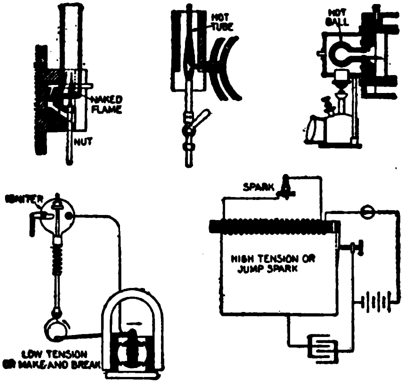


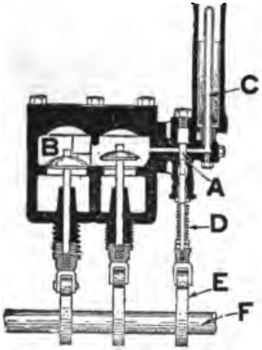
FIG. 7,969.—Indicator card for gas engine illustrating the ***"point of ignition."*** It will be noted that compression continued to the end of the stroke, before the compression curve made an abrupt change into a nearly vertical line, the point of ignition, that is, the piston position at the instant of the spark, the nearly vertical "explosion" line with the high peak coming almost to a point, denotes a strong mixture and a quick explosion.

Point of Ignition.—The "timing" or selection of the point of the stroke at which ignition shall take place is an important factor in the application of any method.

Since there is an appreciable time interval between the spark and the



FIGS. 7,970 to 7,974.—Various methods of ignition. Numerous devices have been tried to fire the charge in gas engines. In the early days, a flame behind a shutter was used, the latter being opened at the proper moment (fig. 7,970). Sometimes the flame was blown out by a too violent explosion so this method gave way to a porcelain tube that was kept at white heat by an interior flame (fig. 7,971). Tube being subject to breakage, spongy platinum, heated by compression, was next tried and found to work, if not too moist from watery vapor in the gas mixture, or if the engine speed were not too high. Another method consists in heating a spherical projection (hot ball) of the cylinder head (fig. 7,972). Electricity is now universally used. Hence, in order to gain an understanding of ignition principles, it is necessary to have at least an elementary knowledge of electricity. Figs. 7,973 and 7,974 show ***make and break*** and jump spark methods of electric ignition.



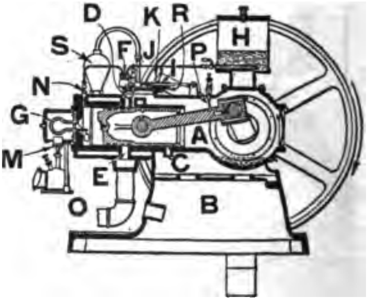


FIG. 7,975.—Hot tube ignition. ***In construction,*** a valve A, commonly called the timing valve, is provided, and which is interposed between the admission valve chamber B (communicating with the clearance space of the cylinder) and the interior of the hot tube C. This valve is normally held closed by the spring D. When the piston reaches its inner dead point at the end of the compression stroke, a cam E, on the secondary shaft, opens the valve and allows a portion of the compressed charge to pass into the hot tube where it ignites. The timing valve is held open throughout the power and exhaust strokes, thus permitting the products of combustion to be carried out of the tube with the exhaust.

FIG. 7,976.—Meitz and Weiss two cycle oil engine with hot ball igniter. ***In operation*** the charge is automatically ignited on the compression stroke by contact with the heated walls of the hollow igniter ball G. ***Before starting,*** the igniter ball is heated for a few minutes by a small oil burner M. The oil jet from the injection nozzle N, strikes the projection O, extending from the igniter ball and is sprayed, vaporized and mixed with the air and steam in the compression space. The igniter ball is maintained at a dull red heat by the heat of the explosions. A, crank chamber; B, base; C,D, ports; E, exhaust put; F, pump; G, igniter ball; H, resevoir; I, plunger guide; J, dome pipe; K, pin; M, oil burner; N, injection nozzle; O, projection; P, projecting tube; R, pump plate; S, dome.

maximum pressure of combustion, it is clear that the spark should occur earlier for an engine running at high speed than for one running at low speed. ***In general*** the *spark should be* ***advanced*** *as much as possible, consistent with smooth running and economy,* ***in order that*** *the temperature at release, or when exhaust begins, should not be high enough to injure the exhaust valves.*

Methods of Ignition.—The charge in the cylinder of a gas engine may be ignited in several ways, as

1. By means of a naked flame;

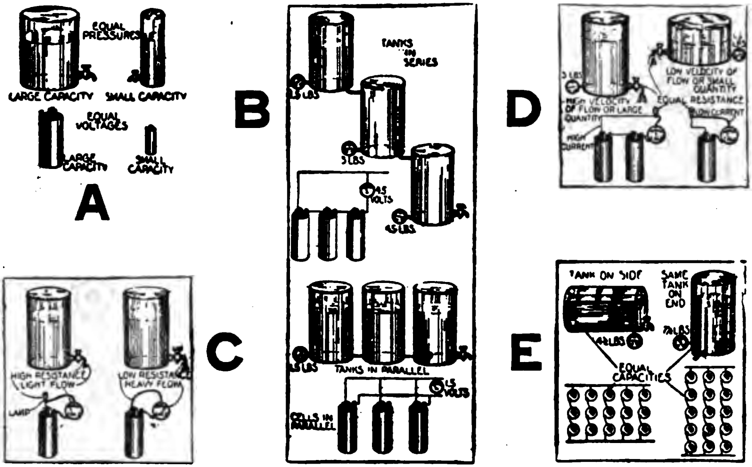
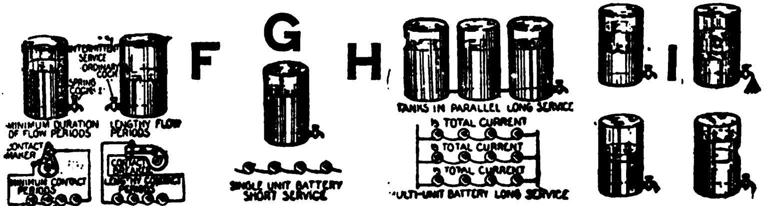


FIG. 7,977 to 7,981.—***Hydraulic analogies:*** Figs. **A**, *capacity;* figs. **B**, *pressure;* figs. **C**, *resistance;* figs. **D**, *current;* figs. **E**, equal capacities at different pressures.



FIGS. 7,982 to 7,985.—Hydraulic analogies. Figs. **F**, *useful service;* figs. **G**, series coonection; figs, **H**, *parallel connection;* figs. **I**, *recuperation.*

2. By means of a highly heated metallic surface;
3. By an electric spark,
4. By the heat of very high compression.

The naked flame is practically obsolete, and the hot surface or hot tube is used to a very limited extent, except in the case of some types of oil engine. Many builders of standard engine, however, are prepared to furnish hot tube ignition. ***Electric ignition is now the prevailing method.***

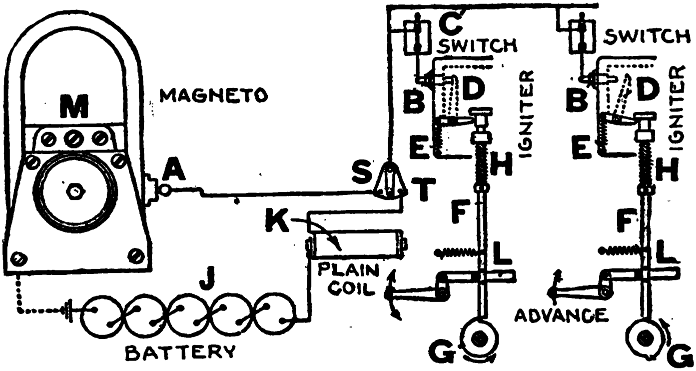
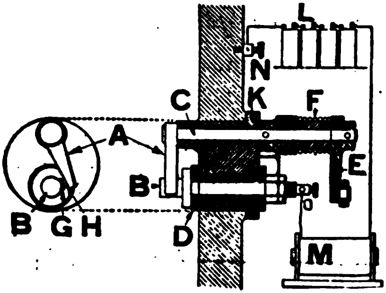


Fig. 7,986.—Low tension or make and break ignition. ***In starting, say on the battery***, the arm of the two way switch is turned upon point T. The movable electrode D, of the first cylinder being in contact with the insulated electrode B, by the spring E, the current will flow from the battery J, through the coil K, thence through the two way switch and the single throw switch to the insulated electrode B. The movable electrode D, being in contact with the insulated electrode B, the current returns to the battery through D and the metal of the engine, thus completing the circuit. As the cam G, revolves in the direction indicated by the arrow, its nose passes from under the lower end of F, the latter drops with great rapidity by the action of spring H, and in so doing a shoulder at the upper end of F, strikes the external arm of D, a blow causing the contact point of D, to be ***quickly snapped*** apart from B, producing an arc which ignites the charge. This cycle of operations is repeated by the ignition mechanism of each cylinder in rotation.

Low Tension or "Make and Break" Ignition.—In this system there is a device known as an ***igniter***, *placed in the combustion space of the engine cylinder*.

This consists of two electrodes, one of which is stationary and the other movable. The stationary electrode is insulated, while the other, having an arm within the cylinder and placed conveniently near, is capable of being moved from the outside so that the arm may come in contact with the stationary electrode and be separated from the latter with great rapidity.



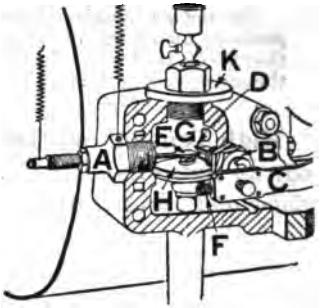
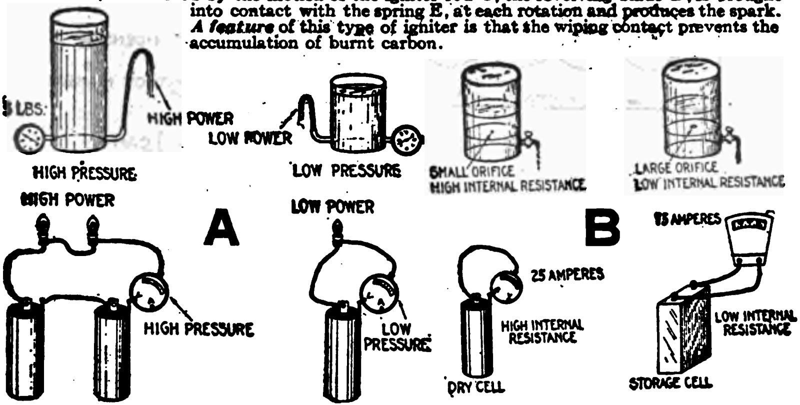


Fig. 7,987.—Hammer break igniter. ***It consists of*** two metallic terminals A and B. The terminal A, is mounted on a movable shaft C, while B, is stationary and ***insulated*** from the cylinder wall by the lava bushing D. A suitable cam rod, attached to the crank E, provides the means for rocking the terminal A, so as to bring it in contact with the terminal B, ***and then quickly separate*** the terminals to produce the spark. The helical spring F, provides a semi-flexible connection between the shaft C, and the crank E. The contact points of the two terminals are tipped with two small pieces of platinum G and H, and both terminals are mounted in the removable plug K, which is usually inserted through the wall of the cylinder head, so that the igniter points extend into the compression space of the cylinder. In the circuit is a battery L, and primary spark coil M.

Fig. 7,988.—Wipe contact igniter. ***It consists of*** two independent electrodes, the stationary electrode A, and the movable electrode B. The igniter is located in the inlet chamber G, directly over the head of the admission valve H, and either one of the electrodes can be reached for inspection or removal independently by removing the cap K. ***In operation,*** when B, is revolved by the motion of the igniter rod C, the revolving blade D, is brought into contact with the spring E, at each rotation and produces the spark. ***A feature*** of this type of igniter is that the wiping contact prevents the accumulation of burnt carbon.



Figs. 7,989 to 7,996.—Hydraulic analogies. Figs. **A,** *power;* figs. **B,** *internal resistance.*

The circuit includes a ***primary induction coil.*** Current may be derived from either a primary battery, storage battery, or low tension magneto.

The *sudden breaking of the circuit by the* ***quick*** *separation of the electrodes produces an electric arc or* ***primary spark*** caused *by the* ***inductance***—that is—by the "inertia" or tendency of the current to continue flowing after the separation of the contact points.

High Tension or "Jump Spark" Ignition.—In this method, *an automatic device is placed in the primary circuit, which closes and opens it at the time a spark is required.*

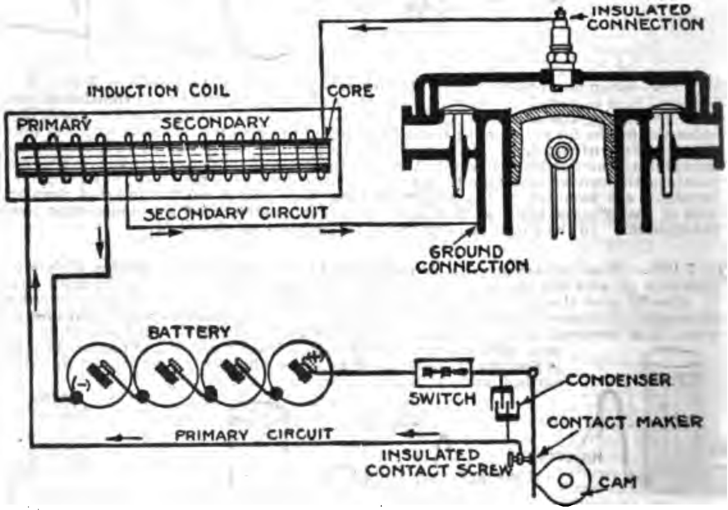


FIG. 7,997.—High tension or jump spark ignition. ***In operation,*** the nose of the cam in revolving engages the contact maker which completes the primary circuit and allows current to flow from the battery through the primary winding of the coil; this magnetizes the core. The primary circuit is now broken by the action of the cam and magnetic changes take place in the coil which induce a momentary high tension current in the secondary circuit. The great pressure of this current forces it across the air gap of the spark plug and as it bridges the gap a spark is produced. The arrows indicate the paths of the currents. At break, the primary current is "slowed down" by the condenser, thus preventing an arc between contact breaker contacts.

When the circuit is closed, the primary current flows through the primary winding of the coil and causes a secondary current to be induced in the secondary winding. A spark plug being included in the secondary circuit, opposes the flow of the current by the high resistance of its air gap. Since

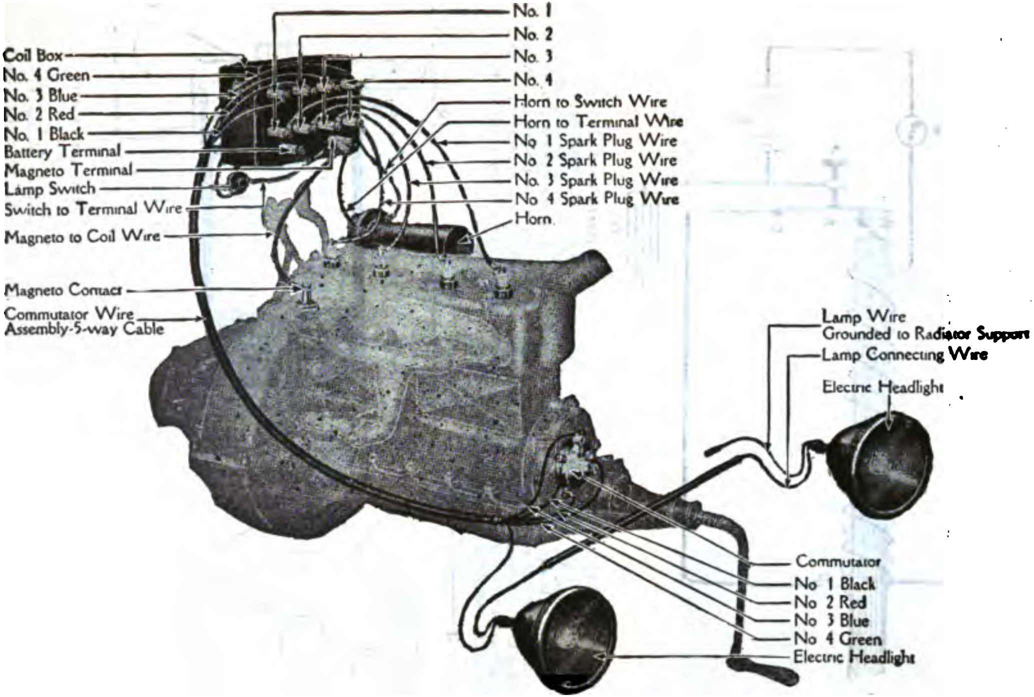


FIG. 7,998.—Wiring of Ford, horn, ignition and lighting systems showing commutator, spark coils, etc. The engine is started with current from storage battery and operated with the magneto, the latter being built onto the fly wheel.

the pressure of the secondary current is sufficient to overcome this resistance, it flows or "jumps" across the gap, and in so doing, intense heat is produced, resulting in a spark.

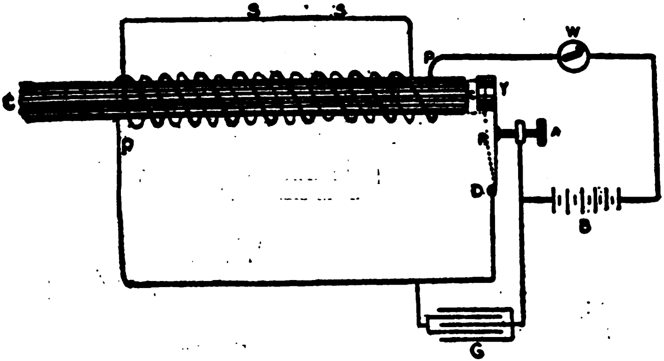
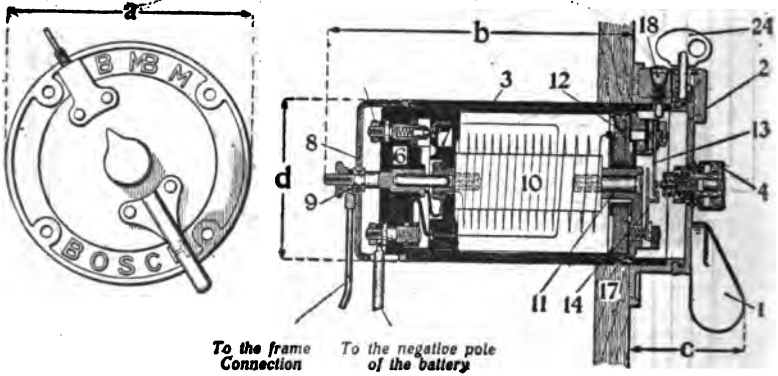


FIG. 7,999.—Secondary vibrator type induction coil. ***The parts are:*** A, contact screw; B, battery; C, core; D, vibrator terminal; G, condenser; P, primary winding; S, secondary winding; W, switch; Y, vibrator. ***In operation,*** when the switch is closed, the following cycle of action takes place: ***a,*** *the primary current flows and magnetizes core;* ***b,*** *magnetized core attracts the vibrator and breaks primary circuit;* ***c,*** *the magnetism vanishes, inducing a momentary high tension current in the secondary winding, producing a spark at the air gap;* ***d,*** *magnetic attraction of the core having ceased, vibrator spring re-establishes contact;* ***e,*** *primary circuit is again completed and the cycle begins anew.*



FIGS. 8,000 and 8,001.—Bosch type C horizontal secondary coil. ***The parts are:*** 1, switch handle; 2, movable cover; 3, coil housing; 4, starting press button; 6, fixed connection plate; 7, movable switch plate; 8, cable cover; 9, milled edged nut; 10, iron core; 11, plate carrying the starting arrangement and the condenser; 12, condenser; 13, contact spring; 14, vibrator; 15-16, auxiliary contact breaker; 17, vibrator spring; 18, stop screw for switch handle; 24, locking key.

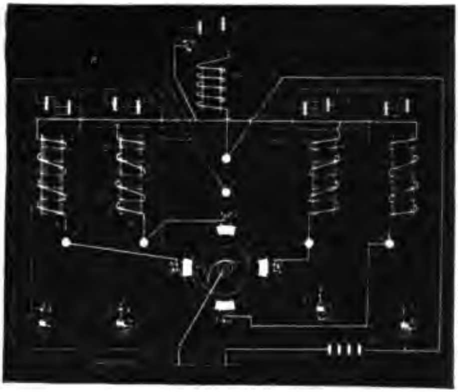
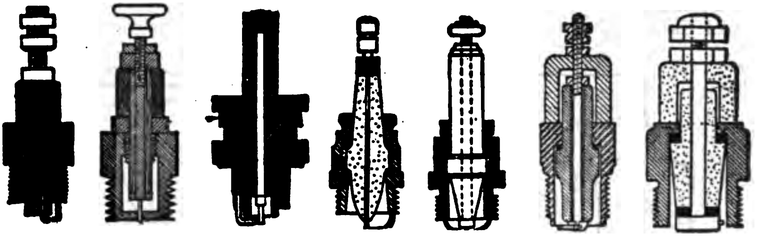
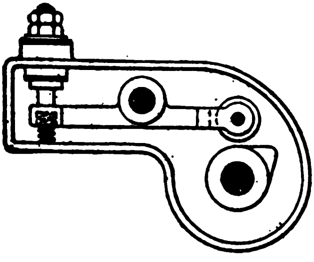


Fig. 8,002.—Circuit diagram of a master vibrator coil. B, is the battery; C, the unit coils; C1, C2, etc., the condensers; P, the primary windings and S, the secondary windings; H1, H2, etc., the spark plugs; T, the timer; MP, the master primary; V, the vibrator; W, the common primary connection; 1, 2, etc., the stationary contacts of the timer.



Figs. 8,003 to 8,009.—Sections of well known spark plugs. The first five have procelain insulation; the last two, mica.



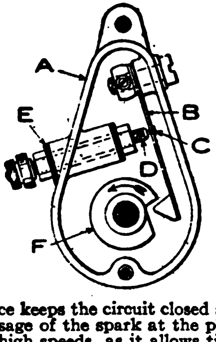


Fig. 8,010. — Contact maker and mechanical vibrator. ***In operation,*** as cam F, the weight on the end of blade, B, drops into the recess no the cam causing the blade to vibrate and make a number of contacts with D, thus producing a series of sparks when in operation.

Fig. 8,011.—Contact breaker. This device keeps the circuit closed at all times except during the brief interval necessary for the passage of the spark at the plug points. It is used to advantage on engines running at very high speeds, as it allows time for the magnetic flux in the core of the coil to attain a density sufficient to produce a good spark.

A form of high tension ignition called *synchronous ignition*, employs a *distributer* and a single coil for the several cylinders of a multi-cylinder engine.

Magnetos.—There are many types of magneto in use for ignition. They may be classified,

1. With respect to the armature, as
   - *a*. Stationary;
   - *b*. Oscillating;
   - *c*. Rotating.
2. With respect to the kind of current generated, as
   - *a*. Low tension;
   - *b*. So-called high tension
     - **with separate coil;**
     - **with self-contained coil.**
   - *c*. True high tension.

Inductor Magnetos.—In this class of magneto, ***the armature is fixed*** so that it does not revolve and is located with the sector shaped heads of the core at right angles to the line joining the field poles. This position of the core furnishes the least magnetically conducting path. An annular

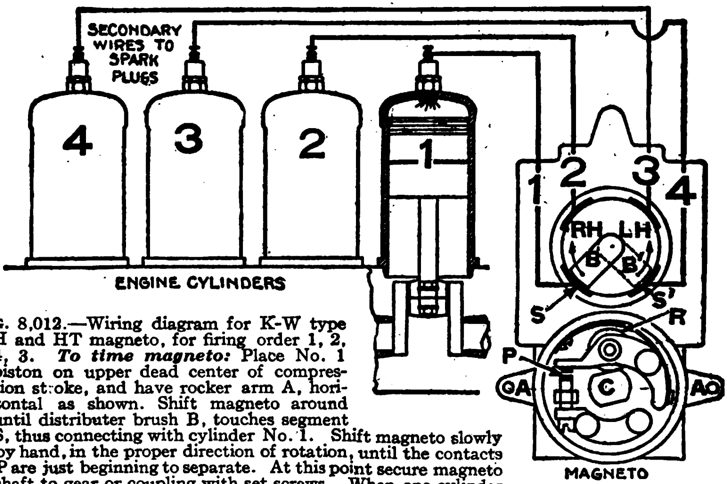
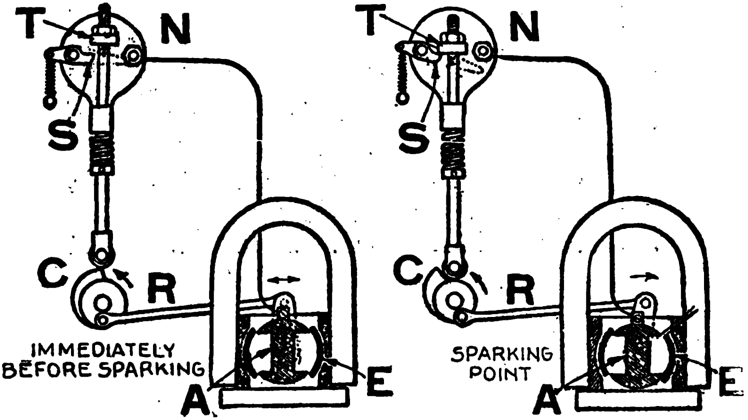


FIG. 8,012.—Wiring diagram for K-W type H and HT magneto, for firing order 1, 2, 4, 3. ***To time magneto:*** Place No. 1 piston on upper dead center of compression stroke, and have rocker arm A, horizontal as shown. Shift magneto around until distributer brush B, touches segment S, thus connecting with cylinder No. 1. Shift magneto slowly by hand, in the proper direction of rotation, until the contacts P are just beginning to separate. At this point secure magneto shaft to gear or coupling with set screws. When one cylinder is timed, proceed to connect the others as follows: Ascertain the firing order of the engine, then crank engine slowly and connect plug cable from next cylinder that fires to distributer segment No. 2 and so on until all the plug cables are connected. The secondary connections on the hard rubber distributer block are numbered in consecutive order, 1, 2, 3, 4. etc. These numbers do not refer to the engine cylinders, and it is necessary to determine the order in which the cylinders fire and connect secondary cables accordingly.

space between the armature and the field poles is provided for the rotation of an *inductor*.

The magnetic condition of the armature core depends entirely upon the position of the inductor. The latter is arranged, 1, to revolve continuously with a gear drive from the engine, or 2, to rotate to and fro through a small arc by link connection to the half time shaft.

Low Tension Magnetos.—Generators of this class may be used to supply a current of low voltage for, 1, make and break ignition or for, 2, high tension ignition with induction coils or coil spark plugs. A low tension magneto has an armature winding consisting of about 150 to 200 turns of fairly thick wire, covered with a double layer of insulating material.



FIGS. 8,013 and 8,014.—Low tension ignition with inductor magneto. *In operation,* the cam C, on the half time shaft, makes a contact just before sparking, and immediately breaks it again by permitting the hammer T, to fall on the cam S. A spark is produced at the instant of break of the ignition contacts. The winding of the armature A, has one end grounded through the base of the magneto, the current returning through the engine to the point S; the other end of the winding is led through an insulated post to the nut N, by which it is connected with a stud brought through the cylinder wall, where a wiper, indicated by dotted outline, normally rests against it by means of a spring. *In make and break ignition the quicker the break the better and spark.* which means that *the spring operating hammer T, should be amply strong.*

One end of the winding is grounded to the armature core and the other, brought to a single insulated terminal. When this terminal is connected to any metal part of the magneto or engine (since the latter is in metallic contact with the base of the magneto), the circuit is complete. The wiring therefore is very simple, which is one of the advantages of the system.

The "live end" of the armature winding is brought out by means of a metallic rod passing lengthways through the shaft of the armature; a hard rubber bushing is provided as insulation between the shaft and the rod. The live end of the winding is located at one end of the armature shaft.

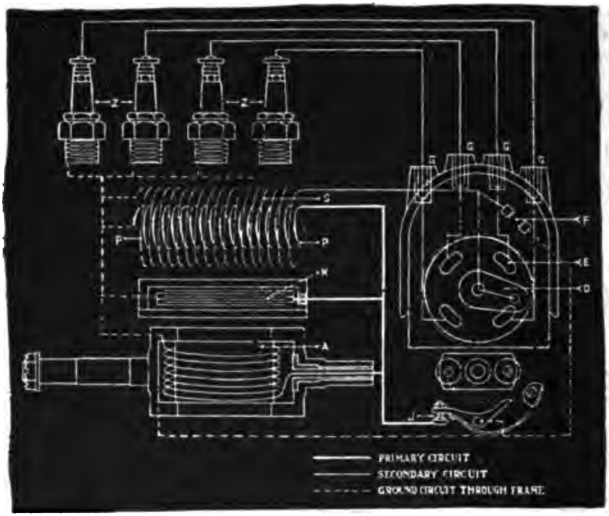


FIG. 8,015.—Circuit diagram of a magneto with self contained coil. A is the armature winding; P, primary of transformer; S, secondary of transformer; D, distributing brush carrier; E, contact segments; F, safety spark gap; G, terminals to plugs; U, interrupter; Z, spark plugs. ***In operation,*** alternating current flows from the armature having two points of maximum pressure in each armature revolution. As the current leaves the armature, it is offered two paths: 1, the shorter through the interrupter U to the ground, and 2, the longer through the primary P of the induction coil to the ground. A third path through the condenser K is only apparently available; it is obstructed by the refusal of the condenser to permit the passage of the current, as the condenser will merely absorb a certain amount of current at the proper moment, that is at the instant of the opening of the interrupter. The interrupter being closed the greater part of the time, allows the primary current to avail itself of the short path it offers. At the instant at which the greatest current intensity exists in the armature, the interrupter is opened mechanically so that the primary current has no choice but must take the path through the primary P of the induction coil. A certain amount of current is at this instant also absorbed by the condenser K. This sudden rush of current into the primary P of the induction coil, induces a high tension current in the secondary winding S of the coil which has sufficient pressure to bridge the air gap of the spark plug. The sharper the rush of current into the primary winding P, the more easily will the necessary intensity of current for a jump spark be induced in the secondary winding S. ***The distribution of the current*** in proper sequence to the various engine cylinders is accomplished as follows: the high tension current induced in the secondary S of the induction coil is delivered to a distributing brush carrier D that rotates in the magneto at half the speed of the crank shaft of the engine. This brush carrier slides over insulated metal segments E—there being one for each cylinder. Each of these segments E connects with one of the terminal sockets that are connected by cable with the spark plugs as shown. ***At the instant of interruption*** of the primary current, the distributing brush is in contact with one of the metal segments E and so completes a circuit to that spark plug connected with this segment. Should the circuit between the terminal G and its spark plug be broken, or the resistance of the spark plug be too great to permit a spark to jump, then the current might rise to an intensity sufficient to destroy the induction coil. To prevent this what is known as a safety spark gap is introduced. This will allow the current to rise only to a certain maximum, after which discharges will take place through this gap. ***In construction*** the spark discharges over this gap are visible through a small glass window conveniently located.

from which the current flows to an insulated terminal by means of a metal contact which is pressed against the revolving rod by a spring.

High Tension Magnetos.—These are *erroneously* divided into three classes, viz.: 1, those in which the induction secondary wiring is wound directly on the armature; 2, those having a secondary induction coil contained within the magneto; and 3, those having the coil in a separate box usually placed on the dash. Strictly speaking the first mentioned type is the only real high tension magneto. Forming part of a high tension magneto is a ***distributer*** which delivers current to the cylinders in proper sequence.

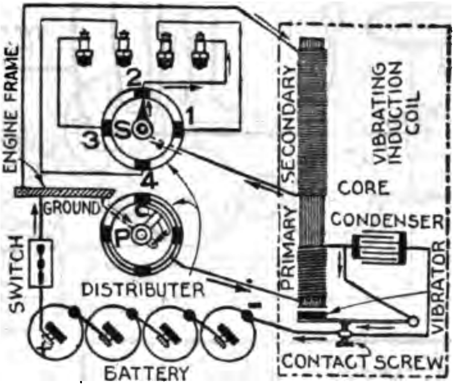


FIG. 8,016.—Synchronous high tension ignition. Here a single coil in combination with a *distributer* is used for any number of cylinders.

Synchronous Drive for Magnetos.—In order that the periods when a spark is desired shall coincide with the periods when the voltage is at or near a maximum, it is ***necessary that a magneto be driven synchronously***, that is at a speed in a definite rate to that of the engine, as otherwise the sparking periods might occur with a zero point of electrical generation, and no spark would be produced.

To meet these conditions the drive is made positive and usually consists of toothed wheel gears.

Dual Ignition.—As defined, a dual ignition system is *one having two separate current sources with* ***some parts*** *of the ignition apparatus* ***in common.***

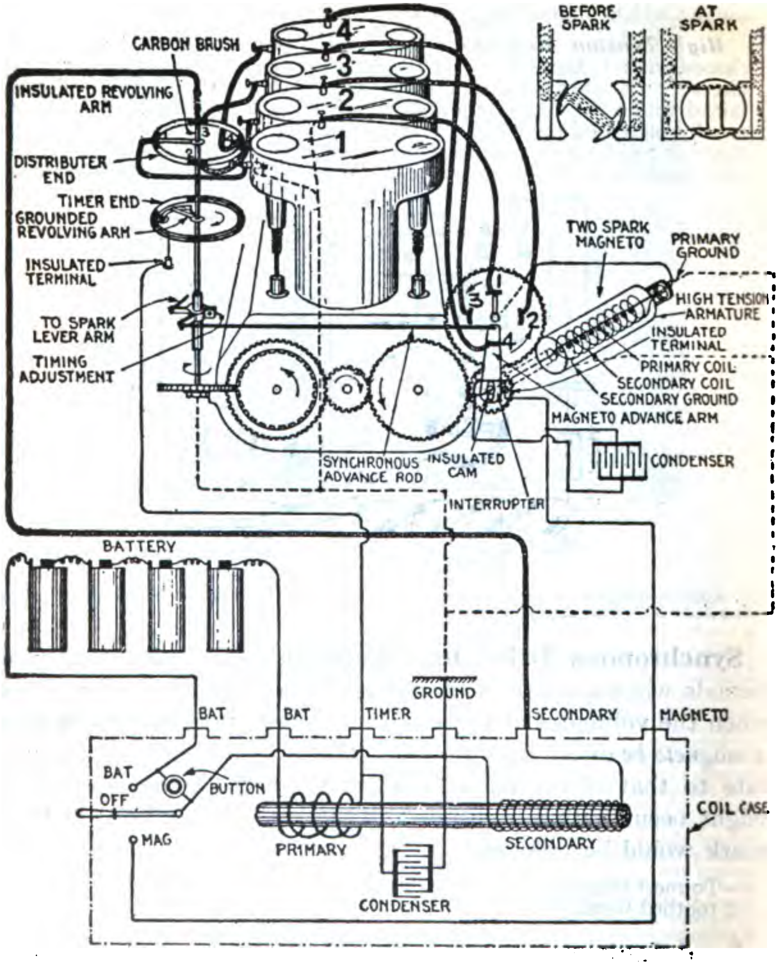


Fig. 8,017 to 8,019.—Double ignition consisting of a two spark high tension magneto system and a battery synchronous ignition system with engine driven distributer. Fig. 8,017, elementary diagram of connections; fig. 8,018, position of magneto armature just before time of spark; fig. 8,019, position of armature at time of spark.

Most magneto systems are examples of dual ignition, that is the distributer which forms a part of the magneto is used to distribute the current from either the magneto or a battery. Thus, if a short circuit occur in the armature, by turning a switch, current may be *furnished* by the battery and *distributed* by the magneto. Moreover, because of the difficulty of cranking an engine fast enough to start on the magneto, the battery is usually used for starting and the magneto for running.

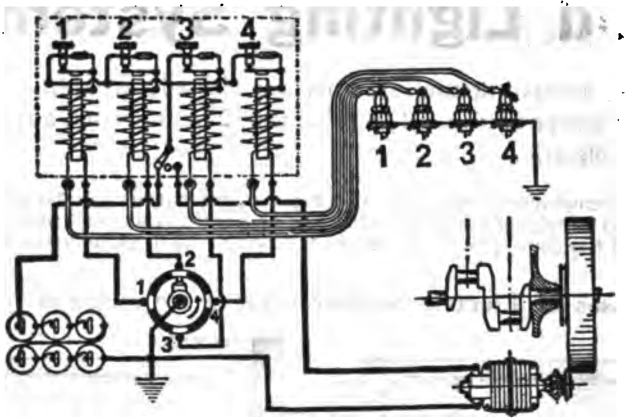


FIG. 8,020.—Dual jump spark ignition for a four cylinder four cycle engine. Current is supplied by the battery when the switch is in the position shown in the figure. By turning the switch to the right, a current from the magneto will be furnished. **Operation** with the battery in the circuit and the timer in the position shown, current flows from the positive terminal of the battery, to the switch, thence, to the contact screw of coil number two. From here, it flows through the vibrator blade, primary winding of the coil timer and the metal of the engine, and returns to the battery. The primary circuit is alternately opened and closed with great rapidity by the vibrator so long as the rotor of the timer is in contact with terminal 2. During this interval, a series of high tension current is induced in the secondary circuit producing a series of spark. The current which flows through the secondary winding is in a direction opposite to that of the primary current. At each interruption of the primary current, an induced high tension current flows through the secondary winding, to the spark plug, across the gap, producing a spark and returns through the metal of the engine, timer, and back to the coil.

Double Ignition.—An extreme provision against failure in operation consists in ***providing** two entirely independent ignition systems*.

For some installations both make and break and jump spark systems are provided, in others, two high tension systems.

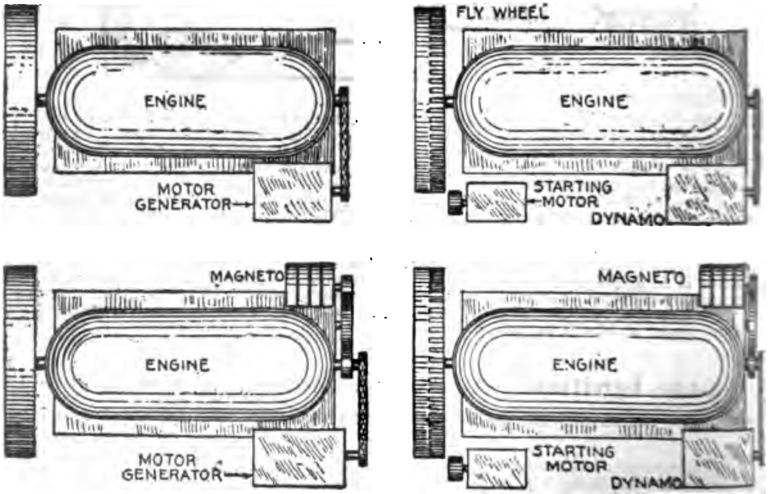
CHAPTER 128

Auto Starters and Lighting Systems

The various starting systems are classed, according to the kind of power used, as: 1, mechanical; 2, compressed air; 3, gas; and 4, electric.

The employment of electricity for gas engine starters has the advantage of also supplying current for lighting and ignition as well, and this has led to the development of systems involving various combinations.

Classes of Electric Starter.—There are numerous electric



FIGS. 8,021 to 8,024.—Classes of starter systems. Fig. 8,021, one unit system; fig. 8,022, two unit system; fig. 8,023 so called two unit system; fig. 8,024, so called three unit system.

starting systems, and they may be classified according to the methods of obtaining current for starting and ignition, and the power element of the starter, as:

1. One unit systems; 2. Two unit systems;
3. Three unit systems.

These several systems comprise respectively: 1. A motor-dynamo; 2. A motor and a dynamo; 3. A motor, a dynamo, and magneto all separate.

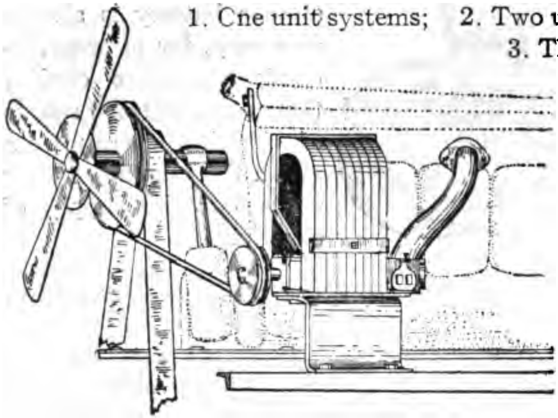
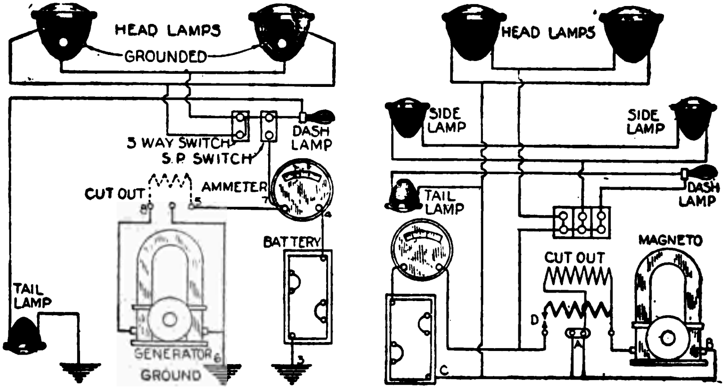


Fig. 8,025.—Holzer-Cabot lighting magneto as installed on model T Ford car. A 60 ampere hour storage battery, if fully charged, will operate the side and tail lamps (6 candle power total) for approximately 50 hours, or the head and tail lamps (34 candle power) for approximately 10 hours. Turn off head lights when car is standing.



Figs. 8,026 and 8,027.—Holzer-Cabot lighting magneto outfit installation. Fig. 8,026, one wire system as applied to double bulb or turn down head lamps: fig. 8,027, two wire system, suitable also as a general guide for motor boat wiring.

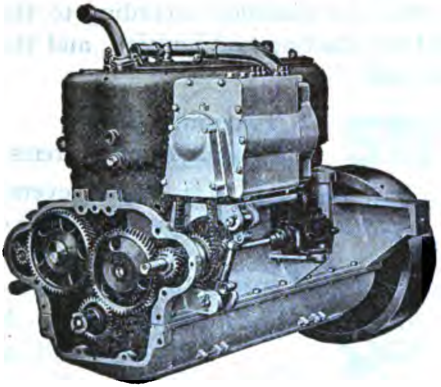


Fig. 8,028.—Entz single unit starting and lighting system; view showing mounting of motor dynamo on engine and silent chain drive.

Electric Starters Require a Storage Battery.—In any electric system a storage battery is always necessary, for in order, to crank a gasoline engine, there must be some source of electrical energy from which the cranking motor may draw its supply of electricity.

Without it there would be no electric cranking devices. The first function, therefore, which the storage battery serves is to supply electricity for starting purposes, it being charged by a dynamo driven by the engine.

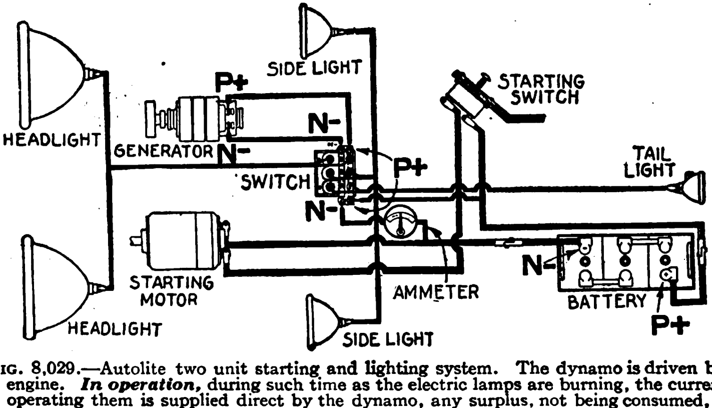


Fig. 8,029.—Autolite two unit starting and lighting system. The dynamo is driven by the engine. *In operation,* during such time as the electric lamps are burning, the current for operating them is supplied direct by the dynamo, any surplus, not being consumed, being stored in the battery. When the engine is running in the day time and no current is being consumed by the lamps, the entire amount of current being produced is being stored in the battery. The dynamo has a speed governor contained in a drum that is a part of the drive. A reverse current circuit breaker is placed between the dynamo and battery to break the circuit when the battery pressure exceeds that of the dynamo. The circuit breaker is housed between the magnets of the dynamo and is a part thereof. An ammeter reading in both directions for zero is mounted on the dash. The capacity of battery is 120 ampere hours.

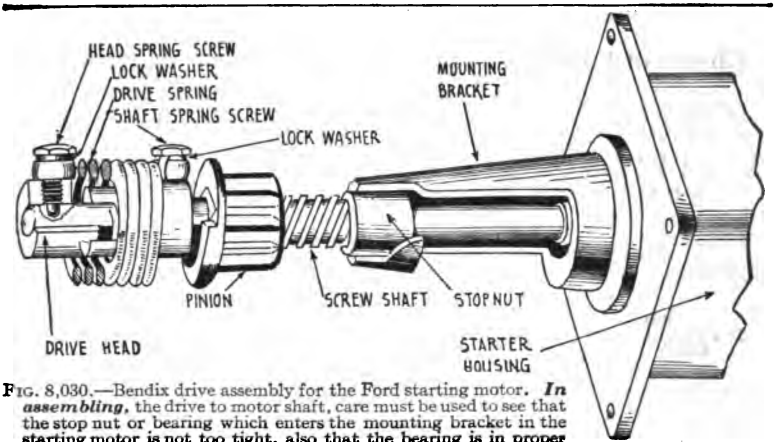
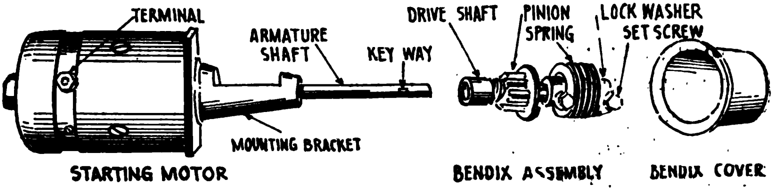
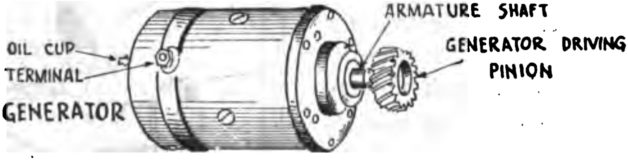


FIG. 8,030.—Bendix drive assembly for the Ford starting motor. *In assembling,* the drive to motor shaft, care must be used to see that the stop nut or bearing which enters the mounting bracket in the starting motor is not too tight, also that the bearing is in proper alignment with the bracket. The bearing should be oiled and then fitted so that it can be turned readily with the fingers. If the bearing be too tight, it should be dressed down with an oil stone. Too tight a fit will cause the bearing to freeze to the bracket, resulting in serious damage to the starter.





FIGS. 8,031 to 8,034.—Starter and dynamo assembly. *To remove dynamo,* first take out the three cap screws holding it to the front end cover and by placing the point of a screw driver between the dynamo and front end cover, the dynamo may be forced off the engine assembly. Always start at the top and face dynamo backward and downward at the same time. Plates may be obtained from nearest dealer if car is to be operated with dynamo removed. *In replacing dynamo,* the drive pointer must be properly meshed with the large time gear, the bracket to which the dynamo is bolted is separate from the cylinder block and the meshing of the generator driving pinion with the large time gear can be regulated by the use of one or more paper gaskets between the bracket and the cylinder block. The bracket should rest tightly on the crank case gasket and line up with the face of the time gear case. If these gears be meshed too tightly, a humming noise will result, also the dynamo shaft will be thrown out of alignment.

Choice of Voltage.—The pressure used on the different lighting and ignition systems is six volts, and were it not for the problem of cranking, there probably would not be any reason to change.

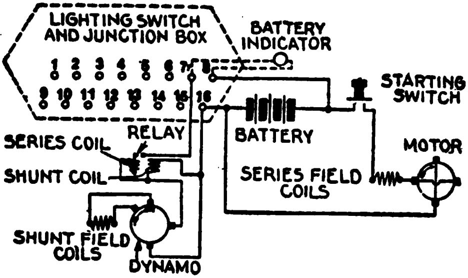


FIG. 8,035.—Wiring diagram of *Wagner* two unit starting and lighting system. The connections shown in dotted lines are put on by the automobile manufacturer, and they may or may not be correct for all cars using the *Wagner* system of starting and lighting. However, they are correct for a Studebaker car.

The advantage of low voltage is that the circuits are easily protected from electrical leakage. Low pressure lamps are manufactured with less difficulty than those designed for higher pressure.

Voltage of Units.—The weight of six volt batteries is less than that of the higher voltage type. Were it not for these considerations, starting motors would be designed for high pressure, as they are smaller and consequently lighter. High voltage for the motor does not necessarily mean high voltage for the dynamo and lights.

There are three general combinations:

1. All one voltage, either 6, 12, 16, or 18 volts;

FIG. 8,036.—Method of driving a generator direct from engine fly wheel by friction pulley with spring or cushion base; the latter relieves the stress on the shaft from excessive vibration. The governor regulates the speed of the machine and prevents burning out of the lamps. The illustration shows a K-W magneto installed on an early Maxwell car.

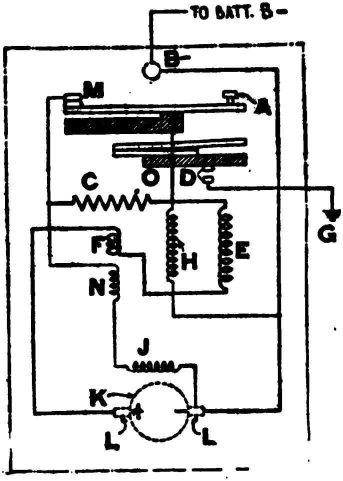
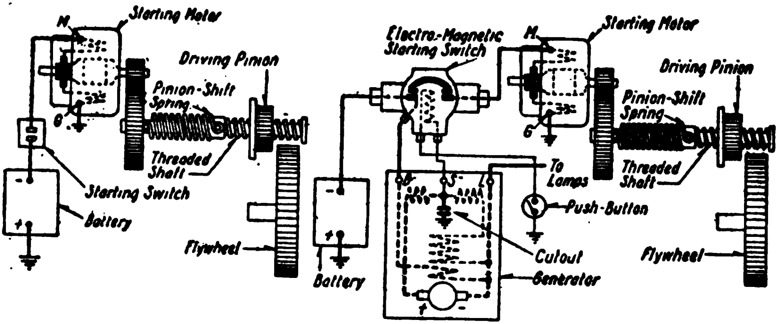
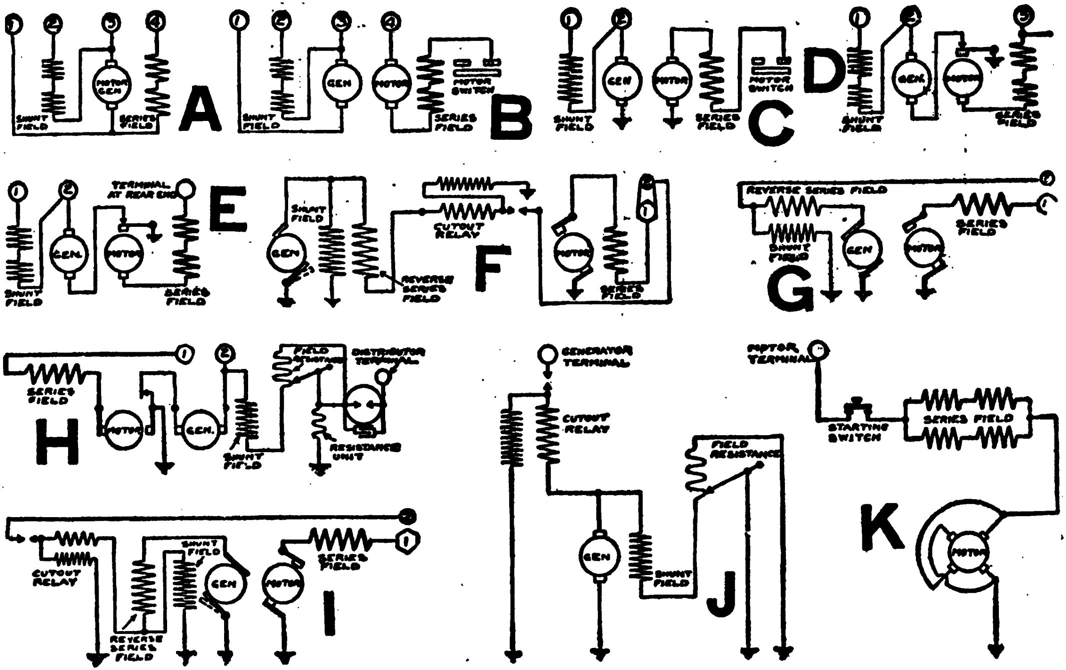


FIG. 8,037.—Diagram of connections of Westinghouse dynamo with self-contained regulator. The regulator performs two functions: 1, that of a cut out, and 2, that of a voltage regulator. Each function is performed by its individual element but the operation of the second function depends upon that of the first. When the dynamo is being operated at a speed below the predetermined "cut in" speed, the contacts of the cut out are open, and *vice versa*. The cut in speed varies from five to ten miles per hour on high gear, depending upon the gear ratio and wheel diameter of the car. ***For voltage regulation,*** the shunt fields of the dynamo are so designed that a voltage in excess of normal would be regularly generated when dynamo is operated at high speed and no load. This excess voltage is prevented and the voltage is held constant by the automatic voltage regulator. When the dynamo is operating below cut in speed, the regulator contacts are closed, and remain closed till there is a voltage in excess of the predetermined value. This voltage is fixed by the setting of the voltage regulating screw. When, due to increased speed of dynamo, the voltage tends to exceed the value for which the regulator is set, the regulating contacts open, opening the direct shunt field circuit and cutting in the regulating resistance. This causes a momentary drop in voltage so that the contacts close again. This opening and closing of the contacts is repeated so rapidly as to be imperceptible to the eye, and holds the voltage constant. **A**, voltage regulating screw; **B**, battery terminal; **C**, regulating resistor; **D**, cut out contacts; **E**, series coils; **F**, series compensating coils; **G**, ground; **H**, regulator shunt coil; **J**, dynamo shunt coil; **K**, commutator; **L**, brushes; **M**, regulating contacts; **N**, shunt compensating coil; **O**, cut out armature.



FIGS. 8,038 and 8,039.—Diagrams of Westinghouse electrical and mechanical connections of double reduction motor and switch for automatic screw pinion shaft. Fig. 8,038, with hand or foot operated starting switch; fig. 8,039, with electro-magnetically operated starting switch controlled by push button. In the figures, when the starting switch is closed, the full battery voltage is impressed on the motor, and it starts immediately. The pinion, when the motor is at rest, is within the screw shift housing and entirely away from the fly wheel gear.



Figs. 8,040 to 8.050.—Internal circuits of motors, generators, and motor generators in Delco Systems (Phillips and Copland diagrams). *A,* 1912 Cadillac, 1913 Cole, Hudson, Oakland and Oldsmobile. *B,* 1913 Cadillac and Packard 13-38. *C,* Buick 14-54, 55, Oldsmobile 6-54, Oakland 43, 48, 62, Cole 4-40, 4-50, 6-60, Moon 4-42, 6-50. *D,* 1914 Cadillac. *E,* 1914 Hudson 6-54. *F,* 1914 Buick 24, 25, 36, 37, Cartercar 7, Paterson, Oakland 36, Hudson 6-40. *G,* 1915 Buick, 24, 25, Cartercar, 9. *H,* Buick 36, 37, 54, 55, Cadillac 8, Cole 6-50, Hudson 6-40, Moon 6-40, 6-60, Oakland 37, 49, Oldsmobile 42, Paterson and Westcott Model U. *I,* 1915 Westcott 4. *J* and *K,* 1915 Cole 8.

2. Generating and starting at 12, 16, or 18 volts, and lighting at 6, 8, and 16 volts respectively.
3. Generating and lighting at 6 volts, and starting at 24 or 30 volts.

One Unit Systems.—The term "one unit" as applied to an electric starting system means that *there is a motor and dynamo* ***combined*** *in one machine*, or motor dynamo, as it is called, the dynamo furnishing current for the starter, and for charging the storage battery.

Two Unit Systems.—This classification indicates that the *motor and dynamo are* ***separate units***, as distinguished from the one unit system.

There is another system, ill advisedly called two unit, consisting of a *motor dynamo, and a magneto*. The reason for this confusion is because some dynamos are arranged to furnish current for ignition when not charging the battery, thus ignition has to be considered in the classification to distinguish the last mentioned system from the arrangement of three independent units.

Three Unit Systems.—This division comprises those systems which have a *motor*, *dynamo*, *and magneto* ***each separate.***

Here, each unit has a single function and is only electrically associated with the rest of the apparatus in the system. Thus, the dynamo supplies current for charging the battery, which in turn delivers current to the motor and ignition system at starting, and also to the lighting system, the magneto furnishing current for the ignition system, when the engine is running.

The term three unit system applies only to "starting, lighting and ignition systems," as distinguished from "starting and lighting systems."

Control.—In any electric system where there is a dynamo and a storage battery, two control elements are necessary for the proper working of the system:

1. Means for preventing reversal of current when the dynamo is charging the battery; 2. Means for limiting dynamo voltage.

When the engine is slowed down the speed of dynamo is also reduced, which causes the pressure induced in the armature to become less than the battery pressure against which it must force the current in charging, and accordingly, unless some automatic device be provided to break the circuit when such condition obtains, the current will reverse and flow out of the battery. This automatic device is called a ***discriminating cut out*** or ***reverse current circuit breaker***, and consists of an electromagnet connected in the dynano circuit, which, when the dynamo generates sufficient pressure to charge the battery, will attract an armature and close the circuit between the dynamo and battery, and which will also open the circuit when the battery pressure becomes greater than that induced in the dynamo.

Again when the engine speeds up, the voltage increases and some form of regulator must be provided to prevent undue rise of voltage otherwise the battery would be charged at too high a rate. This regulation may be effected : 1, mechanically; 2, electrically, or 3, thermally.

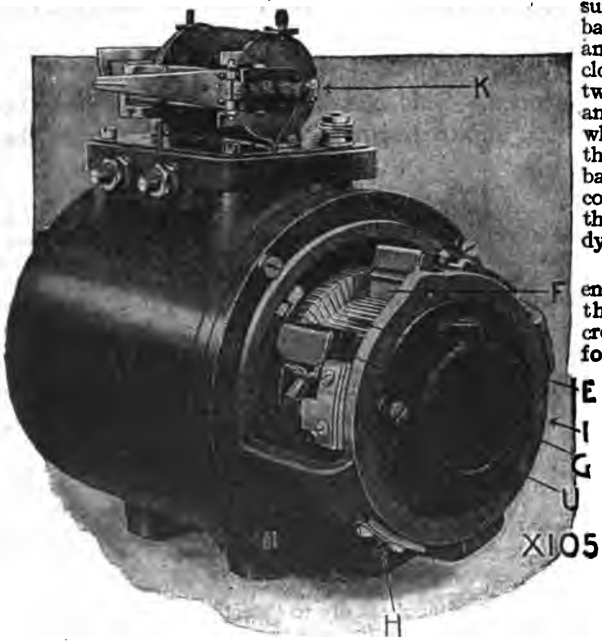


FIG. 8,051.—**Wagner dynamo of two unit starting and lighting system.** The drive is through a train of gear or equivalent. The windings and internal connections are of such character that no regulating devices are required except a cut out. ***In construction,*** the commutator E, and brushes F,G,H, and I, are located under the cover which in this cut is removed. The brushes H and I, collect the current from the commutator and furnish this current for charging the battery through the cut out K. The brushes F and G, collect the current from the commutator and furnish this current for exciting the fields.

CHAPTER 129

Electric Vehicles

Vehicles propelled by electric motors supplied with current for storage batteries have a travel capacity ranging from 75 to 100 miles per charge, with controller arrangements for providing speeds varying from 6 to 25 miles per hour. In these cases the number of cell in each battery may vary from 10 to 30 according to the make and number of plates in each cell. The number of plates in each cell may vary to suit special conditions.

Gasoline-Electric Vehicles.—A not altogether successful attempt has been made to eliminate the shortcomings of each by combining the gas engine with a dynamo connected to a storage battery, for supplying the power required by the electric motors.

Such a combination will operate at practically constant speed at all loads, as the dynamo with the storage battery serves to furnish the necessary overload, or consumes that portion of the energy which is not needed.

Motors for Electric Vehicles.—These are of the enclosed type of construction, which of necessity they must be, in order to protect them from dust, etc., in their exposed positions under the car. They are designed for overloads of 200% or more.

Drive or Transmission.—Because of the relatively high speed of the motor as compared with that of the rear wheels of the car, a system of gearing is necessary between the motor and

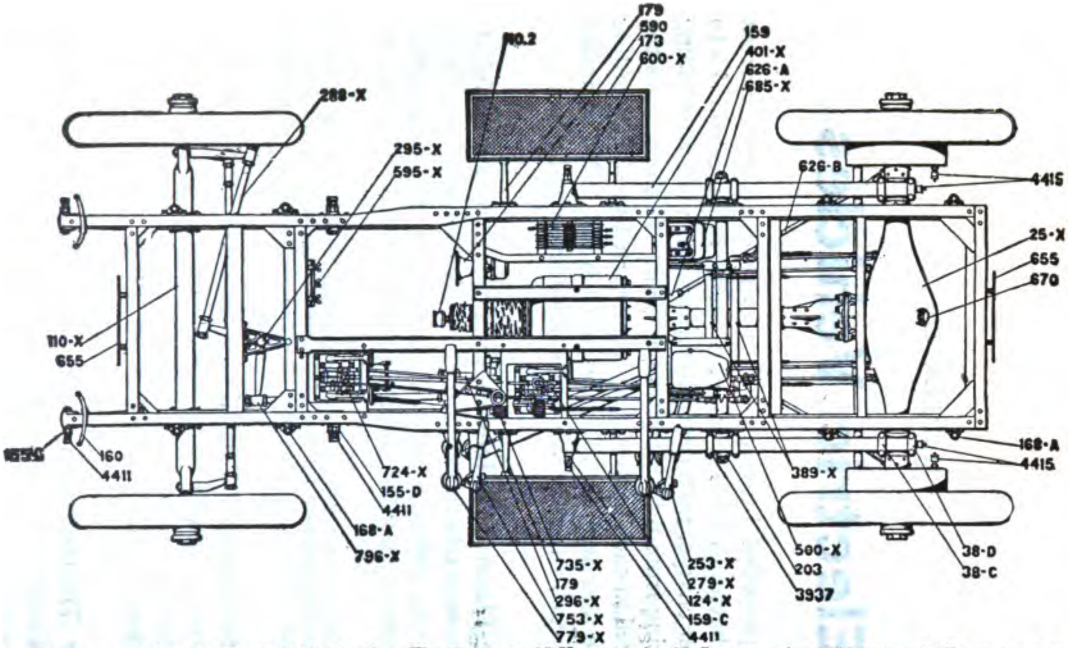


FIG. 8,052.—Plan view of Baker electric chassis. The parts are: 25-X, rear axle; 38-C, rear spring yoke front; 38-D, rear spring yoke rear; 110-X, front axle; 124-X, front levers, rear; 155-C, front spring bolt, front; 155-D, front spring bolt, rear, 159, rear spring; 159-C, rear spring bolt; 160, head lamp bracket; 168, A, fender bracket; 173, step pad; 179, step bracket; 203, rear spring seat, center; 253-X, rear control mast; 279-X, steering mast, rear; 288-X, lower steering rod, bell crank to spindle; 295-X, bell crank; 296-X, lower steering rod, mast to mast; 389-X, brake shaft; 401-X, motor; 500-X, controller; 590, horn; 595-X, fuse box; 600-X, resistance; 626-A, brace rod clevis; 626-B, brace rod; 655, license bracket; 670, oil inlet; 685-X, contactor ;724-X, foot levers, front; 735-X, interlock, 753-X, front control mast; 779-X, steering mast, front; 796-X, lower steering rod, mast to bell crank; 3,937, rear spring clip; 4,411, 4,415, No. 2 grease cups.

rear axle to obtain the necessary velocity reduction. Moreover, in some cases, other gears must be provided so that the power may be applied to the rear shaft when the motor shaft and rear shaft are at right angles to each other.

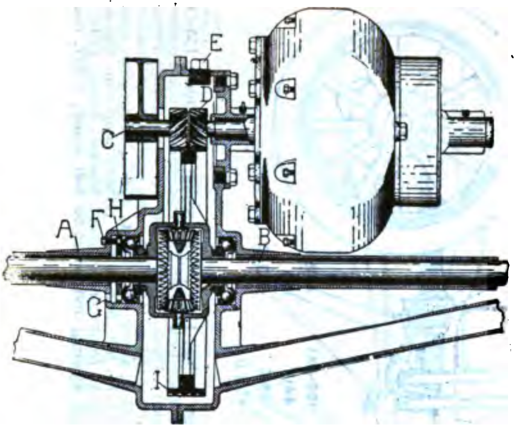


Fig. 8,053.—Single motor attached to rear axle through *herringbone* single reduction gears

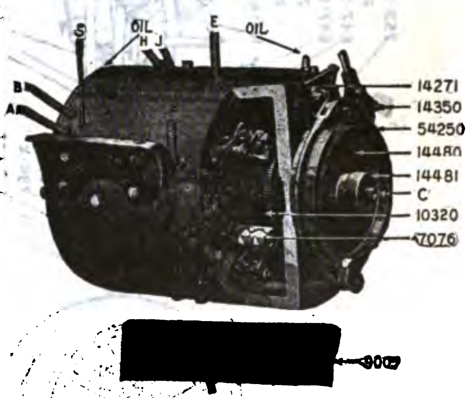


Fig. 8,054 and 8,055.—Rauch and Lang vehicle motor. *Instructions for care of motor:* The two oil covers lead to the ball bearings in the motor yokes. A good grade of light cylinder oil is recommended for these bearings. The commutator, 10,320, should be at all times kept clean, free from any gummy or gritty substance. The carbon brushes 7,076 should make perfect contact with the surface of the commutator and should be replaced with new ones when worn out. These brushes are originally 1⅝ inches long and should be replaced with new ones as soon as the measurement is reduced to 1¼ inches. It is safer to replace these brushes often, rather than allow them to become too short. Very serious damage may result from using brushes that are too short or ones that make poor contact with the commutator. Brushes that are too short or that are making poor contact will pit, burn and blacken the surface of the commutator. Replacement of brushes should be made only by an experienced person. The motor leads are lead out of motor through insulated holes. These holes, lettered J,H,B,A,S,E and F, correspond to the letter contacts on the controller into which they are connected. The motor brake may be adjusted for wear by means of the winged nut 14,350. Clearance between brake jaws and wheel may be adjusted by means of the screw 14,271. To remove brake wheel from armature shaft, take the $^{5}/_{16}$ screw C, out of the cap 14,481. A ½ inch, 12 pitch bolt, 3 inches or longer, or a cap screw may then be screwed through the threads in the cap and up against the end of the armature shaft. Continue to turn this screw and the pulley will be drawn off the shaft.

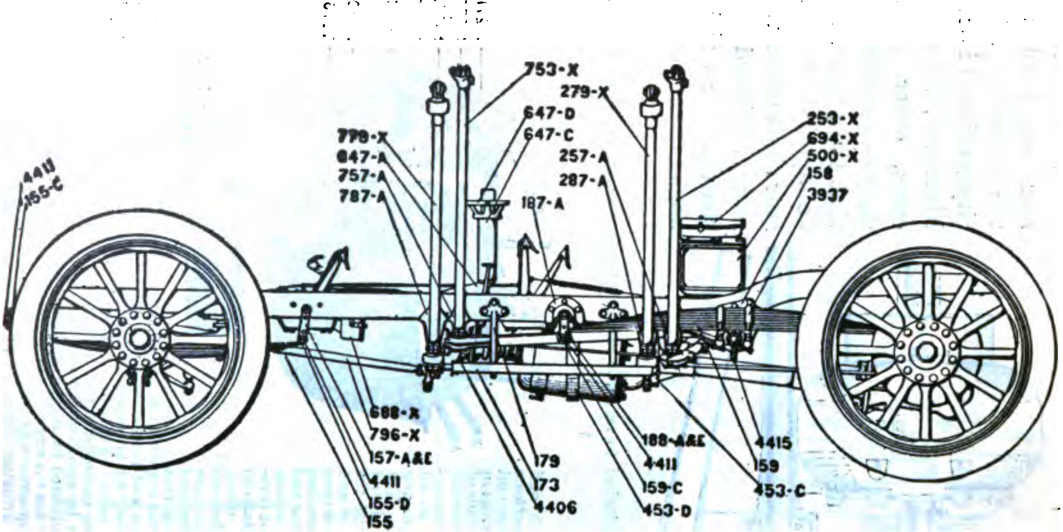


FIG. 8,056.—Side view of Baker electric chassis. The parts are: 155, front spring; 155-C, front spring bolt, front; 155-D, front spring bolt rear; 157-A, front spring shackle; 157-E, front spring shackle lock plate; 158, rear spring bracket center; 159, rear spring; 159-C, rear spring bolt; 173, step pad; 179, step bracket; 187-A, front hanger for rear spring; 188-A, rear spring shackle; 188-E, rear spring shackle lock plate; 253-X, rear control mast; 257-A, rear control mast bracket, lower; 279-X, steering mast, rear; 287-A, steering mast bracket, rear; 453-C, safety loop, short; 453-D, safety loop, long; 500-X, controller; 647-A, seat pedestal bracket, left; 647-C, seat pedestal tube, left; 647-D, seat pedestal stop cup; 688-X, opening switch; 694-X, closing switch; 753-X, front control mast; 757-A, front control mast bracket, lower; 779-X, steering mast, front; 787-A, steering mast bracket, front; 796-X, lower steering rod, mast to bell crank; 3,937, rear spring clip, 4,406, 4,411, 4,415, grease cups.

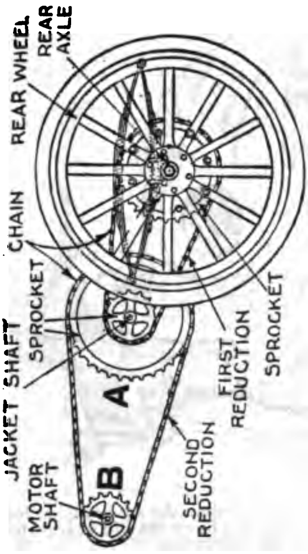


FIG. 8,057.—Double chain drive. The rear axle is of the "dead" type and each rear wheel has a sprocket with which the chains mesh. The jack shaft is parallel to the rear axle and upon the maintenance of parallelism between the two axles depends the satisfactory working of the chain. The cut illustrates single and double reduction chain drive. For single reduction the motor would be located at A, and for double reduction, at B.

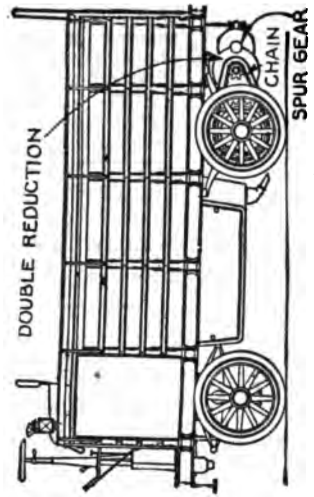


FIG. 8,058.—Chain and sprocket double reduction gear for heavy trucks. As here shown, the motor is hung above the springs, missing the jars of travel.

There are several forms of drive, as by 1. Herringbone gear; 2. chain gear; 3. worm gear.

Herringbone drive.—This drive is extensively used because of its freedom from noise, its simplicity and durability owing to the parts being enclosed.

Chain Drive. — This form of drive is desirable for heavy service, as on very large trucks. It is a noisy and dirty mode of power transmission, and when not enclosed is subject to rapid wear. A very objectionable feature of chain drive is the fact that the chain sometimes climbs the teeth due to considerable wear or to too little clearance.

Combination Chain and Gear Drive.—For very heavy trucks where a considerable reduction in speed is required between the motor and wheels, a double reduction is sometimes used. The motor is usually hung above the springs, thus being protected from the jars of travel.

There are several forms of double reduction using light high speed motors by means of various combinations of gear and chain, with silent, roller chains or herringbone gears for the first reduction, and single or double roller chains, bevel gears or herringbone gears for the second reduction.

Controllers. — The form of controller adapted to electric vehicle use consists of *a rotatable insulated cylinder carrying on its circumference a number of contact, arranged to make the desired connections with the terminals of the various apparatus in the circuit through a wide range of variation*

Some controllers are constructed with a cylindrical surface, upon which bear single leaf springs, the desired electrical connections being

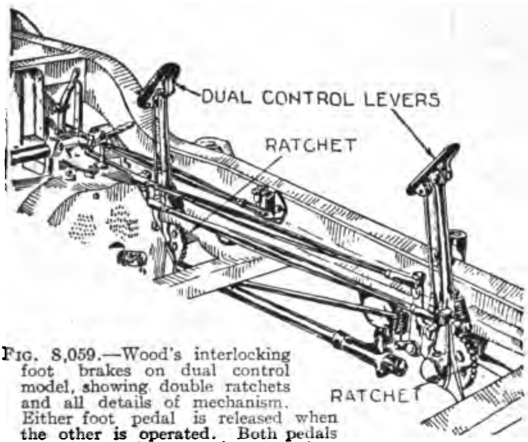


FIG. 8,059.—Wood's interlocking foot brakes on dual control model, showing double ratchets and all details of mechanism. Either foot pedal is released when the other is operated. Both pedals are automatically released when controller is moved to first speed.

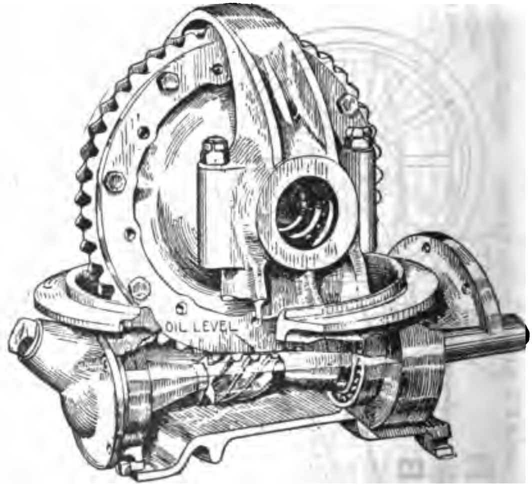
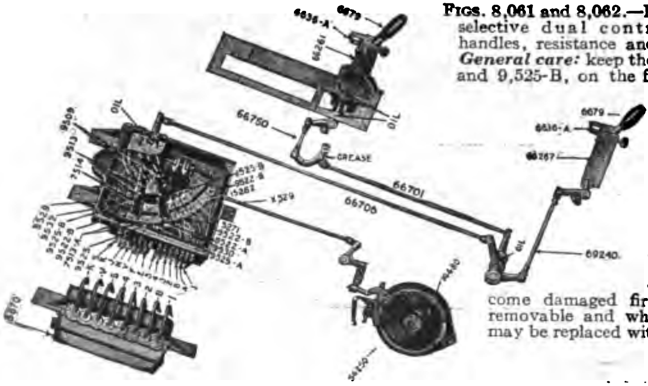


FIG. 8,060.—Lancaster type of worm drive as used on some electrics. An advantage claimed for this form of worm drive is the fact that mounting the worm below the ring gear permit, it to be placed in a bath of oil, assuring constant and ample lubrication.



Figs. 8,061 and 8,062.—Baker R and L, selective dual controller, control handles, resistance and motor brake. *General care:* keep the plates, 9522-B and 9,525-B, on the face of the controller and the shoes 7,513-A on the movable arm clean and free from burned and rough edges. The contact plates 9,522-B and 9,525-B, and the shoes 7513-A, are the ones that become damaged first. They are removable and when badly worn may be replaced with new ones.

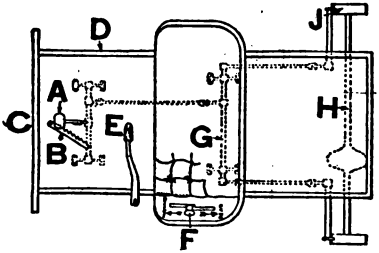
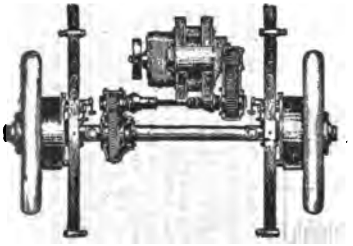


Fig. 8,063.— Diagram of the controlling apparatus of a light electric vehicle. A, brake pedal; B, ratchet retaining pedal in place, operated by left foot; C, dash board; D, body sill; E, steering handle; F, controller handle; G, rocker shaft for setting hub brakes; J, brake band on wheel hub; H, rear axle.



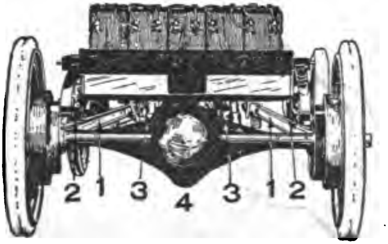
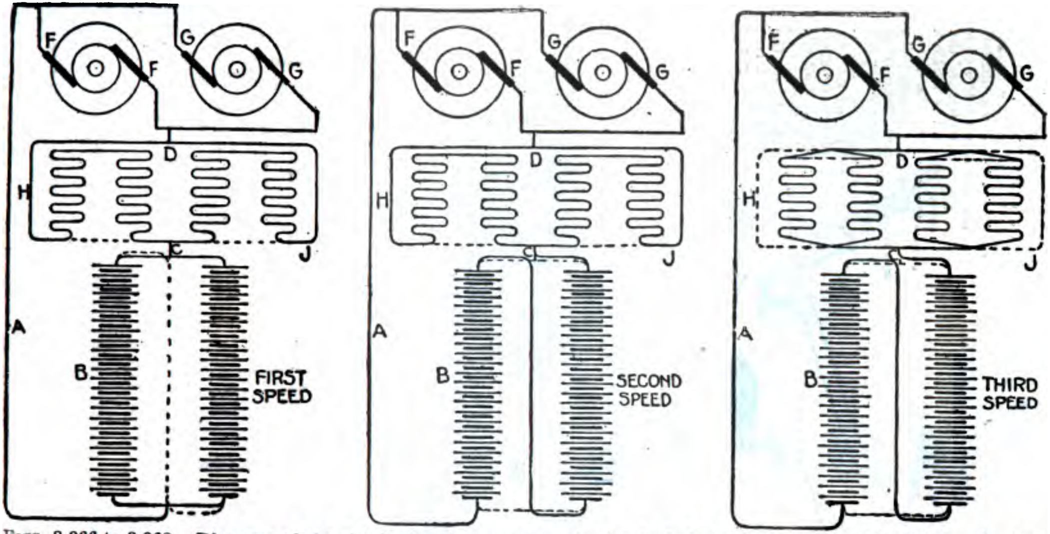
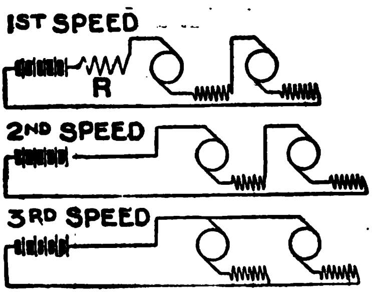


Fig. 8,064.—Waverly double reduction gear or combination herringbone and so called "silent" chain.

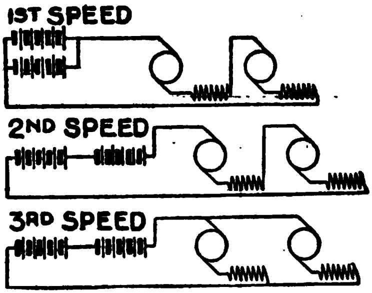
Fig. 8,065.—Rear view of Wood's chassis with battery showing the following *features of construction:* 1, radius rods extending from rear axle to sub-chassis frame; 2, rear springs rest on radius rods, instead of on rear axle; 3, motor, showing ball and socket spring suspension; 4, worm drive, showing location of worm below rear axle.



FIGS. 8,066 to 8,068.—Diagrams of the circuit changing arrangements of a typical electrical vehicle. The full lines in these diagrams indicate the closed or active circuits; the dotted lines the open, or inactive circuits. As may be readily understood, the whole scheme of the circuit changing depends on employing several different circuit connections between battery and motor, which may be opened and closed, as desired. Here A and C are the lead wires between battery, B, and motor brushes, FF and GG, and the field windings H and J, and the wire D. Fig. 8,066 shows first speed; two units of the battery B are connected in parallel, which means that the voltage is reduced to the lowest point. The wire C, connected to the bridge between the positive poles of the battery, leads the current to the field windings, H and J, which, in this figure, are connected in series-parallel, which gives the lowest speed and power efficiency of the motors. By the wire, D, the current is carried to the brushes, FF and GG, which, according to this scheme, are permanently connected in parallel, the return path to the negative pole of the battery being through the wire A. In fig. 8,067, the circuit is varied so as to connect the two units, so as to give its highest pressure efficiency. But, since the field windings of the motors are also connected in series, or in series parallel, as in this case, the efficiency in speed and power is reduced nearly one-half. In fig. 8,068, the two units of the battery are connected in series, which, as in the former case, indicates the greatest efficiency in power output; but the field windings are connected in parallel, which means that the voltage generated by their operation is equivalent to the voltage of only one motor, with the result that the speed and power efficiency is raised to its highest point.



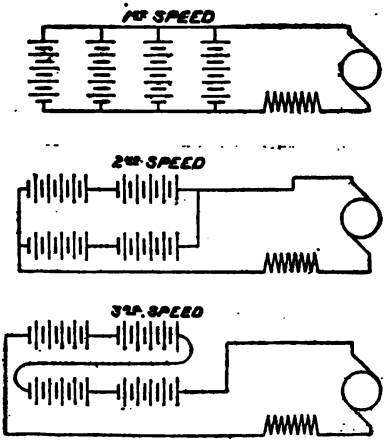
Figs. 8,069 to 8,071.—Diagrams showing methods of speed changing in a typical one battery unit, two motor circuit. ***The first speed*** shows the two motors in series, with a resistance coil interposed; ***the second,*** the motors in series, without the resistance; ***the third,*** the motors in parallel.



Figs. 8,072 to 8,074.—Diagram showing methods of speed changing in a two battery unit, two motor circuit, showing combinations for three speeds. ***The first speed*** is obtained with the battery units in parallel, and the motors in series, ***the second,*** with the battery units in series and the motors in series; ***the third,*** with the battery units in series and the motors in parallel.

made by suitably connected conducting surfaces on the cylinder circumference, and cut outs being similarly accomplished by insulating surfaces, bearing against the spring contacts at the desired points. This type of controller is one of the most usual forms for motor vehicle purposes.

Troubles.—In order to properly cope with the numerous disorders and mishaps likely to be encountered, the following points relating to troubles may be found helpful:



Figs. 8,075 to 8,077.—Diagrams showing combinations for three speeds in a typical four battery unit, single motor circuit. The only changes made in these circuits are in the battery connections. ***For the first speed*** the battery units are in parallel; ***for the second,*** in series parallel; ***for the third,*** in series. The motor connections are not varied.

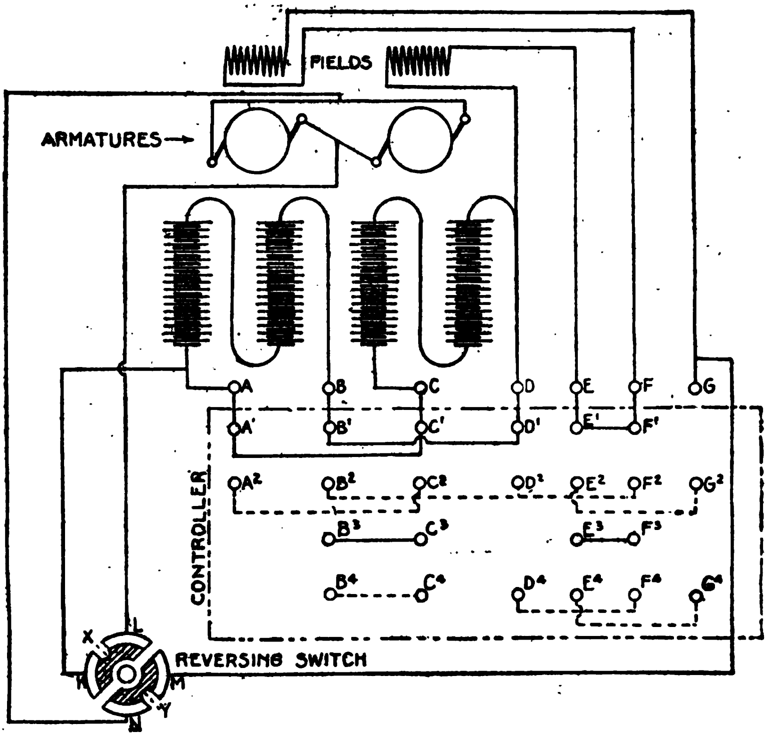


FIG. 8,078.—Diagram plan of the several parts of an electric vehicle driving circuit. The field windings and armatures are shown projected, the proper wiring connections being indicated. The periphery of the controller is laid out within the broken line rectangle, the contacts and connections through it for varying the circuits through four speeds being shown. *For first speed* the controller is rotated so that the row of terminal points, A, B, C, D, E, F, G, are brought into electrical contact with the row of terminal points on the controller, A′, B′, C′, D′, E′, F′, G′; this connects the two unit battery in parallel and the field windings of the two motors in series. A further movement of the controller, bringing the points, A, B, C, etc., into contact with A^2, B^2, C^2, etc., *gives second speed,* the batteries now being in parallel and the fields in series parallel. *For third speed,* the points B and C are brought into contact with B^3 and C^3, and E and F with E^3 and F^3, which means that the batteries are connected in series, and the fields in series. Similarly, for fourth speed, the points B and C are brought into contact with B^4 and C^4, and D, E, F, G, with D^4, E^4, F^4, G^4, which means that the batteries are in series and the fields in parallel. The connections between the battery, the armature brushes, and the motor fields, are made as indicated through the rotary reversing switch by the terminals, K, L, M, N. The switch may effect the reversal of the motors by giving a quarter turn to its spindle, which means that the contacts of segment X, will be shifted from L and K to K and N, and the contacts of segment Y, shifted from M and N to L and M, thus reversing the direction of the current.

1. If vehicle run too slow, look for the following:

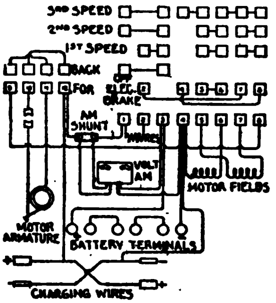
a. Deflated tires. *b*. Slow tires, due to other makes having been substituted for those furnished by the manufacturer of the vehicle. *c*. Broken bearings in wheels, countershaft or motor. *d*. Shoes not making perfect contact on face of controller. *e*. Brushes not making perfect contact on commutator due to being too short, or commutator being dirty. *f*. Broken battery jar, solution having partly leaked out. *g*. Brakes rubbing when they are supposed to be thrown off. *h*. Battery exhausted.

2. If the current be higher than usual when running on the level, look for the following:

a. Tight bearings. *b*. Brakes rubbing. *c*. Silent chains too tight. *d*. Front wheels out of alignment. *e*. Tires deflated.

3. If needle on ammeter vibrate more than usual, moving up and down very rapidly, look for the following:

a. Blackened commutator. *b*. Commutator brushes worn too short. *c*. Loose connections at battery terminals or at connections on controller. *d*. Broken wire leading to meter.



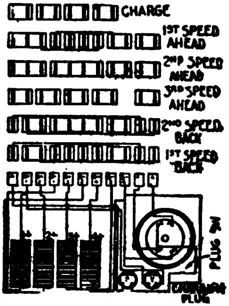


FIG. 8,079.—Diagram of controller connections of one unit, one motor circuit, with variable fields.

FIG. 8,080.—Diagram of controller connections of a four unit one motor circuit, with constant series connections for fields and armatures in forward and backward speeds.

4. If vehicle refuse to run, look for the following:

a. Broken jar in battery. *b*. Broken connections between cells. *c*. Broken terminals. *d*. Open motor leads. *e*. Broken connections on any part of vehicle.

5. In case vehicle do not run on any of the speeds, first examine those connections that are easiest to get at, viz:

a. Those at the end of the batteries. *b*. The connecting straps, connecting one cell to another. *c*. The wires going into the circuit closing switch. *d*. The springs on the controller arm and the copper shoes. Be sure that they make contact with plates on the controller face. *e*. See that there are no wires hanging loose, that appear to belong in the controller. *f*. If the trouble be not found in some one of these points, it would be best to have an expert examine the machine.

CHAPTER 130

Electric Railways

The extensive development of the electric railway has given rise to numerous systems, which may be classified in several ways, thus

1. With respect to the current, as
   - *a*. Direct;
   - *b*. Alternating;
2. With respect to the method of current generation, as
   - *a*. Mechanical {steam; hydraulic; gas engine.
   - *b*. Chemical {storage battery.
3. With respect to the power system, as
   - *a*. *D. c.* transmission and distribution;
   - *b*. *A. c.* transmission, *d.c.* distribution;
   - *c*. *A. c.* transmission and distribution
4. With respect to the current collecting device, as
   - *a*. Trolley;
   - *b*. Surface contact;
   - *c*. Third rail;
   - *d*. Conduit.
5. With respect to the location of the electrical source, as
   - *a*. External {power station.
   - *b*. On the car {storage battery; gas-electric.
6. With respect to the distribution pressure, as
   - *a*. Low tension {[illegible]
   - *b*. High tension {[illegible]
7. With respect to the service, as
   - *a*. City lines {elevated; surface; subway.
   - *b*. Interurban or suburban;
   - *c*. Long distance lines;
   - *d*. Industrial short lines.

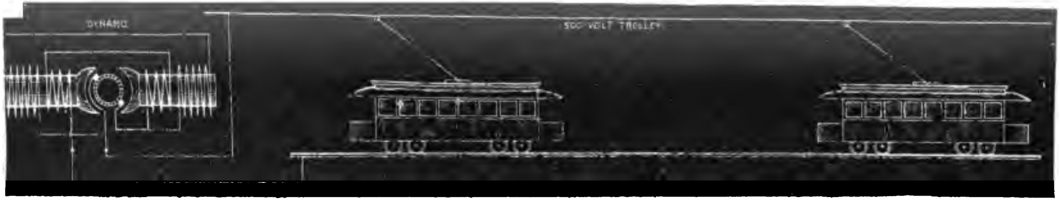


Fig. 8,081.—*Direct current transmission and distribution.* Impressed pressure 550 volts, or 500 at the motors. Application: short lines of radius 5 to 8 miles from power house; greater radii necessitate the use of boosters.

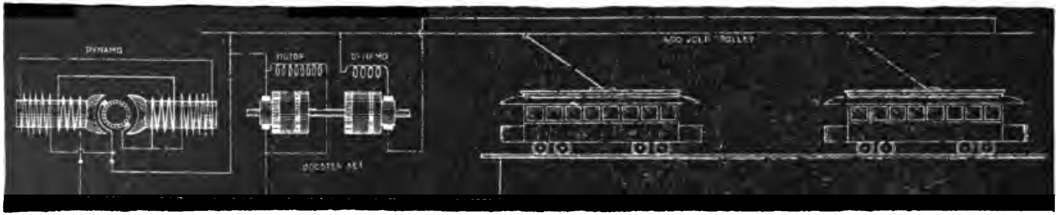


Fig. 8,082.—*Direct current transmission and distribution with booster.* 650 volts at dynamo; radius 7 to 15 miles from power house. Some stations employ storage batteries to take care of the peak loads. By means of reversible boosters, the battery is caused to take current from the power house feeder at time when the power demand is low on the section supplied for the sub-station, thus storing up current which it subsequently delivers to the line when the power demand is heavy. In some cases the batteries are simply *floated* on the line and tend to equalize the demand and the voltage. By these means the radius of successful operation of direct current systems is extended to about 15 miles from the power house.

D.C. Transmission and Distribution.—This system is especially adapted *for densely populated sections as in large cities.*

It is not well adapted to the operation of roads covering large areas and is becoming obsolete, owing to the great amount of feeder copper required to transmit large amounts of energy at 600 volts, which is the usual pressure used.

The standard pressures are 600, 1,200, 1,500 and 2,400 volts; 600 and 1,200 volt motors are used.

FIG. 8,083.—*Direct current transmission and distribution.* 1,200 volt two stage generator; radius 10 to 20 miles from power house. Either one 1,200 volt, or two 600 volt motors (connected in series) may be used. With 600 volt for motor equipment, the pairs are connected in series and parallel to give the excellent result obtained by series parallel control.

A. C. Transmission, D. C. Distribution.—This system is in general use *for suburban roads and the larger city systems.*

The advantages accruing from the use of both alternating and direct current must be evident, thus, a large amount of power can be transmitted by alternating current at high voltage reducing the cost of copper to a minimum, and by means of rotary converters, converted into direct current of suitable working voltage for the motors at the distribution points.

A.C. Transmission and Distribution.—For current supply, a single phase alternator may be used, or one leg of a three phase machine.

For short lines the alternator may be wound for the trolley voltage, but for long lines a high pressure machine is used with step down transformer substations, or a medium pressure machine with step up and step down transformers. Trolley voltages of 3,300, 6,600, 11,000 and as high as 13,000 are in use.

Overhead Trolley System.—In this arrangement which is largely used in towns and cities, the current for the motors *is taken from an overhead wire by means of a "trolley"* with grooved wheels, which is held up against the wire by a flexible pole.

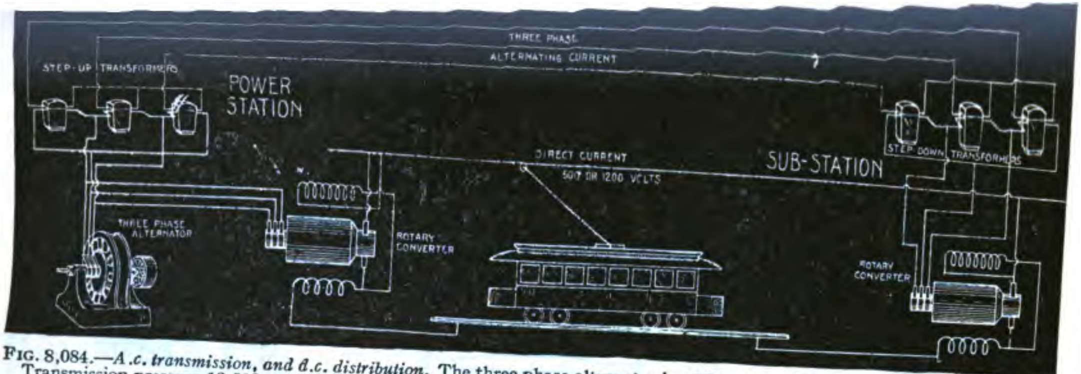


FIG. 8,084.—*A.c. transmission, and d.c. distribution.* The three phase alternator is a 25 cycle machine wound for 360 to 390 volts. Transmission pressure 13,500 volts. ***This system may be varied in several ways*** to satisfy special conditions, for example; 60 cycles may be used where the general lighting circuits are supplied from the same power house, and storage batteries may be installed in the sub-stations for equalizing the demand and reducing the rotary converter capacity necessary.

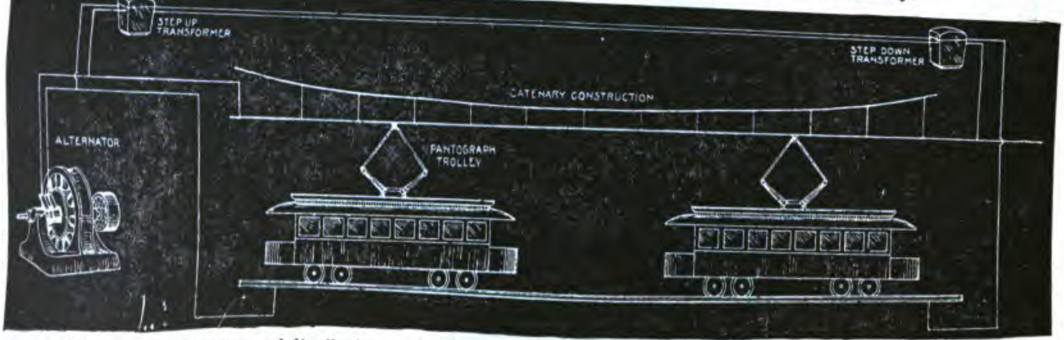


FIG. 8,085.—*A.c. transmission and distribution.* ***For short lines*** the alternator may be wound for the trolley voltage, but ***for long lines*** a high pressure machine must be used in connection with step down transformer sub-stations or a medium pressure machine with step up and step down transformer as here shown. Trolley voltages of 3,300, 6,600, 11,000, and as high as 13,000 are in use, but the usual pressure is 6,600 volts ordinarily,

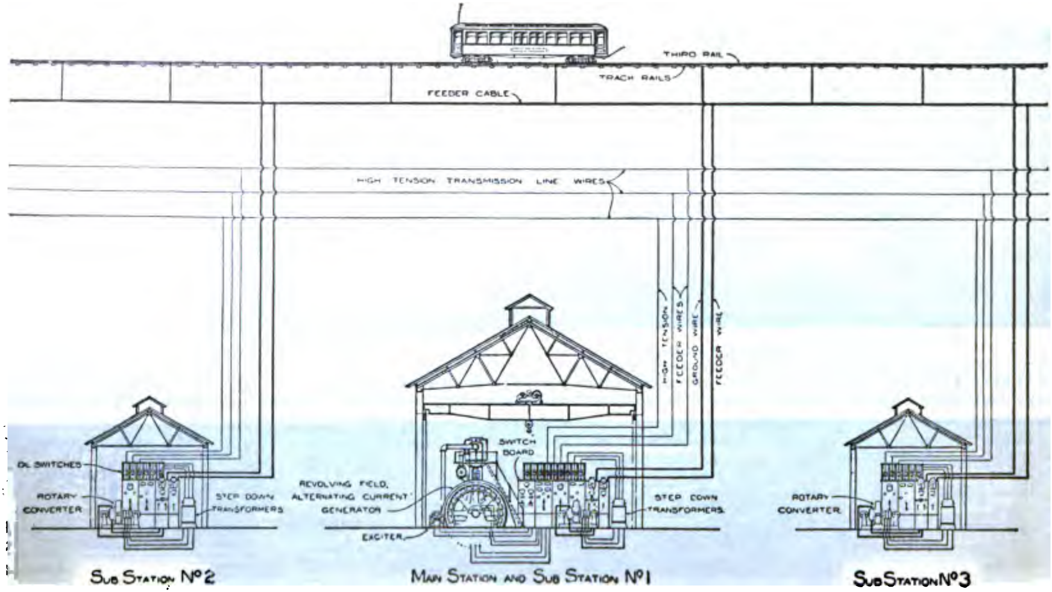
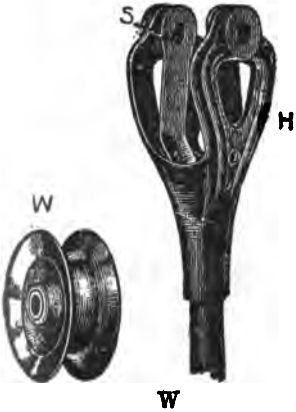
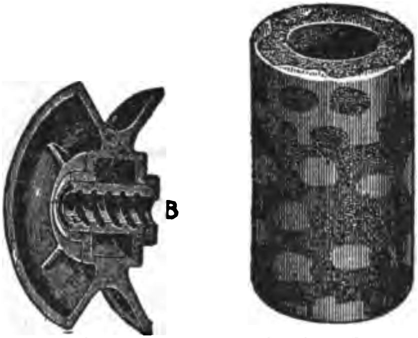


FIG. 8,088.—*Alternating current transmission, direct current distribution.* The diagram shows the main station and two sub-stations with apparatus and connections to the line. ***In the system*** here shown, three phase current is generated at the main station, where it passes to *step up* transformers to increase the pressure a suitable amount for economical transmission. At various points along the railway line are *sub-stations*, where the three phase current is reduced in pressure to 500 or 600 volts by *step down* transformers, and converted into direct current by rotary converters. The relatively low pressure direct current is then conveyed by *feeders* to the rails, resulting in a considerable saving in copper in moderate and long distance lines.

The wires from the contact wheels pass down the pole to the car controller and thence to the motor, the return circuit usually being through the rails.

Surface Contact System.—This system may be advantageously used in some *industrial works where an overhead trolley is objectionable, and a third rail is not permissible.*





Figs. 8,087 and 8,088.—Trolley wheel and harp. The spring S, attached to frame H, pressing against the side of the trolley W, maintains good electrical contact.

Figs. 8,089 and 8,090.—Section through trolley showing lubricating bushing B, and view of bushing removed from trolley.

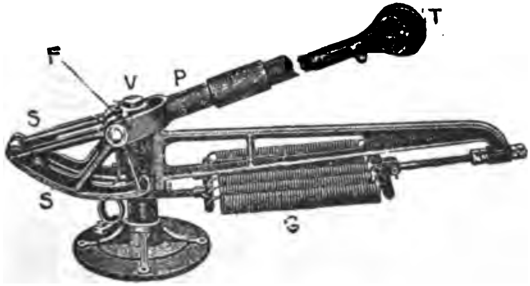


Fig. 8,091.—Trolley base. *As shown,* the pole P, terminates in a fork F, attached to a pair of sector S,S, forming a frame, capable of revolving about a vertical axis V, so as to accommodate the pole and trolley to turns or curves in the track and trolley wire. The spiral springs G, maintain a tension upon these sectors tending to force the pole P, upward.

The Westinghouse surface contact system requires no poles or overhead wires and leaves yards and buildings free of all obstructions. The current is supplied to the motors through contact buttons which are connected to a feeder cable laid along the track, through electromagnetic switches the buttons are "dead" except those directly under the motor cars or locomotives.

Third Rail System.—In this system a rail called the "third rail" is laid outside the track rails. The current is taken by

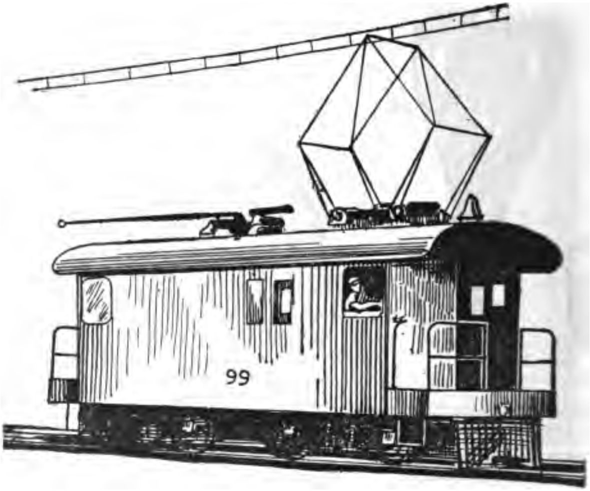
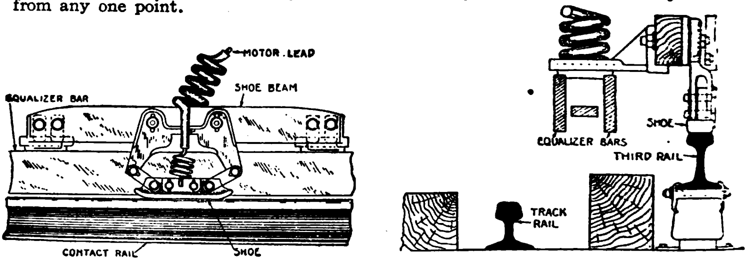


FIG. 8,092.—Pantograph trolley for use on high speed, high pressure lines. It is nominally held in contact by a spring and may be raised or lowered by compressed air control in the motorman's cab. The trolleys on the entire train may be thus simultaneously controlled from any one point.



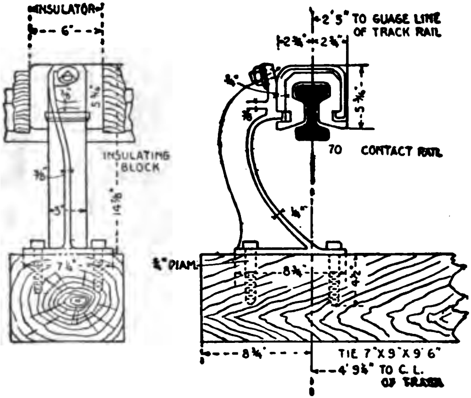
FIGS. 8,093 and 8,094.—Details of third rail and contact shoe as used on the Manhattan Elevated Railway, New York City.

means of a suitable contact shoe which slides along the rail, and the car is controlled by the motorman as in the case of a trolley car. This system is extensively used on elevated railways and subway systems.

Underground Trolley or Conduit System.—This is a metallic circuit system, there being two insulated conductors supported in a conduit.

The current is taken by a trolley which extends from the car into the conduit through a central slot and makes sliding contact with the conductor.

This system is used in the streets of large cities where the use of overhead trolley wires are objectionable, but the cost of construction is very great.



FIGS. 8,095 and 8,096.—Details of New York Central Railroad inverted third rail.

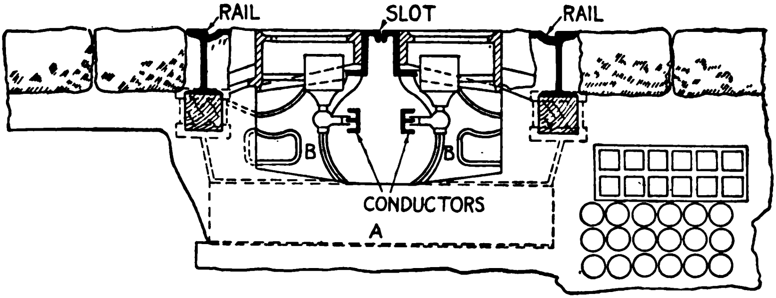
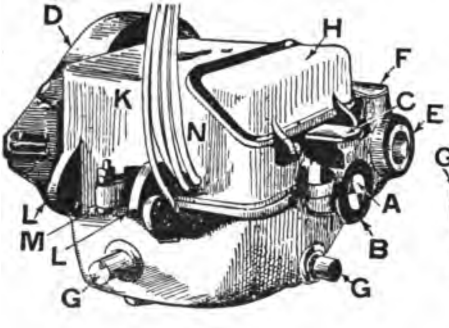


FIG. 8,097.—Sectional view of conduit system of the Third Ave. street railway, New York City.

Motor Types Employed.—There are three types of motor in use for electric railways; the direct current motor, the single phase commutator motor, and the three phase induction motor.

Motors.—The severe operating conditions of railway service demand *a motor differing in many respects from the ordinary machine.*



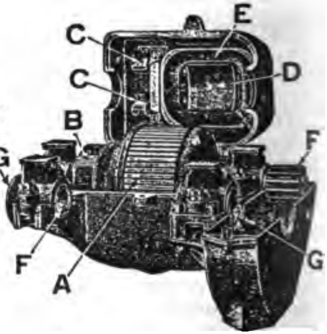
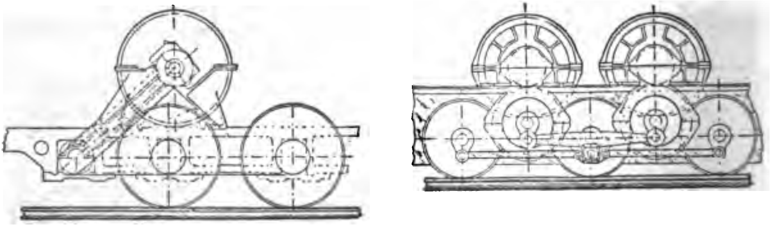
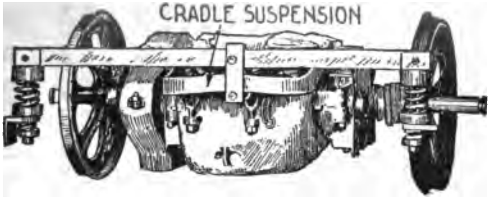


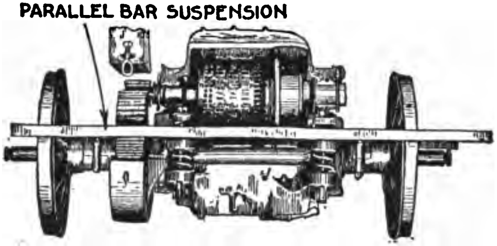
FIG. 8,098.—*D.c.* railway motor, casing closed. ***As shown,*** the armature shaft A, projects through its bearing B, lubricated by the grease box C, and is connected with the car axle by gear wheels enclosed in the gear cover D. The gears serve to reduce the speed of the car, and also to increase the effective pull of the motor. The car axle passes through the bearing E lubricated by the grease box F. The motor is supported on the truck by the lugs G,G. The commutator door H gives access to the brushes, while a more complete inspection of the working parts may be obtained by throwing back the upper half of the casing K, upon the hinges L,L, after unscrewing two bolts, one of which is shown at M. The insulated cables shown at N, pass through the casing and supply current to the motor.

FIG. 8,099.—*D.c.* railway motor casing open. ***As shown,*** A, is the armature; B, commutator; C,C brushes; D upper pole; E, upper field. The pinion F, secured to one end of the armature shaft engages with a gear wheel on the car axle, which passes through the bearings G,G, corresponding to the bearings designated E, in fig. 3,514.

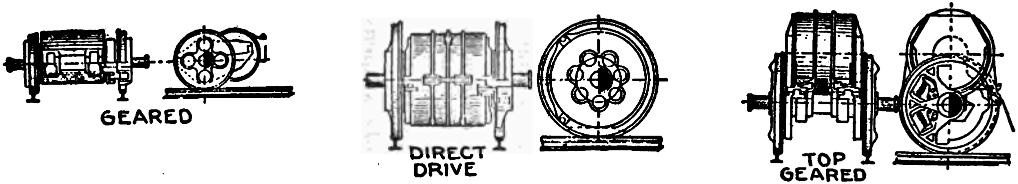


FIGS. 8,100 and 8,101.—Various motor suspensions. Fig. 3,532, Pennsylvania gearless motor with connecting rods; fig. 3,533, geared motors with yoke, or erroneously called Scotch yoke.





[illegible] motor suspensions. Fig. 8,102, [illegible] 103, cradle suspension; fig. 8,104



Figs. 8,105 to 8,107.—Various motor suspensions. Fig. 8,105, New Haven geared motor; fig. 8,106, New Haven gearless motor; fig. 8,107, New Haven top geared motor.

The principal requirements are: 1, that it shall be dust and water proof because of its exposed location beneath the car; 2, it must be capable of very heavy overloads to secure quick acceleration at starting; 3, it must be compact because of the limited space available; 4, large bearings with efficient self-oiling devices must be provided to secure long operating periods without attention.

Motor Suspension.—Usually the motor is constructed with a set of bearings on one side of the frame, in which bearings the axle of the car wheels rotate.

Mounted upon this axle is a large gear which meshes with the pinion gear on the end of the armature shaft, the gears being protected from dust, etc., by a casing. The side of the motor opposite to that containing the car axle is usually fastened to a bar, which in turn is mounted upon springs connecting it to the car truck.

There are numerous forms of suspension, and these may be classed as: 1, cradle suspension; 2, nose suspension; 3, yoke suspension; 4, parallel bar or side suspension; 5, twin motor suspension.

The ***cradle suspension*** consists of a U shaped bar fastened to the truck at the middle of the U. It is intended to relieve the bearings of the weight of the motor, and is now semi-obsolete.

Nose suspension consists in casting a projection or nose on the motor frame and fastening it to the motor truck by means of a heavy link, the object being to distribute the weight of the motor between the car axle and the truck. It is the prevailing method.

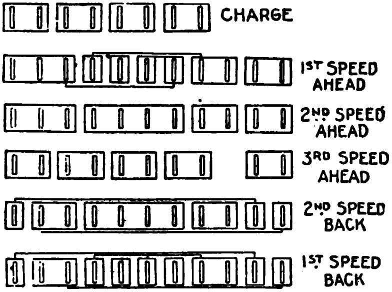
Yoke suspension consists in rigidly bolting a cross bar to seats cast on the motor casing, the ends of these bars being spring supported to the truck frame.

In ***parallel bar*** or ***side suspension*** there are two parallel bars fastened to the car truck, supporting the motor on springs at its center of gravity.

With ***twin motors,*** two motors of equal capacity are mounted above each axle. Each motor is provided with a pinion and the two pinions of the pair of motor mesh with a single gear which is mounted on a quill surrounding the driving axle.

Motor Control Systems.—The speed requirements for traction motors give rise to several control systems, and the apparatus employed to effect the proper sequence of connection corresponding to the system of control adopted is known as a controller. A comprehensive classification would divide the various systems

1. With respect to the method of operation, as
   - *a.* Hand control;
   - *b.* Automatic control; *c.* Master control.
2. With respect to the current, as
   - *a.* Direct;
   - *b.* Alternating.
3. With respect to character and sequence of connections, as



FIGS. 8,108 to 8,115.—Controller of the Rauch and Lang electric vehicles. It is of the flat radial type. Two movable copper leaf contacts of ample size make all commutations necessary to obtain the various speeds. Five speeds forward and reverse are provided.

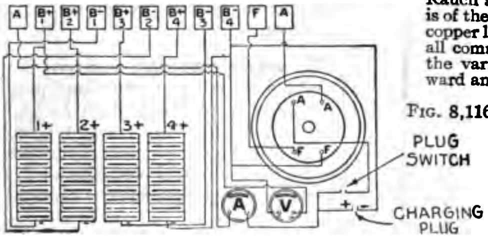


FIG. 8,116.—Diagram of controller connections of a four unit one motor circuit, with constant series connections for fields and armatures in forward and backward speeds.

a. Direct current
- rheostatic;
- field;
- series parallel;
- multi-unit (master control).

b. Alternating current
- single phase
  - rheostatic;
  - compensator;
  - induction regulator;
- three phase
  - rheostatic;
  - changeable pole;
  - cascade
    - single;
    - parallel single;
  - combined changeable pole and cascade.

4. With respect to the method of transition, as

a. With power off;
b. With series resistance;
c. Bridge.

With ***hand control*** the motorman, by moving the controller handle can vary the current value without any time limit device.

Automatic control includes certain automatic devices which prevent the motorman applying to the motors a current greater than a predetermined value.

The master or ***multi-unit control*** system, ill advisedly called multiple unit control, is one in which the motors on each car of a train of several cars are controlled from one master controller.

Rheostatic control consists in progressively cutting out sections of a resistance connected in series with the motor.

The method of ***field control*** consists in varying the intensity of the motor field magnets, by dividing the coils into two sections and arranging the controller to give a proper sequence of connection.

The ***series parallel control*** is used with two or four motor equipments. The sequence of connection for a two motor car during the control period is as follows: 1, both motors connected in series with control resistance, 2, control resistance progressively reduced, 3,

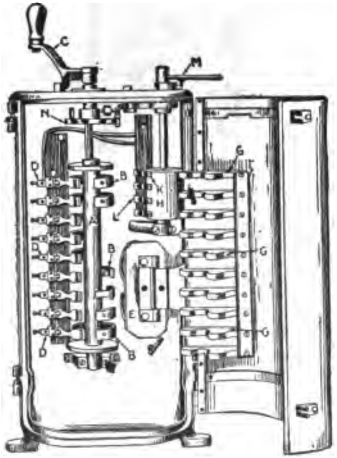
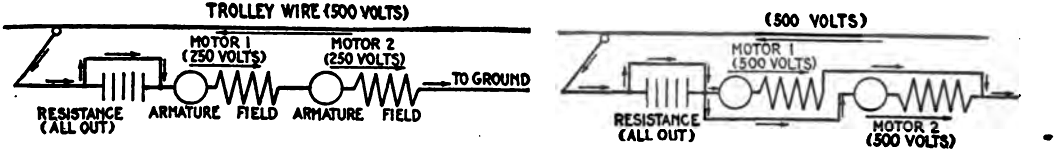
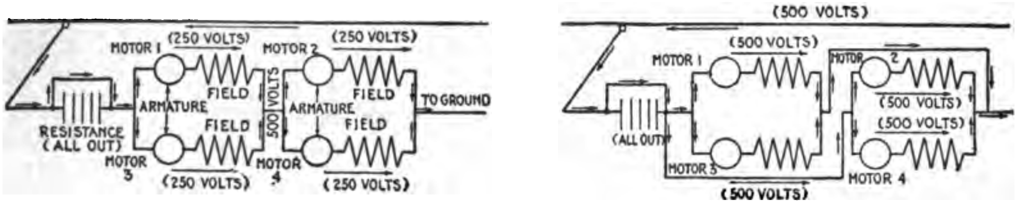


FIG. 8,117.—Ordinary rheostatic controller. ***In operation,*** the current passing through the motor passes through the coils of the magnet E, and converts its core into an electro-magnet which produces a powerful magnetic flux around the contact surfaces of the springs D,D,D. At the instant the circuit is broken either in changing connections or when the current is entirely shut off, the influence of this powerful magnetic flux prevents the severe sparking which would naturally occur otherwise by blowing out the arcs as soon as they are formed. The reversing cylinder H, carries four conducting segments K, and a corresponding number of contact spring L. By moving the handle M, through an arc of about 60 degrees, the segments in contact with the springs L, can be changed and the direction of the current through the armature of the motor reversed, thereby causing it to rotate in the opposite direction and back the car. As the reversing operation cannot be safely accomplished while the motor is running, the handles C and M, are made interlocking so that the latter cannot be moved unless the former be in the "off position." The proper operation of a controller requires that all the successive contacts be made and none omitted. This is insured by the action of the star wheel located at N.



Figs. 8,118 and 8,119.—Diagrams of series parallel two motor control. Fig. 8,118, series running position, all resistance cut out; fig. 8,119, parallel running position, all resistance cut out.



Figs. 8,120 and 8,121.—Diagrams of series parallel four motor control. Fig. 8,120, series running position, all resistance cut out; fig. 8,121, parallel running position, all resistance cut out.

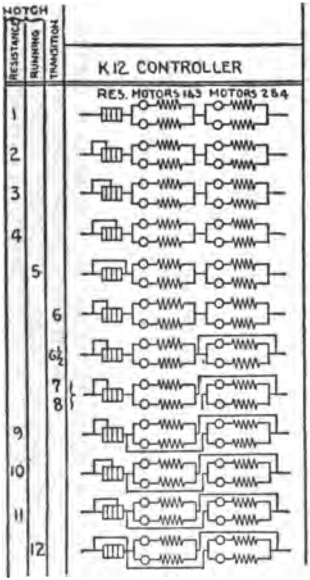
in circuit in series with parallel connection of motors, 4, control resistance progressively reduced, 5, both motors in parallel with control, no resistance.

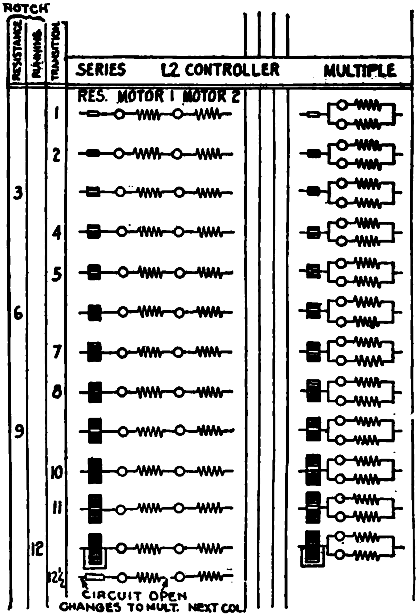
The mode of transition divides the series parallel control into several types, as 1, power off, 2, series resistance, and 3, bridge transition. In the power off method of transition, the controller is so arranged that the power is cut off from both motors in changing the motor connections from series to parallel. Now semi-obsolete.

In series resistance transition, during the transition from series to parallel, a resistance is placed in series with one motor and the other motor is first short circuited, then disconnected from the main circuit, and finally placed in parallel with the other motor. The bridge method of transition consists in grouping the motors and their resistances like the arms of a ***Christie***, or erroneously called Wheatstone bridge.

bridge, so that after the two motors are in full series position, the resistances may be placed in circuit again in parallel with the motors without opening the circuit. The two motors are then connected in parallel with each other and each in series with its own resistance.

A.C. Control Systems.—In the compensator method, the impressed pressure *is gradually increased by progressively cutting out sections of the compensator or auto-transformer.*



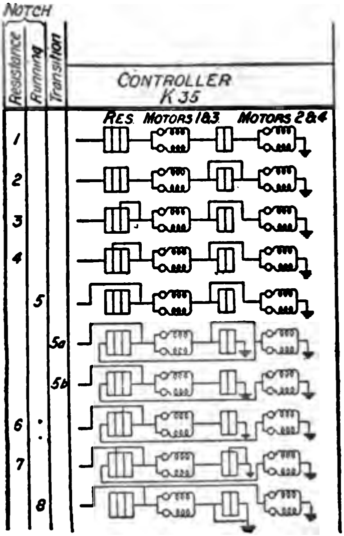


Figs. 8,122 to 8,133.—Westinghouse type K-12c ontroller connections. In changing the motor connections from series to parallel, it will be noted that the controller short circuits one pair of motor, but the current continues to flow to the other pair. The ***series method*** here employed consists in connecting the total amount of resistance in series and then progressively short circuiting the various connections until all are cut out.

Figs. 8,134 to 8,157.—Westinghouse type L-2 controller connections. This type controller opens the circuits to both motors before making the change from series to parallel. In this parallel method additional sections of resistance are connected in parallel with the first section on each successive step. The value of the resistance in circuit is decreased as each new section is added in parallel with the first section and, finally on the last step the entire group is short circuited.

The induction regulator method employs an induction regulator which consists of two coils: a primary, and a secondary, which are wound upon separate cores and are capable of angular adjustment for changing the direction of the flux from the primary through the secondary so that the voltage generated in the secondary increases or decreases the voltage supplied to the motors by the auto-transformer according to the relative angular position of the secondary to the primary.

Three Phase Induction Motor Control.—Rheostatic control is applied to three phase induction motors *by arranging a variable resistance in series with the armature winding and progressively reducing it as the motor speeds up*, till at full speed or the last step of the control all the resistance is cut out.



FIGS. 8,159 to 8,168.—Westinghouse type K-35 controller connections.

With this control the slip ring or external resistance motor is used. In the changeable pole method the number of pole may be altered to secure variable torque either by providing the motor with independent field windings, or by regrouping the field coils.

Cascade operation consists in the various combinations of two motors. The armature of the two motors are mechanically connected, the field of the first is connected to the supply and the armature to the field of the second motor; the armature of the second motor is connected to the external resistance at start. As the motors speed up, the external resistance is cut out till armature of second motor is short circuited. For motors of equal number of pole, after reaching maximum speed, they may be separated and each, having resistance inserted in its armature circuit, may have its field connected to the supply. For maximum effort the external resistances may now be progressively cut out resulting in full parallel operation.

In the single control cascade method the second motor is cut out after the period of concatenation. In parallel single cascade control, motors are employed having a different number of pole, or different gear ratios.

In operation, when the motor with the greater number of pole reaches synchronism, it is cut out. If the motor with the lesser number of pole be cut out instead, the train will operate at a speed between that corresponding to concatenation and that for the free running of the motor with the lesser number of pole with armature short circuited.

The changeable pole and cascade methods are combined by first making the sequence of pole change and then applying either of the cascade methods, thus giving several speeds.

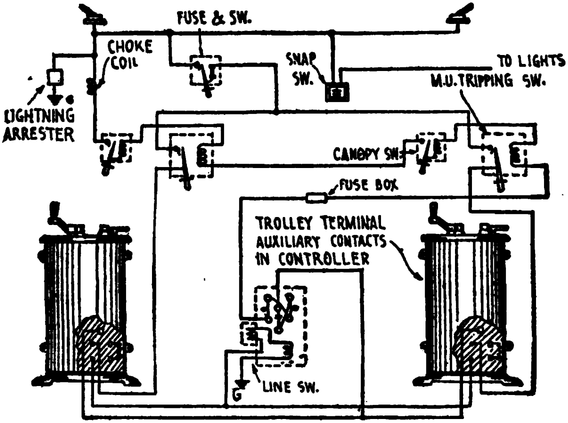
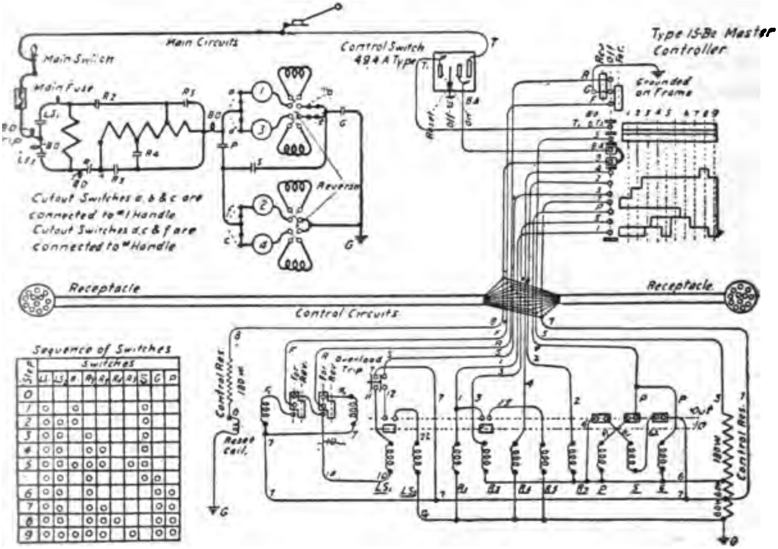


FIG. 8,169.—Westinghouse auxiliary contactor equipment. A contactor equipment consists of a powerful pneumatically operated switch, or "contactor," mounted beneath the car and connected to the main reservoir of the air brake system. The switch is controlled by means of a magnet valve, which is operated by current from the trolley. The circuit of this magnet valve is carried through a pair of auxiliary contacts located on the drum of the controller. When the handle is moved toward the off position, the circuit of the auxiliary contacts, and hence the circuit of the magnet valve is broken before the main power circuits are broken, and thus the main power circuit is always opened by the pneumatically operated switch beneath the car rather than by the controller contacts.

Combined D.C. and A.C. Control.—In changing from *a.c.* to *d.c.* (or from direct to alternating) it is ***necessary to guard against the possibility of wrong connections*** upon the car for the current received, that is, to prevent disaster should connections be made for 600 volts direct current operation and accidental contact be made with 6,600 volts alternating current trolley.

To guard against this, the main switch of the direct current and alternating current car equipment is provided with a retaining coil so designed that it will open when the motor current is interrupted.

Where *a.c.* and *d.c.* trolley sections adjoin, a dead section is left between the two for a length not exceeding a car length, so that a car may pass from



Sequence of Switches

Step	Switches									
	LS1	LS2	R	R1	R2	R4	R3	S	G	P
0										
1	○		○					○		
2	○	○	○					○		
3	○	○		○				○		
4	○	○		○	○			○		
5	○	○	○	○	○		○	○		
	○	○		○				○	○	
6	○	○		○					○	○
7	○	○		○	○				○	○
8	○	○		○	○	○			○	○
9	○	○	○	○	○		○		○	○

FIG. 8,170.—Diagram of connections Westinghouse unit switch control (type HL) for quadruple equipment of 75 horse power motors or less. In type HL control the various main circuit connections between trolley, starting resistors and motors (which, in drum type control, are made by the overhead circuit breaker and the power drum and contact fingers of the controller) are made by pneumatically operated switches assembled in a common frame designated as a switch group, which is located underneath the car. Each switch is closed when desired by compressed air from the brake system, acting on a piston. The reversing connections ordinarily made by the reverse drum of the platform controller are made by a reverse drum similar to that of the controller, but of more substantial construction, pneumatically operated and mounted in a separate case underneath the car. The complete reverse drum with its operating mechanism is termed a *reverser*. The admission or release of compressed air to the pistons for operation of the switches and reverser is regulated by means of electrically operated magnet valves, one of which is attached to each piston cylinder. The circuits from the various magnet valves are controlled by a master controller on either car platform through a control train line, which extends the length of the car and terminates at each end in a twelve conductor train line receptacle. By moving the handle of the master controller from notch to notch, the various switches in the switch group are operated and the proper motor connections are established. If the adjacent train line receptacles on two or more cars be connected by suitable train line jumpers, the operation of either master controller on any car will cause the various switches on all of the cars to close or open simultaneously for train operation.

one section to the other at full speed, in which case the main car switch opens on the dead section through lack of power to operate the retaining coil, and will reset automatically for alternating or direct current operation as the case may be, after leaving the dead section.

Locomotives.—Numerous types of electric locomotive have been built for a variety of purpose, from yard switching to the hauling of heavy passenger trains at high speeds. They may be classed

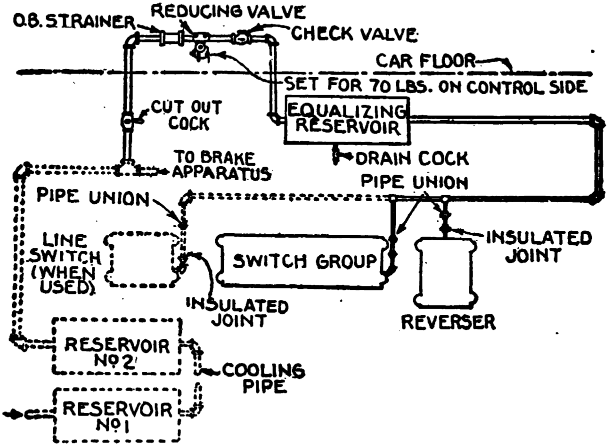


FIG. 8,171.—Arrangement of piping of Westinghouse unit switch control, type HL. The piping here shown is for the compressed air which operates the control apparatus, the air supply being taken from the brake system. The amount of air required for operating the switches is so small compared to that required by the brakes and whistle that it is practically negligible.

1. With respect to the power source, as
   - *a.* External;
   - *b.* Storage battery;
   - *c.* Steam-electric.
   - *d.* Gas-electric.

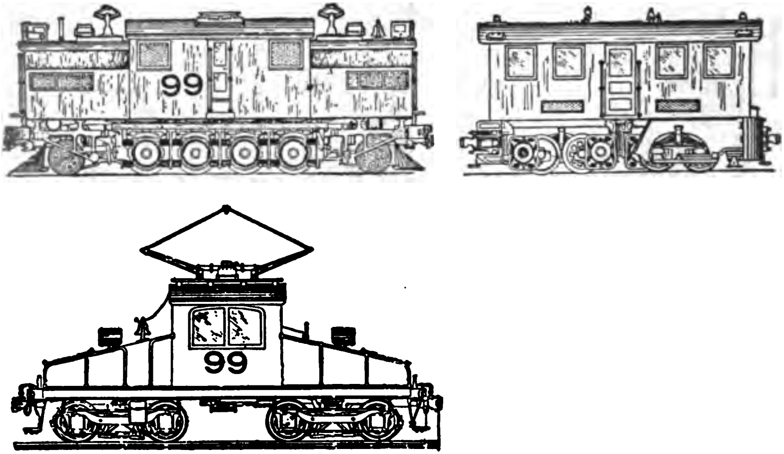
2. With respect to the transmission, as
   - *a.* Gearless;
   - *b.* Geared;
   - *c.* Connecting rods;
   - *d.* Scotch yoke;
   - *e.* Combination gear and connecting rods.

A gearless locomotive is one having the armatures built on the axles of the driving wheels; a geared locomotive has speed reducing gears between the motor and axle.

In the side rod driven type the motors are placed in the cab and the driving torque communicated to the drivers by means of connecting rods.

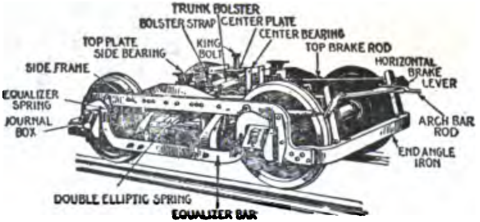
In the Scotch yoke arrangement, the yoke drives one axle through a sliding block and the others through rods connected to the yoke by knuckle pins.

The combination gear and connecting rod drive comprises motors geared to jack shafts which in turn transmit the power to the drivers by means of connecting rods.



FIGS. 8,172 to 8,174.—Various electric locomotives. Fig. 8,172, New York Central 1-4-1 locomotive; fig. 8,173, ordinary form of locomotive; fig. 8,174, Baltimore and Ohio, 160,000 lbs., 0-4-0 locomotive.

The Running Gear.—There are two general types of truck for electric cars: 1, those in which the car body rests upon the truck bolster or side bearings which are supported by springs for the side frames carried by the axle journal boxes, and 2, those in which the car body rests upon the truck bolster supported from the truck frame which rests upon springs carried by equalizer bars resting on the axle journal boxes.



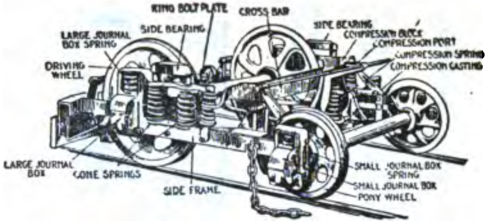


Fig. 8,175.—Standard motor Co. M.C.B. type high speed truck.

Fig. 8,176.—Brill maximum traction truck. On tangent track 75 per cent. of the weight of this truck comes on the motor axle which has the large wheels. When on a curve, part of this weight is shifted to the trailing wheels. This type is used extensively in city street car service and is not adapted to high speed. One motor is used on each truck.

Figs. 8,177 to 8,179.—Center and side bearings of a truck. These form the contact points between itself and the car body. The car body is practically carried on the center plates on the truck bolster and comes in contact with the truck only at this point; but in order to prevent more than a slight displacement of the car body from the vertical, side bearings are placed over the side frames of the trucks, and so adjusted as to leave sufficient space between side bearing top plate and the plate on the car to take up the maximum compression of the springs when the car is fully loaded.

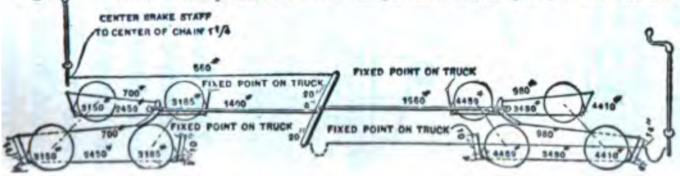


Fig. 8,180.—Hand brake system. One of the objectionable features of this arrangement is the use of a single *sway, bar* and *floating lever*, which results in the application of the greater braking pressure to the rear wheels or truck instead of to the front wheels or trucks where it should be capplied to secure the most effective braking.

Brakes.—The several types of brake used are classed as: 1, hand brakes; and 2, air brakes.

The familiar hand brake needs no description, and air brakes have been described at great length in Guide No. 3.

Car Lighting.—There are several systems in general use and the following descriptions give the essential features.

Stone System.—The equipment consists of a dynamo, a storage battery to act as auxiliary when the dynamo is inoperative, and an automatic switch to close the dynamo circuit when the critical speed has been attained.

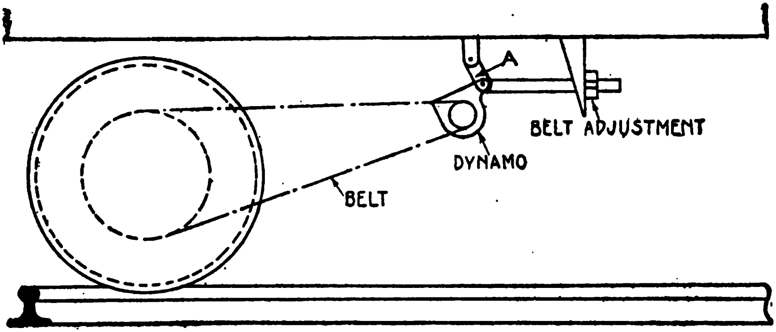


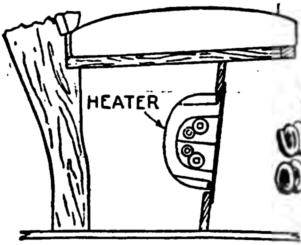
FIG. 8,181.—Method of suspending Stone system car lighting dynamo. ***As hung,*** the belt draws the dynamo out of the diagonal position in which it would naturally hang, thus putting a definite tension on the belt, just sufficient to absorb the power required. It is obvious that when the pull on the belt exceeds that due to the offset suspension of the dynamo that the dynamo will be drawn toward the axle and the belt allowed to slip. Thus the dynamo will run at practically constant speed for all values of train speed above the critical value. A mechanical governor automatically closes the dynamo circuit when critical speed has been reached. A storage battery is suspended underneath the car to act as auxiliary in lighting the lights when the dynamo is inoperative. Another function of the storage battery is that it acts as a ballast or regulator to keep the lights constant, absorbing the variations of dynamo output.

The principle underlying the operation of this equipment is that regulation is obtained by allowing the belt to slip. As the speed of the train rises the dynamo voltage will tend to rise proportionally, this causing a great battery charging current to flow, thus increasing the dynamo output and belt pull.

McElroy System.—In this system the dynamo is mounted directly on the trucks and is driven by a gear and pinion similar to those used on the motors of trolley cars; these being enclosed in a wrought iron gear case which is made dust proof with leather packing.

"Axle" Lighting of Cars.—This is the prevailing method and consists of a dynamo belted to the truck axle, storage battery, and necessary auxiliaries for proper control.

Car Heating.—The amount of power consumed by electric



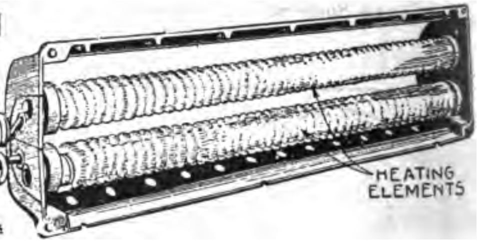
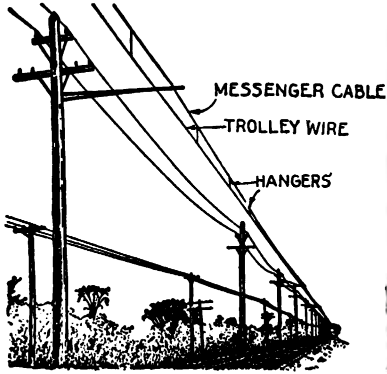


FIG. 8,182.—Section through car seat, showing location of panel heater.

FIG. 8,183.—Two unit coil of panel heater. The front is provided with a wire grating, to protect passengers' clothing from contact with the coil which in operation reaches a temperature above ordinary ignition point.



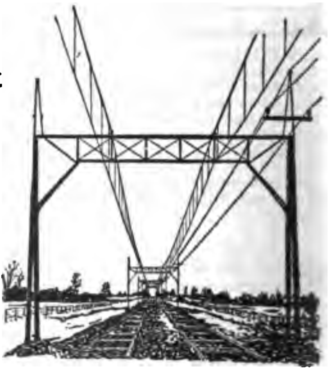
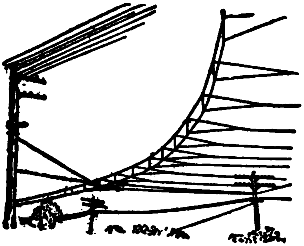


FIG. 8,184.—Eleven point bracket catenary construction for single track, suitable for ordinary interurban service.

FIG. 8,185.—Bridge type single catenary construction for double track, suitable for heaviest class of service, such as electrified steam railroads, and substantial interurban roads handling heavy freight traffic as well as heavy passenger traffic.

heaters naturally varies with the climatic condition, but for cars ranging from 24 to 34 feet in length the power consumption for average and severe weather conditions varies from 5 to 7 kilowatts, respectively, so that the electric heater loads on both street railway and interurban systems compose a very large part of the total energy consumed.



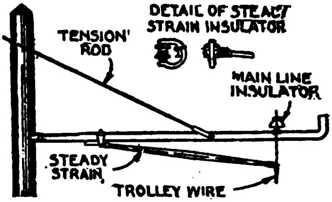
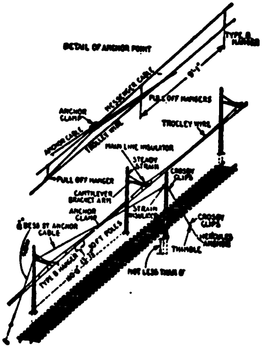


FIG. 8,186.—Single catenary curve construction. ***In locating*** the bracket arms on poles and the poles on curves, the effect of super-elevation and the lateral overhang of the cars or locomotives must be allowed for. as well as the position of the current collector. ***Anchor spans*** should be placed at the ends of curves and at frequent intervals on tangents.

FIG. 8,187.—Detail of bracket arm with steady strain.



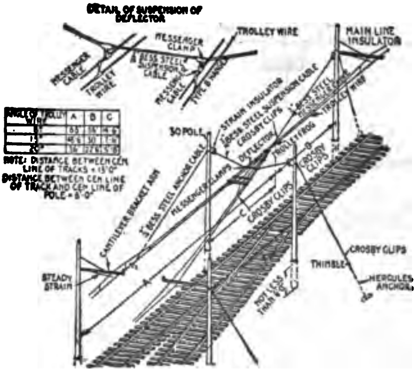


FIG. 8,188.—Catenary construction at anchor span.

FIG. 8,189.—Trolley deflector construction at switch. ***The method of construction*** employed at turn outs and sidings depends upon the type of current collector used.

Track.—This varies with the service and method of power transmission employed.

The track construction for overhead trolley line systems differs but little from other forms of railway construction, with the exception of the *bonding* of the rail joints. With the use of a track return this is absolutely necessary to secure a continuous metallic path, thereby reducing the resistance which would otherwise be introduced into the circuit.

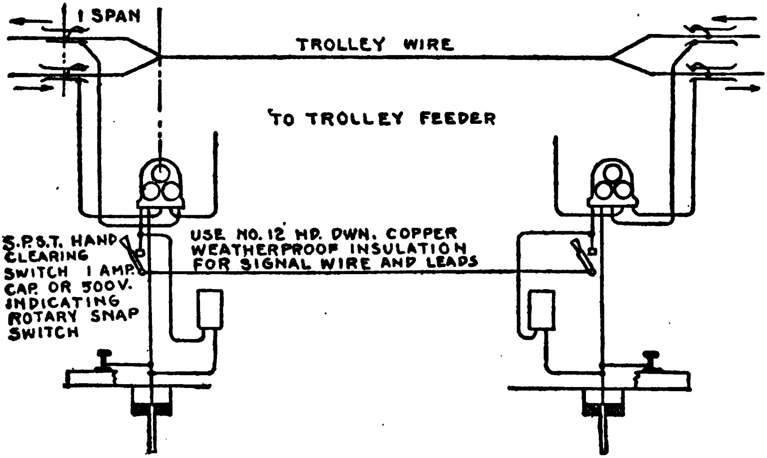


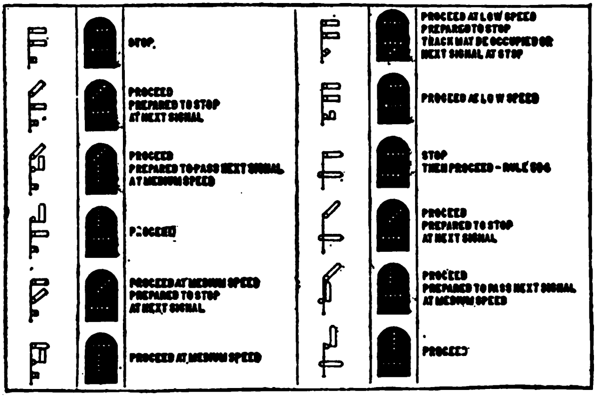
FIG. 8,190.—Automatic block signal system. The boxes are located at the end of each block and are provided with white and red semaphore discs operated automatically by trolley switches.

Trolley Line Construction.—The various methods of trolley line construction may be divided into two classes: 1, bracket construction, and 2, span wire or *catenary* construction.

There are two general classes of catenary construction: the single catenary, and the double catenary. In both of these the principal object aimed at is the maintenance of the trolley wire at a constant distance from the top of the rails.

In the single catenary construction the cable is carried by the brackets, spans, or bridges.

Signal Apparatus.—There are two general classes of railway signal: 1, block system, and 2, interlocking system.



FIGS. 8,191 to 8,202.—Corresponding aspects of semaphore and position light signals with their indications.

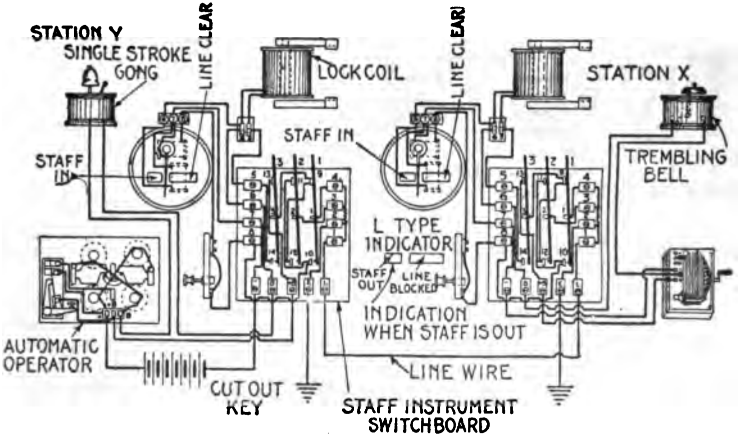


FIG. 8,203.—Automatic operator system. ***In operation,*** when current is passed through the line, the armature is rotated in a direction to cause it to lift the weight on which the normally closed contact is fixed. When current through the line is broken, this weight causes the armature to rotate in the opposite direction a sufficient distance to close the other contact and cut in a local battery. Current from this battery passes through a pair of coil holding the armature in this position, and releases the staff at opposite ends of the block. When the circuit is again broken, battery is cut out of the line.

Block signaling has to do with keeping trains which are running on the same track, at a proper distance apart. Inter-locking signaling is for the control of trains over tracks which intersect at points of crossing or divergence, and has for its object the prevention of conflicting movements, the proper routing of trains, and the insurance that the movable parts of the track are in their right positions before the signals governing movement over them can be made to give a proceed indication.

Railway Signals.—These consist of colored lights, colored flags or by metal signal banners. Some roads use a green signal for precaution while others use a yellow signal. Red is the danger signal.

The caution, stop, and proceed signals are in general use.

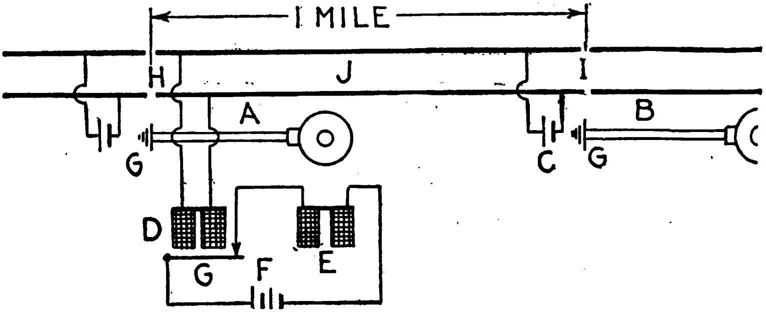
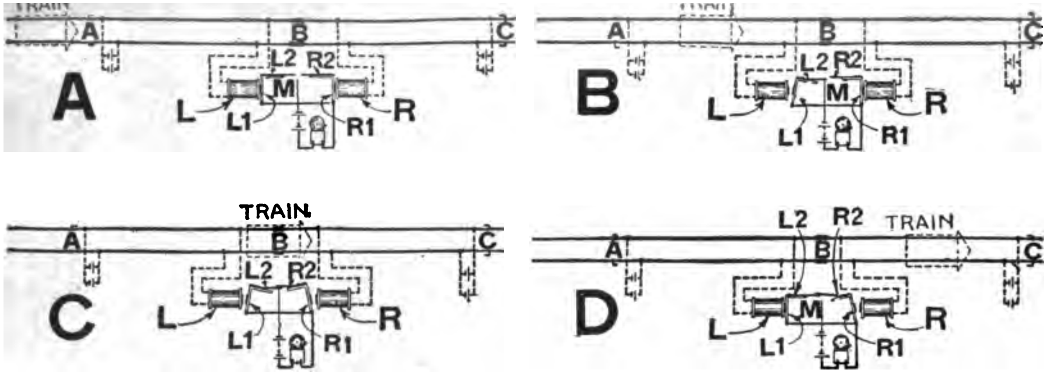


Fig. 8,204.—Simple track circuit whereby a signal is operated by a train in a block.

Flags or metal signals are used during the day and lights of various color at night.

Disc signals are displayed by movable shutters or discs in front of a fixed background; semaphore signals, by the position of a movable arm in a plane at right angles to the track and mounted on a high pole. The semaphore arms of distant signals have notched ends while the home signals have straight ends. When a home semaphore signal is *up* it means to stop; danger ahead. When a distant semaphore signal is up it means to proceed with caution and the next home station signal will indicate if the block be clear. Whether or not a relay be used in the track circuit, a bell is generally rung. At distant crossings only the bell is used, but near stations the relay is used to not only ring a bell but to throw a home signal.

Trolley Car Operation.—To start the car, see that the



Figs. 8,205 to 8,208.—Diagrammatic sketches illustrating the interlocking feature of universal crossing bell relay. Fig. **A**, track circuit AB and BC, unoccupied, bell circuit open; fig. **B**, train has entered track circuit. AB, relay magnet L. De-energized armature L1, causes contact finger L2, to make contact with M, bell circuit closed; fig. **C**, train in track circuit AB and BC, (at crossing) relay magnet R, de-energized contact finger R2, resting on L2, bell circuit closed; fig. **D**, train in track circuit BC, relay magnet L, energized contact finger R2, resting on L2, bell circuit open. When train passes out of track circuit BC, all parts normal as in fig. **A**, operation similar in either direction.

brakes are off, the canopy switches closed; then move the controller handle to the first notch.

After the car is well started, move to the second notch, and after a short time to the third, and so on to the last. Don't stop the handle between notches, and don't move it too slowly. On the other hand, do not move too rapidly from the first notch to the second.

In shutting off the current the handle may be moved around as rapidly as desired to "off" from whatever position it may happen to be on. When stopping at any point, the reverse lever is sometimes used to make the car go backward. Never reverse while the car is running, unless to avoid an accident. But if it be absolutely necessary to stop the car quickly, pull the brake on with the right hand and shut off the current with the left at the same time; then with the right hand free, throw the reverse lever and turn on a very little current.

After bringing the car into the car house, have the controller at "off," take off the controller handles, pull down the trolley and tie it a few inches below the trolley wire.

Car Does Not Start.—If the car fail to start when the controller is "on" and both overhead switches are closed, the trouble is due to an open circuit, and probably to one of the following causes:

1. The fuse may have blown or melted. Open an overhead switch or pull off the trolley and put in a new fuse, removing the burned ends from under the binding posts before doing so. Never put in a heavier fuse than that specified by the company, as it might result in damage by allowing too large a current to flow.

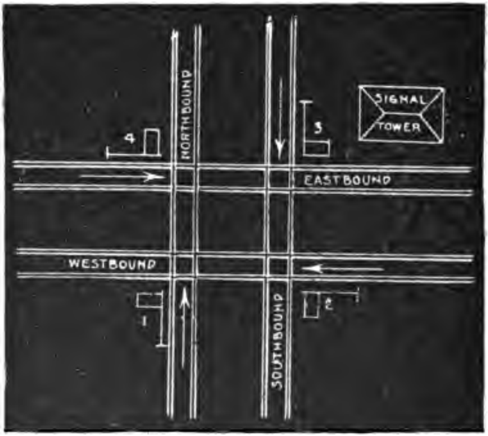


FIG. 8,209.—Intersection of two double track lines, with their respective signals. If these be *automatic* track relays properly interconnected, they can be readily arranged to give the protection desired. If they be *semi-automatic*, electric interlocking will be introduced to prevent confliction of routes. Thus, when signal 3, is at clear, to allow a south bound train to pass, 2, and 4, must be locked in the normal or stop position when electric locking or interlocking is used and prevented moving to clear if the ordinary automatic system be employed.

2. On a dry summer day, when there is much fine dust on the track, it happens that the car wheels do not make proper contact with the rail and the car fails to start. In such a case try to establish contact by rocking the car body. Should this fail to work, the conductor should take the

switch bar or a piece of wire and, holding one end firmly on a clean place on the rail, hold the other against the wheel or truck. This will make temporary connection until the car has started. The conductor should be sure *to make his rail contact first and keep it firm during this operation* or he may receive a shock.

3. If the track conditions be apparently good, it may be that the car stands on a piece of dead rail, a piece of rail on which the bonding has been destroyed. In that case the car conductor would have to go to the next rail section with a piece of wire to connect the two rails and then order the motorman to start his car.

4. A brush or two may not have been placed, or, if placed, may fit too tightly in the brush holder, so that the springs do not establish contact between the brush and the commutator. If this be the case, remove the brushes and sandpaper them until they go into the brush holder easily.

5. The contact fingers on a controller are rough, burnt, and perhaps bent so that the drum cannot make contact. It may also be due to wear on both the contact surfaces of the drum and the finger, which may have been burnt and worn away to such an extent that contact is not established when the controller handle is placed in the first notch. Try to smooth the burnt surface with sandpaper and bend the fingers or contacts into their proper position. Should this fail, then operate the car with the other controller. In this case the conductor should be on the front platform to handle the brake and give orders to the motorman when to start and stop, as the occasion requires. Under these conditions the car should never be allowed to travel at a high speed.

6. A loose or broken cable connection. This can be located and placed and fastened in its position. It is, in most instances, a cable connected to one of the motors, rheostat or lightning arrester, and very seldom in the controller stand.

7. A burnt rheostat. A rheostat may have received too great a current for some time and the first contact terminal may be broken. In such a case, if temporary connection cannot be conveniently established, the car will not start at the first notch, but at the second it will start with a jerk.

8. If the car refuse to start on the first contact, but start all right on the second and acts normal thereafter, then there is an open circuit in the rheostat, either internally, or the first cable connection is broken.

Abnormal Starting.—Sometimes a car will start with a jerk, but afterwards run smooth and normal.

This indicates a short circuit in the rheostat. Examine the rheostat terminals, as the trouble may be due to the crossing of the cables or a loose cable touching another terminal of the rheostat; do not touch it but run car back to barn.

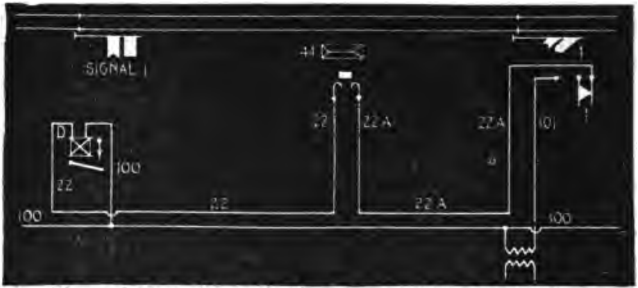


Fig. 8,210.—Advanced block distant signal. ***In operation*** when the towerman **pulls a lever** numbered the same as the distant signal he desires to operate, he **completes a circuit between** the two springs which causes the distant signal blade to clear.

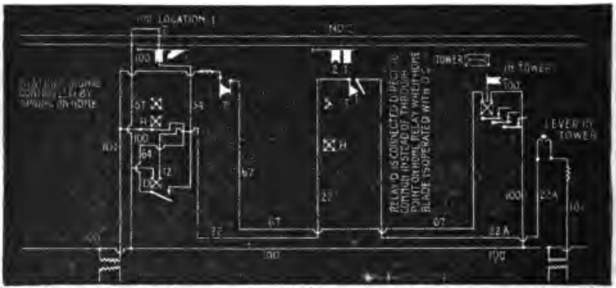


Fig. 8,211.—Distant signal and repeater circuit. Here, through a lever connection, **when the lever** is pulled out in the tower, current is allowed to flow to and complete a circuit **through a** contact spring operated by the signal mechanism. As soon as the distant blade **clears,** according to this circuit, a repeater located in the tower is de-energized **and drops its** armature, which shows the position of the blade whose action governs its source **of energy.**

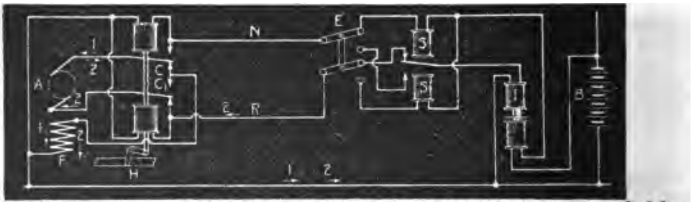


Fig. 8,212.—Diagram illustrating electric interlocking. **A switch and lock movement is driven by** a direct current motor, the shaft of which is connected by a magnetic clutch to an **ex**tension working a cam drum which operates the switch and lock. When the drum is **re**volved by the motor, first the lock rod and then the switch move in proper operation. **After** the switch has been moved against the stock rail it is automatically locked and a **knife** switch throws open the control circuits and closes the indication circuit. The direc**tion** of rotation for reversing the switch is controlled by a double field winding in the **motor,** one part of which is cut out while the other is in circuit.

Troubles.—Heavy flashing and smoking in the controller is ıe to dirt, moisture, metal dust in the controller, or the too ow turning off of the controller.

Open the overhead switch and blow out the dust from the ring terminals, also remove all dust at the lower ends of the controller and see that it is dry.

Should the lamps not light upon turning the lamp switch examine lamp circuit fuse.

If fuse be not blown, either a lamp is not screwed up or one is burned out. In either case none will burn because they are connected in series.

Motor Troubles.—A few motor troubles often met with are ven here:

A sharp rattling noise when the car is traveling at high speed is the consequence of an uneven commutator.

A commutator that is flat in places, or a few bars that have become loose and project slightly, cause the brushes to be quickly forced away from the commutator by the high bars, and to be forced back onto the lower ones by the brush holder spring as soon as a high bar has passed. This causes heavy sparking at the brushes and excessive heating of the commutator segments, besides the rapid wearing down of the brushes. The rapid succession of these changes causes the noise, and this can be remedied only in the repair shop. It should be reported.

A dull thumping noise, also connected with sparking at the brushes, may be due to the armature striking or rubbing against the pole pieces. If this be due to loose bearings the cap bolts should be tightened, but if, on account of worn out boxes, the car should be taken to the barn at a reduced speed.

Abnormal heating of one of the motor armatures may be due to its striking the field poles when rotating.

Heating of the motor may also be due to a defective brake, caused by weak release springs or too short a brake chain.

Again, heating may be due to the oil or grease used which does not melt properly, if at all.

A full grease or oil cup is no sign of proper lubrication.

If it be found that bearings heat, in spite of full grease cups, take a clean stick, make a hole through the grease down to the shaft, pour in soft oil and go ahead.

It may be well occasionally to feel the car axle bearings, which get pretty warm when insufficiently supplied with oil.

Before Starting.—When the train is turned over to the motorman he should:

1. Pass along the outside and carefully examine the bus line and cable jumpers between cars, to assure himself that all connections are properly made and that the main switches are closed;

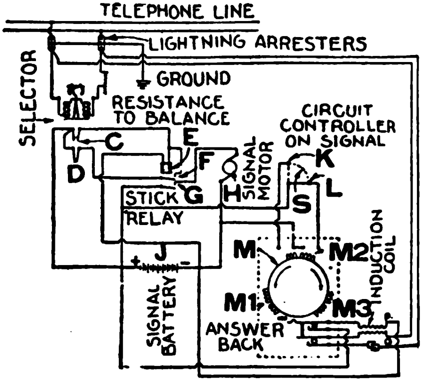


Fig. 8,213.—Standard home and distant semaphore signals. ***In operation,*** until either blade has reached a position approximately 30 degrees from the vertical it will indicate the same as though at the full horizontal position. This is effected by using several spectacles, each held in place by independent bezel rings, semaphores vary in length from 4 to 5 feet, about 4½ being regarded as standard.

Fig. 8,214.—Train dispatcher's selector system. ***This is used*** to indicate to the train engineer whether he is to proceed on the main line or to take a side track. When the indicator signal is turned from the normal to the reverse position a special "answer back" device is also operated, which makes an audible noise and informs the dispatcher that the signal has operated properly. To display a "take siding" signal the dispatcher turns a switch or depresses a key which operates the selector by closing the normally open contacts marked C. The "stick relay" throws signal battery current into a motor which operates the signal. To restore the signal to normal position the dispatcher operates the selector in the reverse direction, which opens the contacts marked C. This causes the "stick relay" to restore to normal position and throws a reverse signal back to the dispatcher. This system is semi-automatic.

2. Pass through the train, closing air compressor and third rail switches in each car, and opening master control switches in all cars except head car or car from which train is to be operated;

3. Pass along outside the train again and satisfy himself that the air compressors are working properly;

4. Take position in the motorman's compartment at forward end of train and note the brake pipe pressure, and close master controller switch;

5. Set circuit breakers by moving the circuit breaker switch over the master controller to the on position, holding it there about one second to allow time for all circuit breakers to set;

6. Test the air brakes, and if same work satisfactorily, the train is ready to start.

Train Fails to Start.—If, when all the connections are made and the controlling handle operated properly, the train do not start, the fault may be due to various causes, as: 1, failure of power; 2, fault in master control circuit; 3, fault in motor control circuit; 4, non-release of air brakes.

To detect failure of power, try the lights. Some faults liable to occur in the master control circuit are: loose cable jumper; grounded train cable; poor contact in master controller; master control fuse blown.

A loose cable jumper is detected by noting if the contactors on each car be working while the train is accelerating.

A grounded cable is detected by operating the master controller; if the master controller fuse blow, it indicates that one or more wires of the train cable are grounded.

To locate a ground in the train cable, disconnect train cable on operating car from rest of train by removing train cable jumper from its socket on second car. If the fuse now blow, when the controller handle is operated, it indicates that the ground is either in the operating car or its train cable jumper.

To determine which be grounded, remove jumper, if fuse blow when the controller handle is operated, the ground is in the car; if it do not blow, the ground is in the jumper.

To detect poor contact in the master controller, open master controller switch, remove cover from the controller and turn the handle slowly, noting if each finger make good contact with the drive.

A blown master controller fuse is indicated if, in turning the master controller handle to the first notch and thus opening the master controller switch, no arcing occur, the fuse is blown or is imperfect.

Fault liable to occur in the motor control circuit are: main fuse blown; shoe or trolley fuses blown; bus fuses blown; loose or disconnected bus jumper; circuit breakers open.

The blowing of the main fuses should not occur often. It is caused by short circuit or grounding in the motor circuit. Before renewing main fuse, open the main switch.

The grounding or short circuiting of the wiring on a car or truck may cause the trolley fuse to blow. The trolley or trolleys should be pulled down and trolley switch opened before replacing trolley fuse.

A shoe fuse may blow for short circuit, grounding of the car wiring on some part of the car or truck, or may be caused by a contact shoe on the car or train grounding. In replacing fuse, first open the third rail switch and insert the wooden paddles, provided for that purpose between all shoes on that car that are in contact with the third rail.

A loose or disconnected bus jumper may be detected when the train is at a crossover and current cannot be obtained on operating cars, although other cars of the train have current, thus indicating blown fuse or fuses, or that a bus line jumper is loose or disconnected between the operating and adjacent cars.

CHAPTER 131

Electric Ship Drive

The object of the electric drive is to ***overcome the inherent defects or limitations of the turbine***, that is, its function is similar to the so-called "transmission" of an automobile in that it gives flexibility of control and permits the turbine to run at its most economical speed.

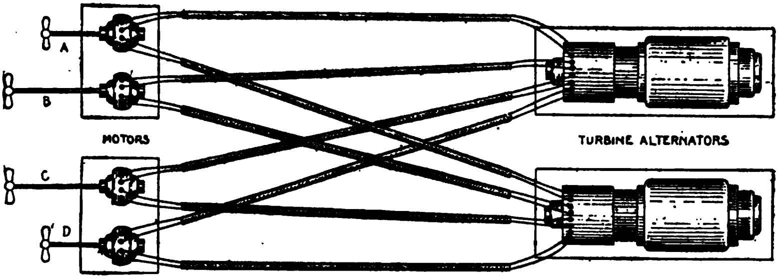


Fig. 8,215.—Elementary diagram illustrating the essentials of electric ship propulsion. Two turbine alternator units are shown on the right which are wired for various connections with the motors; the latter operates the propellers A,B,C and D.

Fig. 8,215 will make clear the plan of the driving mechanism. The generating plant is composed of two independent turbine alternators, each of which is capable of delivering one-half of the total power necessary to run the ship at maximum speed. The driving motors are of the three phase variety and each motor is equipped with two sets of pole piece—one of twenty-four poles and the other of thirty-six. By operating the motors on one or the other set of pole, the speed is changed without impairing the efficiency in any way. The plan of operation is to drive the motors at the lower speed for cruising with only one turbine alternator in operation, while for the greater speed the two alternators would be operated

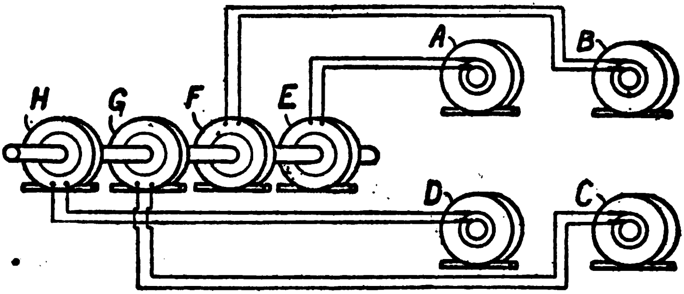


FIG. 8,216.—Hobart's alter-cycle control or induction motors for electric ship propulsion There are four motors E,F,G and H, wound respectively for 24,36,48, and 72 poles. The maximum speed of the propeller shaft is 100 *r.p.m.* with full power of all the motors. To run the motors at 100 *r.p.m.* requires frequencies of 20 cycles for the 24 pole motor, 30, for the 36 pole motor, 40, for the 48 pole motor, and 60 for the 72 pole motor. Thus to obtain equal *r.p.m.* the frequencies of the four alternators A,B,C,D are respectively made 20,30,40 and 60. To obtain these frequencies when the alternators are down say to 600 *r.p.m.* requires respectively 4,6,8, and 12 poles for the alternators A,B,C, and D. To drive the ship at two-thirds speed, motors F and H, are connected to alternators A and C, which provide respectively ⅔ of the frequencies of B and D, to which F and H, were connected for full speed running. Since for the lower speed only about ³/₁₀ as much power is required as for top speed, alternators B and D, and motor E and G, are shut down. For half speed a single motor is sufficient; this can be provided by operating motor H, from alternator B, or G, from A. One-third speed is obtained by operating H, from A.

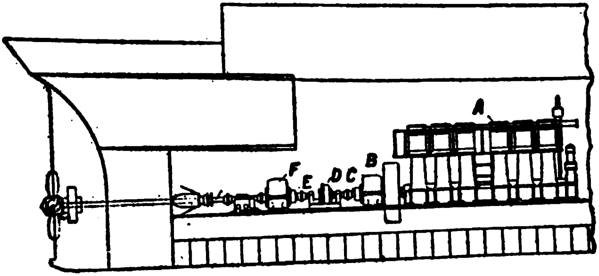


FIG. 8,217.—The ***Menlees system*** of propelling ships by gas engines. In the figure A, is a six cylinder gas engine coupled to a dynamo B. The shaft C, of the dynamo and engine is adapted to be connected by a clutch D, with the shaft E, of the electric motor F, which is connected with the propeller shaft. ***In operation*** at all ahead ship speeds direct driving may be employed, but, for speeds less than half, the electrical transmission may be used, the motor F, receiving electrical energy from the dynamo B. The drive may also be employed for reversing the astern speed by not greater than half the full ahead speed, suitable switches and gear being provided.

FIG. 8 218.—General Electric revolving field of alternator of the turbine driven unit shown in fig. 8,223.

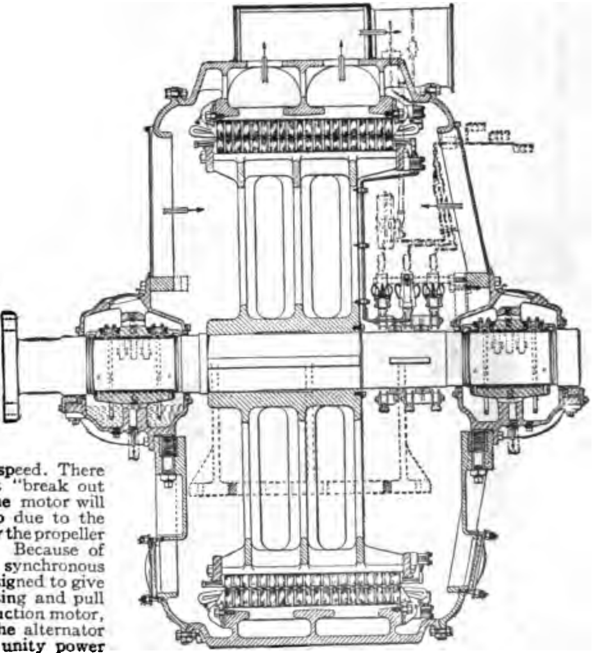


FIG. 8,219.—General Electric synchronous motor as designed for four new cutters for the coast guard service. Motors designed for ship propulsion must be capable of operating successfully under normal load and speed conditions and also of quickly reversing the propeller at full speed. There should be sufficient "break out capacity" so that the motor will not fall out of step due to the overloads imposed by the propeller in rough weather. Because of the fact that the synchronous motor cannot be designed to give quite as much starting and pull in torque as an induction motor, and also because the alternator being designed for unity power factor, is small, it is not possible to obtain sufficient reversing torque without over-exciting the alternator field. It is also necessary when reversing at full speed to reduce the alternator speed until the motor has been synchronized, after which motor and alternator are brought up to speed together. Where very high torque is required to brake the propeller down to zero speed against the action of the water tending to drive it as a turbine, the motor may be operated as a short circuited alternator by reversing the phase rotation between motor and alternator, then establishing field on the motor but with no excitation on the alternator field. After the propeller has been brought to rest, the motor may be started as an induction motor, brought up to speed, and synchronized.

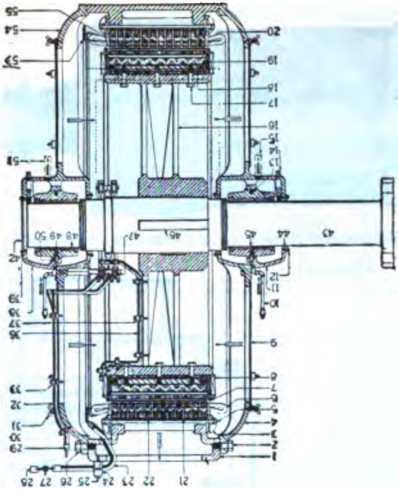


Fig. 8,220.—General Electric induction motor for merchant marine propulsion. The reliability of an induction motor on shipboard is greatly enhanced by the ease with which temporary repairs can be made in case of an electrical break down at sea, without disassembling the motor, so that the boat may continue at full or slightly reduced speed to port.

Fig. 8,221.—Exterior view of General Electric induction motor shown in section in fig. 8,220.

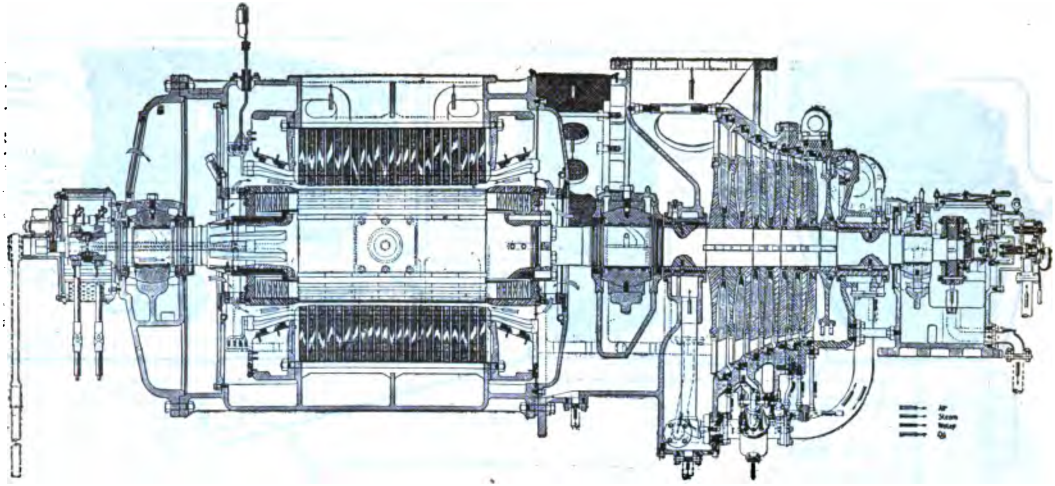


FIG. 8,222.—General Electric turbine driven alternator in which end bearing is carried by end shield.

in tandem with the motors arranged to run at their maximum speed. Thus it will be seen that when cruising, the one alternator is running at its full efficiency as are also the motors, while the second alternator is idle. Likewise, when full speed is required, the second alternator is started and run also at its peak of efficiency.

The author believes the time and money spent in devising such complication of machinery to secure flexibility of control and to obtain the necessary speed reduction between high speed turbines and low speed propellers could have been employed more profitably in perfecting a two speed and reverse gear, or more especially in seeking a commercially successful method of generating steam at considerably higher pressures and degrees of superheat than are common at present, for use in quadruple and quintuple expansion engines.

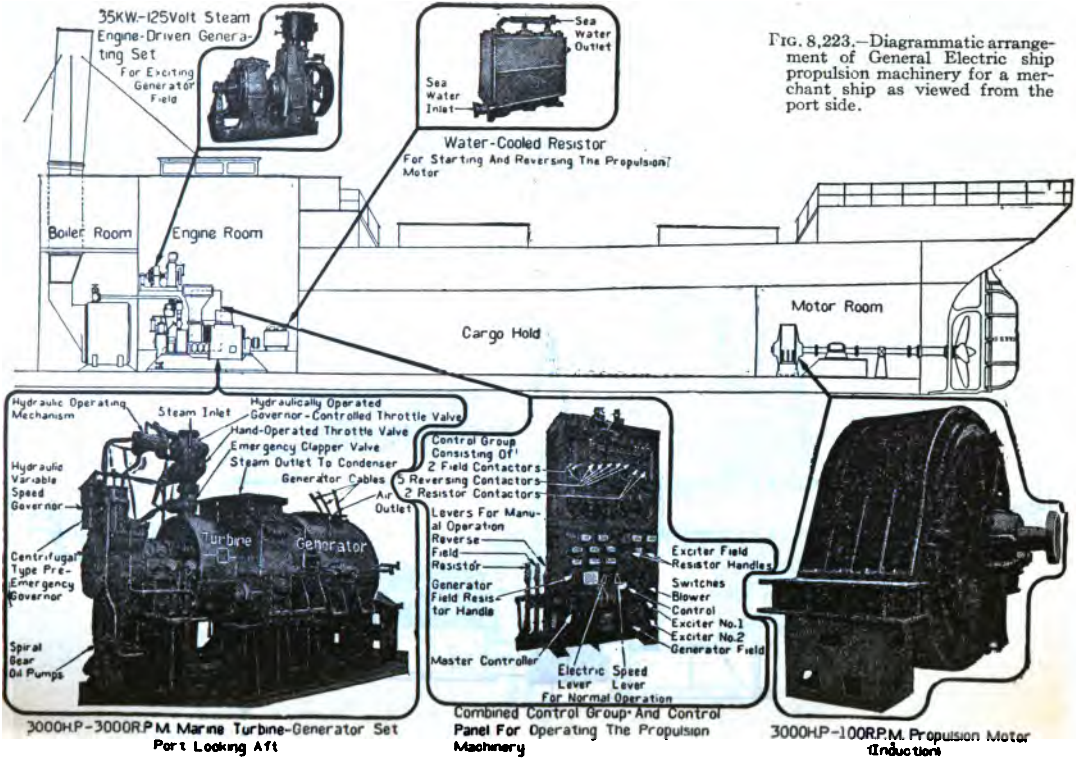


FIG. 8,223.—Diagrammatic arrangement of General Electric ship propulsion machinery for a merchant ship as viewed from the port side.

Table of Electrical Instruments on Control Panel

1. Excitation indicator
2. Generator ammeter
3. Propeller speed indicator.
4. Generator field ammeter
5. Generator volt meter
6. Turbine speed indicator
7. Indicating wattmeter
8. Temperature indicator
9. Exciter voltmeter
10. Exciter ammeter
11. Integrating wattmeter

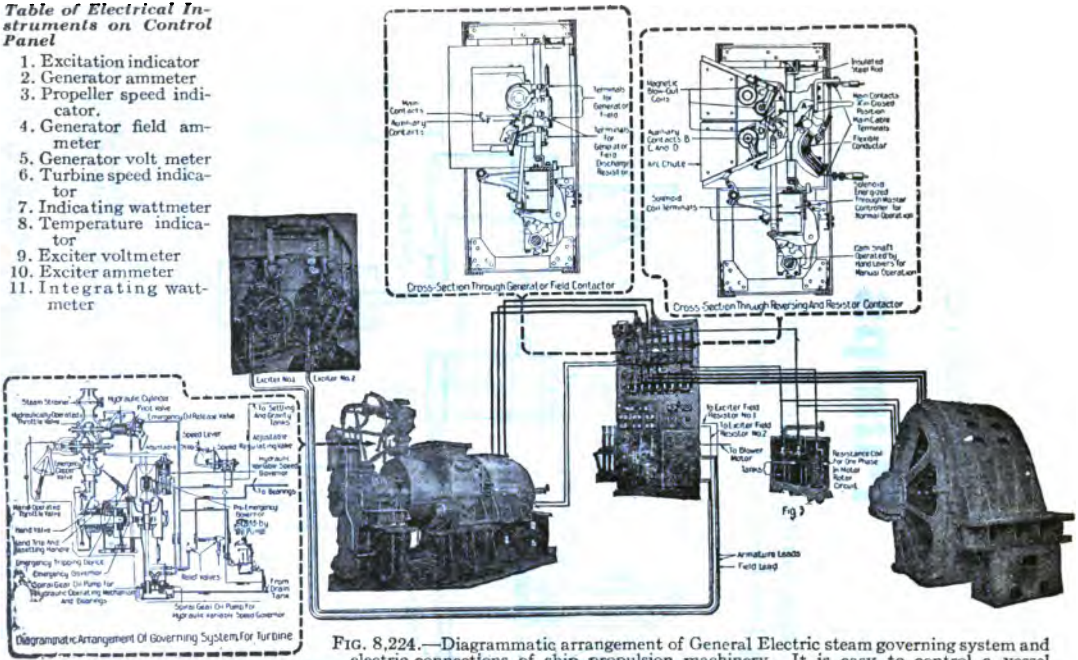
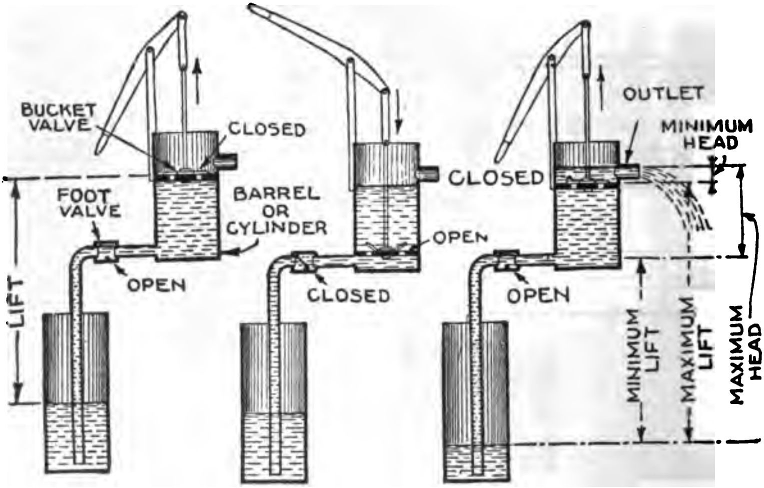


FIG. 8,224.—Diagrammatic arrangement of General Electric steam governing system and electric connections of ship propulsion machinery. It is easy to control a vessel equipped with a turbine driven alternator and propelled by a three phase induction motor mounted on a single driving shaft. Starting, stopping, and reversing are accomplished by means of an easily operated lever which serves to close, open, or reverse the electrical connections between the alternator and the driving motor on the propeller shaft. The speed of the propeller shaft is regulated through a range from one-third to full speed by means of a second lever which changes the speed of the alternator, the efficient driving of the propeller, under varying conditions in a sea voyage is gauged by a set of electrical instruments and governed by a third handle attached to a resistor in the alternator field circuit. This handle adjusts the excitation of the alternator.

CHAPTER 132

Pumps

A very large variety of electric driven pumps are of the reciprocating type being used for almost every condition of service.

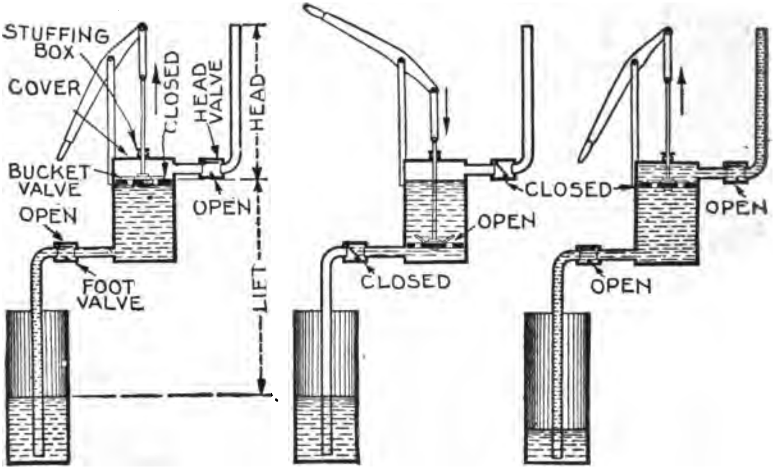


Figs. 8,225 to 8,227.—Elementary single acting lift pump showing essential features and cycle of operation.

They are either single or double acting, single or multi-cylinder, vertical or horizontal, piston or plunger, etc., as may be best suited to any particular installation.

Motors for Reciprocating Pumps.—When *d. c.* motors are used, the *compound wound type is generally selected* for single acting pumps, on account of the rather pulsating load, but for double and triplex pumps having steadier load characteristics, *the shunt wound type is used to advantage*.

Both squirrel cage and phase wound induction motors are suitable, the latter as a rule being selected where it is desirable to reduce the starting current to a minimum, or where a somewhat variable speed is required.

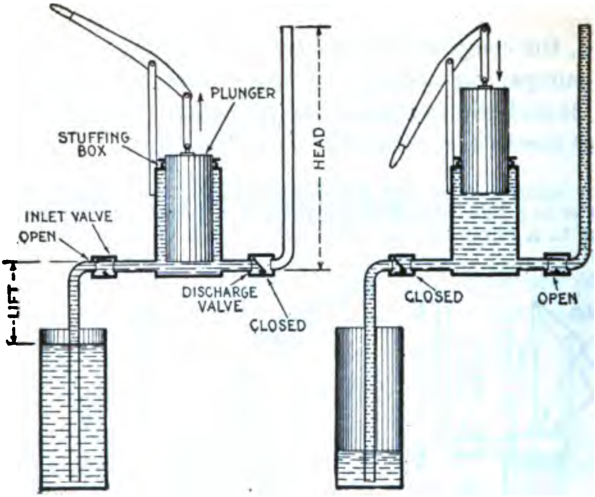


Figs. 8,228 to 8,230.—Elementary single acting force pump showing distinguishing feature of closed cylinder.

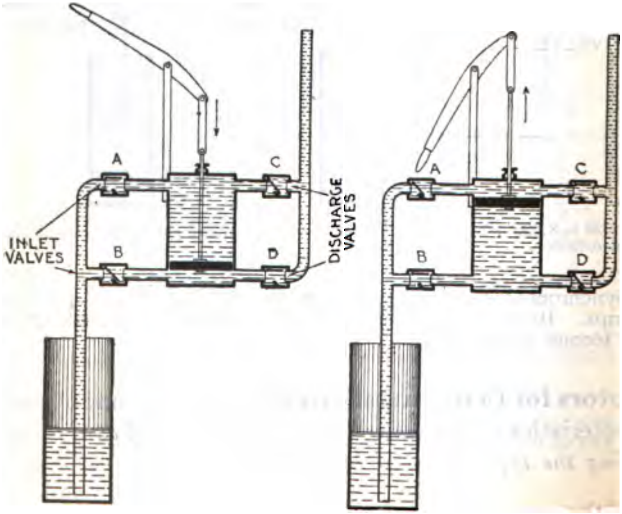
Synchronous motors may be, and are frequently used for driving large pumps. By pass valves must then, however, be provided for reducing the torque at starting.

Motors for Centrifugal Pumps.—On account of the peculiar characteristics of the centrifugal pump, *special care is required in selecting the type of motor best suited*.

With a reciprocating pump operating at constant speed an increase of the resistance increases the pressure and therefore the load on the motor,



FIGS. 8,231 and 8,232.—Elementary single acting plunger pump showing essential parts. ***The distinction*** between a plunger and a piston should be carefully noted.



FIGS. 8,233 and 8,234.—Elementary double acting piston force pump. ***It is a conbination*** of two single acting pumps and gives a nearer uniform flow than the single acting pump.

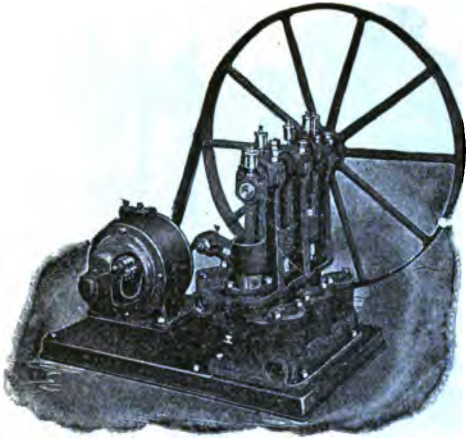
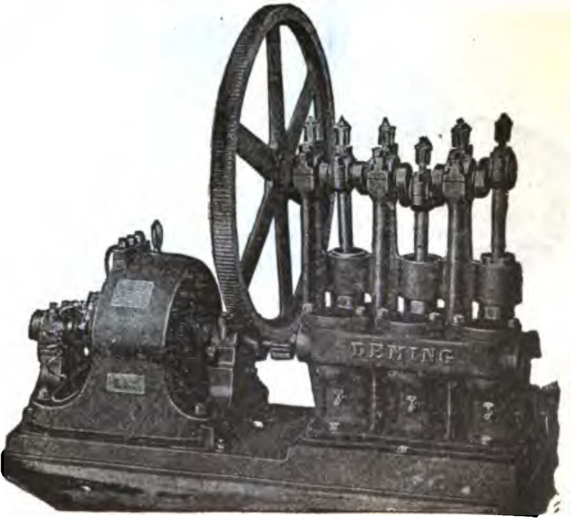


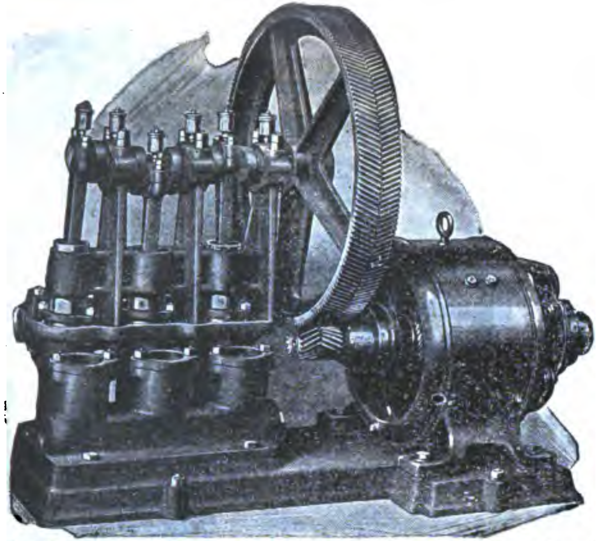
FIG. 8,235.—Deming single acting plunger triplex pump with ***single reduction belt drive.*** This type has the desirable feature of quiet running in addition to its compact arrangement. It makes a desirable arrangement for light service such as tank pumping in residences, apartment houses, hotels, or wherever noise is objectionable. It requires, however, a large pulley and is subject to slippage.

but with a centrifugal pump, an increase of the resistance reduces the load.

The volume of water delivered by a reciprocating pump is not affected by the reduction of the head, but the required power is reduced. A reduction of the head with a centrifugal pump, however, increases the volume of water, and as the efficiency at the same time goes down rapidly, the load increases. It is accordingly of importance to know what this overload, caused by a reduction of the head, amounts to—the duration of this overload. The capacity of the motor should as a rule be governed

FIG. 8,236.—Deming single acting plunger triplex pump with ***single reduction spur drive,*** with rawhide pinion. This type avoids the large pulley and gives a *positive* connection between motor and pump. This is a compact drive and is suitable for light service where space is limited and where some noise is not objectionable.





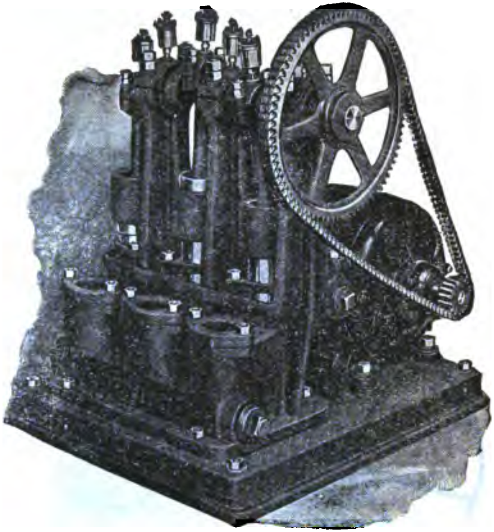


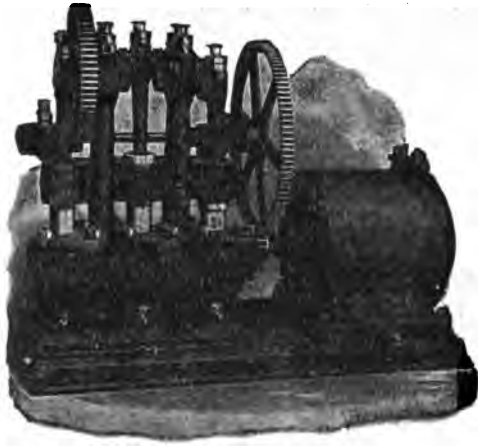
FIG. 8,237.—Deming single acting plunger triplex pump with ***single reduction herringbone drive.*** The features of the herringbone gears are continuous and smooth action, elimination of shock, and reduced wear.

FIG. 8,238.—Deming single acting plunger triplex pump with ***single reduction, so called silent chain drive.*** This drive is desirable where quiet running is essential and space limited.

by the low and not the high head conditions. The condition of starting must also be given careful consideration in selecting the motor.

Shunt wound *d.c.* motors and either squirrel cage or phase wound induction motors are well adapted for centifrugal pumps and will readily meet the above conditions.

A synchronous motor may lead to difficulties unless proper precautions are taken in designing the starting winding and auxiliary starting equipment.



The Drive.—The reciprocating pump, because of the necessarily low speed at which it must operate ***requires a high velocity reduction between the motor and pump.***

Accordingly some form of gearing which constitutes the "drive" must be interposed between the two machines. The various types of drive are shown in the accompanying cuts.

FIG. 8,239.—Deming single acting plunger triplex pump with ***double reduction spur gear drive.*** As is evident, a large speed reduction between motor and pump is obtained in a small space. The arrangement permits the use of a high speed motor with a heavy duty pump.

Control Devices; Power End.—There are various devices for automatically starting and stopping the motor when predetermined conditions of pumping are reached. These consist of pressure regulators, float switches, etc.

Fig. 8,247 illustrates the method of automatically controling an electric house pump when the open tank pumping system is used. The pump is usually placed in the basement, the discharge pipe passing up through the building to the open tank in the attic, where it is generally located.

FIG. 8,240.—Deming single acting plunger triplex pump with ***double reduction combination short belt and spur gear drive.*** This type has the desirable features of quiet running and compactness. When a rawhide pinion is used practically all noise is eliminated.

In the tank is placed a float which follows the water level, and a chain from the float passes over pulleys through the automatic switch arm (the switch being usually located near the tank), and then to a counterweight. Small buttons attached to the chain above and below the switch arm afford a means of regulating the points where the motor will start and stop. The figure shows the starting rheostat, fuse block, main switch, and wiring.

In place of a tank float, control may be effected by means of the varying pressure of the water due to the head.

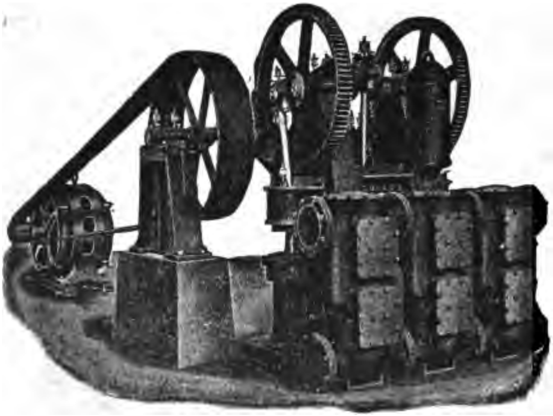


FIG.—8,241.—Gould double acting piston triplex pump with ***double reduction combination long belt and spur gear drive.*** The belt renders the drive less noisy than when both reductions are by spur gear, and yet retaining a high degree of compactness.

How to Figure the Cost of Electric Pumping.—The number of watt required by the motor of an electric pump must be sufficient to furnish power for: 1, lifting the water; 2, loss due to slip; 3, overcoming the friction of water in traversing the system from intake to point of delivery; 4, overcoming the friction of pump and gearing; 5, overcoming the friction of the motor; 6, electrical losses in motor.

Accordingly, as must be evident, the actual power to be supplied to the motor is considerably greater than the theoretical power required to lift the water.

For illustration, assuming that a certain pump have an efficiency of 85 per cent. and the motor which runs it, 88 per cent., then the combined

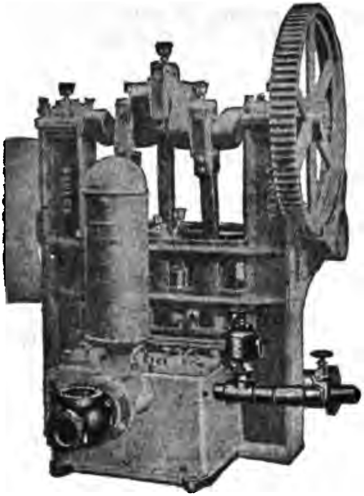


FIG. 8,242.—Goulds type L automatic pressure regulator and by pass.

efficiency, or efficiency of the system is .85 × .88 = .75. That is to say, if the electrical power delivered to the motor be 100 horse power and the efficiency of the system be 75 per cent., then only

$$100 \times .75 = 75 \text{ horse power}$$

is available for elevating the water.

To get the actual electrical power required, first, the theoretical head should be increased by the loss of head in feet due to friction in the pipe line, as determined from hydraulic tables. The result determined in this way must then be considered for the power loss in the pumping unit. This is determined by dividing the theoretical horse power by the efficiency of the system expressed as a decimal, thus:

$$\left.\begin{array}{l}\text{H.P. required}\\ \text{by motor}\end{array}\right\} = \frac{W \times H}{33{,}000 \times E} \quad \ldots (1)$$

in which

W = weight of water pumped per minute in pounds;

H = total dynamic head;

E = efficiency of the system comprising pump, motor, and gearing connecting them.

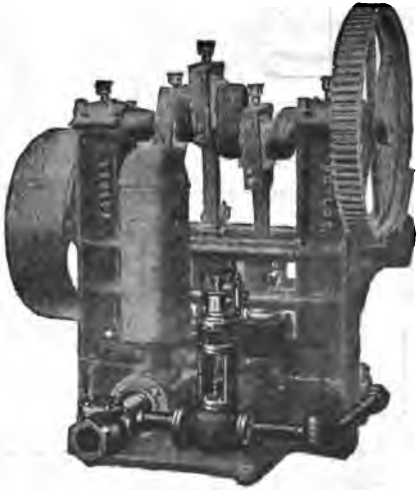
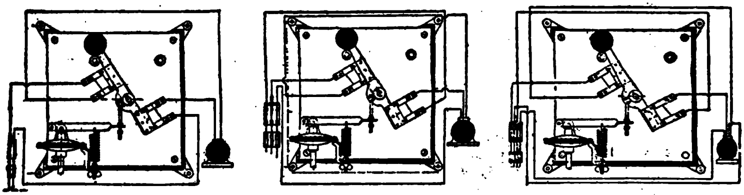


FIG. 8,243.—Goulds type K by pass control consisting of gate valve, discharge check valve and relief valve.

Example.—It is required to pump 300 gallons of water per minute against a combined static lift and head of 200 ft. The pipe line is 400 ft. long and contains 5 ninety degree elbows.

From table showing friction of water in pipes the friction loss in 100 ft. of 5 in. pipe, discharging 300 gals. per min. is 2.25 ft. Accordingly for 400 ft. it is 4 × 2.25 = 9 ft. From table showing friction of water in elbows one 5 in. 90° elbow, discharging 300 gals. per min. = .36 ft. Five elbows = 5 × .36 = 1.8 ft.



FIGS. 8,244 to 8,246.—Wiring diagrams for Hill double pole automatic pressure tank switch. Fig. 8,244, direct, or alternating current, single phase, two wires; fig. 8,245, alternating current, three phase, three wire; fig. 8,246, alternating current, two phase, four wire.

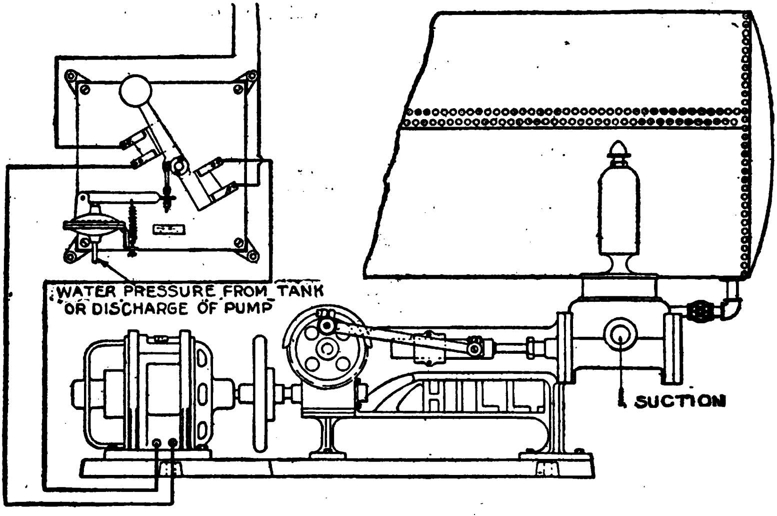


FIG. 8,247.—Hill double acting single cylinder piston tank pump with ***single reduction worm drive and pressure control apparatus.*** ***In operation*** of the control, as pressure rises, diaphragm moves lever until ball falls across center, throwing switch open suddenly. When pressure in tank decreases, on account of lowering of the water level, lever is moved until ball falls to the opposite side, closing switch and again starting motor and pump. The apparatus is set for different pressures by adjusting the thumb nut.

CHAPTER 133

Elevators

There are numerous kinds of electric elevator designed to meet the varied conditions of service. They may be classified with respect to the control, as:

a. Non-reversible;
b. Reversible;
c. Mechanical;
d. Semi-mechanical;
e. Semi-magnet;
f. Full magnet;
g. Push button;
h. One speed;
i. Two speed,
etc.

The various methods of applying the power and other mechanical details have been described at length in Guide No. 7.

Elevator Motors.—Either *d.c.* or *a.c.* motors may be used but *d.c.* is preferable, because of the high starting torque of the *d.c.* motor.

The chief difficulty experienced with alternating current motors is this lack of ability to start under heavy loads, and for this reason proportionally larger sizes must be used, the increase in horse power required being fully 33 per cent.

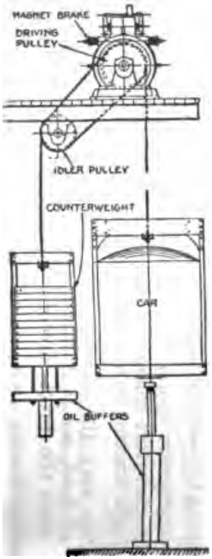
The adjustable speed *d.c.* motor having a small percentage of compound winding is the type giving the best control.

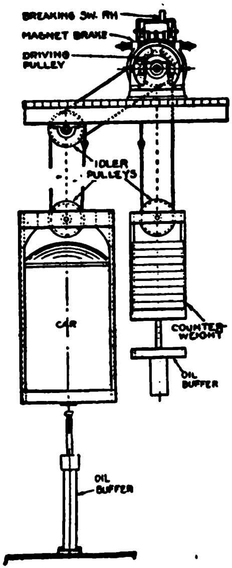
The squirrel cage induction motor should be used only for slow and constant speed freight elevators where the impairment of the line regulation, caused by the high starting current, is not important.

It is not possible to vary the speed of the ordinary induction motor under all conditions of load, nor is it ever possible to employ with it the dynamic brake used with the direct current motor.

Elevator squirrel cage motors, when thrown across the line, should not take more than 2½ to 3 times the normal current.

The polyphase slip ring, or external resistance motor is the type of *a.c.* motor suitable for high speed elevators.





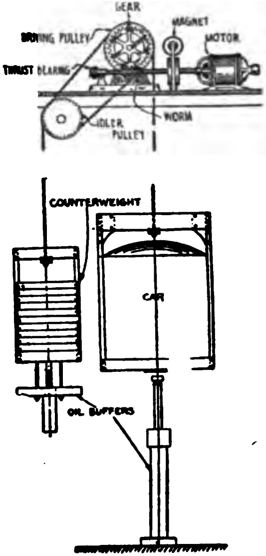


FIG. 8,248.—Overmounted 1 to 1 traction elevator. The control is full magnet, that is, the controller is actuated by a master switch in the car.

FIG. 8,249.—Overmounted 2 to 1 traction elevator. The motor is compound wound and runs usually at about eight hundred revolutions per minute at full car speed and load. The series field is used only at starting to obtain a highly saturated field in the shortest possible time, and this is then short circuited, allowing the motor to run as a plain shunt wound type. *In stopping,* a comparatively low resistance field is thrown across the armature, providing a dynamic brake action and a gentle slowing down of the car, the brake being called upon only to effect the final stop and to hold the load at rest.

FIG. 8,250.—Overmounted traction elevator with multi-reduction or worm drive. Clearly, the worm gives a large velocity reduction permitting the use of a high speed motor. The magnetic brake being located to act on a brake pulley attached to the fast revolving motor shaft [illegible] braking power [illegible] on the brake pulley.

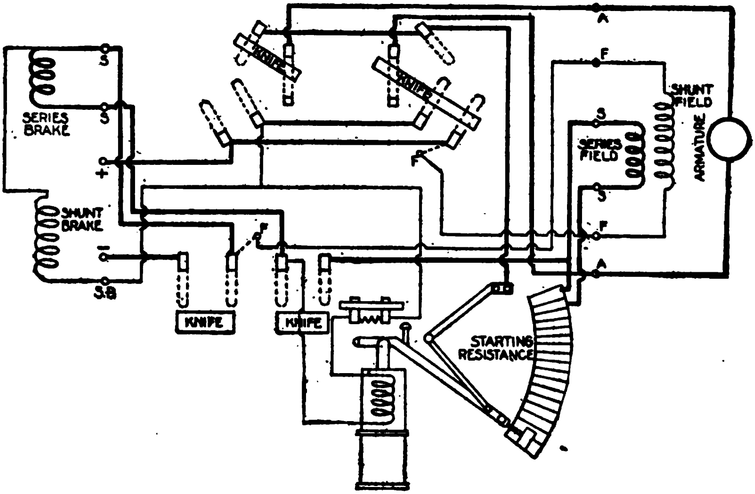
Controllers.—The controller performs a number of functions, *uch as releasing the brake, starting, accelerating, slowing, and uickly starting the car.* Its control may be classified:

1. With respect to the rotation of the motor, as

   a. Non-reversible; *b.* Reversible.

2. With respect to the current, as

   a. Direct; *b.* Alternating.

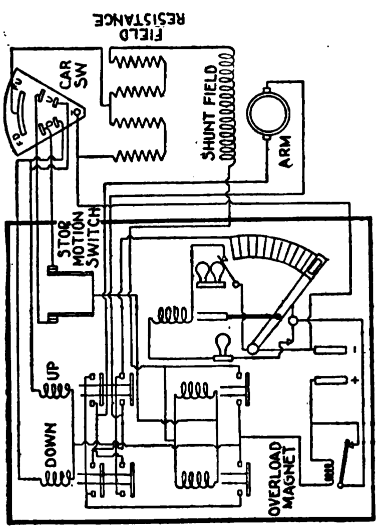


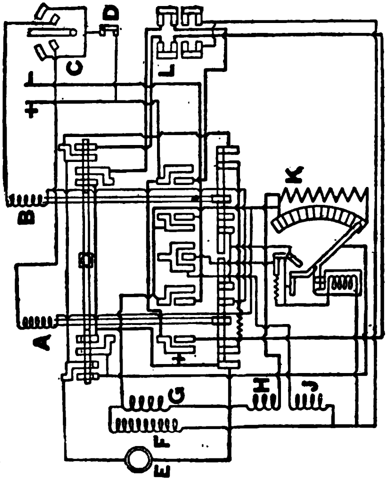
IG. 8,251.—Diagram of A. B. See No. 4 mechanical controller.

3. With respect to construction, as

   a. Full mechanical; *c.* Semi-magnet;
   b. Semi-mechanical; *d.* Full magnet.

The simplest way in which a motor can be installed to drive an elevator, is to arrange it so as to drive a counter-shaft continuously, in which case the elevator is stopped and started by throwing belts on the tight or loose pulley.





FIGS. 8,252 and 8,253.—Diagram of A. B. See No. 4 magnet controller. Diagram of Cutler-Hammer, two speed magnet controller.

This system may be fully classified as a continuous operating non-reversible full mechanical control system. Obviously the term non-reversible refers to the motor which always runs in one direction as distinguished from motors which reverse their rotation to reverse the motion of the car.

The distinction between the various classes of controller, known as non-reversible, reversible, mechanical, semi-mechanical, semi-magnet, full magnet, and push button is illustrated in the accompanying cuts.

Full Magnet D. C. Controllers.—A typical direct current control apparatus of the full magnet type consists of several slate panels, mounted on an angle iron frame with all the connections made on the back of the board.

The solenoid switches mounted on the slate panels are arranged to perform the following functions:

1. To disconnect in the off position both sides of the line from the armature, series field, resistance, and brake magnet.

Shaft limit switches may be installed so as to be operated either by the car or by the counter-weight, or by both.

The Safety Switch.—In order to insure the stopping of the elevator, even should some accident render the regular control from the car switch inoperative, a safety switch should be provided. This consists usually of a single pole switch enclosed in a cast iron box, the handle of the switch projecting through a slot in the enclosing case.

This safety switch is designed to be connected, by means of a separate three wire cable, to that part of the control circuit which is in the side of the line opposite to that in which the car switch is connected. The third wire in this cable is desirable as a spare. The opening of the safety switch will therefore entirely disconnect one

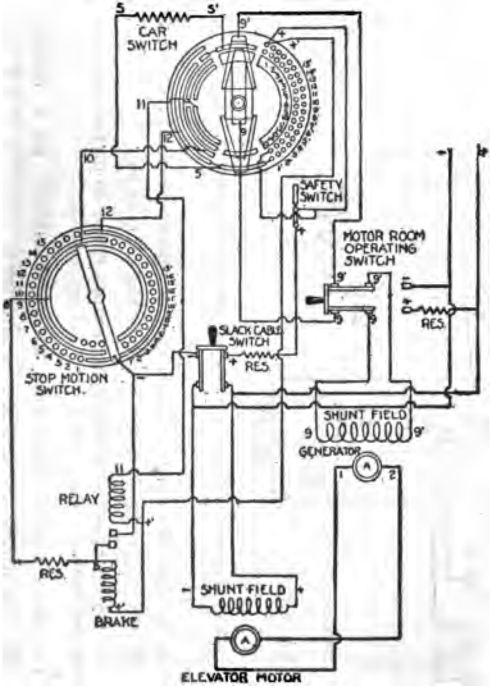


FIG. 8,254.—Diagram of Otis mechanical reversing control with type B reversing switch.

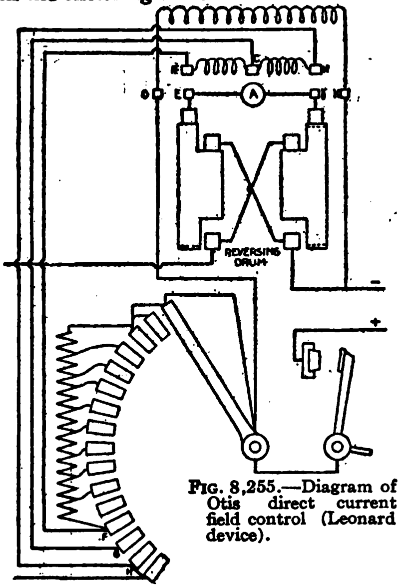


FIG. 8,255.—Diagram of Otis direct current field control (Leonard device).

side of the control system from the line, and this switch, in connection with the car switch, makes it impossible for any combination of ground or short circuit to prevent the operator stopping the car at will.

2. To accelerate the motor automatically by cutting out the armature starting resistance step by step, and also the series field with the last step of armature resistance (this by means of individual series relay control) giving smooth acceleration under all load conditions.

3. To control the speed of the elevator by cutting resistance in or out of the shunt field circuit of the motor, affording positive speed control under widely varying loads.

4. To bring the elevator quickly, but smoothly, from high to low speeds, regardless of load, making accurate stops at landings an easy matter.

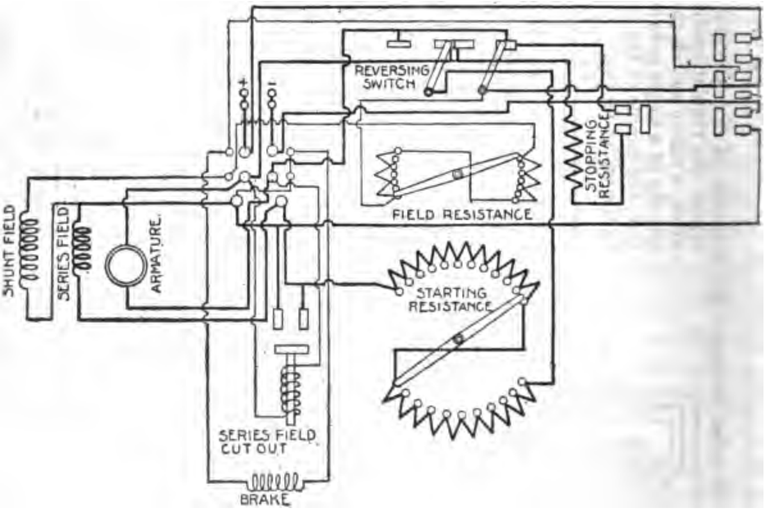


Fig. 8,256.—Diagram of Electron direct current mechanical controller.

5. To open the circuit to the motor should an overload current flow.

6. To apply the dynamic brake in the off position.

7. To operate the elevator at normal speed from the switchboard for test purposes.

To these seven functions may be added, as a modification of the standard controller equipment:

8. To open the shunt field circuit in the off position of the controller.

The Mechanical Brake.—The proper functioning of the mechanical brake is rendered positive by disconnecting both terminals of the brake magnet winding from the line and from the motor armature in the off position of the controller. This makes it certain that no possible combination of grounds or short circuits can keep the brake magnet energized and the brake released when the car switch is thrown to the off position. So long as the brake mechanism is in good working order mechanically, the positive application of the brake is assured.

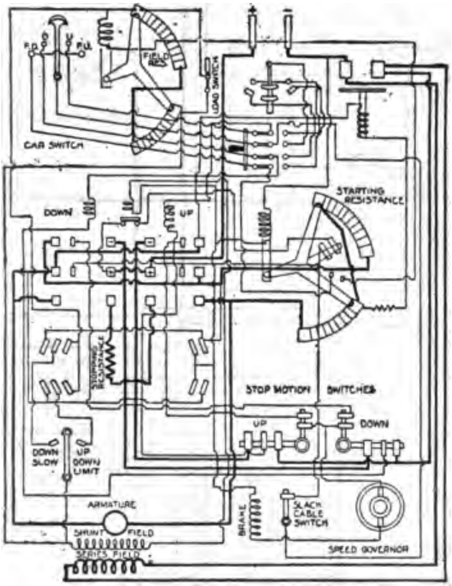


Fig. 8,257.—Diagram of Electron direct current two speed magnet controller.

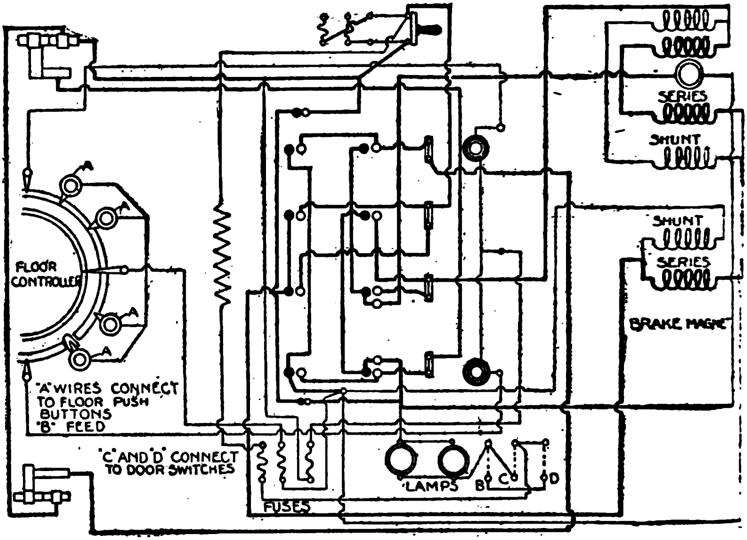
The Dynamic Brake.—Power for the operation of the dynamic brake switch is taken from the motor armature and the brake resistance is applied directly across the armature terminals.

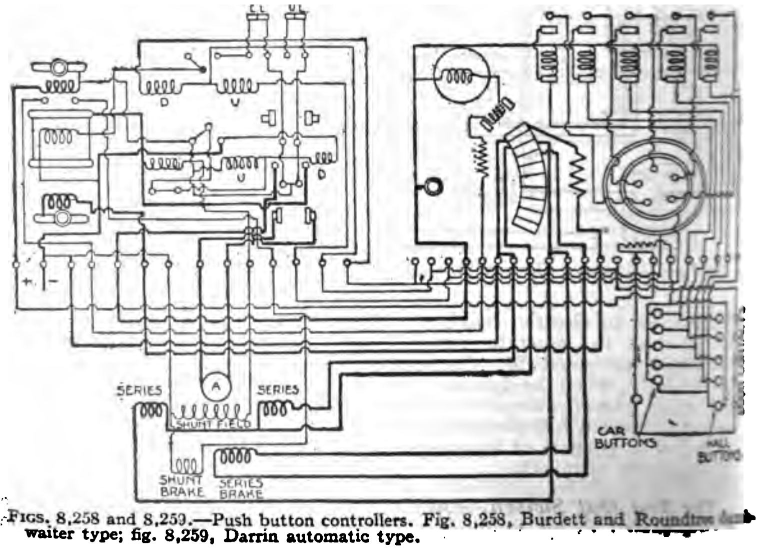
The application of this brake depends, therefore, not on the line voltage but solely on the motion of the armature.

In any form of elevator braking, mechanical or electric, the energy represented by the inertia of the moving parts must be dissipated in the form of heat in order to stop the motor.

In mechanical braking this energy is transformed into heat by the friction of the brake shoe; in electric braking it is transformed into heat by causing the motor to generate current and dissipating this energy in a resistance provided for that purpose—the dynamic brake resistance. Accordingly, when the dynamic brake is used in connection with the mechanical brake, the effectiveness of the latter is increased since it is not called upon to arrest a full powered motor, but one which has already been deprived of a portion of its energy by having a resistance shunted across its armature terminals.

The Try Out Switch.—Operators are usually instructed to go to the switch board every morning before entering the car and to test the





Figs. 8,258 and 8,259.—Push button controllers. Fig. 8,258, Burdett and Roundtree dumb waiter type; fig. 8,259, Darrin automatic type.

operation of the elevator by means of a *try out switch*, so as to ascertain that every part of the installation is operating properly. In this way the car may be run up and down the shaft several times each morning, testing not only the control apparatus, but also the motor, limit switches, brake solenoids, etc.

The try out switch consists of a single lever normally locked in the central position, and in the position completing the circuit to the car switch.

It is, therefore, not possible to operate the elevator from the car while the try out switch is in use, this fact enabling the try out switch to be used also as a safeguard against the operation of the elevator while the regular operator is absent from the car.

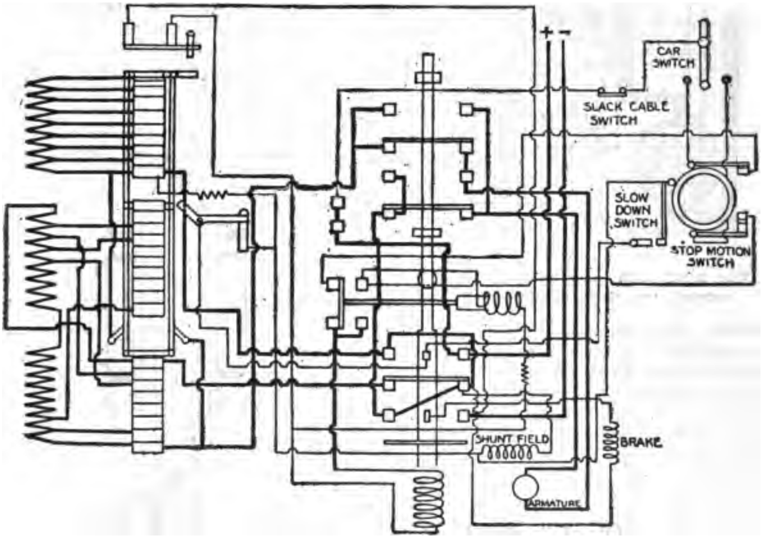


Fig. 8,260.—Diagram of National direct current type A, one speed gravity rheostat controller.

The Service Switch.—It sometimes happens that the main line knife switch ordinarily used as a service switch cannot be so located that it may be conveniently opened at night, or at other times when the elevator is idle for considerable periods. This condition is frequently met with in over mounted installations, and unless some provision be made for opening the circuit to the motor from the car, or from one of the lower floors of the building, the operator will be obliged to leave the elevator at the top of the shaft each night, walking down stairs every evening and up stairs every morning.

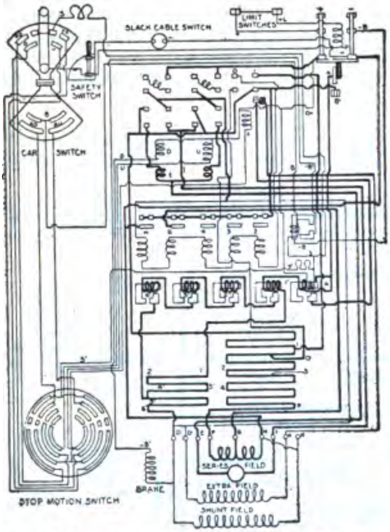


FIG. 8,261.—Diagram of Otis style B, direct current, two speed magnet controller.

The service switch remains closed normally while the elevator is in operation, not being connected in any way to the car switch or other speed regulating portion of the apparatus. Connection to the single pole service switch may be either through the safety switch, installed in the car, or through any other suitable pilot switch installed on the landing at which the operator usually leaves the elevator for the night. The opening of the switch disconnects one side of the line from the controller switchboard, enabling the operator or janitor of the building to open the circuit to the motor without going to the main line switch. The service switch controls, from one set of contact, the continuity of both the armature and shunt field circuits. This arrangement is necessary for safety, so that it will not be possible to open or close the armature circuit without also opening or closing the shunt field circuit.

Machine Type Limit Switch.—This switch is intended to insure the slowing down of the car from any speed not exceeding 300 feet per minute, and its stoppage at the predetermined limits of elevator travel. The slow down is accomplished by means of single pole switches in the control circuit, while the complete stoppage of the car is

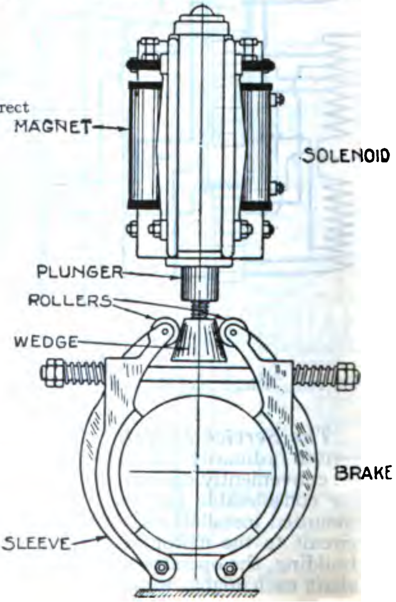


FIG. 8,262.—Typical arrangement of brake magnet having a wedge acting between rollers to release the brake.

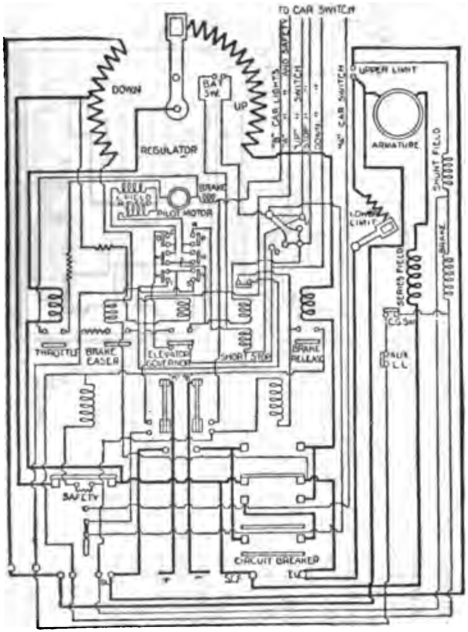


FIG. 8,623.—Diagram of Otis style GS direct current, two sweed controller.

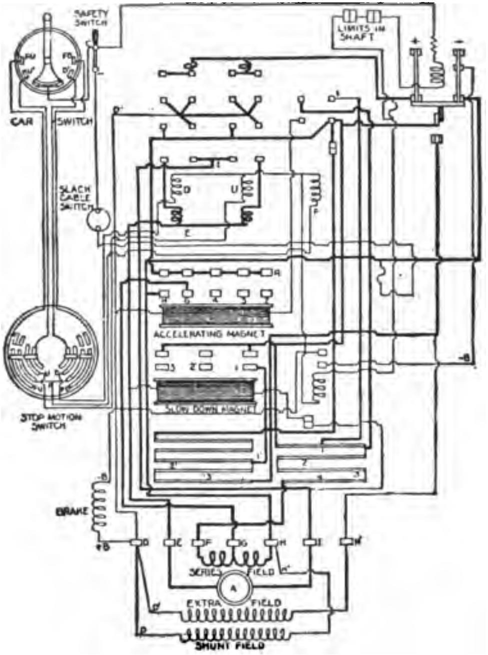
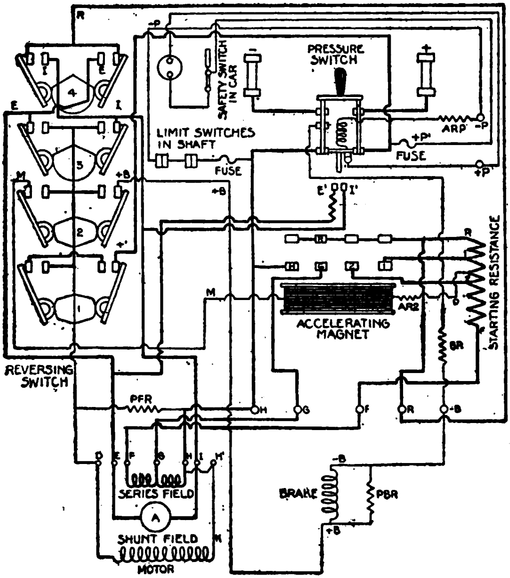


FIG. 8,624.—Diagram of Sprague direct current pilot motor controller for type A, Sprague elevator.



brought about by double pole switches which disconnect both sides of the lines from the control system, thus insuring that the motor will be stopped even under conditions which might otherwise tend to impair the control of the car, such for instance, as grounds or short circuits in some part of the control system.

Connections to the limit switches are so designed that after the car has been stopped automatically at either limit of elevator travel it is possible for the operator to start and immediately accelerate to full speed in the opposite direction.

Fig. 8,265.—Diagram of Otis style 2H mechanical reversing switch.

Shaft Limit Switches. — In addition to the machine type limit switches just referred to, over travel switches should be installed in the elevator shaft as an extra precaution. These shaft limit switches are arranged to be operated by the car which, on passing a given point, opens the switch thus introducing an additional break in the

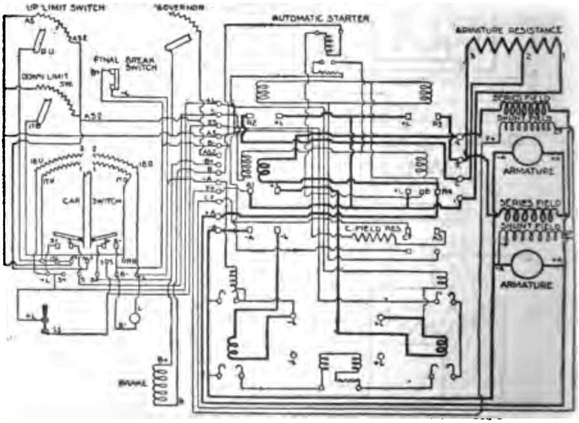


Fig. 8,266.—Diagram of Fraser direct current duplex motor controller.

control circuit and insuring the stopping of the elevator through the opening of the line and reverse switch.

Shaft limit switches, when used as over travel switches, should be so arranged that it is impossible for the operator to move the car after the switch has opened without first going to the elevator machine, thus insuring attention to the defect which caused the shaft limit switch to operate. These switches are sometimes installed alone in preference to the machine type of limit switch on drum type elevator machines.

On traction type elevator machines they obviously have to be used for both the automatic limits and over travel. For automatically slowing down and stopping the car three single pole shaft switches at either limit of elevator travel should be used, making a total of six switches in all. One switch in each of the two sets of three is used to slow down the car while the other two operate in unison as a double pole switch to bring the car to a standstill.

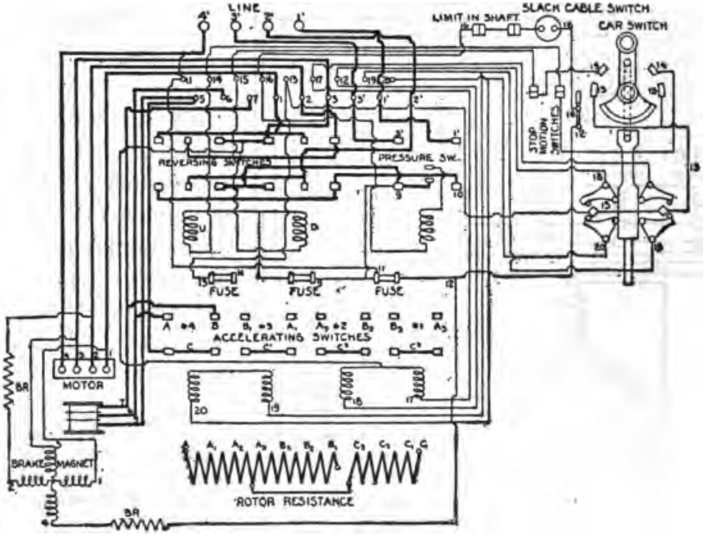


Fig. 8,267.—Diagram of Otis-type VAS alternating current, two phase magnet controller.

In addition two single pole shaft limit switches should be used for protection against over travel.

Alternating Current Controllers.—Since *a. c.* should preferably be limited to moderate speeds, because it is not feasible to employ dynamic braking.

This means that the car must be slowed down and stopped by the application of the solenoid brake alone, and the speed must therefore be one that will permit this being done with safety and comfort under all the widely varying conditions met with in elevator service.

A typical alternating current full magnet controller consists of several slate panels mounted on an angle iron frame which serves also as a support for the resistance.

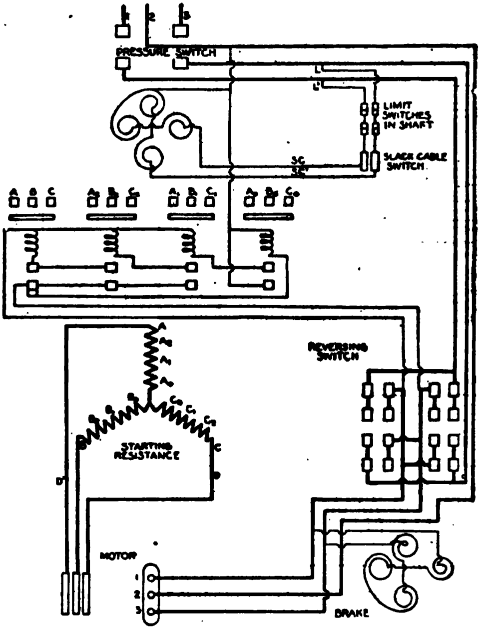


FIG. 8,268.—Diagram of Otis-type alternating current two or three phase mechanical controller.

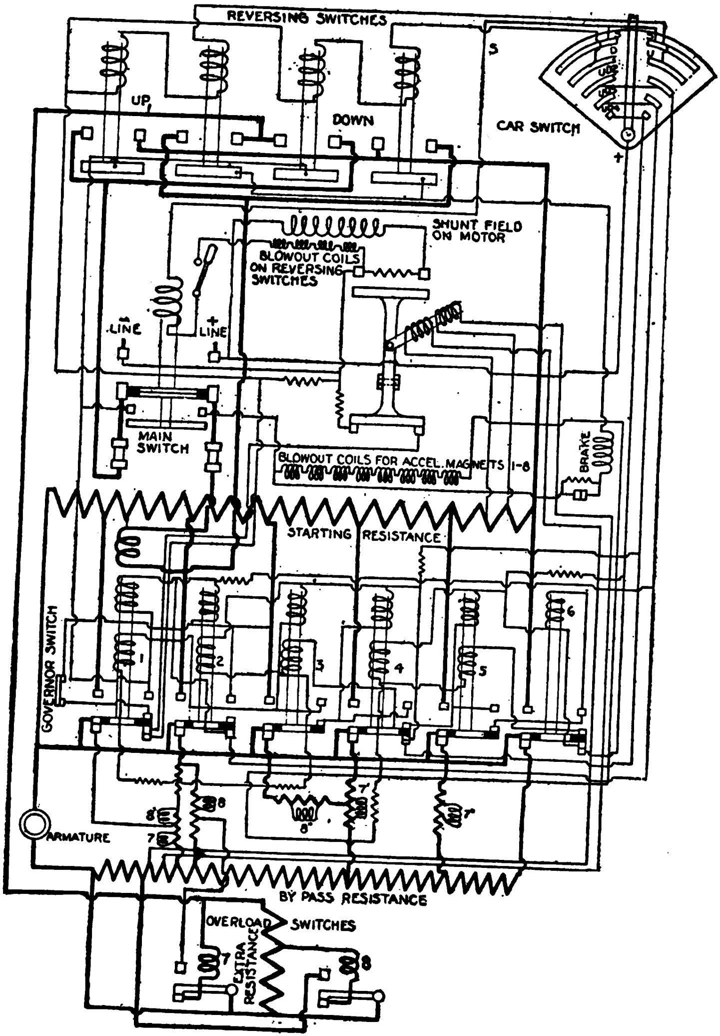
A. c. solenoid switches mounted on the face of the panel and connected to the resistance (all connections being made at the back of the board) are arranged to perform the following functions:

1. To disconnect the primary wires from the motor and brake solenoid in the off position of the controller.

2. To accelerate the motor automatically by cutting the starting resistance out of the rotor circuit step by step (using series relay control) and giving smooth acceleration at all loads.

3. To operate the elevator from the switchboard for test purposes.

Current Relay Acceleration.—The acceleration of the motor is accomplished by a parallel solenoid self-starter with secondary starting



G. 8,269.—Diagram of A.B.See traction controller.

resistance. A suitable number of double pole alternating current solenoid switch are used, these being so connected as to cut a section of resistance out of each of the three phases of the rotor circuit simultaneously, the rate of acceleration being governed automatically by a number of current relay in the rotor circuit. By suitable adjustment of these relays the starting current is limited to a predetermined maximum.

The office of the relay is to lift and open the circuit to the succeeding switch when the starting current rises as each switch in turn is closed, thus preventing the cutting out of the next step of resistance until the motor has properly accelerated and the surge of current incident to the closing of the previous switch has died down.

Limit Switches.—The automatic stopping of the car at the two limits of elevator travel, in the case of a drum type elevator machine, is usually accomplished by a limit switch of the rotating cam or traveling cam type. These switches are designed to open both sides of the control circuit to the solenoid switches on the controller switch board, thus insuring the stopping of the car through the opening of the motor circuit.

Shaft limit switches may be used in place of the cam type limit switches, if desired, and should be used in the case of traction machines.

Two shaft limit switches should be used as over travel switches, in both cases, and should be so connected in the control circuit as to make it impossible for the operator to move the car in the reverse direction after over traveling without first going to the winding machine. This insures protection against phase reversal.

The Brake Solenoid.—This is designed to be connected directly to the motor terminals. When the circuit to the motor is closed, the solenoid is energized and the brake released. Upon the opening of the main line circuit (whether this be done intentionally in operating the elevator, or is the result of accident) the solenoid is de-energized and the brake applied. The operation of the brake solenoid is very rapid, and the force applied to the brake considerable. It is recommended, therefore, that the parts of the brake mechanism used with these solenoids, be of rugged construction, a simple toggle or wedge mechanism being most desirable. It is desirable also that the brake itself be so designed as to permit of the gradual, rather than a sudden braking effect, so as to avoid jarring the car by stopping it too quickly.

OPERATING INSTRUCTIONS

Before Starting.—The main switch connecting the motor with the supply circuit must be closed. This switch should not be closed, however,

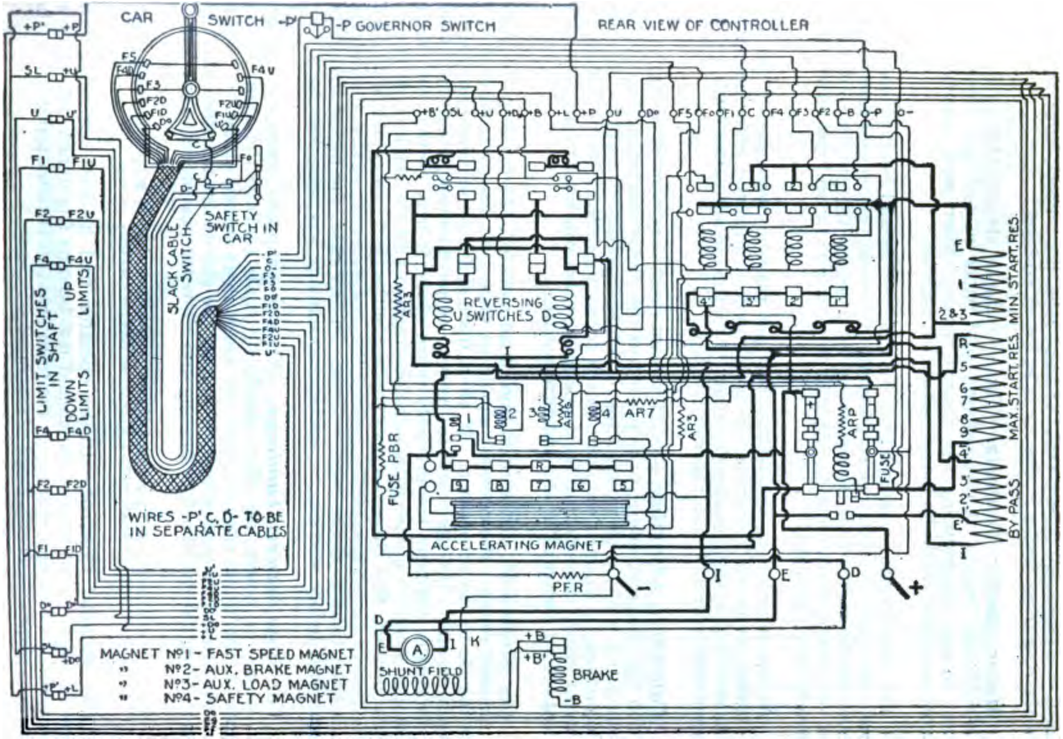


FIG. 8,270.—Diagram of Otis type MF4 direct current magnet controller for traction elevator.

until it is positively known that the hand rope, pilot wheel, lever, or switch of the operating device in the car is in its off position.

Motor Starter Contacts.—These contacts should always be kept smooth and bright. A piece of fine sand paper rubbed over them is the best means of producing the desired result. After sand papering, the loose particles should be blown out with a bellows.

The bearings and cams of the motor starter should be kept clean and well oiled, and if a dash pot be provided to prevent the contact arm moving over the contacts faster than is necessary to secure the proper acceleration of the motor, this should be adjusted so that the arm will descend in from five to seven seconds.

As the retarding action of the dash pot may be overcome by gravity, a spring, magnetic attraction, or by the motion imparted from the motor, the shafting, or the elevator machine, the method of adjustment will depend upon which form of motor starter be used.

Caution in Adjusting.—An important point to remember in connection with the cleaning, oiling, or adjusting of the motor starter, and in fact in connection with the cleaning, oiling, or adjusting of any parts of the elevator equipment, is to open the main switch connecting the motor to the supply circuit before commencing these operations; this will tend to prevent accidents of an electrical or a mechanical nature.

Car Stops.—If, in the operation of an elevator, the car stop for some unknown reason, the operator should at once shift his controlling device in the car to the off position. If, then, upon shifting the controlling device again to start, the car refuse to move in either direction, some one of the following occurrences has probably taken place: It may be that the car or counter weight has met with some obstruction and the slack cable device has operated; that there is a poor contact in the switch or connections; that the fuse or circuit breaker has opened the motor circuit; or that the current has been turned off the supply wires. In any case, the motor should be examined before starting, to see that no damage has been done to it.

Car Stops between Landings.—When this happens, owing to a failure in supply of power, an effort should be made to have the main switch opened, the brake released, and the worm shaft turned either by pulling on the brake pulley or with a wrench on the end of the armature shaft so as to bring the car to a floor landing and allow the passengers to get out.

In some elevator motors, the free end of the armature shaft is purposely made square to facilitate turning the shaft with a wrench as just mentioned.

Car Beyond Control.—If the operator find he has lost control of the car and cannot stop it, he should not become frightened but allow it to make the full run, relying on the limit stops to automatically bring the car to a standstill at either end of its travel.

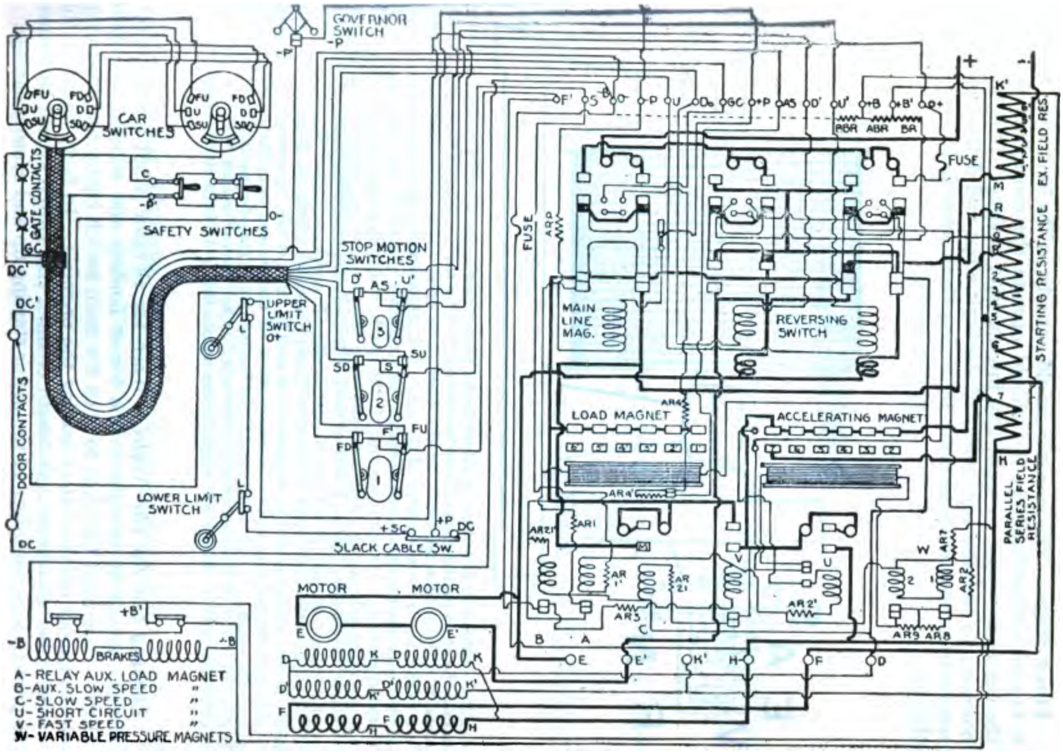


FIG. 8,271.—Diagram of Otis style 7 direct current duplex controller.

Limit Stops.—The operator should not rely on the limit stops to make a top or bottom landing, but should operate the controlling device in the car as he would to make any intermediate landing. It is advisable, however, to test the adjustment of the limit stops and determine if they remain in proper working order by trying them once daily by means of the car.

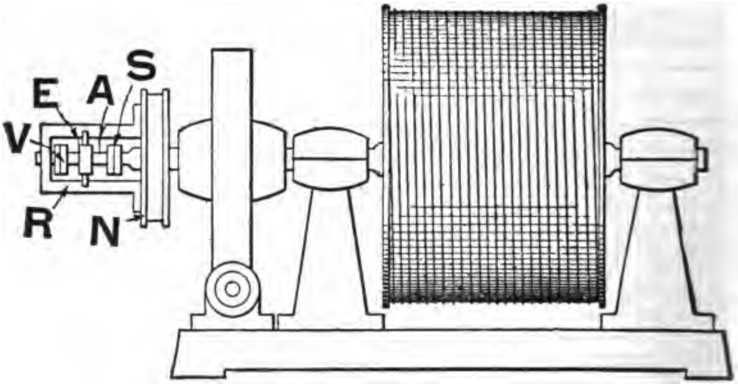


Fig. 8,272.—Machine limit stop or safety device placed on the machine to prevent over travel in case the stops on the shipper rope become inactive by the breaking of the rope. *It consists of* a threaded extension A, on the drum shaft upon which a traveling nut E, moves in a fixed ratio to the movement of the car. The shipper rope pulley N, is on that portion of the drum shaft which is not threaded, and carries a bracket R, that extends over the threaded portion. Owing to two lugs on the nut E, which fit in slots in the bracket, the nut can move only parallel with the shaft when the drum rotates unless the shipper rope sheave N, moves also. On each side of the nut E, there are claws that engage with similar claws on the inner sides of the nuts V, and S, when E, and V, or E, and S, come together. Check nuts on the outer sides of the nuts V, and S, securely clamp the latter to the drum shaft, so that when the nut E, engages either with V, or S, it will, by means of the bracket S, shift the shipper rope sheave N, thus cutting off the current from the motor and applying the brake. If the nuts V, and S, be located ont he threaded portion of the shaft so that contact is made between them and the nut E, when the car reaches its limits of travel, the operation of the device will stop the car automatically at both these points.

Leaving Car for the Night.—When the elevator is left for the night, the car should be brought to the lowest landing and allowed to remain there. Care must be taken to open the main switch connecting the motor to the supply circuit, before leaving the premises. In fact, whenever the car is to be left idle for any length of time, this switch should be opened to prevent any possibility of the motor starting up and causing damage.

CHAPTER 134

Cranes

By definition, a crane is *a machine for lifting, lowering, and moving a load in a horizontal direction*, as distinguished from a hoist which simply lifts and lowers a load.

With respect to range of movement, cranes may be classed as: 1, rotary; 2, rectilinear; and 3, combined rotary and rectilinear.

In addition to the ordinary forms coming under these heads, there are some miscellaneous types known as

1. Sheer legs;
2. Transporters;
3. Telphers {cableways; mono-rail systems.

Rotary Cranes.—In this type of crane, the construction is such as will permit the load *to be lifted, lowered, and moved radially*.

It is usual for the framing to be capable of making a complete circle. To reach a given point a radial and an angular movement are necessary.

Rectilinear Cranes.—This form of crane differs from the preceding type in that the load is *moved linearly instead of radially*.

To reach a given point, a longitudinal and a transverse movement are necessary.

Combined Rotary and Rectilinear Cranes.—A modification of the traveling crane, which *combines the functions of the two classes, rotary and rectilinear*, consists in pivoting one end of the bridge of a traveling crane and supporting the other end on a circular gantry. Most of the mechanism is identical with that of the traveling crane.

Transporters.—By definition a transporter is *a lifting and transporting machine designed to carry loads between two fixed points.*

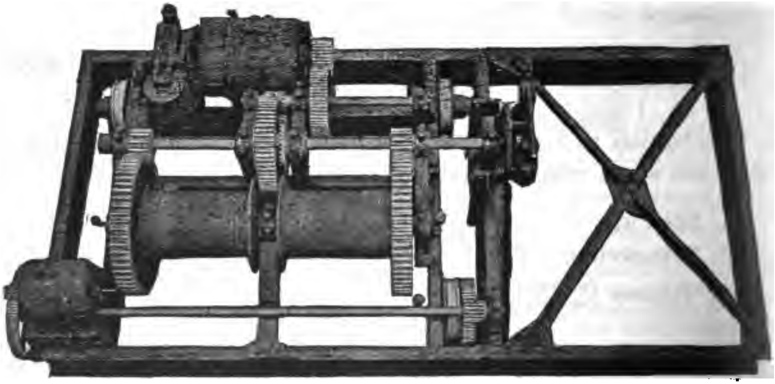


FIG. 8,273.—Niles crane construction: Standard grab bucket trolley suitable for operation with a two rope grab bucket, one rope being attached to bail of bucket and the other attached to the opening mechanism. The trolley framing consists of heavy steel channels securely riveted together, making a self-contained and rigid construction to which the mechanism is attached. The trolley is of the double drum type, each drum being operated independently of the other or in unison through the medium of one train of compensating gears. The hoisting drums are finished all over, and have grooves cut so that the bucket is lifted vertically without twisting, and the load is distributed equally to both bridge girders. One drum is fitted with a foot brake of the post type, balanced and positively withheld from contact with the brake wheel, except when applied by the operator for the purpose of opening the bucket. The brake is operated by a foot lever conveniently located in the cage. The bucket is held by two sets of rope, the tension in which is always equalized through the compensating gears, avoiding the possibility of slack ropes and insuring the retention of the bucket by one of the ropes should the other break. The hoisting mechanism is controlled by powerful brakes, preventing the dropping of the bucket or running down by gravity under any condition of service. The opening of the bucket or dumping of the load is by the simple application of the foot brake. When the open bucket comes in contact with the material to be handled, the controller is moved to the hoisting position. This closes and thereby fills the bucket, which, without further manipulation, is hoisted to the desired dumping point.

It is used chiefly for handling comparatively light loads at quick speeds and employed largely for the conveyance of materials such as coal in bulk. For the latter service it is provided with an automatic grab instead of a hook.

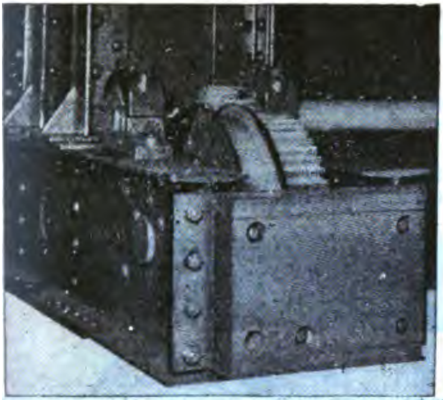


FIG. 8,274.—Niles crane construction; Bridge end trucks showing the two bearings for bridge drive shaft and the steel plate with bumper block at end of truck.

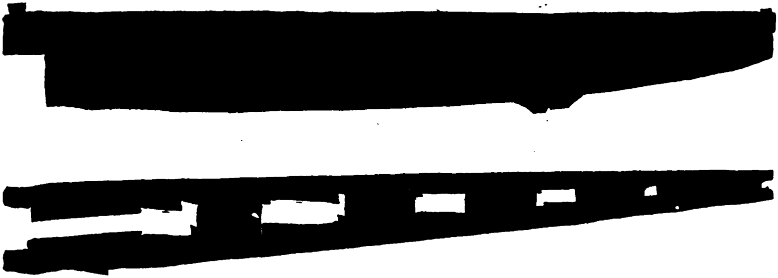
Crane Motors.—For driving the traveling, traversing, and slewing motions of crane, *series wound motors of a generally similar type to those used for electric traction give satisfactory results*, this work being in fact a simple class of electric traction.

FIGS. 8,275 and 8,276.—Niles crane construction: bridge ends or trucks. The bridge ends are built up of plates and angles, as illustrated, or of heavy steel channels or I beams, depending upon the type and capacity of the crane. Heavy gusset plates connect the girders and bridge ends, and prevent the girders getting out of square. The bridge ends extend beyond the wheel and are capped at the ends with a removable steel plate, provision being made for attaching wooden bumper blocks, which prevent the wheels and gears of two cranes coming in contact when several cranes are on the same runway. The truck wheels may be easily removed by taking off the steel caps, jacking up the bridge ends just enough to remove the weight from the wheel, withdrawing the axle and rolling the wheel out. Lubrication of the truck wheels is provided by internal oiling through the center of the axle. The bridge drive shaft is carried at the ends by self-oiling cap bearings, so located as to eliminate overhung gears or pinions.

The driving of the hoisting motion presents a more difficult problem, for though it is easy to lift the load up, it is not always so easy to get it down again in a satisfactory manner.

Automatic Electro-magnetic Brakes.—It is customary to fit the hoisting motion with an electro-magnetic brake.

This may consist of a band brake which is normally kept on by a spring or weight and released by an ironclad solenoid, or it may be a disc brake



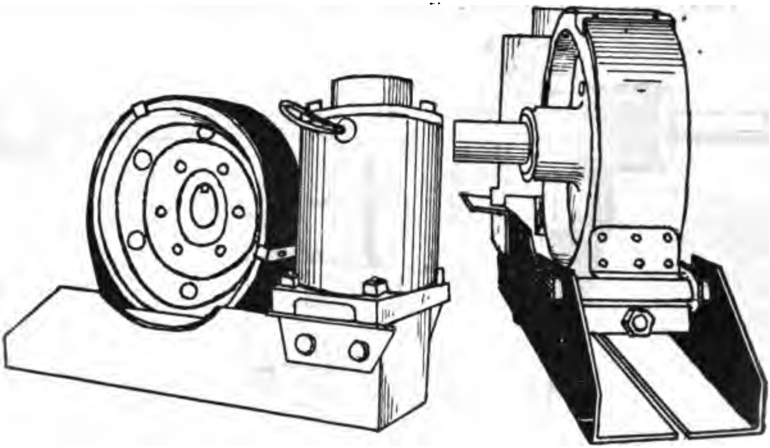
FIGS. 8,277 and 8,278.—Niles crane construction: Box section bridge girders. The standard box section girders are built up of two web plates, four heavy angles and universal mill top and bottom cover plates. The web plates are reinforced at frequent intervals by heavy vertical angles and connected together by diaphragms to prevent vibration and skewing diagonally when the crane is started suddenly. The bridge motor is bolted in a horizontal position to a heavy structural steel bracket, riveted to the girder adjacent to one set of vertical angles and diaphragm plates connecting the web plates described above, in order to prevent distortion of the girders. At the ends of the girders are placed heavy vertical and horizontal angles which reinforce the webs and serve as a connection to the bridge ends.

FIG. 8,279.—Niles crane construction: Bridge drive for box section girders. The web plates of the box section girders are reinforced by heavy stiffening angles, placed near the bridge drive motor and are connected by diaphragms, preventing distortion of the girders by motor or gears. A substantial platform with angle iron hand rail extends along the girder on the bridge drive side, providing easy access to the bridge motor, gears and bearings.

in which the discs are normally pressed together by a spring, an electro-magnet being provided to pull back the pressure plate and release the discs.

The coil of the solenoid or electro-magnet is in circuit with the hoisting motor, so that when current is switched on to the motor, the brake is released, and when it is switched off, the brake is applied. This makes an excellent safety device, but as it can only be off or full on, it cannot be used to regulate the descent of the load when lowering.

In cases where the driver has access to the gear, as in locomotive jib cranes and derricks, an addition may be made to the electro-magnetic brake in the form of a hand or foot release lever, by which the brake can be released or its pressure regulated. Loads are then hoisted by the motor, and are allowed to run down by their own weight, the speed of descent being regulated by the brake.



FIGS. 8,280 and 8,281.—Niles crane construction: Electric brake. It is of the ironclad solenoid type and is fitted with a removable brake band which engages almost the entire circumference of a turned and balanced wheel. The band is of special steel and lined with a renewable friction wearing surface. The brake is always on when there is no current flowing through the motor and is always off when motor is running.

Where the driver operates the gear from a distance, the arrangement just described is not practicable, and some automatic or electrically controlled arrangement must be used to check the speed of descent of the load.

Automatic Mechanical Brake.—This type of brake is usually of the disc type, and is arranged *to allow the gear to run freely* *in the direction of hoisting, but holds it from running in the opposite direction*, being applied by a screw, or it can be arranged to be operated automatically by the load.

The brake is released by running the motor in the direction of lowering. As the motor releases the brake, the load tends to put it on again; consequently the speed of descent depends upon the speed of the motor, and this can, of course, be regulated by the driver by means of the controller.

Eddy Current Brake.—This type of brake is only used to a limited extent. It consists of a wheel, generally of copper or other metal of low electrical resistance, which is arranged to rotate between the poles of an electromagnet.

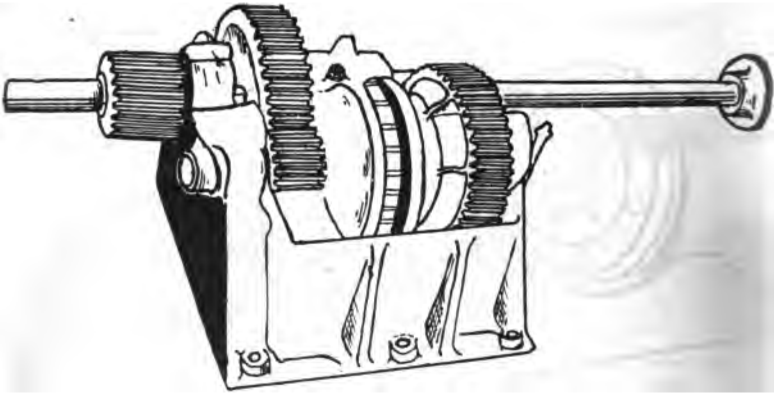


FIG. 8,282.—Niles crane construction: Mechanical load brake. It is of the double disc type with hard bronze wearing surfaces. It is automatic in action and self-contained, all thrusts being taken up within itself. The brake will not permit the load to run down unless the motor is revolved by power in the lowering direction.

The wheel is driven by the descending load, and eddy currents are generated in it, which give rise to a retarding torque. The eddy currents and the consequent torque are regulated by varying the strength of the magnet by means of a regulating switch and resistance.

Rheostatic Brake.—For this form of braking, the controller is provided with several positions on the lowering side, called *brake points*.

In these positions the controller alters the connections of the motor to those of a series dynamo, so that it generates current when driven by the descending load, the energy being absorbed by the controller resistance. The speed of lowering is regulated by varying the resistance.

Regenerative Control.—Instead of a series motor, a *shunt wound motor may be used* to drive the hoisting motion.

FIGS. 8,283 to 8,285.—Niles crane construction: Contact-type limit switch. ***It consists of*** a worm wheel with machined teeth actuated by a turned steel worm which is attached directly to the hoisting drum shaft. The release mechanism is operated by a positive stop on the worm wheel with a by pass attachment which prevents damage to the switch by over hoisting. The switch blades are of a quick break type operated by a powerful spring. When the switch is open the motor cannot be operated until the switch is set by hand, after which the hook can be hoisted to the maximum height in the danger zone. When the hook is out of the danger zone, the release stop is automatically reset.

A shunt motor has the advantage that its speed can be efficiently regulated over a fairly wide range by inserting resistance in its field circuit. By this means considerable variation of speed in lifting and lowering may be obtained without the necessity of having variable speed gear in the hoisting train, and when lowering, the shunt motor, if overhauled by a load, becomes a dynamo and feeds current back to the circuit, thus automatically controlling the speed of lowering.

Collector Gear.—For overhead cranes copper wires about one-quarter to three-eighths inches diameter are stretched along the gantry, being supported at the ends by globe strain insulators. Trolley wheels or slides, mounted on the end carriage, make contact with these wires.

Controllers.—The drum type is generally used, *the various combinations of connection for hoisting, lowering, etc.*, being obtained by rotating this drum into different positions

Telpherage.—This word is defined as: *Automatic aerial transportation as by the aid of electricity, especially that system in which carriages having independent motors are run on a stout wire conducting an electric current.*

Telpherage properly includes those systems employing a wire or cable for a track, but the term is erroneously applied to systems using a rail. There are two divisions of telphers: 1, automatic; and 2, non-automatic.

The control of the automatic type is remote from the telpher,

FIG. 8,286.—Niles electric mono-rail hoist, built in capacities from three-quarters to six tons. They will run on straight and curved tracks, and are generally provided with a separate motor for traversing. The hoist is self-contained in one heavy cast iron frame to which the motors are attached end on, and the power is transmitted directly from the armature shaft to the drum shaft through worm and worm wheel. The traversing mechanism is also driven by worm and worm wheel, similarly to the hoisting mechanism except that, when the trolley is arranged to run on a single I beam, a double set of transmission gears is used. The worm gear mechanism is enclosed in oil and dust proof casings, and is noiseless in operation. In addition to the braking effect obtained by use of the worm and worm wheel, a powerful electric brake is attached to the hoist motor.

the non-automatic type being controlled by an operator who travels with the load who operates both the telpher and hoists from a cab or case which is attached to the telpher or carriage.

Telpher Motors.—The sizes of motor for telphers and hoists will depend upon the class of work to be done; the motors for telpher tractors vary from 5 to 15 *h.p.* and for the hoists, from 3 to 75 *h.p.*, the loads being from 500 lb. to 30,000 lb. The driving wheels and the motors may be connected by gears or by chain drive. Slow or medium speed motors are used.

Brakes.—The mechanical type of telpher brake is used and the hoist brake is of either the electro-mechanical or electro-dynamic types.

Spur gears and chain drive on the tractor transmit the power from motor to track wheels, and either spur or worm gear is used to transmit power to the hoisting drum.

Trackage.—Telphers either run in one direction on a closed track circuit, or to and fro over a single line.

On the single line and automatic telphers reverse themselves on completing their trips.

The spacing between the cars is regulated automatically by a block system.

Cableways.—The term cableway may be defined as a rectilinear *hoisting and conveying apparatus supported by a cable.*

A cableway will take up and deposit loads anywhere along a line directly underneath the main cable, and by means of switch blocks it may be made to serve an area having a width of about 15 feet or so each side of the cable.

CHAPTER 135

Electric Bells

The great multiplicity of bells may be classified

1. With respect to the ringing feature, as
    - *a.* Trembling or vibrating;
    - *b.* Single stroke;
    - *c.* Combination vibrating and single stroke;
    - *d.* Continuous ringing;
    - *e.* Buzzers.
2. With respect to the magnet winding, as
    - *a.* Series winding;
    - *b.* Shunt winding;
    - *c.* Differential winding;
    - *d.* Combined differential and and alternate winding;
    - *e.* High voltage winding;
    - *f.* Alternating current winding (polarized).
3. With respect to the form of of the interrupter, as
    - *a.* Contact breaker;
    - *b.* Contact maker.

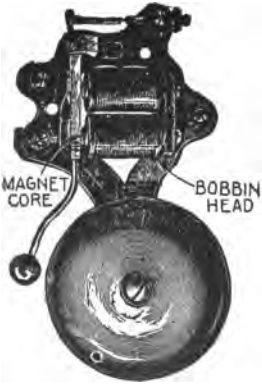


FIG. 8,287.—Bunnell vibrating bell. It has a skeleton type frame, pivoted armature, cast gong, and platinum contacts. Made in sizes 2½ inch to 12 inch.

TABLE SHOWING PROPORTION OF PARTS OF ELECTRIC BELLS

Diameter of bell	Length of magnet cores	Diameter of magnet cores	Length of bobbin	Diameter of bobbin head	B. W. G. of wire on bobbin
2½"	2"	5/16"	1¾"	¾"	24
3	2¼	⅜	2	⅞	24
3½	2½	7/16	2¼	1	22
4	2¾	½	2½	1⅛	22
4½	3	9/16	2¾	1¼	20
5	3¼	⅝	3	1⅜	18
5½	3½	11/16	3¼	1½	16
6	3¾	¾	3½	1⅝	16
6½	4	13/16	3¾	1¾	16
7	4¼	⅞	4	1⅞	16
7½	4½	15/16	4¼	2	14
8	4¾	1	4½	2⅛	14
8½	5	1 1/16	4¾	2¼	14
9	5¼	1⅛	5	2⅜	14
9½	5½	1 3/16	5¼	2½	14
10	5¾	1¼	5½	2⅝	14
10½	6	1 5/16	5¾	2¾	12
11	6¼	1⅜	6	2⅞	12
11½	6½	1 7/16	6¼	3	10
12	6¾	1½	6½	3⅛	10

4 With respect to the magnet, as

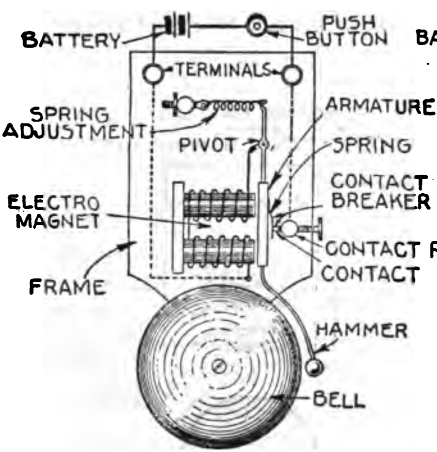
- *a*. Single magnet;
- *b*. Double magnet;
- *c*. Four magnet (double acting).

5. With respect to the frame, as

- *a*. Skeleton;
- *b*. Iron box;
- *c*. Wooden box.

6. With respect to the mode of operation, as

- *a*. Single acting;
- *b*. Double acting;
- *c*. Electrical-mechanical;
- *d*. Relay.



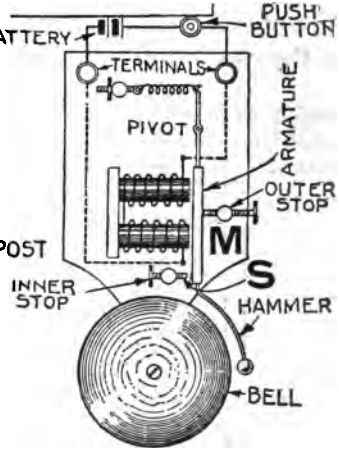


FIG. 8,288.—Elementary series vibrating bell. It consists of an electro-magnet, armature, contact breaker, pivoted hammer, bell, and frame. ***In operation,*** when the push button is pressed, the current energizes the magnet which attracts the armature causing the hammer to strike the bell, but before it reaches the end of the stroke, the contact breaker breaks the circuit and the hammer, influenced by the tension of the armature spring rapidly moves back to its initial position thus completing the cycle.

FIG. 8,289.—Elementary single stroke bell. ***In operation,*** when the push button is pressed, the current energizes the magnet and attracts the armature causing the hammer to strike the bell. The armature remains in the attracted position so long as the current flows through the magnet. When connection with the battery is broken, the hammer spring pulls the armature back against **M**. A stop **S**, averts the motion of the armature, momentum springing the lever and causing the hammer to strike the bell.

Trembling or Vibrating Bells.—This form of bell is perhaps more extensively used than any other. It consists, essentially,

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NOTE.—The series of cuts representing various elementary bells are intended to illustrate ***principles,*** metallic circuits being shown for simplicity. ***It should be noted that in construction,*** the metal frame of the bell is used as a "ground" or return instead of a separate wire.

of: 1, an electromagnet; 2, pivoted armature; 3, hammer; 4, contact breaker; 5, bell; and 6, frame, as shown in fig. 8,288.

Single Stroke Bells.—This type of bell is one which *gives only a single tap each time the battery is connected in circuit.* Such operation is often desirable, as in signalling with a code.

Combination, Vibrating and Single Stroke Bells.—This type of bell is simply a *combination of the two bells just described,* as the classification indicates.

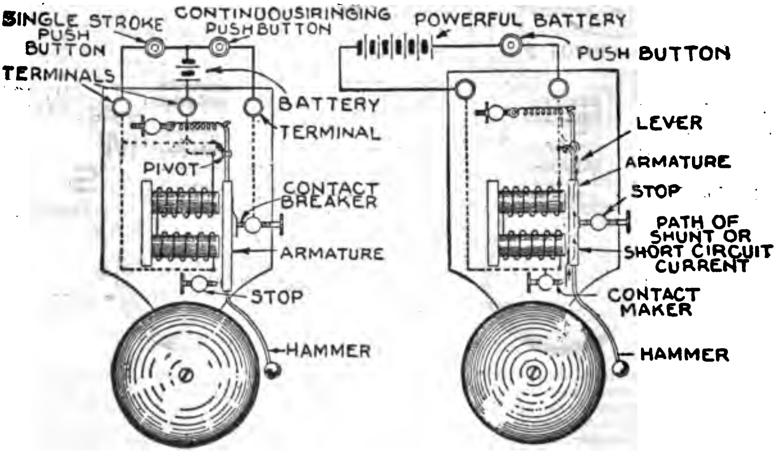


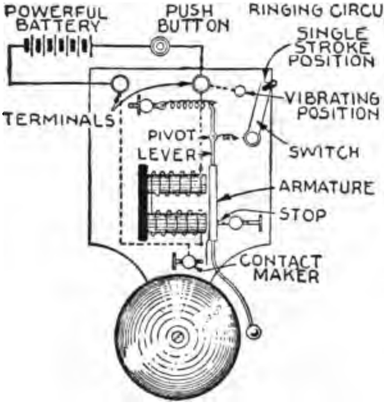
Fig. 8,290.—Elementary combination vibrating and single stroke bell. It is essentially a vibrating bell as shown in fig. 8,288, with a third terminal, and a stop to prevent continued contact of the hammer with the bell when working single stroke.

Fig. 8,291.—Elementary shunt or short circuit, combination vibrating and single stroke bell. This is simply an ordinary shunt bell with a switch arranged so that the short circuit through the contact maker, armature, and lever may be cut out, thus restricting the current to the magnet winding.

Any vibrating bell may be made single stroke by bringing out a third connection so that the current may pass through the magnet without traversing the interrupter.

A vibrating bell may be made single stroke by adjusting the contact breaker spring so that it does not open the circuit.

Shunt, or "Short Circuit" Bells.—In this form of bell the current, during operation, is not broken, but *as the magnet attracts the armature, the current is shunted or short circuited*, and thus being offered a path of very little resistance as compared with that of the magnet winding, most of the current flows through the short circuit.



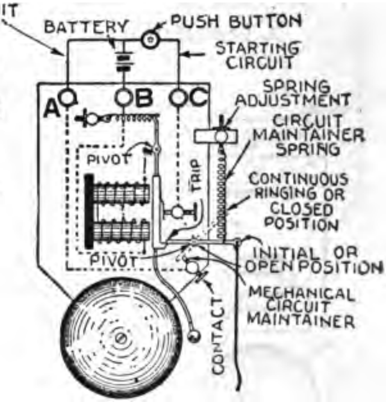


FIG. 8,292.—Elementary shunt bell with single stroke switch. ***Shunt*** cycle when the push button is pressed: 1, Current magnetizes the electro-magnet; 2, magnet attracts armature; 3, contact maker short circuits the current; 4, magnet loses practically all of its magnetism; 5, momentum acquired by moving element causes hammer to strike bell; 6, tension of the hammer spring overcomes weak magnetism of magnets and pulls armature away from magnet; 7, near end of outward swing, contact maker breaks circuit; 8, current again magnetizes the magnet; 9, momentum acquired by the moving element causes it to continue its outward swing (against the attraction of the magnet) to the stop.

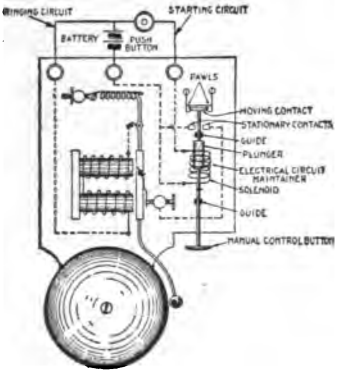
FIG. 8,293.—Elementary continuous ringing bell with *mechanical circuit maintainer*. ***It is essentially*** an ordinary vibrating bell fitted with a mechanical circuit maintainer and connections as shown. ***In operation,*** when the battery circuit is closed momentarily, the path of the current is via terminals B and C. On the swing of the armature toward the magnet the circuit maintainer trips and its spring causes it to move to the continuous ringing position, thus switching terminal A, wire to contact breaker via trip lever. With this circuit it is evident that the bell will continue ringing irrespective of whether the push button be held down or released, and also that the ringing will continue until the circuit maintainer is reset in its initial or open position by a pull on the manual control cord. ***This type*** bell is useful for burglar alarms.

Since this reduces the magnetism to such a small amount that the attraction of the magnet becomes less than the pull of the hammer spring, the hammer swings back to its initial position.

Continuous Ringing Bells.—This classification represents a form of vibrating bell, provided with *a suitable attachment for maintaining the circuit after it has been once established by pressing the push center*, regardless of the fact that the latter may be only momentarily held in the closed position.

There are three types of continuous ringing bell, classified with respect to the circuit maintaining device, as those with

1. Mechanical circuit maintainer;
2. Electrical circuit maintainer;
3. Combination mechanical and electrical circuit maintainer.



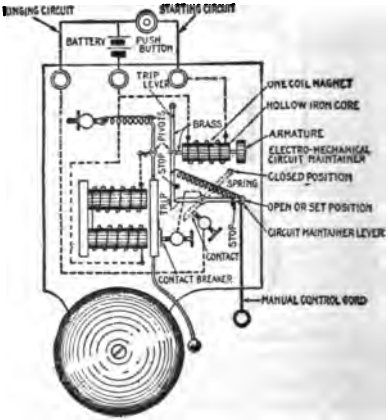
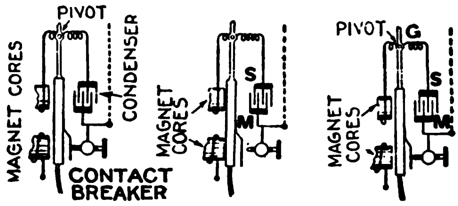


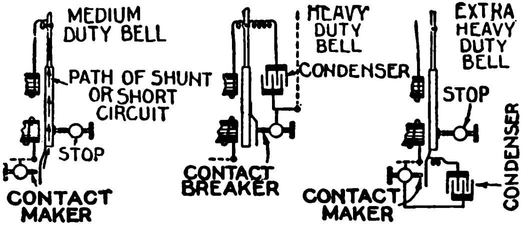
FIG. 8,294.—Elementary continuous ringing bell with electrical circuit maintainer. ***In operation,*** when the *starting circuit* is *closed* by depressing the push button, current flows through the solenoid and draws down the plunger, thus ***closing the ringing circuit.*** The bell will now ring until the ringing circuit is broken by pushing upon the manual control button. To reset the circuit maintainer the manual control button is pushed upward until the moving contact rises above the pawls and the latter spring back to their normal (vertical) position, then the weight of the moving element is held by the pawls.

FIG. 8,295.—Elementary continuous ringing bell with *electro-mechanical circuit maintainer.* ***In operation,*** when the starting circuit is closed by depressing the push button, current energizes this one coil electromagnet attracting the armature which disengages the trip. The spring snaps the circuit maintainer lever over to the closed position as shown by the dotted lines, the trip lever being drawn back by the spring against the stop when the push button is released. The bell beginning to ring as soon as the circuit maintainer lever closes the circuit through the contact breaker and bell magnet. ***To reset,*** the manual control is pulled down until the circuit maintainer lever strikes the stop, the trip end will then engage with the claw of the trip lever.

Buzzers.—A buzzer may be defined as *an electric call signal*



FIGS. 8,296 to 8,298.—Detail showing part of the elementary heavy duty high voltage bell (fig. 8,296) and illustrating the action of the condenser in preventing sparking. In fig. 8,296, current has just begun to flow, to energize the magnets. Fig. 8,297 shows the circuit broken by the contact breaker. Since an electric current cannot be *instantly* stopped, it will, when its path is suddenly interrupted, as here shown, jump the air gap resulting in a spark, unless another path be provided to gradually bring it to rest. This is accomplished by the condenser as indicated in the diagrams—electricity "piling up" on one set of plate M, increasing the pressure thereon, and leaving the other set of plate S, reducing the pressure thereon. When contact is again made by the contact breaker, as in fig. 8,298, the excess pressure on plates M, assists the battery pressure in starting the electricity, the current thus started dividing at the junction G, part flowing back into the plates S, until the pressure is equalized, that is to say the outflow at M, and inflow at S, reduces the difference of pressure between M and S, to zero.



FIGS. 8,299 to 8,301.—Suggestions for the prevention of sparking on special bells. Fig. 8,299 contact maker and shunt circuit for medium duty bell; fig. 8,300 contact breaker and condenser for heavy duty bell; fig. 8,301, contact maker and condenser for extra heavy duty bell.

which makes a buzzing noise caused by the rapid vibrations of a contact breaker.

It operates on the same principle as the electric bell and can be adjusted to emit a pleasing musical hum.

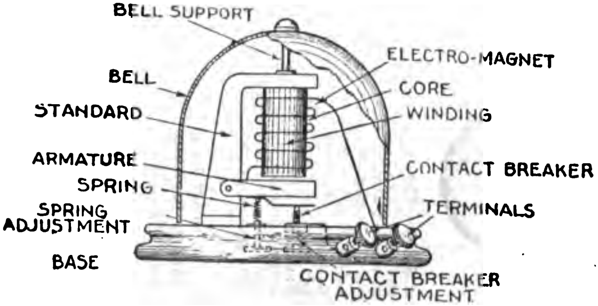
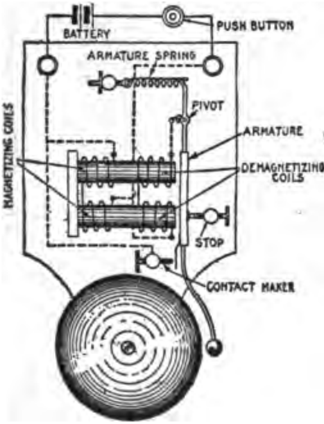


FIG. 8,302.—Sectional view of a buzzer.

Differential Bells.—This type of bell represents one of the numerous schemes to eliminate sparking at the contacts of the interrupter.

The electro-magnet is provided with two windings which, for convenience to distinguish their function, may be spoken of as: 1, the magnetizing winding; 2, the demagnetizing winding.



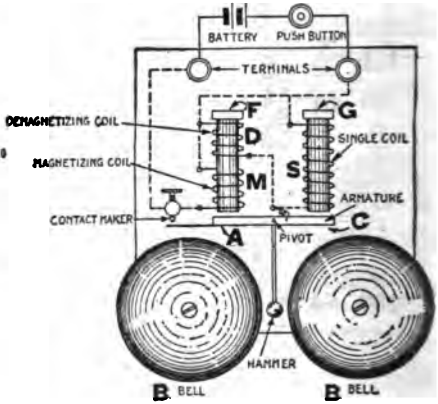


Fig. 8,303.—Elementary differentially wound vibrating bell. *In operation,* when the battery circuit is closed: 1, Current flows through the magnetizing winding and energizes magnet; 2, magnet attracts the armature; 3, contact maker closes circuit through demagnetizing coils; 4, demagnetizing coils demagnetize the magnet; 5, armature spring pulls armature back against the stop, while, 6, the contact maker breaks the circuit through demagnetizing coils.

Fig. 8,304.—Elementary differential and alternate bell. *In operation,* when the battery circuit is closed: 1, current flows through the magnetizing winding M, and energizes magnet F; 2, magnet F, attracts end A, of the armature; 3, contact maker closes circuit through demagnetizing coil D, and single coil S, (of magnet G); 4, demagnetizing coil demagnetizes F, and 5, magnet G, attracts end C, of the armature; 6, contact maker breaks the circuit through demagnetizing coil D, and single coil S, (of magnet G).

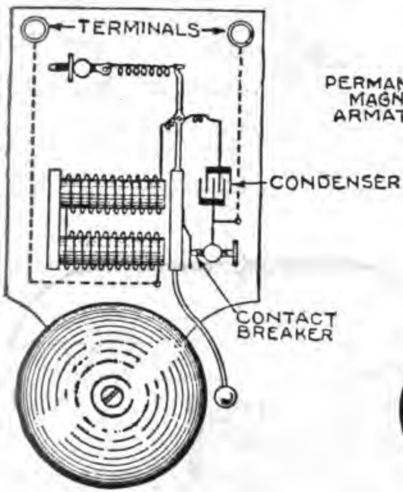
In order to get the desired effect, a *contact maker* is used instead of a *contact breaker;* it operates to control the current in the demagnetizing winding only.

Combined Differential and Alternate Bells.—In this type of bell *there are two separate electro-magnets, and an armature pivoted centrally between them,* so that it is alternately attracted, first by one magnet, then by the other as in fig. 8,304.

High Voltage Bells.—In designing a bell for operation on high voltage currents, that is, on circuits of voltages higher than is usual in ordinary battery installations, provision must be made:

1. To limit the current to the proper value;
2. To secure the proper working conditions at the interrupter.

The first requirement is met by proportioning the magnet winding so as to avoid an undue amount of current. Sparking at the interrupter may be prevented by the use of a condenser.



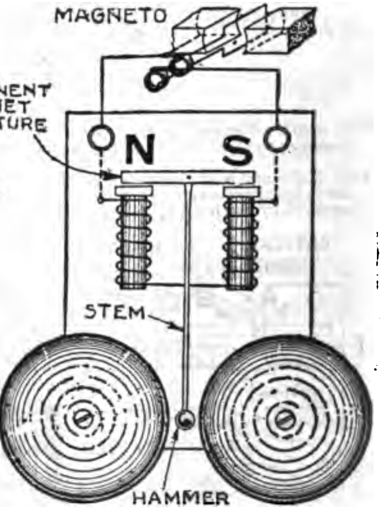
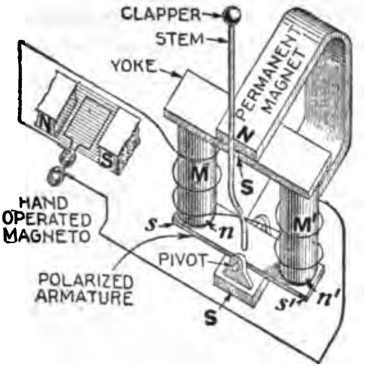


FIG. 8,305.—Elementary heavy duty high voltage bell. The winding is of fine wire to secure enough resistance to keep down the current to proper value. Sparking is avoided by connecting a condenser across the contact breaker as shown.

FIG. 8,306.—Elementary alternating current bell with permanent magnet armature. In construction the electro-magnets are wound similarly, that is, *in the same direction*, so as to produce like poles which simultaneously repel and attract the armature ends.

Alternating Current Bells.—A type of bell used extensively



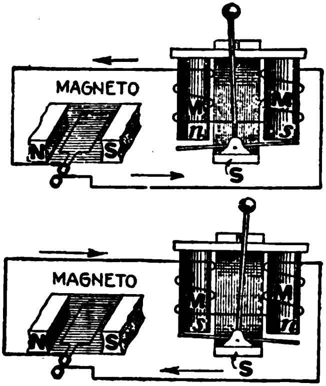
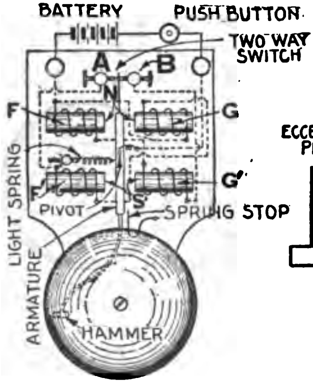


Fig. 8,307.—Elementary *a,c,* bell polarized by magnetic induction. N and S, are permanent magnet poles, and *n* and *s,* poles *induced* by the permanent magnet.

Figs. 8,308 and 8,309.—Operation of the elementary *a.c.* bell of fig. 8,307. The figures show the induced poles and movement of the armature during one cycle of the low frequency *a.c.* supplied by the hand operated magneto.



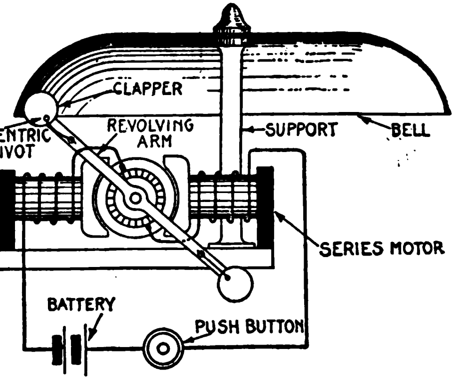


Fig. 8,310.—Elementary double acting bell. ***In operation,*** magnets F,G′, and F′,G, are alternately energized. Assuming the current to flow first through F,G′ and then through G F′, F and G′, will have N and S poles, and G and F′,S and N poles; these will induce unlike poles in the ends of the armature attracting it at both ends.

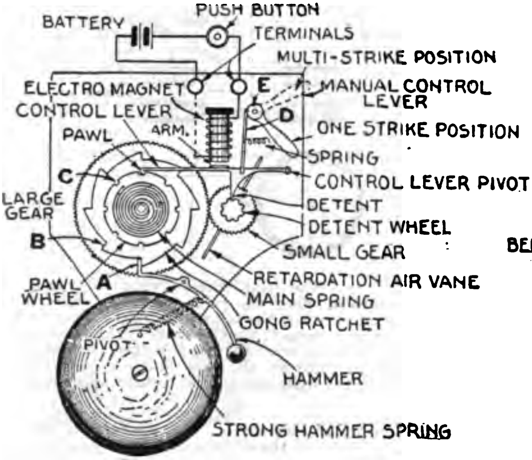
Fig. 8,311.—Elementary motor driven, or revolving strike bell. ***In construction,*** the motor has a revolving member attached to the shaft and an eccentrically pivoted clapper at either end, which in operation delivers two blows to the bell at each revolution of the motor. A desirable type of bell for use where a very loud ringing alarm is required.

in telephone work, to operate on the alternating current furnished by the magneto is shown in fig. 8,306, and its operation illustrated in figs. 8,308 and 8,309.

Double Acting Bells.—This type of bell is desirable *for railroad signals or any place where an extra loud alarm is desirable.*

Motor Driven Bells.—This type of bell is desirable *for use where a loud ringing alarm or signal bell is required.*

It consists essentially of a motor having a double striker mounted at



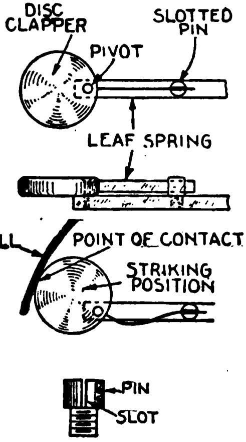


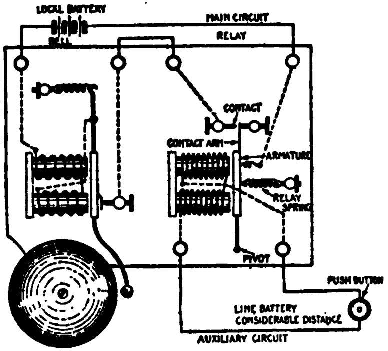
FIG. 8,312.—Elementary electro-mechanical bell. ***In operation,*** the main spring having been wound up, a momentary push on the push button will energize the electro-magnet, attracting the control lever and raising the pawl out of engagement with the pawl wheel and also the detent clear of the detent wheel, allowing the gears to revolve. If the push button be now released, the pawl will ride on the pawl wheel, keeping the detent out of engagement with the detent wheel. As the large gear turns counter-clockwise, the finger A, rides on the ratchet, gradually drawing the hammer away from the bell against the tension of the hammer spring. As the finger rides off the point B, the hammer is suddenly released and strikes the bell a powerful blow. At the same instant the pawl falls into the depression C, on the pawl wheel and the detent engages with one of the numerous depressions in the detent wheel, thus stopping the mechanism. A moderate velocity of rotation of the gears is obtained by means of the retardation air vane.

FIGS. 8,313 to 8,316.—Construction details of clapper for motor driven bell, and view showing action of clapper on striking the bell.

the armature shaft as shown in fig. 8,311, giving two strikes to each revolution.

Electro-Mechanical Bells.—Where a very powerful bell is required to operate at a distance with little battery capacity, the electro-mechanical bell is well suited.

In this type of bell, *the electric current is used simply to* **control** *a spring operated mechanism which supplies the energy to ring the bell.*



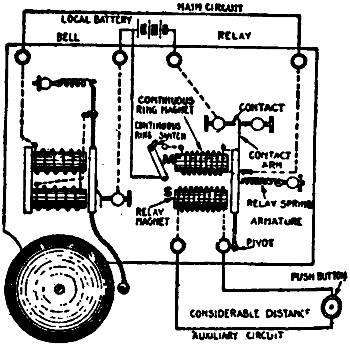
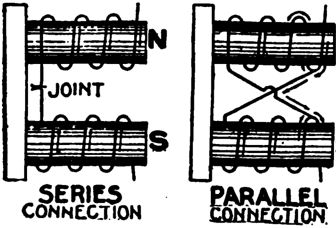


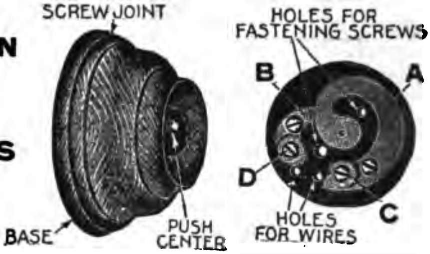
FIG. 8,317.—Elementary relay bell and connections. The relay here shown is in principle identical with the telegraph relay. ***In operation,*** when the push button is depressed current for the line battery in the auxiliary circuit energizes the relay magnets which attract the armature, moving the contact arm against the contact, thus closing the main circuit and ringing the bell. Clearly the operation continues until the push button is released, that is, when current ceases to flow in the auxiliary circuit, the relay magnets loose their magnetism, the relay spring pulls the armature to the right moving the contact arm against the stop, thus breaking the main circuit.

FIG. 8,318.—Elementary relay bell having *continuous ring device.* ***In operation,*** when the push button is depressed, magnet S, is energized and the same action takes place as in fig. 8,317. Now if the continuous ring switch be closed, magnet M, also becomes energized as soon as the main circuit is closed by magnet S. Since M, is now connected with the battery, it will hold the contact arm in the closed position, irrespective of whether the pushed button be depressed or released, causing a continuous ringing of the bell until the continuous ring switch is opened by hand.

Relay Bells.—Where bells are to be operated *at a considerable distance a relay is usually employed*, especially in the case of large heavy duty bells requiring considerable energy to operate them.

Bell Wiring.—Always start to wire at the push, and run the wires from the push to the bell, and to the battery.

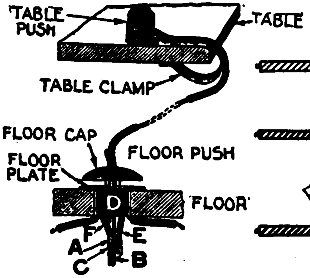




Figs. 8,319 and 8,320.—Reducing resistance of bell coils. When connected in parallel (fig. 8,320) the resistance is reduced one half, allowing more current to flow through the coils for a given voltage.

Figs. 8,321 and 8,322.—General construction of an ordinary push button. Fig. 8,321 exterior view; fig. 8,322 interior view.

Fig. 8,323.—Special push button with indicating buzzer inside, useful for any system where the caller desires to know positively that the bell has given the signal.



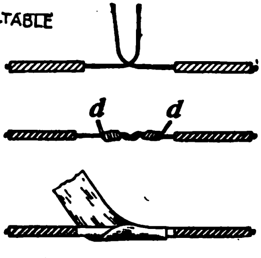
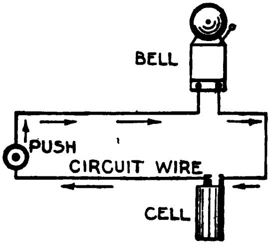


Fig. 8,324.—Paper weight type of multi-push button, suitable for desk use.

Fig. 8,325.—Combination floor and table push button suitable for dining room. The table clamp renders the push portable, permitting it to be moved at any time.

Figs. 8,326 to 8,328.—Proper method of making a joint in covered wires. First scrape off about 3 ins. of the insulating covering on the end of each wire; scrape the bared copper wire until it is bright and clean; bend these wires into the position shown in fig. 8,326; and then firmly twist them around each other as shown in fig. 8,327. Second, cut off the projecting pieces *d*, *d*, close to the joint, and then solder the latter to prevent corrosion. This corresponds to a Western Union splice. Third, wrap a piece of adhesion or friction tape around the joint over about half an inch of the insulating covering of each wire, as in fig. 8,328.



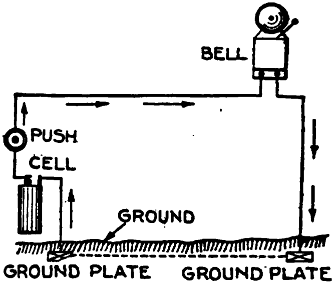
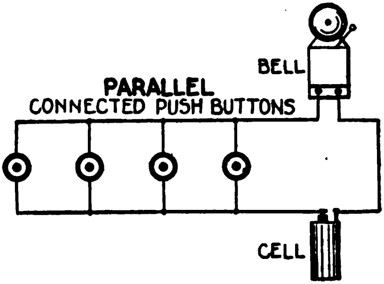


FIG. 8,329.—Simple bell, metallic circuit.

FIG. 8,330.—Simple bell circuit with *ground* return. Instead of using ground plates, a more convenient method consists of connecting the ground wires to a gas or water pipe.



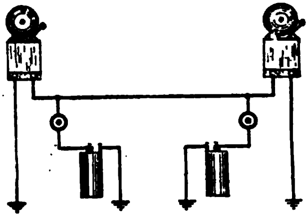
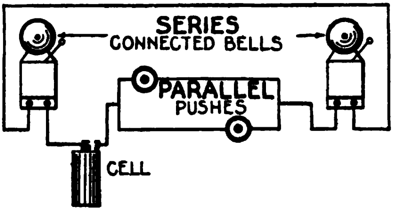


FIG. 8,331.—Parallel connected push buttons for ringing one bell from several points. It is obvious that if the push button were connected in series, all would have to be closed to complete the circuit.

FIG. 8,332.—Series circuit connections for ringing two bells from either one or two push buttons. In this diagram the bells are in series, and one of them must be arranged for single stroke.



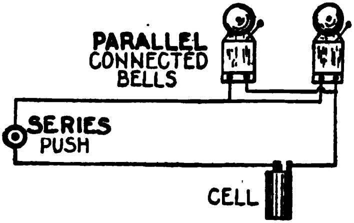
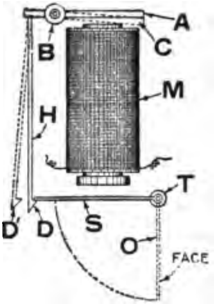


FIG. 8,333.—Series connected bells for ringing two bells from either one or two pushes.

FIG. 8,334.—Parallel connected bells for ringing two bells from either one or two pushes.



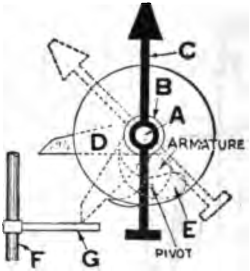
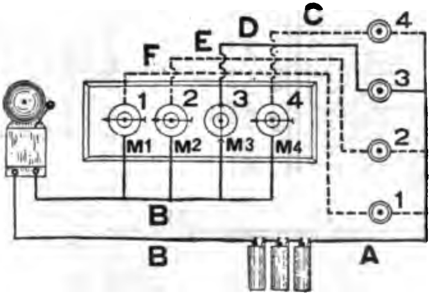


Fig. 8,335.—Gravity drop annunciator. *In operation,* the shutters are reset by turning the knob seen on the side of the case.

Fig. 8,336.—Shutter or gravity annunciator drop. *In operation,* when the circuit is completed by the depression of a push center, the current flows through the coils of the electromagnet M, and energizes its core, and the latter attracts the armature A, pivoted at B. When the armature is drawn to the position C, the claw D, is thrown to the position D′, thereby releasing the shutter S, pivoted at T, allowing it to drop by gravity to the position O, thus displaying the number marked upon its face.

Fig. 8,337.—Arrow or needle annunciator drop. *In operation,* when the current flows through the coils of the electromagnet, the armature E, turns on its pivot towards the magnet core A, thereby releasing the arm D, which in falling rotates the arrow to the position shown in dotted lines. The arrow is reset by pressing a button, which raises the rod F, carrying the arm G.



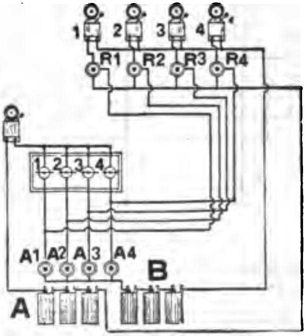


Fig. 8,338.—Method of wiring an annunciator.

Fig. 8,339.—Western Electric return or fire call annunciator system. *In operation,* when one of the annunciator pushes A1, A2, etc., is pressed, battery B, becomes connected in series with the bell 1 or 2, etc., as the case may be. When one of the room pushes R1 R2, etc., is pressed, its corresponding bell is cut out and the circuit becomes similar to an ordinary annunciator circuit.

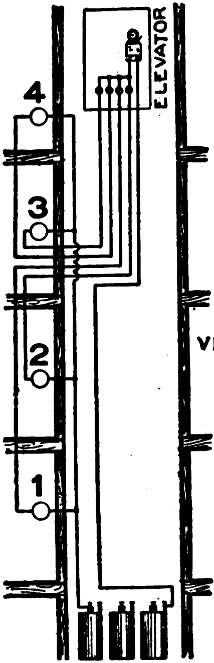


FIG. 8,340.—Annunciator circuit for single elevator.

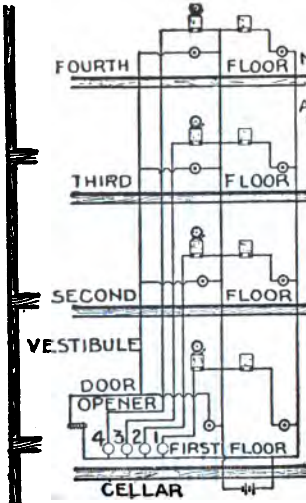


FIG. 8,341.—Bell and buzzer circuits for an apartment house.

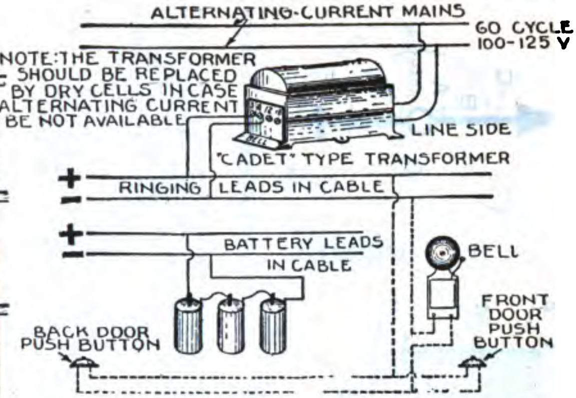
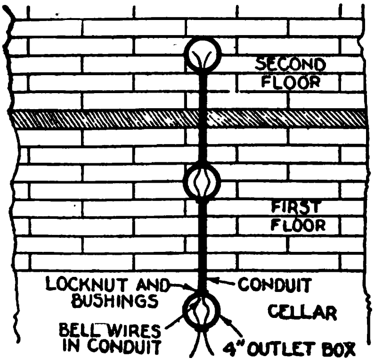


FIG. 8,342.—Method of connecting a bell ringing transformer for ringing inter-phone bells and door bells. Dotted lines show wiring for door bell using same source of ringing current.

fasten each wire lightly to the woodwork with staples or double pointed tacks.

The wire from the push to the battery may be run through holes bored in the floor directly under the push, but inside the front door, then along the cellar beams to the battery. In many houses the wire from the push to the bell may also be run along the cellar beams. In such cases, a second hole should be bored in the floor by the side of the one accommodating the wire from the push to the battery, for the wire from the push to the bell.



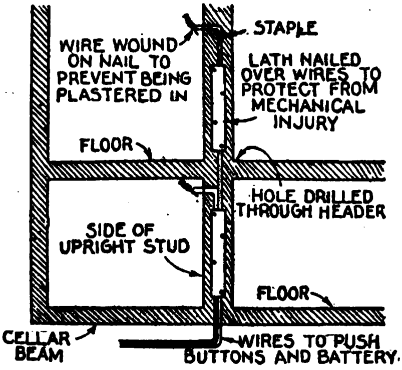


FIG. 8,343.—Method of installing bell wires in brick house.

FIG. 8,344.—Method of installing bell wires in unfinished house of wood construction.

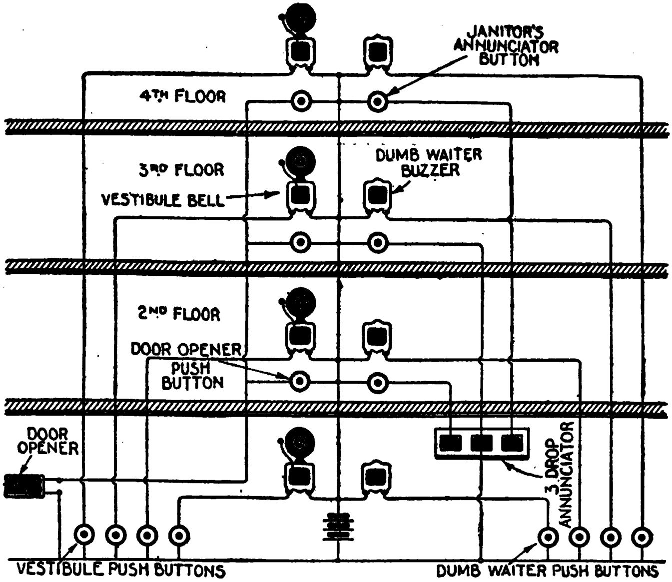
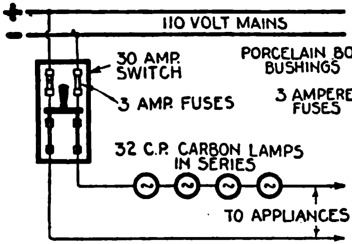


FIG. 8,345.—Wiring diagram for bells, door opener, janitor's annunciator and dumb waiter buzzer of a four story apartment house.



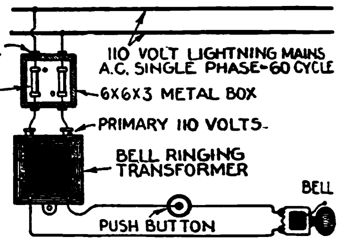


FIG. 8,346.—Connections for reducing lighting main voltage. If voltage be too strong, more lamps.

FIG. 8,347.—Method of connecting bell ringing transformer.

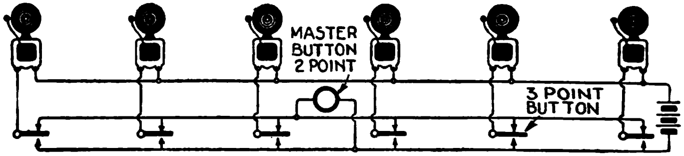


FIG. 8,348.—Selective and master button system; master button rings all bells simultane

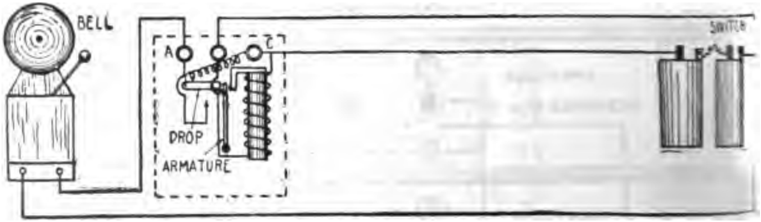


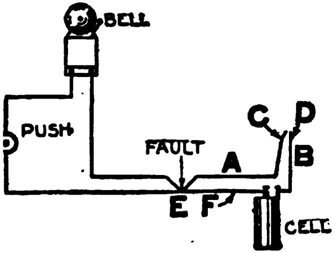
FIG. 8,349.—Automatic burglar circuit with gravity drop circuit maintainer to give c ous ringing. *In operation,* when the switch is closed, the circuit maintainer ma winding is connected in series with the battery and the armature is drawn up again core of the magnet so that the drop is released and allowed to fall against the contact p connected with the A, binding post. The drop, which is connected with C, binding p thereby closes the bell circuit and allows the bell to ring until the drop is again rais its normal position.

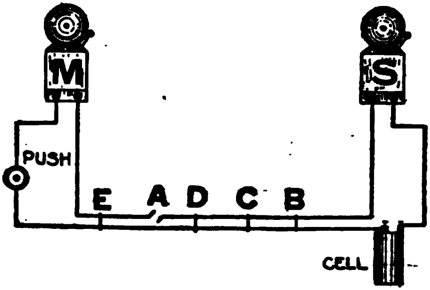
FIGS. 8,350 to 8,353.—Milonite nails and method of tacking two insulated wires. The hea are colored to match insulation and the wires can be tacked down without cutting or inj the insulation.

Bell Troubles.—These are due to a variety of cause, which nay be easily rectified.

When the armature sticks to the magnet cores and fails to make contact with the screw, the trouble is generally due to weak spring, or to the loss of brass pieces, which are inserted in the ends of the cores to prevent actual contact with the armature. A piece of paper stuck over the ends of the cores will often serve as a satisfactory remedy.

When the bell makes a screeching sound, the trouble may be due to a too rapid vibration of the armature; too much battery power; or to the fact that the contact screw is too far forward. If the excessively rapid vibration is caused by too little play, or too much battery power, the fact will be indicated by violent sparking.

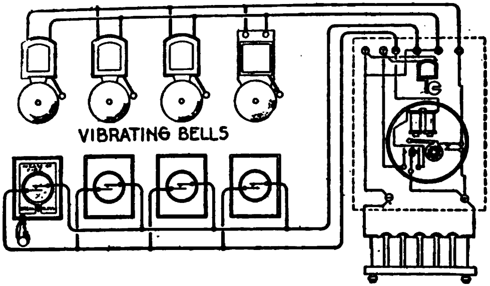




'IG. 8,354.—Test for crossed wire in bell circuit. E, represents short circuit. *In testing,* disconnect the wire from one terminal of the battery; connect a short piece of wire B, to that terminal, and place the two ends C and D, on the tongue. If the circuit wires be touching each other at some bare spot E, the current will flow from the battery along F, to the point of contact E, thence along A, to the tongue, and along B, to the battery. The flow of current will be indicated by a metallic taste upon the tongue, or by connecting a telephone receiver between C and D, the diaphragm will be made to vibrate. Without this indication, or the absence of the metallic taste on the tongue, it is probable that the trouble is due to a break.

'IG. 8,355.—Test for break in bell circuit. A, represents the break. *In testing,* take a bell to the battery and connect it between the circuit wires and the battery at the points B, C, D, and E, working towards the push. At each of the points cut away a little of the insulating covering of the wires, and short circuit the latter, beyond the bell and the battery with a knife blade. If the bell ring at the points B, C, and D, but fail to ring at the point E, the break will be located at A, somewhere between D and E.

Dirty contacts and loose contact screws increase the resistance of the circuit, tend to decrease the current allowed to pass through the magnet coils, and often prevent the bell ringing at all. It should be noted that the contacts are of platinum, as German silver and other similar metals are soon corroded away by the sparking. The contact screws should not be readjusted unless it be found necessary to do so because of loosened screws.



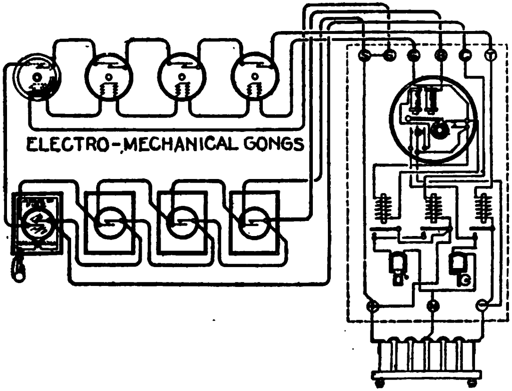


FIG. 8,356.—*Open* circuit fire alarm system. ***In operation,*** when the glass is broken at any of the boxes, it causes a small electromagnet in the code relay to trip a clock mechanism which is equipped with a wheel upon which are mounted a number of contacts arranged so that that circuit is open and closed a number of times successively until the spring of the clock mechanism is unwound. Which takes at least three minutes which is ample time to give sufficient alarm.

FIG. 8,357.—*Closed* circuit fire alarm system. ***In operation,*** this system is the same as the open circuit code system, except that a closed circuit relay is installed in the master box.

Bell Circuits Troubles.—Faults, other than those caused by weak push and bell springs, dirty and loose contacts, and run down battery are generally due to crossed wires, or broken wires.

Fig. 8,354 shows the method of making a simple test for a cross, and fig. 8,355, for determining location of a break. Short circuits are often caused by double pointed tacks or small staples cutting through the insulation and injuring the wire. This is often the result of carelessness and too much haste in tacking up the wires. ***No more than one wire should be placed under one staple.***

CHAPTER 136

The Telegraph

The simplest form of telegraph system consists of: 1, live wire; 2, battery or other source of electricity; 3, a transmitting instrument or *key* 1 and 4, receiver or *sounder*.

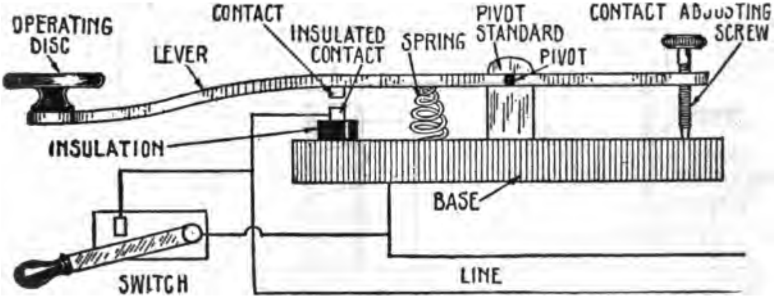


FIG. 8,358.—Elementary transmitter or *key*. *It consists of* a pivoted lever provided with a contact and adjusting screw, and carried on a base having an insulated contact and a spring to keep the lever normally in the open position. A switch is provided to close the circuit when the key is not in use. *In operation,* the disc is grasped by the 1st, 2nd, and 3rd fingers; depressing the disc causes the two contacts to touch the circuit. Closing the circuit for a short period corresponds to a "dot" and, for a longer period, to a dash. The periods in which the circuit is closed are indicated audibly by the "sounder."

Classification.—The telegraph, like other inventions, has been considerably developed, resulting in numerous systems. A classification of these various systems, to be comprehensive must be made from several points of view, as with respect to:

1. The kind of circuit, as
   - *a*. Ground return;
   - *b*. Metallic.
2. The method of operating the circuit, as
   - *a*. Closed;
   - *b*. Open.

3. The transmitting capacity
   - *a.* Single Morse line;
   - *b.* Diplex;
   - *c.* Duplex;
   - *d.* Quadruplex;
   - *e.* Multiplex;
   - *f.* Phantoplex.

4. Method of receiving as
   - *a.* Non-recording;
   - *b.* Recording { by perforations; by printing.

Morse Single Line System.—This ordinarily includes a *battery for supplying a low tension current and a line wire connecting two or more stations serving to establish a circuit between them;* a return connection to the battery, formed either by another wire or by the earth to a transmitting key, and a sounder or recording apparatus at each station.

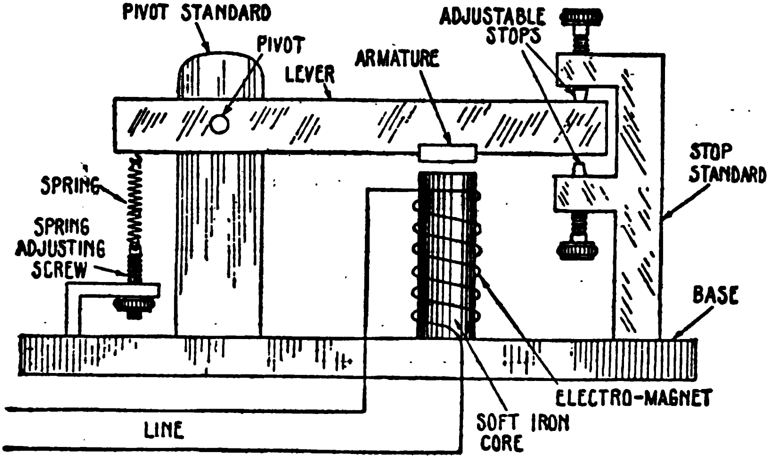


FIG. 8,359.—Elementary sounder. ***It consists of*** a heavy pivoted lever arranged to vibrate between two stops and held normally against one of these stops by the action of a spring, there being an electromagnet which when energized acts on an armature attached to the lever causing the latter to move from the upper stop to the lower stop, the blow thus produced, owing to the heavy construction of the lever, being distinctly audible.

Ques. On what does the operation of the telegraph depend?

Ans. An electromagnet can be magnetized and demagnetized with great rapidity on respectively making and breaking the magnet circuit, the magnetic action thus obtained being used to operate a sound producing mechanism so that the various combinations of "dots" and "dashes" representing the letters of the alphabet are indicated audibly.

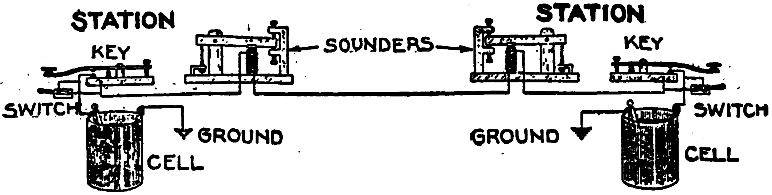


Fig. 8,360.—Elementary short line *closed circuit* system. When not in operation the switches are closed and current flows which energizes the magnets and holds the instrument armatures in the down position. This necessitates the use of a closed circuit cell as for example the crow foot gravity type which is capable of supplying a very weak current for a long duration of time.

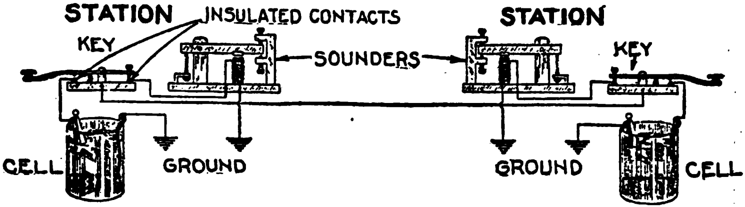


Fig. 8,361.—Elementary short line *open circuit* (European) system. ***As arranged,*** the battery is in operation only when a message is being sent. A main battery is necessary at each station, whereas in the *closed system*, employed in America, main batteries are required only at the terminal stations.

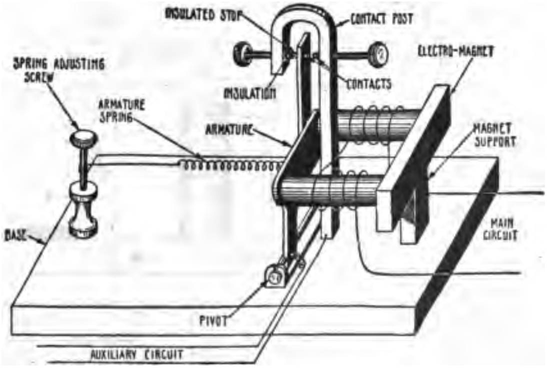


Fig. 8,362.—Elementary relay. Note the delicate armature construction as compared with sounder, thus requiring very little energy to operate. A relay is virtually a very delicate sounder with a contact maker at the end of the armature lever.

Relays.—In general, a relay is *a device which opens or closes an* **auxiliary circuit** *under predetermined electrical conditions in the* **main circuit.**

Its function is to act as a sort of ***electrical multiplier,*** that is to say, ***it enables a comparatively weak current to bring into operation a much stronger current,*** thus reducing considerably the battery capacity required.

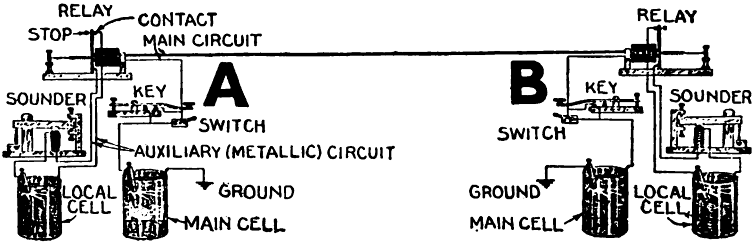


Fig. 8,363.—Elementary short line with relays. Normally both switches are closed; this energizes the relay magnets and keeps the auxiliary circuits closed by holding the relay contacts together. ***In operation,*** the sender opens his switch and with the key sends the message by successively making and breaking the main circuit in proper sequence. This causes the relay armature to move back and forth against the contact and stop, thus making and breaking the auxiliary circuit in synchronism with the movements of the key. In this way, the very weak main current is enabled to bring into action the much stronger current of the auxiliary or local circuit, thus, the movements of the delicate relay armature are reproduced by the heavy armature of the sounder.

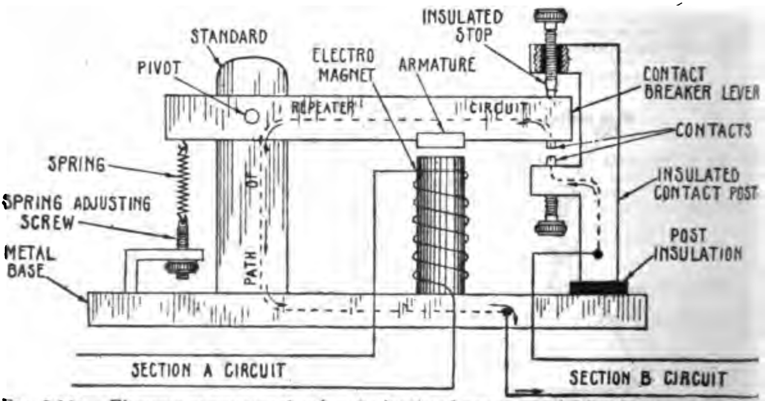


Fig. 8,364.—Elementary repeater showing the insulated parts essential for the contact maker, and path of the current through the repeater portion of the instrument. The Insulated stop on the upper arm of the contact post is shown in sectional view to clearly indicate the insulation at this point. Compare this instrument with the elementary sounder fig. 8,359 and note the essential points of difference.

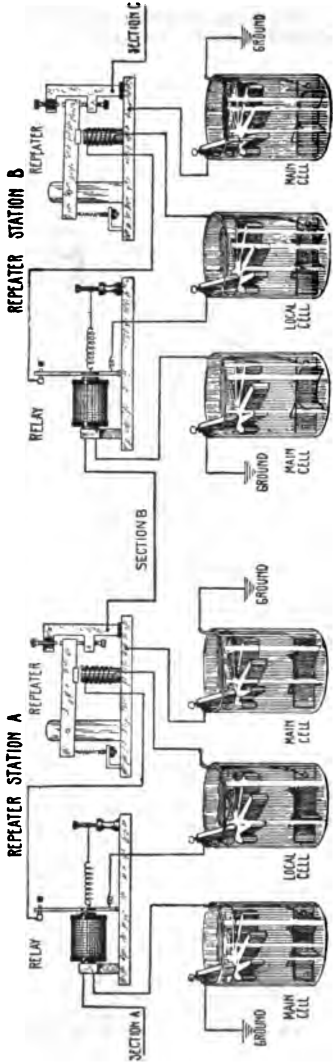


FIG. 8,365.—Elementary repeaters as connected in a circuit. *In operation*, if the home station or beginning of section A, line send a message, the movements of the relay at station A, will cause similar movements of the repeater, this in turn is repeated at station B, and all other stations on the line.

Repeaters. — When the length of a telegraphic circuit exceeds a certain limit, the working margin becomes so small that satisfactory signals cannot be transmitted even by the aid of increased battery capacity.

This limit under existing conditions is much less in wet weather than in dry weather. Under such conditions it was formerly necessary to retransmit all communications at some intermediate station, but this duty is now performed by an instrument called a *repeater*.

By definition a repeater is a *sounder provided with a circuit maker, for synchronously controlling a second circuit.*

It repeats a message from one section to a second section of a line by aid of a separate battery.

Diplex Telegraphy. — By definition this is *a system which permits* ***two messages*** *to be transmitted in the same* ***direction*** *at the* ***same time*** *over a single wire.*

In principle the receiving instrument at the home station, while free *to respond to the signals of the key at the distant station, shall not respond to the signals of its associate key.*

Duplex Telegraph.—This system is one which permits the

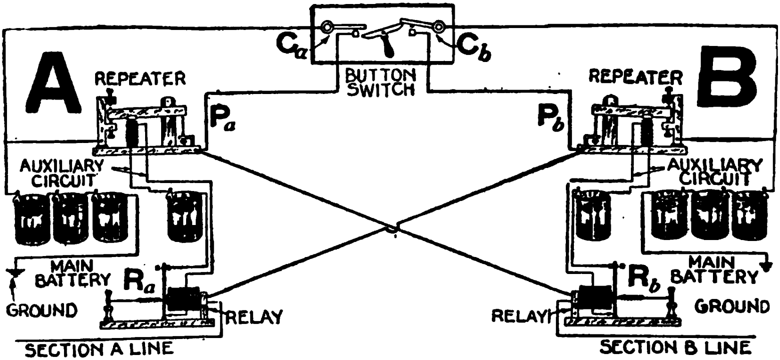


FIG. 8,366.—Elementary so-called "button" repeater (properly called repeater system with button switch). *In operation,* if say section B line be opened by the key of the operator, the armature of section B relay will open, which in turn opens section B repeater, whose circuit breaker breaks the circuit of section A. This causes the armature of section A relay to open, followed by that of section A repeater, the circuit breaker of the latter also breaking the circuit of section A. The operator of section B line cannot now close the circuit, because it is still open in another place, viz., at the circuit breaker of section A repeater. The button switch eliminates this difficulty, for when it is swung to the left, it closes a spring contact C_a, forming a connection between the circuit breaker of section A repeater, enabling the operator of section B to open and close its circuit, at pleasure, while his signals are repeated into section A by the action of the circuit breaker of section A repeater.

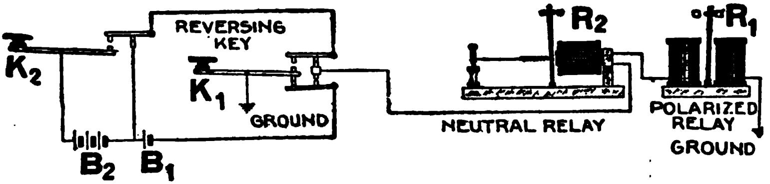
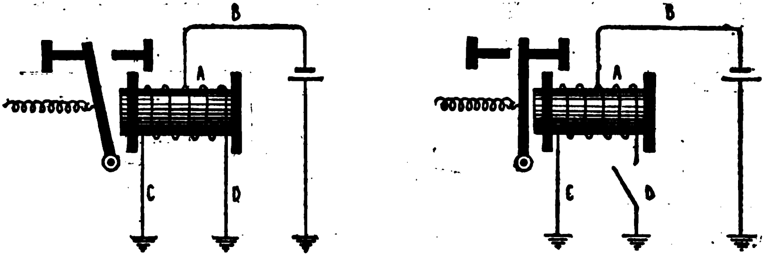


FIG. 8,367.—Elementary duplex system. *In operation,* if the sender depress key K_2, this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R, to be attracted. If now another signal be sent by the depression of key K_1, the full strength of the current traversing the neutral relay R_2, will be reversed. If the armature spring of the neutral relay R_2, be adjusted so that it cannot respond to the weak current of battery B_1, it is evident that signals may be sent by reversing the smaller battery B_1, by means of K_1, which will operate R_1, but not R_2.

sending of two messages simultaneously in opposite directions over a single wire.

There are several systems of duplex telegraphy, namely:

1. Differential; 2. Polar {with battery; with dynamo; 3. Bridge.



FIGS. 8,368 and 8,369.—Detail of the differentially wound third spool of relay of the Weiny-Phillips system. In fig. 8,368, one terminal of the battery is shown grounded while the other terminal is shown connected differentially with two equal windings of the magnet. The current divides at A, half going through each coil. It may be observed that the direction of the winding of one coil is opposite to that of the other. Thus, when current flows through the wire B, the magnetization of the core due to the action of current in the coil A-C is neutralized by the presence of current in the coil A-D, and as a result the core is not magnetized at all; so that the retractile spring attached to the armature holds the latter in the "open" position as shown in fig. 8,368. If, however, while the coil A-C remains closed, the coil A-D be opened, as in fig. 8,369, the core will be magnetized due to the presence of current in the coil A-C while no current exists in coil A-D, the latter no longer neutralizing the magnetic effect of the former. The armature, therefore, is attracted and held in the "closed" position as shown in fig. 8,369.

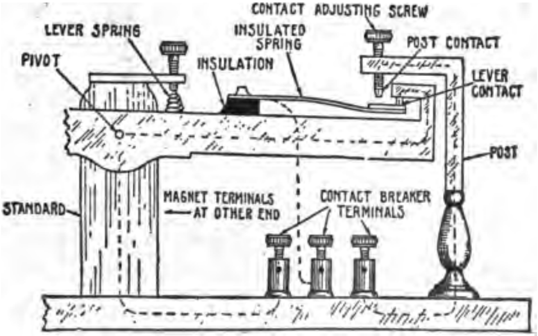


FIG. 8,370.—Detail of contact breaker end of a transmitter showing the three contacts, method of mounting the spring contact, and the circuits from the contacts to terminals. The duration of contact, or portions of the stroke of lever during which the circuit through the post contact and spring contact remains closed is regulated by the contact adjusting screw.

Differential Duplex System.—This method ***employs*** *a relay wound with two sets of coil, in each of which the current flows in a different direction.*

Consequently when two currents of equal intensity are passed through the relay at the same time, they neutralize each other, and the relay does not become magnetized.

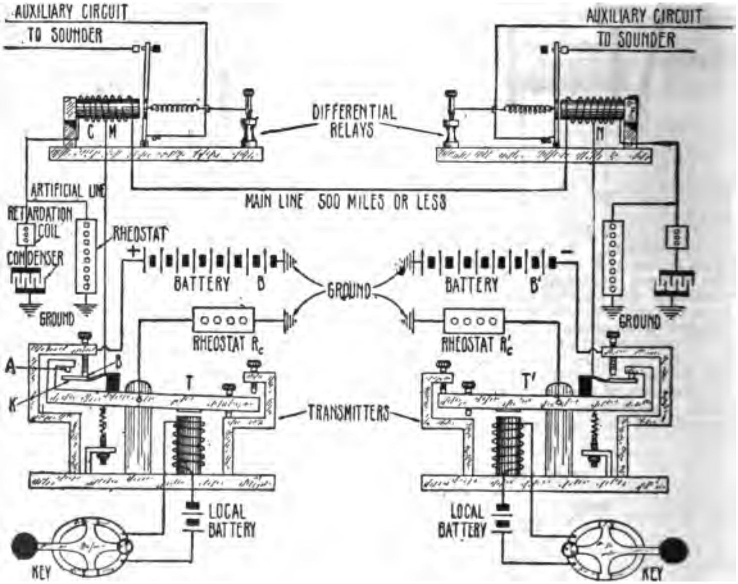


Fig. 8,371.—Stearn's differential duplex system. The circuit can be traced from the tongue contact K, to the point of division M, known as the "split." At this point one branch goes through the right portion of the relay winding to the main line, and the other through the left portion of the relay, the artificial line and to ground. When K, is in contact with B, the circuit is through battery B, to ground, and when in contact with A, it is through the transmitter lever, and rheostat R_c to ground. The purpose of the rheostat R_c is to divide the current passing through the relay coils equally between the main and artificial lines. When this condition is established, the current will pass through the relay with no appreciable effect upon it and the duplex is said to be "*balanced.*"

Each station is provided with a differential relay, and there are two complete circuits, one including the line wire, and the other consisting of resistance coils having a resistance equivalent to that of the line and known as the *artificial line.*

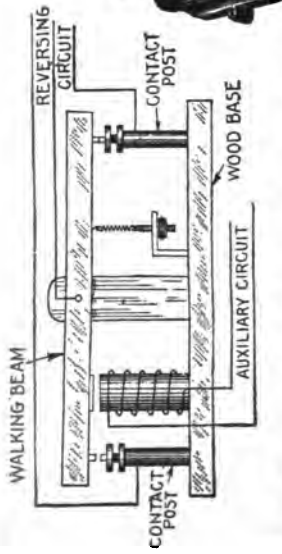


FIG. 8,372.—Elementary "walking beam" pole changer. ***As can be seen,* it is** impossible for all three wires of the reversing circuit to be connected at any instant, that is before each reversal, the circuit is broken, thus interposing an air gap; this is an undesirable condition where dynamos are used for current supply, because, their very small internal resistance would otherwise permit considerable sparking.

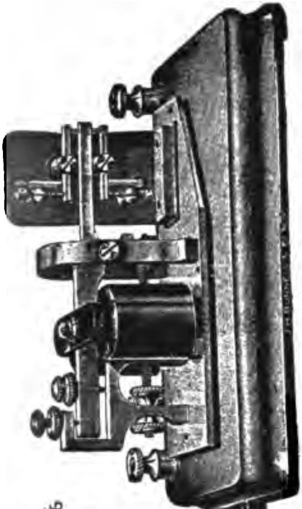


FIG. 8,373.—Bunnell pole changing transmitter or circuit continuity preserving reverser, suitable for battery current.

The key and battery at each station are common to both circuits, the points of divergence being at the relay and at the ground plate.

When the key at one station which may be called the *home station* is depressed, the current flows through both sets of coil of the relay at that station without producing any magnetizing effect. Consequently, the relay and sounder at the home station remain unresponsive, but at the distant station, the current will flow through only one set of coil at that station and will cause it to operate the local sounder. The same effect, of course, is produced when the key of the distant station is depressed.

Polar Duplex System.—Each station is *provided with two batteries or dynamos, which are arranged in such a manner that the direction of the current in the line depends on whether the key is in its raised or depressed position.*

As in the case of the differential method, the current divides at the relay, which instead of being of the differential type is known as a *polarized relay.*

The Bridge Duplex System.—This method is based on the principle of the

Christie or so-called Wheatstone bridge*. It is used in the operation of submarine telegraph cables.

In this method, the relay is placed in the cross wire of a Christie bridge and the key is so arranged that connection is made with

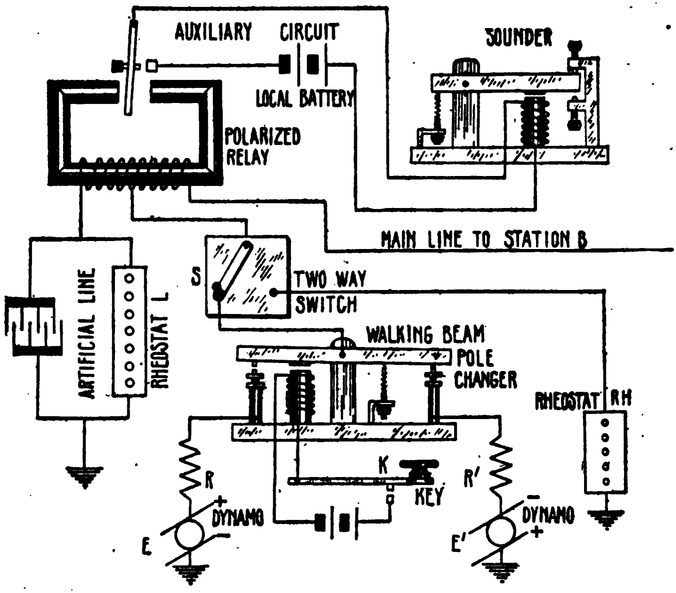


FIG. 8,374.—Dynamo polar duplex system. E and E′, are the dynamos, E, for the positive and E′, for the negative current. These supply their currents through resistance coils R R′, either of German silver wire or of incandescent lamps. K, is the key which closes the local circuit of the walking beam pole changer. The position of the lever of the pole changer determines which current is being sent to line through the pivot of the lever. The two way switch S, is for changing from duplex to ground connection through a rheostat RH, for the purpose of enabling the distant station to obtain a balance. From the switch the current goes to the junction of the two coils of the relay where it divides, one-half going to the main line, if the line circuit be closed at the distant station, and the other half through the artificial line to ground. The resistance in the artifical line is made equal to the resistance of the line and relay coils at the distant station. This is adjusted, not by measurement, but by trial. The operator at the distant station turns his switch to the ground position and signals are then sent by the operator at the home station.

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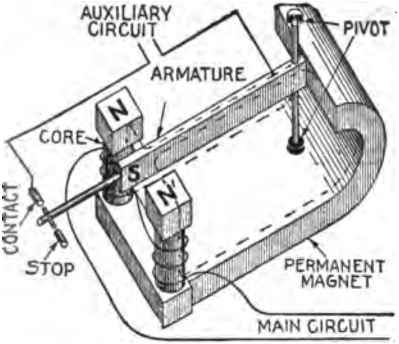
*NOTE.—The author desires to emphatically protest against appplying the name Wheatstone to this bridge. This ingenious and useful system of electrical measurement was first described by ***Samuel Hunter Christie***, in *Phil. Trans. R. S.*, 1833, 95–142. Wheatstone simply directed attention to it and although ***full credit was accorded to Christie by Wheatstone for his admirable device***, electricians have ever since persisted in calling it the ***Wheatstone Bridge***, and it seems probable that it will always continue to be known by that name, despite the injustice of such error.



the battery before the line leading to the earth is broken. Adjustable resistance coils are placed in the arms of the bridge and a wire connects the key with one arm of the bridge, which is completed at the opposite end by a suitable arrangement. If the resistances be equal, the relays will not operate when the

FIG. 8,375.—Elementary polarized relay. ***In operation,*** when no current flows through the electromagnet, the armature (having no spring), when placed midway between the poles of the electromagnet will be attracted equally by each and accordingly will approach neither. When, however, the electromagnet is energized, the magnetism thus reduced in its cores either increases or overcomes that due to the permanent magnet, producing unlike poles according to the direction of the current. Thus the armature is attracted by one and repelled by the other. The magnetism of the electromagnet of the polarized relay changes in response to the reversals of the distant battery and the armature vibrates to and fro between its front and back stops in accordance with those changes.

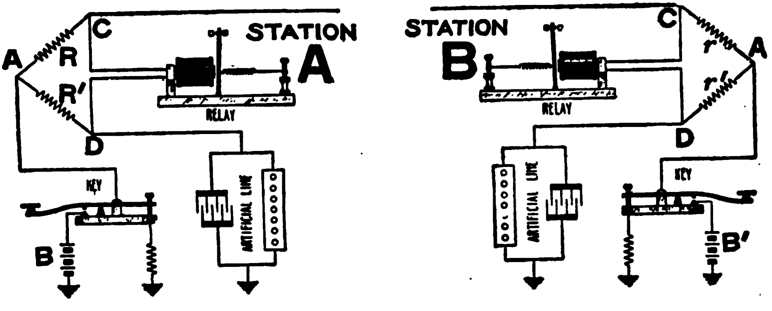


FIG. 8,376.—Diagram illustrating the operation of the bridge duplex system. In the figure, B and B', are the main line batteries, one at each station. R, R', and *r*, *r'* are the bridge resistances at each station. The various connections are clearly shown in the diagram. ***In operation,*** closing station A key sends out a current which divides at A, half passing over the main line to station B. and reaches earth via the apparatus at that end of the line, while the other half passes through the artificial line at station A, reaching the earth at that end of the circuit. Since the resistance between C and D, is the same as R or R', the pressures at C and D, are equal, and no current will flow through station A relay. This holds only when the resistance of station A artificial line is made equal to the resistance of the actual line to ground at the distant end. The relay at **A** is accordingly not affected when **A** sends to **B**. The same condition obtains when **B** alone sends to **A**. Signals from **A** operate the relay at **B** because the incoming signals have a joint path made up of the branches CD and CA, thus setting up a difference of pressure between the points C and D sufficient to operate the relay.

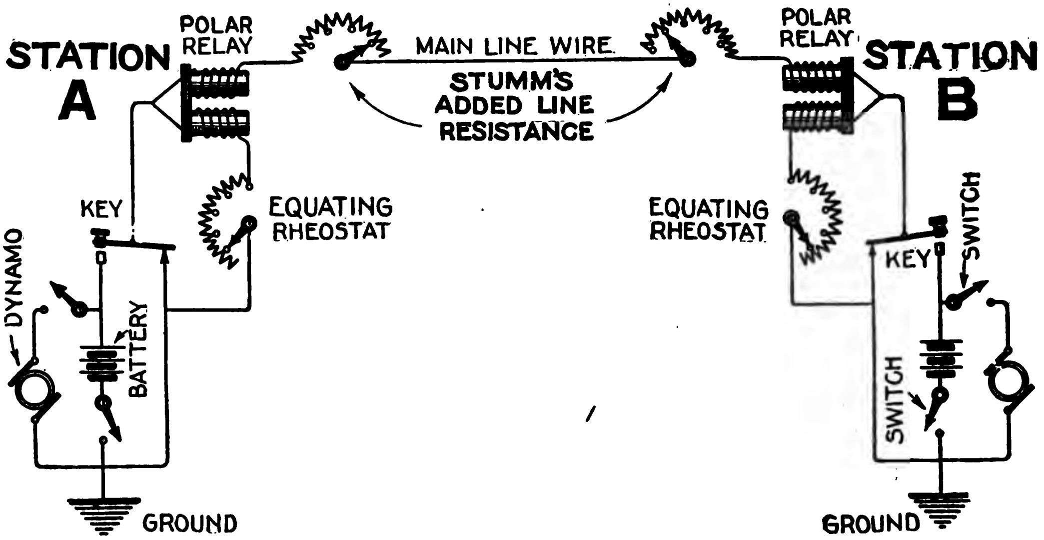


FIG. 8,377.—Stumm's added adjustable line resistance. It is a feature in duplex and all other multiplex office equipment. Formerly all balancing against wet weather line leakage was done on the artificial line rheostat and was always very unsatisfactory and often entirely ineffectual so that quite frequently such circuits had to be abandoned until the weather resumed normality —that is, became dry. The Stumm method leaves the artificial rheostat stand unchanged at normal ohmage, *i.e.*, equal to the actual line resistance in dry weather and when the wet storm begins to cause leakage, line resistance is looped in between the relay and line sufficient to balance the artificial ohmage, and by being added to sufficiently as required maintains a steady working balance reversing the procedure as the storm recedes. This method not only secures a good and continuous working balance but also prevents heating of instrument and other office wires and cables because the resistances in the main and artificial lines remain the same in stormy wet weather as during fair and dry. In other words the actual and artificial lines have flowing in them the proper battery strength for the resistances traversed. The value of the Stumm line resistance is very great as it prevents damaging delay to tens if not hundreds of thousands of telegrams during every general rain storm which inevitably occurred under the old method of wet weather balancing. The coils [illegible] may be differential, if preferred.

current is transmitted, but since the earth is employed to complete the circuit, they will respond to the received current, thus enabling each operator to send and receive signals at the same time.

Quadruplex System.—This method of telegraphy ***permits*** *the simultaneous sending of two messages in either direction over a single wire.*

Theoretically it consists of an arrangement of two duplex systems, which differ from each other so greatly in their principles of operation that they are capable of being used in combination.

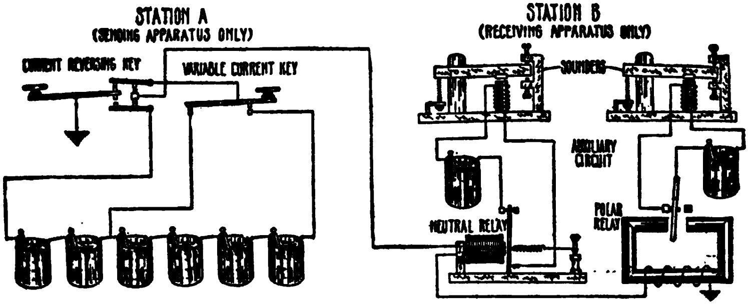


Fig. 8,378.—Elements of the quadruplex system. For simplicity, the receiving apparatus is omitted at station A and the sending apparatus at station B, the complete installation being shown in fig. 3,089. Because of the fact that a polar relay responds solely to changes in direction of the current, and a neutral relay to changes in strength of the current, it must be evident that, if the two relays be connected in series as shown, signals may be produced by the polar relay by operating the current reversing key, and with a sufficiently weak current the neutral relay will not respond; also, if the *direction* of the current be maintained constant by using the variable current key signals will be produced on the neutral relay but not on the polar. Hence, with this arrangement, two messages may be sent from station A to station B simultaneously, and by extension, if the reader imagine each station fitted with both sending and receiving apparatus, four messages may be sent at one time, thus giving quadruplex operation.

The sending apparatus consists of a reversing key and a variable current key (or equivalent), and the receiving apparatus consists of a neutral relay and a polar relay, batteries and connections.

Telegraph Codes.—There are three *codes* or systems of signals used for general telegraphic purposes.

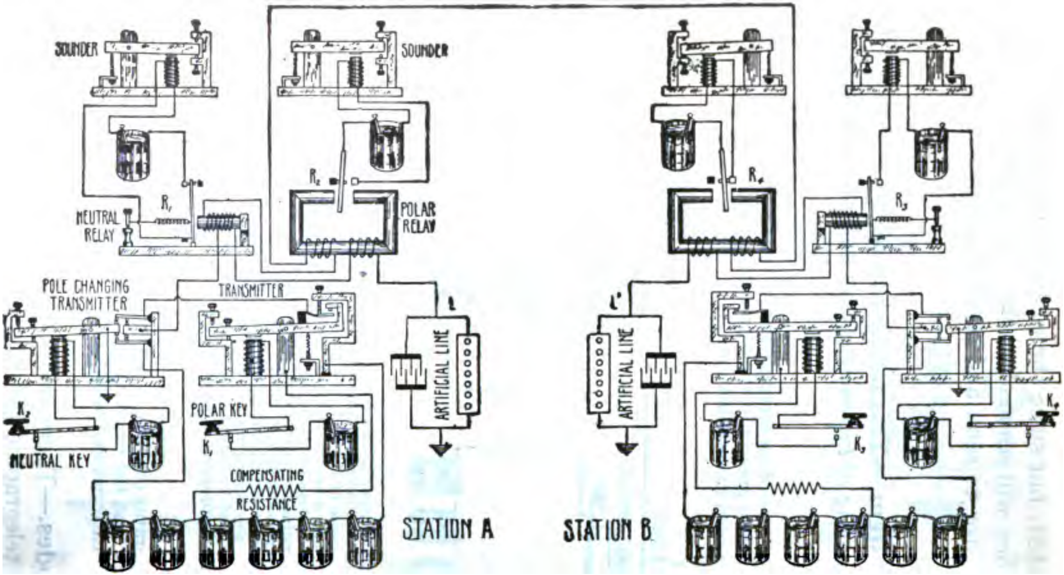


FIG. 8,379.—**Quadruplex system with battery current supply.** The apparatus employed in operating the polar system of the duplex is generally called the "No. 1 side of the system," or the polar side. It consists of the polar key and the polar relay at either station. The apparatus employed in operating the other system of the diplex is called the "No. 2 side of the system," or the neutral side. It consists of the neutral key and of the neutral relay. In operation, when none of the keys are depressed, no current flows through the line, but a comparatively feeble current flows through the artificial lines L and L', insufficient to operate the neutral relays, and to maintain the polarized relay tongues on the dead stops. Consequently, none of the sounders respond. If now K_1, be depressed, a strong positive current is sent to line at station A. This does not affect the relays at A, since it passes through them in opposite directions but on arriving at B, it tends to keep the polarized relay tongue R_4, on the dead stop, while it has sufficient power to operate the neutral relay R_3. In the same way if K_2 alone be depressed, relay R_1 alone will respond. If K_3 alone be depressed, a feeble negative current will flow to line, in a direction which will actuate R_4, but it will not have sufficient power to actuate R_3. If K_4 alone be depressed R_2 alone will similarly respond alone. The depression of any key will cause its corresponding relay to close its local circuit at the distant end of the line, regardless of the condition of the keys at that end. In practice the reversed position of neutral relay stop requires a repeater with contact on the upstroke between each neutral relay and sounder, or the equivalent secured by transposition of battery, for synchronous operation; these modifications are here omitted for simplicity.

The Codes

LETTERS

Morse	Continental	†Navy	*Bain
A ·—	A ·—	A ——	A ·—
B —···	B —···	B —··—	B ·—·
C ·· ·	C —·—·	C ·—·	C ···
D —··	D —··	D ———	D ··—
E ·	E ·	E ·—	E ·
F ·—·	F ··—·	F ———·	F ·———
G ——·	G ——·	G ——··	G ·—··
H ····	H ····	H ·——	H ·——
I ··	I ··	I ·	I ··
J —·—·	J ·———	J ·——	J ···—
K —·—	K —·—	K —·—·	K ·——·
L ⸺	L ·—··	L ——·	L ····
M ——	M ——	M ·——·	M ·— ·—
N —·	N —·	N ··	N ··——
O · ·	O ———	O —·	O —
P ·····	P ·——·	P ·—·—	P —·—
Q ··—·	Q ——·—	Q ·—··	Q —·—·
R · ··	R ·—·	R —··	R ——·
S ···	S ···	S —·—	S —··
T —	T —	T —	T —···
U ··—	U ··—	U ··—	U —·
V ···—	V ···—	V ·———	V ———·
W ·——	W ·——	W ··—·	W ——··
X ·—··	X —··—	X —··—	X —··—
Y ·· ··	Y —·——	Y ···	Y ——
Z ··· ·	Z ——··	Z ————	Z ———
& · ···	&	&	& ————

NUMBERS

Morse	Continental	†Navy	*Bain
1 ·——·	1 ·————	1 ····	1 ·————
2 ··—··	2 ··———	2 ——·—	2 ··———
3 ···—·	3 ···——	3 ···—	3 ···——
4 ····—	4 ····—	4 ———·	4 ····—
5 ———	5 ·····	5 ··——	5 ·····
6 ······	6 —····	6 ——··	6 ————·
7 ——··	7 ——···	7 ·———	7 ———··
8 —····	8 ———··	8 —···	8 ——···
9 —··—	9 ————·	9 ·——·	9 —····
0 ⸺	0 —————	0 —··—	0 ——·——

PUNCTUATION MARKS

Morse		Continental	Phillips
Period	··——··	·· ·· ··	··——··
Colon	—·— · ·	———···	—·— · ·
Colon Dash	—·— ·—··	—·— —·	—·— ·—··
Semi-colon	··· ··	—·—·—·	··· ··
Comma	·—·—	·—·—·—	·—·—
Interrogation	—··—·	··——··	—··—·
Exclamation	———·	——··——	———·
Fraction Line	·	——	··
Dash	—·· ·—··	—·· —··—	—·· ·—··
Hyphen	···· ·—··	—····—	···· ·—··
Apostrophe	··—· ·—··	·————·	··—· ·—··
Dollar Mark	··· ·—··	··· —··—	··· ·—··
Pound Sterling	····· ·—··	—·—··	····· ·—··
Shilling Mark	··— —	—·· —·	··——
Pence Mark	·····	—··	—··
Capital Letter	·· · ·—··	—·—· —··—	·· · ·—··
Colon Followed by Quotation	—·— ··—·	—·— —··—	—·— ··—·
Cents	· · ·	—·—·	·· ·
Decimal Point	—·· · · —	·——·	—·——
Paragraph	————	·—·—··	————
Italics or Underline	··— ·—··	··——·—	··— ·—··
Parenthesis	····· —·	—·— —·—	·····—· ·····—·
Brackets	—··· ·—··	—··· —··—	—··· ·—·· —··· ·—··
Quotation	··—· —·	·—·—·—·—	··—· —· ··—· —·
Quotation in Quotation	··—· ·—··	·—··—·	··—· ·—·· ··—· ·—··
Per Cent	——·——	———···———	——··——

Learning a Code.—The student should first thoroughly commit to memory the groups of signs representing the letters of the alphabet, the numerals and the principal punctuation points, viz., the period, comma, and point of interrogation; the remaining characters can be learned afterwards, as they will be little needed by the beginner. By constant drill the habit of making dots with regularity, uniformity, and precision must first be acquired; then dashes, and lastly in order, group of dots and dashes, letters and words. If possible for the student to obtain a register, he should by all means employ it in his practice, for he will then be more easily enabled to observe and correct the faults in his own manipulation. The student should learn to form the conventional characters accurately and perfectly; speed will come in good time, but only as the result of constant and persistent practice.

†NOTE.—The Navy code is now obsolete, being discontinued Nov. 16, 1912; the Navy at present uses the Morse.

*NOTE.—The Bain code was at one time in use in parts of America and Europe in connection with the Bain chemical telegraph system, but is now obsolete, though of historical interest.

The Morse code is exclusively used in the United States and Canada; ***the Continental code*** in all European and other countries, and in all submarine telegraphy by international agreement; ***the Phillips code*** is used for "press" work in the United States.

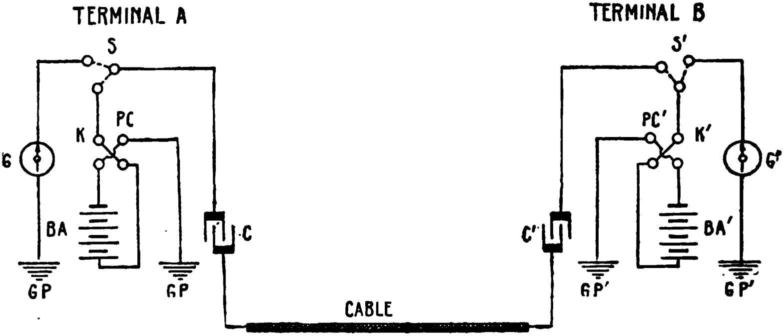


FIG. 8,380.—Diagram of a simple submarine telegraph cable circuit. The equipments of both terminals A and B, are exactly the same, consisting of the transmitting keys K,K', the pole changing switches PC, PC', line switches S,S', galvanometers G,G', condensers C,C', batteries BA, BA', and the necessary ground plates GP, GP'. By means of the switches S and S', the current may be allowed to pass either to the earth through the galvanometers or other recorders, or to the transmitting keys K and K', thence through the batteries BA, and BA', to the earth, depending on whether the signals are being sent or received at the respective terminals. By means of the pole changing switches PC and PC', operated by the keys K and K', either pole of the battery can be connected to the condensers C and C', and thereby to the line at the will of the respective operators, and the cables charged inductively, the corresponding signals being reproduced at the distant terminals by connecting the galvanometer with the line by means of the switches S or S', as the case may be.

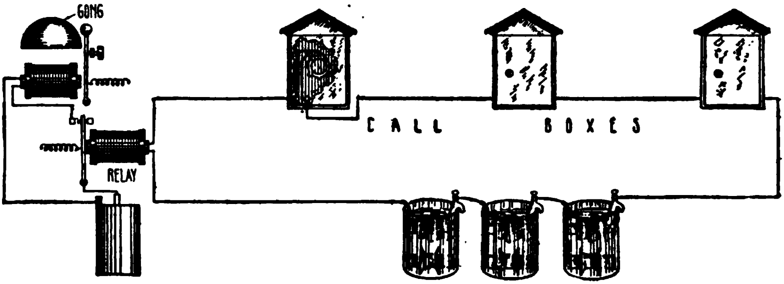


FIG. 8,381.—Diagram of elementary fire alarm circuit. Fire alarm apparatus forms that element of the system depended upon to announce to the fire fighting force the existence of and location of a fire. The equipment consists of gongs and indicators located in the fire department houses, and where volunteers form part of the fire department, public alarms are given by means of devices for automatically striking large bells or blowing whistles.

CHAPTER 137

Telephones

In the electric telephone, *the vibrations of the diaphragm of the transmitter are transmitted to that of the receiver by means of electric currents sent out in the form of electric waves along the conducting wires connecting the two instruments.*

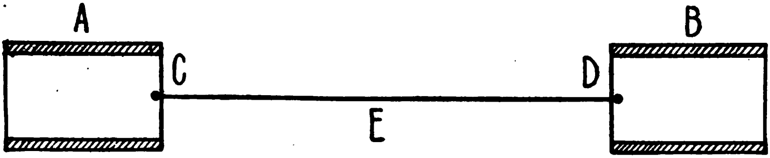


FIG. 8,382.—Simple toy telephone, whose working principle is similar to that of the electric telephone. ***In operation,*** when the open end of the tube A, is placed before the mouth, the vibrations of the membrane C, caused by the varying sound waves constituting articulate human speech, are transmitted with mechanical action by the string E, to the membrane D, and set up in the latter vibrations corresponding to those of C. The vibrations of C, cause sound waves in the air which are propagated according to the principles of acoustics, to the ear, placed at the open end of the cylinder B.

The current used for this purpose is of vibrating or alternating character and its strength at any instant has direct relation to the sound vibrations transmitted by the voice.

A telephone set usually comprises: 1, a *source of electric current supply*; 2, a *transmitter*; 3, a *receiver*; 4, an *induction coil* consisting of primary and secondary windings; 5, a *receiver hook* or automatic switch; 6, a *bell* or ringer consisting of two magnets and an armature and two bell gongs, and 7, a *condenser* with common battery sets.

Current Source.—This varies according to the system used at the exchanges.

The "common battery system" does away with the use of primary cells.

The *d.c.* required for the talking and for the switch board indicating signals is obtained from storage batteries charged from power driven dynamos and the *a.c.* for operating the subscriber's polarized bell or ringer is obtained from alternators.

Transmitter.—Fig. 8,383, shows a form of transmitter largely used.

The speaker talks into the mouth piece M, and the sound waves caused by his voice impinge on the metal diaphragm D, producing corresponding vibrations therein. Attached to the center of the diaphragm is a button and cup of hard carbon B, opposite to which and fastened to the frame is a second brass button E, and carbon cup A.

The space between the two cups is filled with coarse granules of carbon C. The buttons A and B, constitute the electrodes of the transmitter. The electric current from the battery passes from one to the other of the electrodes, through the carbon granules which form a conducting path consisting of an indefinite number of loose contacts. The resistance of the circuit, and consequently the strength of the current, can be regulated by varying the rate of vibration of the carbon granules. The button B, communicates the vibrations of the diaphragm D, to the carbon granules; therefore the voice of the speaker, characterized by the inflections and articulations of human speech, is reproduced in the varying strength of the electric current.

Receiver. — There are numerous forms of receiver, the Bell receiver being the form now generally used, as in fig. 8,384.

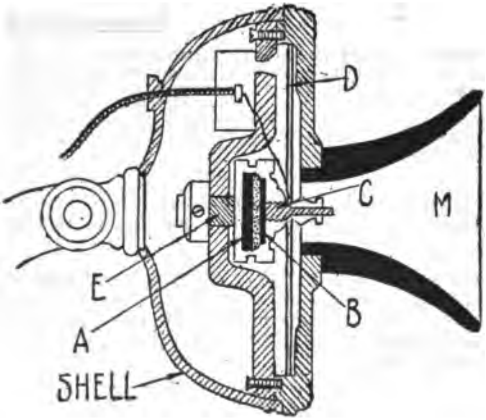
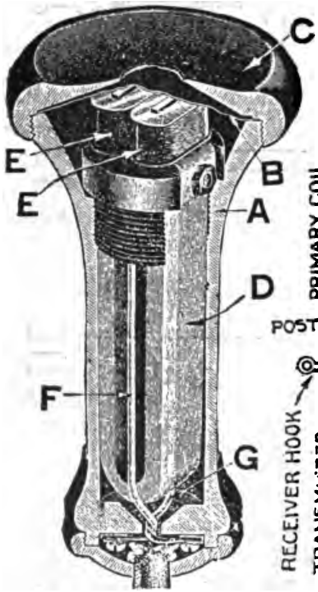


FIG. 8,383.—White solid back transmitter. ***In construction,*** the carbon chamber is formed by two mica diaphragms supporting the electrodes and brass ring collar. Each electrode is fastened to a brass disc. The use of two mica diaphragms provides for any vibration of the front electrode, which is transmitted through the granular carbon to the rear electrode. The whole chamber is caused to vibrate, which keeps the carbon granules alive and precludes their becoming packed.

In operation the varying strength of the electric current produced by the vibrations of the diaphragm of the transmitter causes corresponding variations in the magnetic state of the electromagnet D, making it act upon the diaphragm B, with different degrees of intensity, so that the listener's ear placed close to the receiver cap readily recognizes the characteristics of the speaker's voice.

Call Bells.—These devices, for attracting the attention of the party desired, usually consist of a *polarized bell operated by current from a magneto located in a box.*



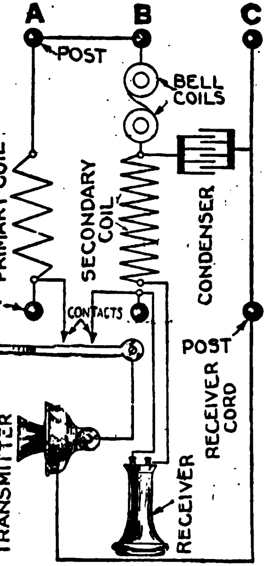


FIG. 8,384.—Bell Standard bi-polar receiver. *It consists of* a hard rubber case A, hollowed out at its upper extremity, and containing the thin, soft iron diaphragm B. Cap C, which screws on case A, is capable of vibrating freely. D, is a permanent magnet of the horse shoe type and E, E, an electromagnet located directly under the diaphragm B, which is in close proximity, but not in contact with, the poles of the magnet. These coils have soft iron cores screwed fast to the ends of the steel magnet so that when heavy alternating currents traverse through their windings the permanent magnetism of the horse shoe magnet is not disturbed. These coils are connected in series and terminate at the wires F and G.

FIG. 8,385.—Inside connections of telephone bell box. *In operation,* when the receiver is off the hook the contacts there are closed by the upward spring of the hook and the circuits are closed for operation. The line is always connected to the two outer posts A and C, the middle post B, often stamped G, is used for ground connection on party line instruments.

Inter-Communicating Switching Device.—For small systems such as those of hotels, the inter-communicating switching device is often combined with the telephone set.

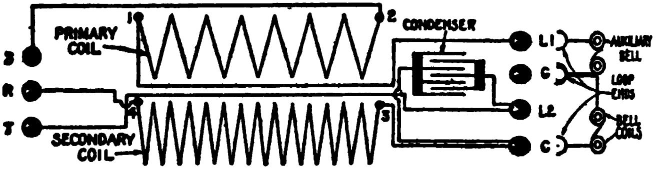


Fig. 8,386.—Improved wiring of bell box by N. Y. Telephone Co. If an auxiliary bell is wired in, the two sets of coil are connected in series and the post G, is used to connect the loops; otherwise the G, post is not used unless for ground connection in party wires. Post marked L1, corresponds to post A in fig. 8,385, post C, corresponds to post B, and post L2 corresponds to post C, in fig. 8,385, C referring to the condenser in each case. Post S, is connected to switch contact, post R, to receiver cord and post T, to transmitter.

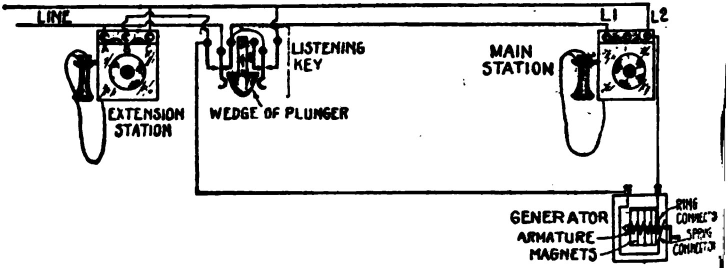


Fig. 8,387.—Two common battery instruments wired so that only one bell at a time can be rung by Central (plan 3 N. Y. Tel. Co.). *In operation,* with the listening key normal (as shown) central can ring only the main station bell but the extension can talk, and by throwing the listening key, the main is completely cut out and allows only the extension to ring and talk. The ringing key must be thrown to ring the extension station from the main which makes the system intercommunicating.

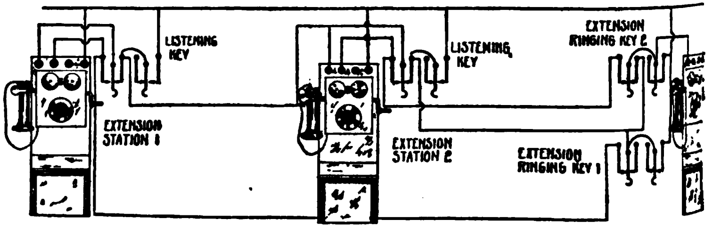
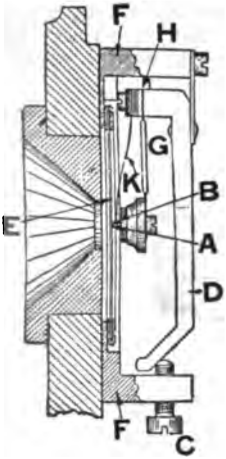


Fig. 8,388.—Three magnetos wired so that only one bell at a time can be rung by central according to which listening key is thrown, permitting talk for any telephone with keys normal.



When there are a large number of subscribers, an exchange or central station is necessary, where the wires connecting the various subscribers or other small stations can be joined at will by the central operators.

Switch Boards.—These are made in sections, called *positions*, for central offices.

Fig. 8,389.—The Blake microphone transmitter. In this instrument a single contact is maintained between the platinum point A, and the polished carbon button B, by means of the adjusting screw C, acting against the strip of iron D, called the anvil. The vibrations of the diaphragm thus affecting the current which passes from the battery through the iron frame ring F, the anvil D, the connection G, the carbon button B, the platinum point A, and out again from the contact H, of the spring K. At one time the Blake transmitter formed a part of the standard equipment of almost every telephone in the United States and was also largely used abroad. No transmitter has ever exceeded it for clearness of articulation but it is decidedly deficient in power in comparison with the modern transmitters. The latter are composed of granulated carbon.

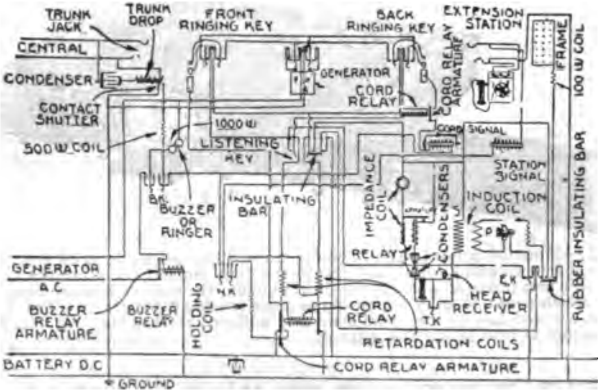


Fig. 8,390.—Positive supervision type of P.B.X. switch board adopted by N. Y. Telephone Co. ***With this type,*** each pair of cord is supervised by the positive supervision relay which controls the bull's eye cord signal. There are as many station jacks and station signals as there are extension stations and as many central jacks and drops as there are central (trunk) lines coming into switch board. There is only one buzzer key B.K., one night key N.K., one generator key G.K., one emergency key E.K., and one telephone receiver key T.K., mounted on each switch board.

The requirements of such exchanges are satisfactorily met by the use of various forms of multiple switch board in which each subscriber's line, instead of terminating in only one jack, connects with several, equal to the number of "positions."

This arrangement enables each operator to make any desired connection of the many thousands registered in the exchange, either by inserting the plug in the jack on her own panel or by reaching with the cord of her calling plug to the panel or position on either side of her.

FIG. 8,391.—Modern ringing keys. In order to meet the needs of every calling subscriber, the operator must perform several different acts in shifting and changing circuits and to facilitate this work, devices to simplify it as much as possible have been developed. The modern ringing keys have greatly helped in the saving of the operators' time. By throwing the little levers a hard rubber bushing makes or breaks the contacts at the springs and throws alternating current ringing power into the line. When the finger pressure is released, the levers fly back again into normal position.

FIG. 8,392.—Mounted trunk drops. Tubular trunk drops are mounted on a metal strip each being held by two small screws underneath the drop shutter. The tubular casing of each drop is soft iron inside of which is the drop winding, the ends of the coil wires terminating at lugs which protrude from the casing and are insulated therefrom. The drop shutters are then screwed fast to the metal strip and adjusted so that they may fall easily when the armature is held up by the magnet.

The Common Battery Telephone System.—This is sometimes called a central energy arrangement. A dynamo at the central office charges storage batteries over night with electricity which supplies current to all subscribers, thus affecting a cost saving.

A feature of this system is that the removal of the subscriber's receiver informs central of the subscriber's presence at the telephone.

The operator's equipment consists of a regular head or hand receiver

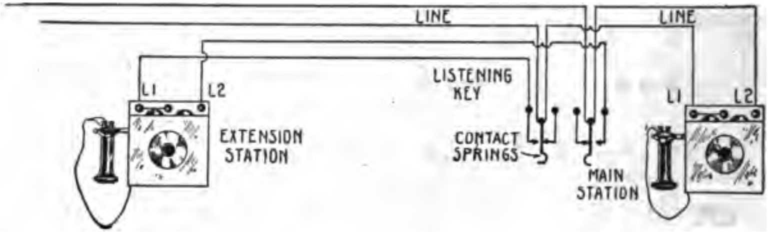


FIG. 8,393.—Wiring diagram showing two telephones with a listening key at the main instrument to cut off the extension-station. This key can be placed at either instrument and the extension wired to either inner or outer contacts. As shown, the key is at the main station and the extension is on the outer contacts. This is called plan 10.

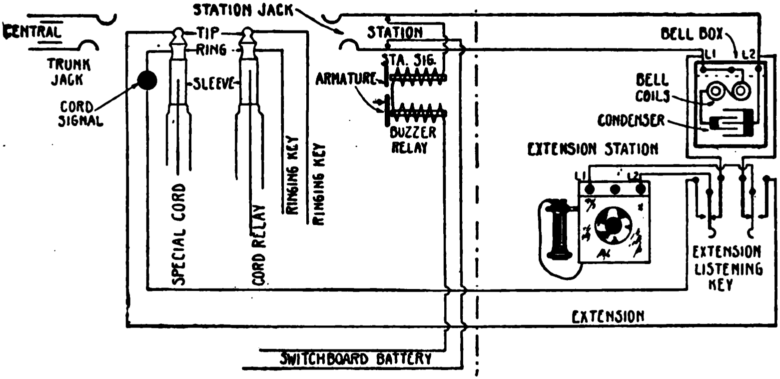
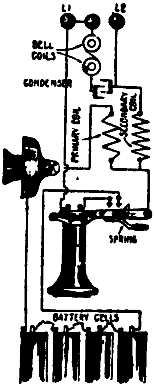
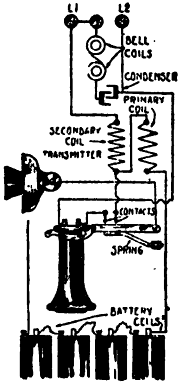


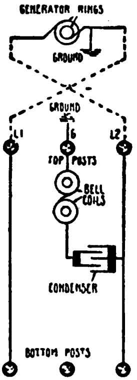
FIG. 8,394.—Private line extension station current from P.B.X. switch board, whereby absolute secrecy with outside exchanges is obtained. When extension listening key is normal, extension signals operator in same way as do all other extensions. After asking for private connection special cord, without listening key being plugged in central (trunk) jack by operator, subscriber throws extension listening key and conversation ensues. If P.B.X. operator's attention be again desired, listening key is thrown normal. Operator calls extension in usual way on any cord except special and rings extension special bell no matter how listening key be thrown. Since there is no listening key on special cord, operator must use any other cord for connection between P.B.X. and extension station.

and a switchboard transmitter supported on an adjustable transmitter arm with cords, or a breast plate transmitter and receiver with head band, cord, and cut in plug, also the necessary condensers, induction coils, and retardation coils, all of which are connected to the listening key circuits.

Central Office Exchange Equipment.—This consists of the necessary apparatus for transmission and signalling between private branch exchange (P.B.X.) switchboards and the exchange.







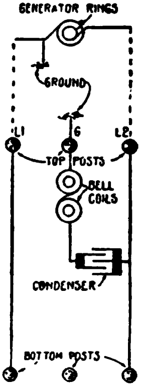


Fig. 8,395.—Booster set with battery connected in the circuit to strengthen transmitting and receiving power of common battery instrument.

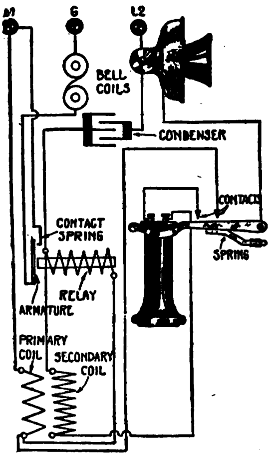
Fig. 8,396.—Independent telephone station wired for local battery talking and common battery ringing.

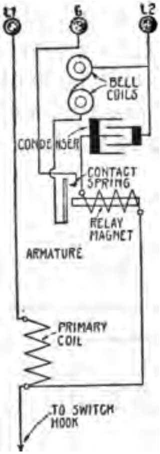
Fig. 8,397.—Wiring diagram of two party line R, bell station with G, post represented as connected to ground and negative side of alternating current generator also grounded. When bell is rung, ringing key throws positive current in instrument at L2, across condenser and through bell and out at G, to negative side of generator through ground.

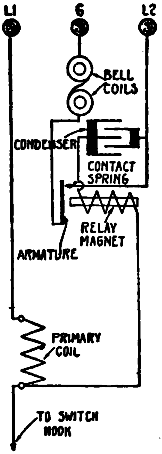
Fig. 8,398.—Wiring diagram of two party line J, bell station with G, post represented as connected to ground and negative side of alternating current generator also grounded. When bell is rung, ringing key throws positive current in instrument at L2, across condenser and through bell and out at G, to negative side of generator through ground.

The operators sit at the various "positions" of the switchboards, there being two types called the A and B boards. When a subscriber lifts the receiver, an electric light burns in a jack and the B, operator answers with the answering or back cord and throws her listening key and says number please.

When the subscriber gives the number she gives the B, operator the number by going into the B, operator's ear over a call circuit button on the A, board, the B, operator then sets the ringing key and gives the A, operator the assignment of a trunk and the A, operator plugs the calling or front cord in the outgoing trunk multiple in the jack which has been given her. The A, operator completes the connection when the subscriber who is connected through the B, board answers, the light or drop on the cord circuit goes out, and stays out until the parties hang up and then the light opens on the A, cord circuit and the A operator takes down the cords







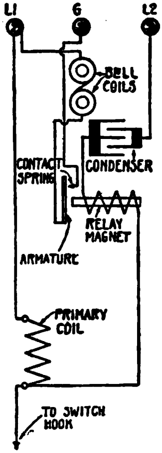


FIG. 8,399.—Four party line R, station showing the primary and secondary of the induction coil and the receiver and transmitter all of which are connected as shown in all party wire instruments. ***In operation,*** when the relay armature is held up against its contact spring, the bell circuit is complete to L1, post and rings through ground.

FIG. 8,400.—Wiring diagram of four party line J, bell station showing the primary of the induction coil, the selective ringing relay, and the condenser connected in series across the line. One end of the bell coil connects with post G, to ground and the other connects with the relay armature. When this armature is held up against its contact spring the bell circuit is complete to L2, post and rings through ground.

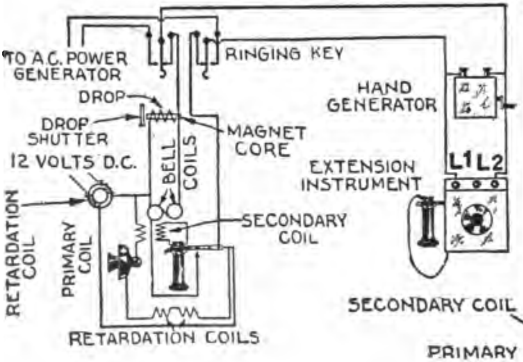
FIG. 8,401.—Wiring diagram of four party line M, bell station showing the primary of the induction coil, the selective ringing relay and the condenser connected in series across the line. One end of the bell coil connects with L2, post and the other end connects with the relay armature. When this armature is held up against its contact spring, the bell circuit is complete to G, post, and rings through ground.

FIG. 8,402.—Wiring diagram of four party line W, bell station showing the primary of the induction coil, the selective ringing relay, and the condenser connected in series across the line. One end of the bell coil connects with L1, post and the other end with the relay armature. When this armature is held up against its contact spring, the bell circuit is complete to ground, and rings through ground.

and as soon as the calling cord or front cord is taken out of the outgoing trunk jack the B, operator gets the disconnect signal and she disconnects the cord from the number in the subscriber's multiple. In all cases A, boards are connected to B, boards by call circuit buttons and the B, operator does not talk to the subscriber.

P.B.X. systems extension stations are arranged to terminate on jacks of the size suitable for the reception of the cord connecting plugs.

Party Lines.—These are so arranged, that the telephones of a number of subscribers may be connected on one circuit so that all have a common drop and jack at the exchange switch board. Systems of this type are frequently adopted where the business is small in proportion to the length of the line.



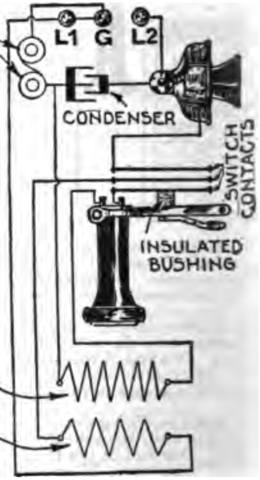


Fig. 8,403.—Stock Exchange extension station as installed in New York City. ***In operation,*** when main wants extension, the ringing key is used with ringing power. The extension bell is not connected but one can talk from the instrument.

Fig. 8,404.—Police signal box, showing the bell and condenser connected as usual across the line between L2 and G posts. ***In construction,*** the switch hook is insulated from the instrument by hard rubber bushings.

90 TELEPHONE TROUBLES

Subscribers' Troubles

1\. Open bell. 2. Open condenser. 3. Open bell strap wire.
4\. Bell out of adjustment. 5. Open auxiliary bell.
Effect: Can call central but central cannot ring subscriber although both can talk.

6\. Open receiver. 7. Open receiver cord. 8. Open secondary coil.
9\. Open switch hook contact. 10. Receiver diaphragm missing.
Effect: Can hear central ring but cannot hear talking with receiver.

11\. Open primary coil. 12. Open switch hook contact.
13\. Open transmitter. 14. Open transmitter cord.
Effect: Can hear central ring and talk but cannot talk back.

15\. Dented receiver diaphragm.
16\. Swinging open (cut out) receiver cord.
17\. Short circuited induction coil.
18\. Reversed secondary connections.
Effect: Can hear bell ring but can hear talking only faintly.

19\. Packed carbon granules in transmitter.
20\. Cut out transmitter cord.
21\. Primary coil reversed.
Effect: Can hear central ring and talk but cannot be heard clearly.

22\. Swinging ground on ring side of line.
23\. Line crossed with other lines.
24\. Party wire biasing spring out of adjustment.
Effect: Bell rings occasionally without cause.

25\. Loose connection at one or both sides of line.
26\. Cut out desk stand cord.
Effect: Noisy line.

27\. Open line wire. 28. Open inside wire.
29\. Badly corroded inside or outside wire.

Effect: Subscriber cannot call or be called. ***Test:*** Strap out opens with test receiver. Disconnect short circuited lines and then test by strapping in test receiver. Shake cut out cords to locate trouble.

Private Branch Exchange (P.B.X.) Troubles

30. Generator feeder not correctly poled.

Effect: Pressing ringing key while plugging cord into any station jack, all extension bells will ring or tap. Clear by reversing connections.

31. Generator feeder open.
32. Buzzer ringer coils open.
33. Buzzer relay contact does not make.

Effect: Central cannot ring P.B.X. operator on any drop. ***Test*** by following out circuit with test receiver.

34. Battery feed open.

Effect: Buzzer relay vibrates while plugging trunk jack until E, key is thrown. ***Test*** by following up battery with test receiver.

35. Short circuited or grounded ring of battery feed.

Effect: Battery of insufficient strength to talk and extensions cannot get switch board. ***Test*** by first removing wires from binding posts at cross connecting box and tapping with test receiver or 24 volt lamp strapped across wires of incoming feed. If lamp light bright or receiver click loud battery is coming in O. K. Reconnect the tip side of feed, connect one side of a test receiver to ring binding post and tap the other side several times on end of loose wire. If receiver click, trouble must be toward switch board. Then at back of switch board open ring side of battery and tap as before at cable end of wires. If click be heard, trouble is in switch board cable; if no click be heard, trouble is in switch board.

36. Short circuited cord plug.

Effect: Cord plugs are hot or plugs emit smoke when dampness has crept in bushings separating the three parts of plug. ***Test*** by throwing up all listening keys and placing operator's receiver to the ear, start from left and depress each ringing key separately. Clicking noise in receiver indicates short circuit. Turn down each cord where clicking noise is heard and disconnect each cord so turned down at cord lug connections.

37. Cord circuit at relay contacts short circuited.
38. Cord circuit shortened by touching of keyboard wires.
39. Ringing key contacts crossed.

Effect: Clicking still heard in operator's receiver when turned down cords are disconnected and ringing keys are again depressed. If ringing key contacts be thought to short circuit because the inner contact spring makes contact with the outer before breaking from the inner, the G, key can be thrown, which will temporarily clear the trouble. Then the contacts must be adjusted.

40. Positive supervision relay sticks.

41. Bull's eye cord signal sticks.

Effect* (*of 41*):** Operator cannot tell when parties have finished talking. ***Test by jarring relay and clear by making good adjustment.

42. Open trunk jack springs.

43. Open trunk line condenser. 44. Open trunk drop winding.

Effect: Central cannot ring local P.B.X. trunk drop.

45. Buzzer relay open. 46. Buzzer contact spring does not ake.

47. 500 ohm resistance coil open.

48. Ring or ground side of battery open.

49. Ground wire open where springs make contact in falling.

***Effect* (*of 49*):** Drop shutters fall when central rings but buzzer does not ring or buzz.

50. Broken wire at trunk jack common to all jacks.

51. Open 100 ohm resistance coil.

Effect: Banging noise is heard when local operator plugs into central jack.

52. Cut out hand receiver cord. 53. Cut out head receiver rd.

54. Cut out transmitter cord.

***Effect* (*of 54*):** Breaking of circuit is noticeable by occasional breaks in the conversation. The conversation may be carried on O.K. if all cords be kept perfectly motionless, but as soon as moved or shaken there are noticeable cut outs in the conversation.

Test: Throw any listening key and place tip of either plug of that pair of cord on first one binding post and then on another of the receivers, at the same time shaking the cords. The trouble is generally located at the cord tips or connections.

55. Transmitter open.

56. Primary coil of operator's set open.

57. Transmitter cord open. 58. Listening key contacts open.

Effect *(of 58):* Central cannot hear local operator on any cords, nor can P.B.X. operator hear central.

59. Receiver open. 60. Secondary coil open.
61. Receiver cord open.

Effect: P.B.X. operator cannot hear central operator but central can hear P.B.X.

62. Short circuited trunk line condenser. 63. Short circuited jack springs. 64. Drop winding crossed with frame.

Effect *(of 64):* Central gets steady light from P.B.X.

65. Open station signal. 66. Open station jack contacts.
67. Open wire between jack and signal.

Effect: One extension station cannot get local operator.

68. Open common wire to jacks.
69. Open common wire to signals.

Effect: All extension stations fail to get local operator.

70. Open plug or cord. 71. Open contact at ringing key.
72. Open positive supervision relay. Open cord relay contacts.

Effect: Cord in question cannot be used.

73. Open condenser at operator's set.

Effect: Operator cannot hear but can be heard O.K.

74. Open between battery feed and listening key. 75. Open between listening key and E, key. 76. Open between battery feed and E, key. 77. Short circuited induction coil.

Effect *(of 71):* Throwing of listening keys does not give usual side tone (live sound heard by tapping on transmitter) until E, key is thrown.

78. Open holding coil. 79. Open N, key contacts.
80. Open upper relay contact.

Effect: When an extension station is connected through to central and receiver is hung up (such as a night connection) the central disconnecting signal shows. The holding coil should prevent this with its high resistance shunted across the line when N, key is thrown.

Plan Troubles

81. Hand generator turns hard.

82. On plan 3 or 5, listening key contacts are crossed.

Effect: System is short circuited.

83. Plan 3 or plan 5 generator handle sticks.

84. Short circuited condenser.

85. Wet desk stand cord.

86. Ringing key contacts on plan 5 are crossed because plunger sticks.

Effect: Both extension station bells will ring when one listening key is thrown.

87. Desk stand cord short circuited on plan 3 or 5 extension.

Effect: That extension bell will ring or tingle at same time that main bell rings.

88. Desk stand cord connected wrong on either extension.

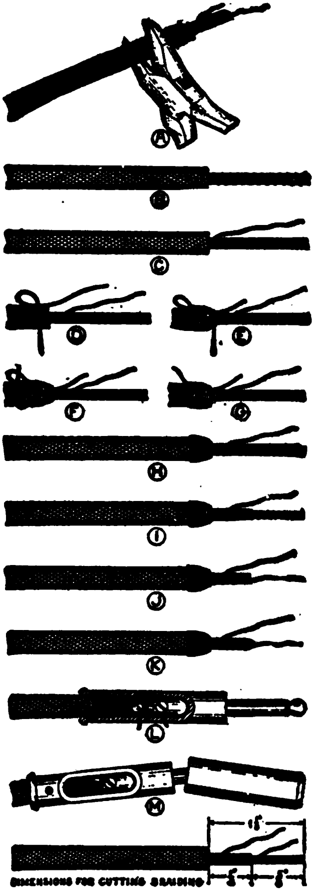
Effect: Plan will become confused and appear to be wired wrong, according to how the cord is wired.

89. Open strap wire at plan 3 or 5 listening key.

Effect: In any case the main instrument would be cut off by an open line and not by a short circuit for which the strap is used.

90. Listening key contacts open on plan 8 key.

Effect: Main station can ring extension but cannot talk. If key be not down normal for ringing and thrown for talking main, cannot get extension station.



FIGS. 8,405 to 8,418.—***Repairing Western Electric Steel Cords.*** A, remove the plug from the cord and cut off the worn end of cord; B, cut back outer braiding and sewing with a pair of snips about 1⅛" leaving sleeve conductor bare; C, pull out spiral sleeve conductor with a pair of pliers and cut to about 1" in length; D,E,F,G, and H, bind outer braiding 5/16" back with W.E. three ply gilling thread; I, cut back inner braiding ½" leaving tip conductor bare; J, pull out tip conductor and trim inner core to length; K, bind inner braiding with gilling thread about 5/16" back from end, the operation in accomplishing this being the same as outlined under D,E,F,G, and H; L, screw into plug; M, fasten sleeve and tip conductors under screws and replace shell.

CHAPTER 138

The Automatic Telephone

The term automatic telephone means *a telephone system fitted with automatic electric devices such that the user, by means of a* **numerical dial** *attached to the instrument can:* **1,** *establish a connection in a large public exchange*, in from three to five seconds; **2,** *be sure that he gets the number he dialed;* **3,** *receive a positive signal, if the line be busy*, and **4,** *break the connection when he desires*—all without the aid of an operator in the central station.

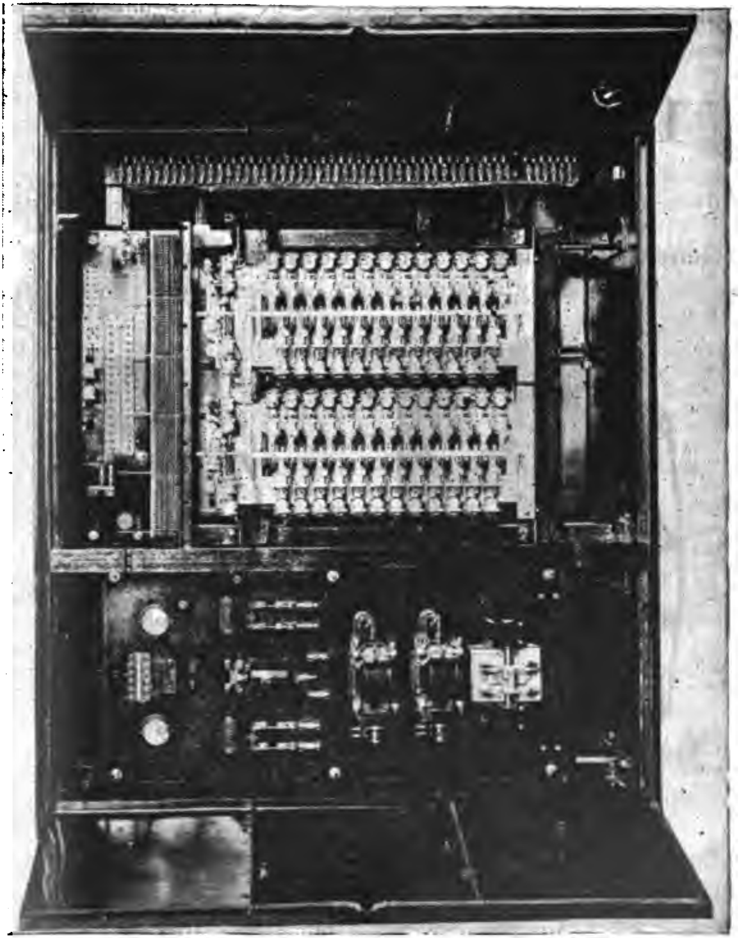
Clearly then the automatic telephone does away with the large force of central station operators, and as the connection is made electrically, instead of by a second person, mistakes are largely avoided, and connections more quickly made. Accordingly, from the standpoint of the user, the appeal of the automatic telephone is due to its speed, accuracy, directness, impersonality and secrecy.

The transmitter, receiver, ringer, and hook switch for an automatic telephone may be of any standard type. The only part of the instrument that is peculiar to the automatic system is the calling device or *dial*. At the central office, the machines which make the connections between subscribers' lines are divided into the following classes:

1. Line switches;
2. Selector switches;
3. Connector switches.

According to the size of the installations the automatic telephone system may be classed as:

1. Single office exchange;
2. Multi-office exchange;
3. Private automatic exchange (P.A.X.).



. 8,419—A 50 line private automatic exchange (P.A.X.) equipped for 25 telephones.

The second system is simply a collection of groups of subscribers, ea group having its central station and arranged for inter-communicati between the several groups.

The private automatic exchange (P. A. X.) is something entirely apar from public exchange operation, being, in fact, a system of automat electric services designed for private ownership by business or industri institutions.

1. SINGLE OFFICE EXCHANGE

General Working of the Automatic Telephone.—Th can be most clearly illustrated by considering the private auto-matic exchange system. The exchange consists of the auto-matic switch board, current supply, terminals, etc.

FIG. 8,420.—Automatic telephone wall type showing *dial* by which the subscriber makes without the aid of a central office operator.

FIG. 8,421.—Automatic telephone, desk type.

The telephone lines (two wires each) entering the room, pass through a main distributing frame and thence to line switches. The line switch is a device for enabling a large number of telephones to use a smaller number of automatic switches, based upon the well-known fact that only a small percentage of the telephones are in use at any one time. Thus fifty subscribers' lines require only seven switches, because no more than seven connections are needed at any one time.

From the line switches wires run to the connector switches, whose function it is to make the connections.

The current is supplied to the automatic switches by a 24-cell lead storage battery, with a controlled pressure of from 46 to 49 volts.

When a user takes the receiver from the hook, the line switch associated with his line extends the latter to an idle connector switch and prevents anyone else using the same switch.

While the first figure of the call number is being dialed, a magnet in the connector lifts the shaft and wiper springs with a step by step ratchet action to a certain row of contacts.

When the second digit is dialed, another magnet rotates the shaft and wiper springs until the latter rest on the pair of contacts to which the desired line is attached. The connector switch then tests the line to see if it be busy. If the line be busy, the connector prevents the completion of the connection and sends a distinctive tone to the calling station, so that the calling person knows the conditions.

The busy tone is created by the rapid interruption of direct current through the primary of an induction coil. Mounted on the converter shaft is a commutator with many segments. The 48-volt battery current is led through this in series with the primary of the induction coil and a pair of interrupter springs. The latter makes the tone come and go periodically, causing it to be recognized clearly as a "busy tone." The secondary of the induction coil is led to the connector switches.

If the line be not busy, the connector switch protects the called line from being seized by anyone else, clears it of attachments and rings the bell of the desired station. The calling person can hear that the ringing is actually taking place. When the desired station answers, the ringing is stopped, and conversation proceeds as in any common battery system.

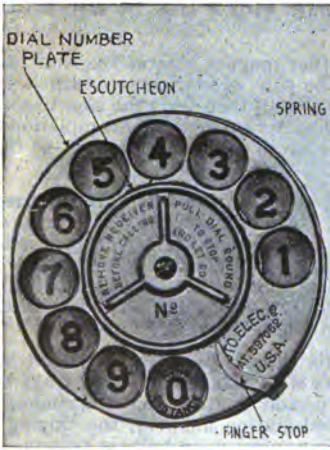
When the conversation is completed and the receivers are hung on their hooks, the connector switch and the line switch both restore to normal, and are at once ready for another call.

Essential Elements of the Automatic Telephone.—The various devices comprising the automatic system by which elephone connections are made without the aid of an operator t central office are:

1. Subscriber's dial;
2. Line switch;
3. Connector switch.

The relay group is considered a part of the connector.

Subscriber's Dial.—The function of this device is *to alter the electrical condition of the line in such a way as to cause the apparatus at the central office to complete the desired connection.*



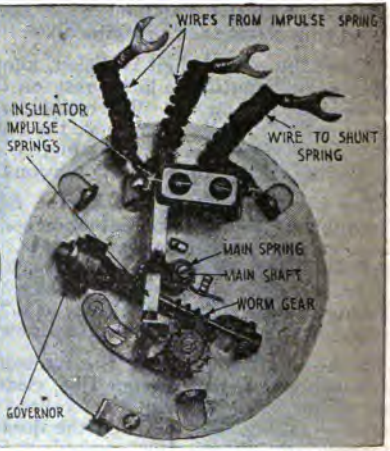


FIG. 8,422.—Subscriber's dial, front view showing holes in disc, numeral sand finger stops.

FIG. 8,423.—Subscriber's dial, rear view showing mechanism.

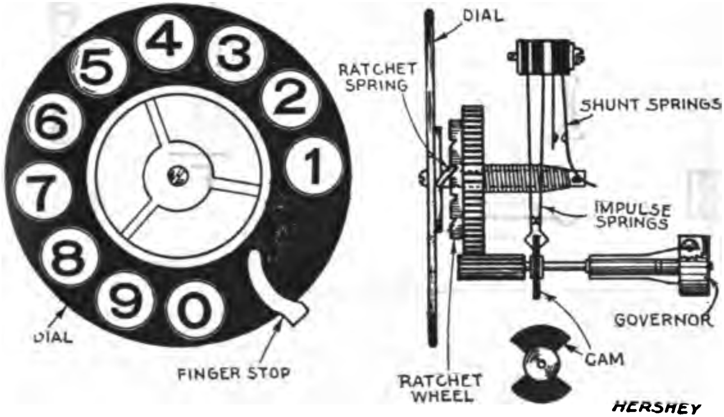
It consists of a dial pivoted at the center and arranged so that it may be turned in a clockwise direction.

As shown in fig. 8,422 it is perforated with ten finger holes, through which appear the numbers 1,2,3,4,5,6,7,8,9,0.

To call the number, say 53, the subscriber places the tip of his finger in the hole through which 5 appears and turns the dial to the right until his finger strikes the stop; he then removes his finger whereupon a spring causes the dial to return to its normal position. Similarly the second number, 3, is "dialed," thus completing the manual operations of calling the number 53.

The mechanism of the dial is such that each time the dial is moved, as just described, an electric circuit is opened a number of times corresponding to the number dialed. Thus when the number 5 is dialed the circuit is opened 5 times. This mechanism is shown in figs. 8,424 and 8,425, and in diagram in fig. 8,426.

Subscriber's Circuit.—Included in this is the receiver, transmitter, shunt and impulse springs of the dial mechanism, line and release relays, as shown in fig. 8,426.



Figs. 8,424 and 8,425.—Front and sectional side view of subscriber's dial, showing mechanism and end view of cam. ***In operation,*** as the dial is rotated by the finger clockwise, a coiled spring is wound, which, after removing the finger on reading the *stop* causes the dial to return to its initial position. This is a ratchet which transmits the return movement to gears and a governor. The gears are in mesh with a pinion on which is a cam which is so geared that when say No. 1 is "dialed," the cam will make one half revolution, opening the impulse spring once. Similarly the impulse spring will be opened a number of times corresponding to the number dialed.

When the subscriber dials a number, *the circuit will be opened a number of times corresponding to the number called* and this is the principle upon which the apparatus at the central station depends to make the connection.

When the dial is moved from the initial position, the shunt springs close contact, maintaining a shunt around the transmitter and receiver until such time as the dial returns to its initial position. This prevents variation of resistace in the subscriber's loop and irregular operation of the central office mechanism.

Connector Switch.—At the central station *the impulses* sent from the subscriber's station by the dial mechanism *act upon a connector switch which makes the connection*

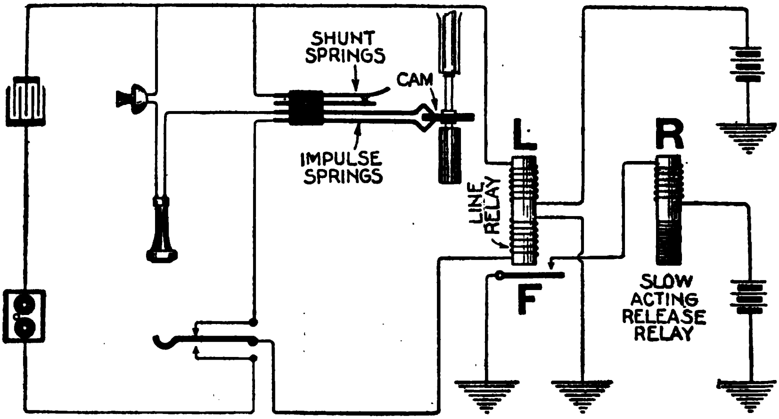


FIG. 8,426.—Subscriber's circuit. *In operation,* when the receiver is lifted from the hook, the circuit is through the upper winding of line relay L, transmitter, receiver, impulse spring, upper contact of switch hook, lower winding of L, to ground. When thus, line relay becomes energized and closes the release line relay, whose circuit is from battery through release relay, contact maker F, to ground. When a number, say 1, is dialed, and the dial released, the cam is given one half turn as it returns to initial position, and one of the cam wings momentarily opens the impulse spring as it passes between them. This momentarily opens the circuit of line relay L, which causes L, to disenergize for an instant, and in turn opens the circuit of relay R. The latter being slow acting remains closed even though its circuit was momentarily opened.

There are two principal differences between the work of an operator on a multiple switchboard and that of an automatic connector. The first lies in the difference in the number of lines to which they have access. The operator has within her reach a multiple jack for every line in the switchboard, be the number of lines 1,000 or 10,000. She may therefore make a connection to any line entering the office, but a connector switch has access to but 100 lines. Secondly, a subscriber's operator takes the orders of and makes the connections for certain predetermined subscribers only. The number she serves seldom exceeds 200 and is often less than 100, but a connector switch is, when idle, ready to handle the order of any subscriber who may wish to connect to any one of the 100 lines to which it has access.

Fig. 8,427 shows a connector switch with cover removed. The lower part of the machine supports two curved banks of contact plates or strips. The under bank, called the line bank, contains 100 pairs of these contact plates arranged in 10 horizontal rows, 10 pairs to the row. These pairs of bank contacts correspond to the line springs in the multiple jacks of a manual board, and may be multipled before any desired number of connector switches.

The upper bank contains 100 single contacts which correspond to the sleeves of multiple jacks. This is the busy test bank, commonly called the "private" bank. The cord and plug of the manual board are represented by the "wipers" on the shaft of the machine.

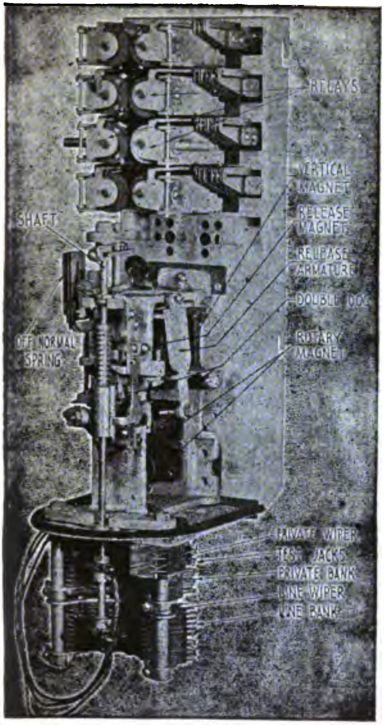


Fig. 8,427.—Strowger type connector with banks. The connector is the final switch of a series used in making a call. *It consists of* a shaft carrying three wiper springs, which by means of a step by step vertical and rotary motion, may be caused to rest on any desired set of contacts in the bank. The relays at the top are used to control the action of the magnets, the busy signal, ringing current, transmission currents, etc.

The lower or line wiper consists, as shown, of a pair of long flexible springs insulated from each other and each soldered to a flexible cord, while the upper or private wiper is a pair of springs connected together to a third cord.

The movement of the wipers, corresponding to those of an operator raising a plug and inserting it into the proper multiple jack, are performed

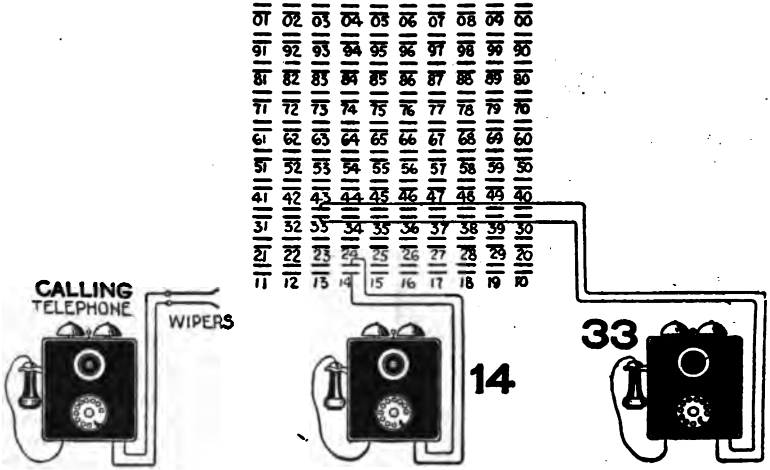


Fig. 8,428.—Diagram of line bank contacts, associated with each connector and numbering system of the telephone lines of which they are the terminals. The number of any set of terminals can be determined by noting the number of vertical and sidewise steps the wipers must be given to reach that set, remembering that ten steps is always represented by zero. Thus six vertical steps and ten rotary steps would cause the wipers to reach contact No. 60.

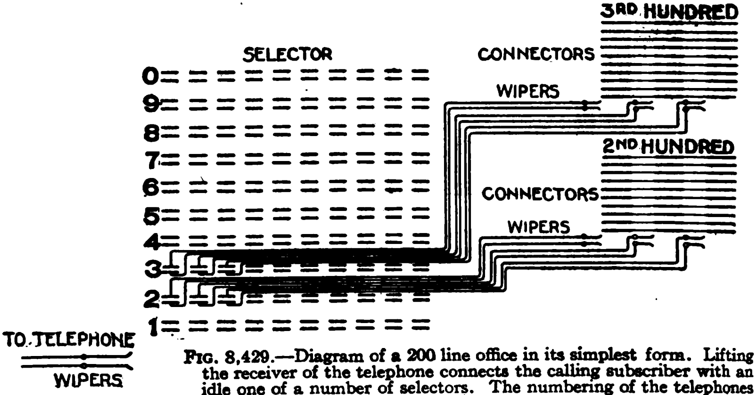


Fig. 8,429.—Diagram of a 200 line office in its simplest form. Lifting the receiver of the telephone connects the calling subscriber with an idle one of a number of selectors. The numbering of the telephones in this office is from 200 to 300 inclusive, since the second and third levels of the selectors are used. Dialing the first figure (a 2 or a 3) steps the selector up to the second or third level and thereby chooses the 200 cr 300 group of lines. Immediately the vertical motion of the selector shaft is complete, the shaft and wipers automatieally rotate to select an idle connector serving that 100 line group. This action is independent of the calling device. The last two figures dialed cause the connector to pick out the desired line.

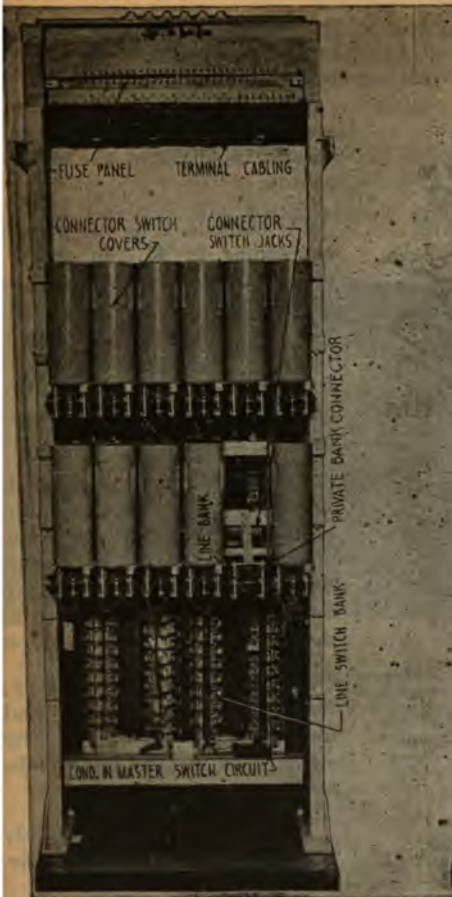


FIG. 8,430.—100 line switch board *front view*. Here are shown 100 subscribers' line switches mounted on a steel frame in four sections of 25. Two sections of 25 are mounted on each swinging shelf and each shelf of 50 are controlled by a master switch. Above the switches may be seen the power panel and terminal assembly.

FIG. 8,431.—100 line switch board *rear view*. On the rear of a line switch unit are mounted the connectors which serve that 100 lines. The incoming subscriber's lines, besides being connected to the line switches are also connected to the connector bank contacts. The capacity of a unit is usually 24 or 28 connectors, although it is seldom necessary to install more than 15 except for party lines.

by the shaft which has a step-by-step vertical movement and a step-by-step rotary movement. These movements are actuated by pawls and ratchets operated by electromagnets controlled by the subscriber from the calling device on his telephone, and are always in accordance with the last two digits of the number he calls.

For example, if he call a number ending in 43, the shaft is raised four steps and then rotated three steps, thus raising each wiper opposite the fourth row of contacts from the bottom of its respective bank and then sliding it over to the third contact in the row.

The machine is then ready to close the circuit of the calling subscriber through to the circuit of the called party, but before doing this it first closes the private wiper circuit only and thus makes an automatic busy test.

If it find the desired line busy, it keeps the connection open and immediately transmits the busy signal back to the calling subscriber.

If the desired line be not engaged, the connector switch immediately

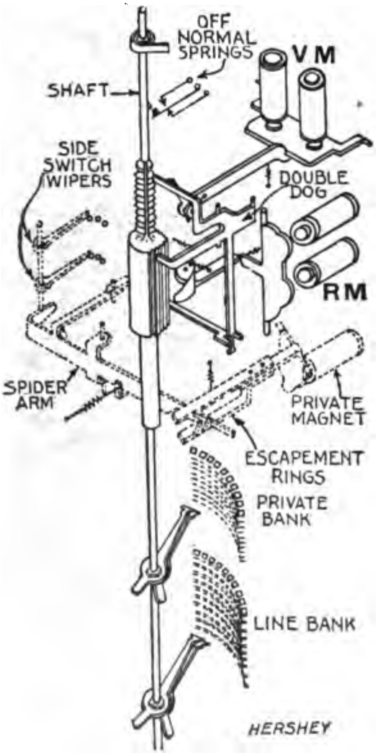


FIG. 8,432.—Diagram of connector switch, and the two banks of contact. The switch consists of a shaft arranged to make under control of magnets, a step by step vertical movement, and a step by step rotary movement. Attached to the shaft near its lower end are two wipers, the lower (double) wiper makes contact with the *line bank*, and the upper (single) wiper makes contact with the *private bank*. Further up on the shaft are vertical teeth by which the shaft is raised step by step, and just below which is a pinion or hub of rotary teeth by which the shaft is rotated step by step. The coiled spring at the top of the shaft causes it to return to its initial position when released. Gravity is utilized to lower the shaft to its initial vertical position.

begins to ring the called party's telephone bell automatically and intermittently. When he answers, the ringing stops and the two subscribers' lines are closed together for conversation.

Talking current is supplied to the transmitters of both telephones from the central office battery through the relay coils of this connector switch, just as in manual practice it is supplied through the relay coils of the cord circuit.

The diagram fig. 8,432 shows clearly the mechanism of the connector switch.

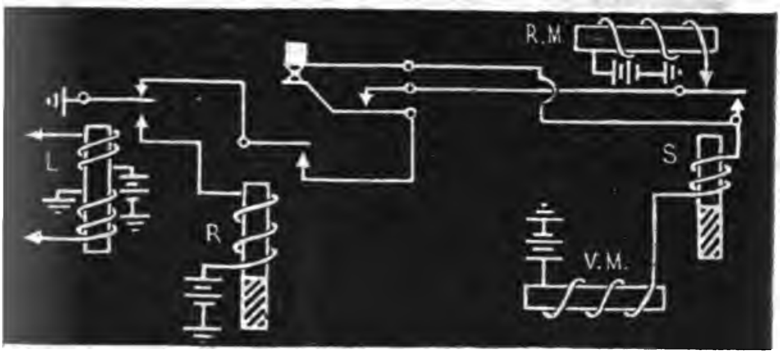


FIG. 8,433.—Connector switch circuit. When the subscriber removes the receiver, relays L and R, are closed as explained in fig. 8,426. Suppose the first number dialed by the subscriber be 4, then the circuit of relay L, is momentarily opened 4 times; which in turn each time opens the circuit of relay R. Since R, is slow acting it does not open. The first time relay L, armature opens a circuit may be traced *from ground, break springs relay L, make springs relay R, break contact "off normal spring" relay S, through vertical magnet to battery.* The current in the circuit causes relay S, and the vertical magnet to operate. S, being slow acting remains in position for fraction of a second. When relay and armature again opens the same circuit is closed, except that since the shaft has already been raised one step, the circuit will pass through the *make contacts of the "off normal spring" and the make contacts of relay S.* Shortly after the last impulse of current has passed through S, it will open and cannot again close because of the open circuit at the off normal springs: When the subscriber dials the second number, each time relay L, opens, a circuit may be braced from *ground break springs relay L, make springs relay R, make off normal springs, break springs relay S, through rotary magnet to battery.* The current in this circuit causes the rotary magnet to close a number of times corresponding to the number dialed, thus rotating the switch to the proper contact.

Connector Switch Circuit.—This circuit includes *the vertical and rotary magnets, which operate the switch.*

Fig. 8,433 shows the circuit, which it should be noted, is a continuation of the subscriber's circuit shown in fig. 8,426, the two relays L and R, of fig. 8,433 being the same relays at L and R, of fig. 8,426.

Private and Line Banks.—As shown in fig. 8,432 these form a part of the connector switch. The diagram fig. 8,434 shows 100 single contacts in the private bank and 100 double contacts in the line bank.

Each telephone is connected to a certain pair of contacts in the line bank. For each pair of contacts in the line bank, there is a corresponding contact in the private bank associated with it.

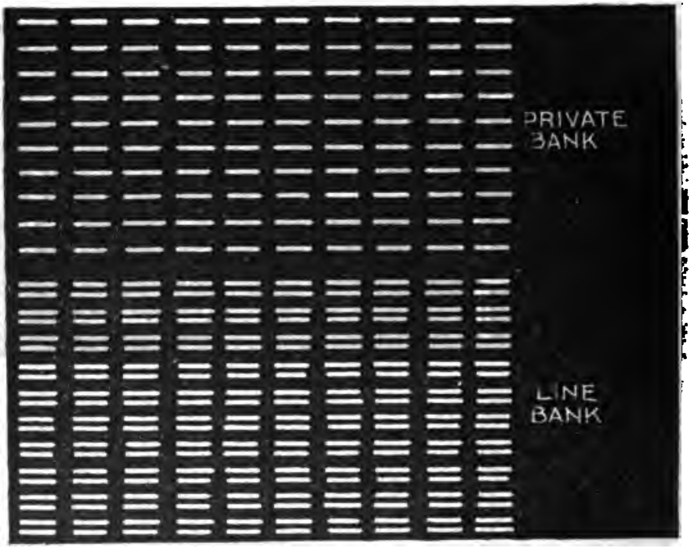


FIG. 8,434.—Diagram showing contacts of line and private banks of a 100 line system. These banks form a part of the connector switch.

The object of the private bank is *to protect a line against intrusion when that line is in use;* it is in other words, a busy test bank and in operation, whenever a telephone is in use the corresponding private bank is grounded.

Private Bank or Busy Test Circuit.—This is shown in fig. 8,435. The spring assembly on relays A, and W, are what are called *make before break* springs.

When current flows through the relay, the make spring strikes the movable spring and causes it to break contact with the stationary spring.

When relay B, is once energized it is independent of the private bank contact ground, hence the busy tone is continued even though the called line becomes idle.

When a busy line is called, the wiper cut off relay W, does not cut the connection through the wipers, hence there will be no interference with those already using the line.

The circuit of the rotary magnet is taken through a pair of break springs on relay B, so that a subscriber, while receiving the busy tone cannot again operate the rotary magnet by interfering with the dial.

The make springs on relay A, prevent opening of the rotary magnets, due to the tendency of relay B, to operate should the private wiper pass over one or more busy contacts.

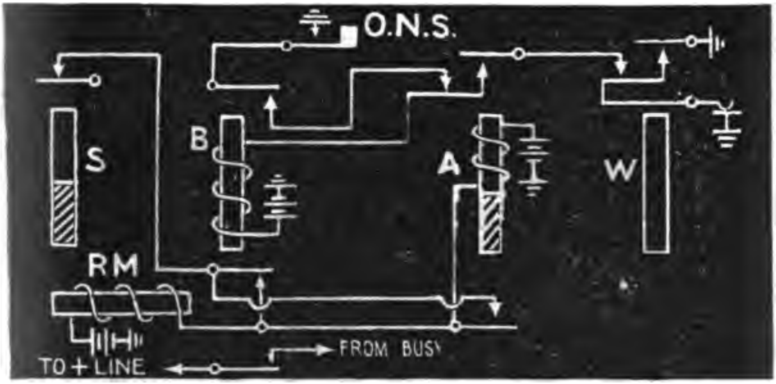


Fig. 8,435.—Private bank or busy test circuit. Assuming a telephone in use and its private bank grounded, relay A, being slow acting, will remain energized momentarily after the completion of the rotary movement. Now a circuit may be traced *from ground at private bank contact, through private wiper, break springs relay W, make springs relay A, through busy relay B, to negative battery*. The current in this circuit will cause relay B, to close forming a locking circuit for itself independent of the ground from the private bank contact. This circuit may be traced from "*off normal spring ground*," *make springs relay B, break springs relay A* (which by this time has opened) *through relay B, to battery*. Further relay B closes a pan of contact which places the busy time on the line indicating to calling subscriber that the line is busy.

If the called line be idle, there will be no guarding ground on the associated private bank contact. After relay A, opens a circuit is closed through the wiper cut off (or ringing) relay W, which grounds the private bank contact, so that any one calling this number will receive the busy tone, thus protecting the busy line against intrusion.

Disconnection of Connector Switch.—After the completion of a telephone conversation means must be provided *for returning*

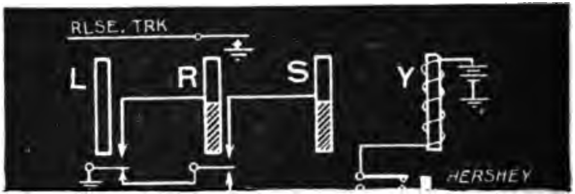


Fig. 8,436.—Release circuit by which the connector switch double dog is operated to restore connector switch to normal. Since during conversation, the line relay remains closed the connector switch release circuit remains open. Now when the receiver is hung on the hook (at the calling station) the line relay opens and a moment after the release relay opens. This completes a circuit *from ground, break springs of line relay, break springs of release relay, off normal springs, through release magnet Y, to battery and ground.* This energizes the release magnet which removes the double dog allowing connector shaft to return to normal position, the release circuit being opened at the off normal springs when the shaft reaches the normal position. On the release relay is a pair of make springs, by which ground is placed upon the release trunk.

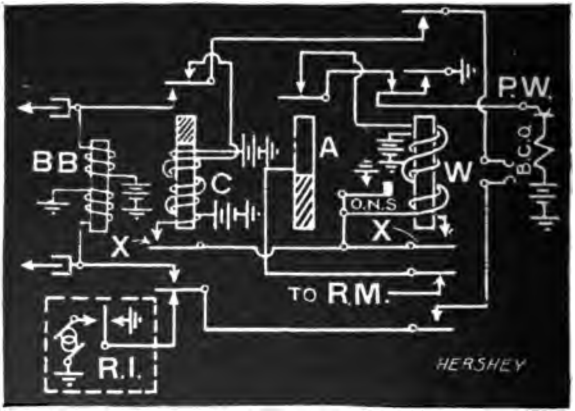


Fig. 8,435a.—*Removal of line wipers during rotation.* When the second number dialed requires several steps of rotation, the line wipers during the rotation make contact with the contacts rotated over. Hence, if any of the lines rotated over be busy an unpleasant sound would be heard as the wipers passed over the contacts unless they be disconnected from the connector during the rotary movement. Assume number 65 has been called and that the line and private wipers are now resting upon the bank contacts associated with telephone number 65. When relay A, de-energizes, following the last rotary impulse, a circuit may be traced from "off normal spring ground," low winding relay W, break springs relay A, break springs relay W, private wiper, private bank contact, through the B.C.O. to negative battery. The lower winding of relay W, will energize sufficiently to close the springs X, thus forming a locking circuit which may be traced *from "off normal spring ground" springs X, through the high winding of relay W, to battery.* The current in the circuit will cause relay W, to fully operate so that the line wipers are cut through to the connector and ground is placed on the private wiper.

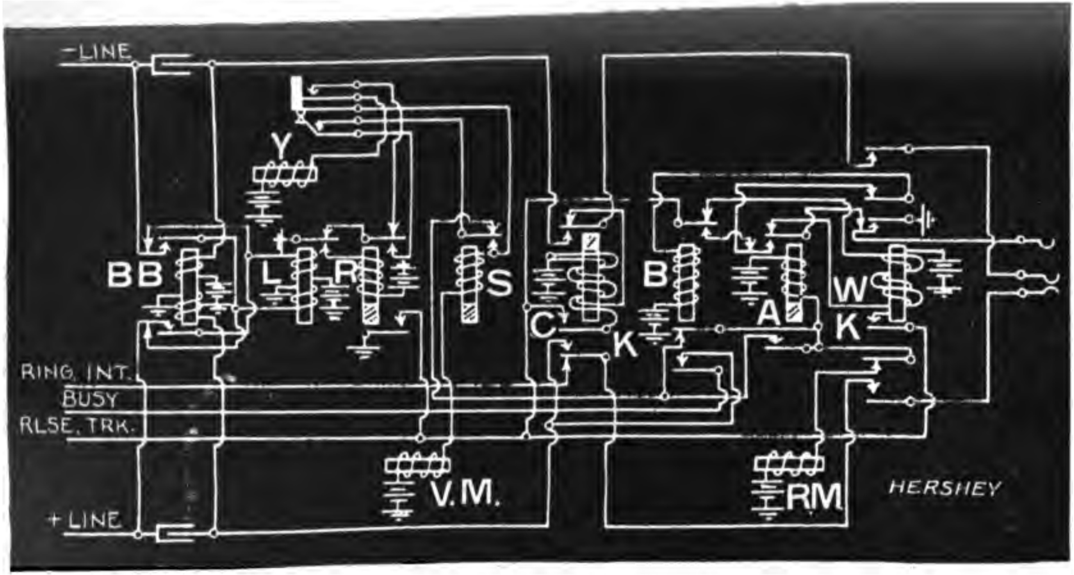


FIG. 8,437.—Diagram of complete connector circuit.

the connector switch to its normal position, when the subscriber hangs up the receiver, thus disconnecting the line.

This is done by a part of the connector switch mechanism called a *double dog* operated by a *release magnet*. The circuit which controls the release magnet, called the release circuit is shown in fig. 8,436.

Complete Connector Circuit.—Connections in this circuit are shown in fig. 8,437.

Included in the diagram are the familiar line and release relays, also, series relay, instantaneous ring cut off relay, busy relay, back bridge relay, wiper cut off relay, release magnet, vertical magnets, rotary magnets, and slow acting rotary control relay. The duties of these various relays are here briefly given.

Line Relay—Receives the dial impulses and repeats the same to the vertical and rotary magnets; also feeds talking battery to calling subscriber.

Slow-Acting Release Relay—Prepares circuit of the vertical and rotary magnet, and maintains the release magnet circuit open until such time as the conversation is completed.

Slow Acting Series Relay—Used to operate the vertical magnets.

Busy Relay—Used to give a calling subscriber a busy tone in case the line called be busy. It also prevents undue rotation of the shaft by the rotary magnets.

Ring Cut Off Relay—Feeds ringing circuit to the called line and releases ringing circuit when the subscriber answers.

Back Bridge Relay—Feeds talking battery to the called subscriber, and reverses polarity of the calling line.

Wiper Cut Off Relay—Cuts connector through to the wipers when an idle line is reached.

Vertical Magnets—Gives vertical movement to connector shaft when first number is dialed.

Rotary Magnets—Gives rotary movement to connector shaft when second number is dialed.

Release Magnet—Removes double dog to restore connector shaft to normal position when receiver is hung on hook at completion of conversation.

Rotary Control Relay—Operates in parallel with the rotary magnets, and closes the circuit through to the busy relay.

Line Switch.—As must be evident the complicated connector switch is a very costly part of the apparatus, and if, as has been assumed in the previous explanation that each line is provided with one of these connectors, the cost of the installation would be prohibitive. Now since only a small number of lines are in use at one time, it will suffice *to employ only a few connectors in* *proportion to the number of lines, if there be provided means by which when a subscriber removes his receiver from the hook, his line will be connected to an idle connector switch.* This is accomplished by what is called the *line switch.*

With this device, it has been found in practice that only ten connector switches are needed for each 100 line installation.

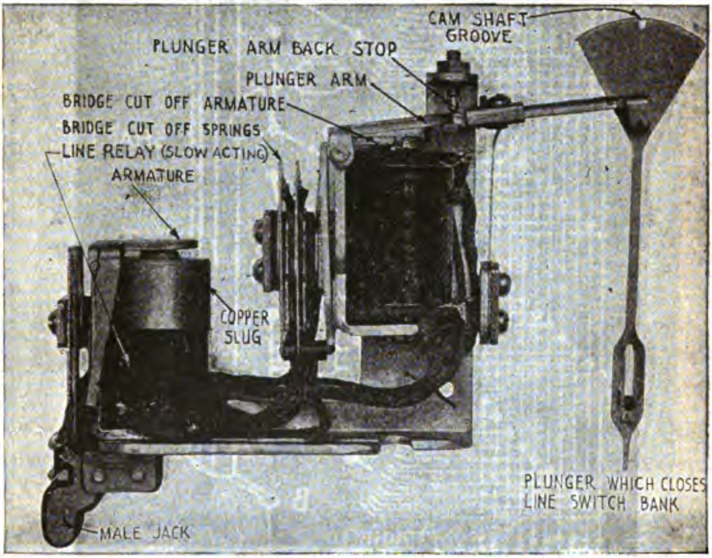


FIG. 8,438.—Line switch. *It consists of* a line relay and a combination "pull down coil" and "holding coil" carrying two armatures. The larger armature carries a plunger, which is pivoted so that its point may be swung by the master switch in front of a bank of contacts. The bank consists of 10 sets of contact springs with which are associated ten trunks. Line switches are mounted in groups of 25, four groups being provided for each 100 line unit. One master switch may be provided for any number of groups of line switches depending upon the trunking capacity desired, since each master switch controls ten trunks. Normally the plungers are at rest poised over bank contacts multiplied to an idle trunk. When a subscriber removes his receiver from his telephone switch hook preparatory to making a call, a circuit is thereby closed which causes the plunger arm of his line switch to be at once pulled down, carrying its plunger out of engagement with the master shaft and thrusting it into the bank. The effect of this is to connect the subscriber's line to a trunk leading to an idle first selector switch, as shown diagrammatically in the right hand portion of the figure. The instant that one line switch thrusts its plunger into the bank, thus occupying the trunk over whose multiple all idle plungers have been poised, the master switch operates and swings the remaining idle plungers forward over the next multiple of bank contacts. If this trunk should be busy, the movement proceeds until an idle trunk is found. It is to be noted that a line switch always uses a pre-selected idle trunk instead of making a selection after a subscriber starts to call.

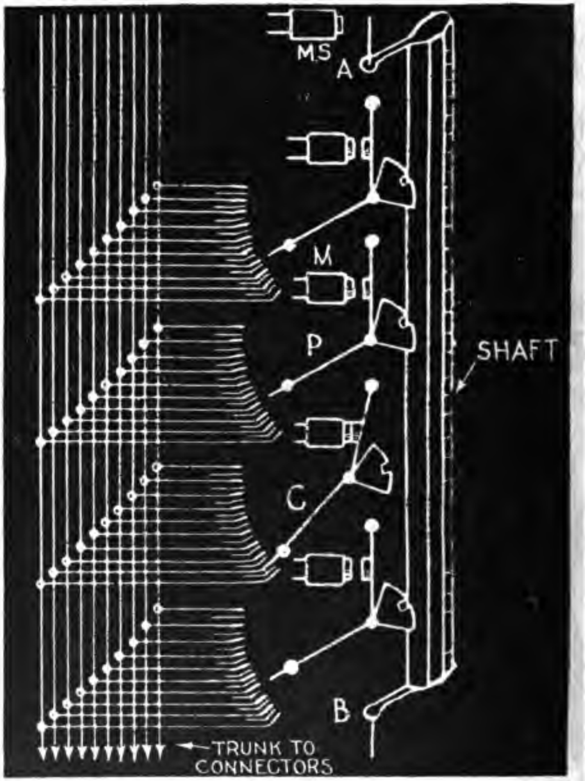


FIG. 8,439.—Diagram of line switch and connections. The switch ***consists of,*** a magnet M, and plunger P, whose head or wing is slotted so that it may engage a projecting edge of the shaft. The shaft is pivoted at A and B, and is capable of a rotary motion of about 40 degrees under control of a master switch MS. The rotary motion causes the plungers of the various line switches to oscillate in front of the terminal of the trunks to the connector switches. Under control of the master switch the shaft comes to rest *only* opposite an idle trunk. If the shaft be holding all the plungers opposite, say the second trunk, and a subscriber remove his receiver, the corresponding plunger will *plunge in* and extend the connection to the connector associated with trunk number two. The plunger when *plunged in* is now free of the shaft as shown at C. The master switch, by means of the shaft moves the remaining plungers opposite an idle trunk, giving what is called *pre-selection of trunks*. When the subscriber who plunged in on trunk No. 2, hangs up his receiver, his plunger will come out of the bank but the slot in the wing of the plunger will not engage the shaft at this time. Hence this plunger will remain opposite trunk No. 2, until the shaft again swings in front of this trunk and picks it up. To prevent a caller connecting on a busy trunk, a plunger must not plunge in while the master switch is seeking an idle trunk. This requirement is met by what is called the *open main battery feed*.

In making a connection, after the line switch (also called the ***non-numerical switch***) connects the line with an idle connector, the connection is completed by the connector switch as already described.

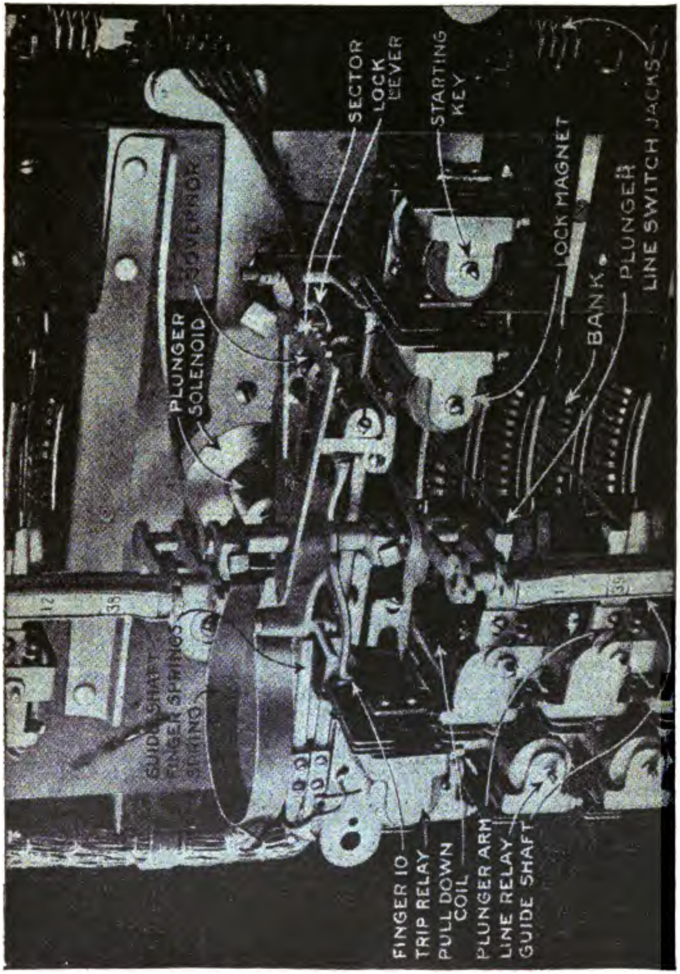


FIG. 8,440.—Mechanism of line switchboard.

Fig. 8,439, shows the working of the line switch, and fig. 8,440, its general appearance.

An important part of the line switch is the solenoid, which operates the shaft of the line switch in seeking trunks and the locking mechanism. This part of the mechanism with its circuit is shown in fig. 8,442.

The shaft of the line switch is moved counter clockwise by a spring, and clockwise by the solenoid. One arm of the locking segment L, is arranged to face springs Y, into contact when the switch is standing opposite the first trunk.

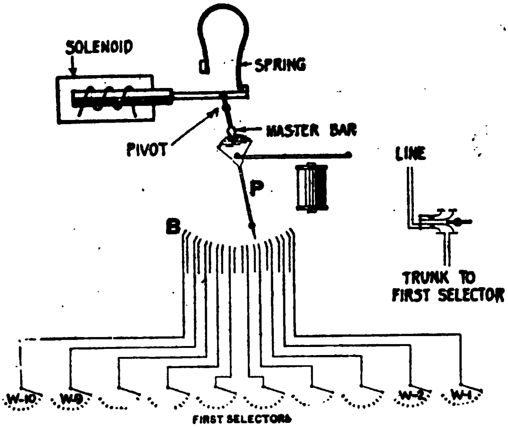
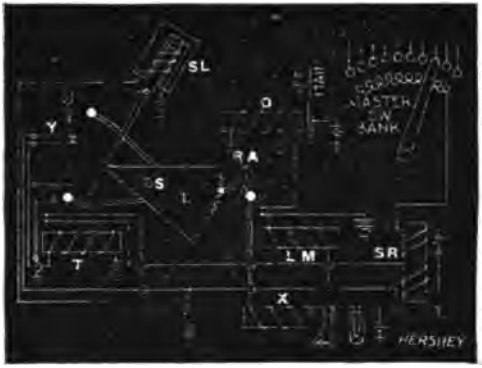


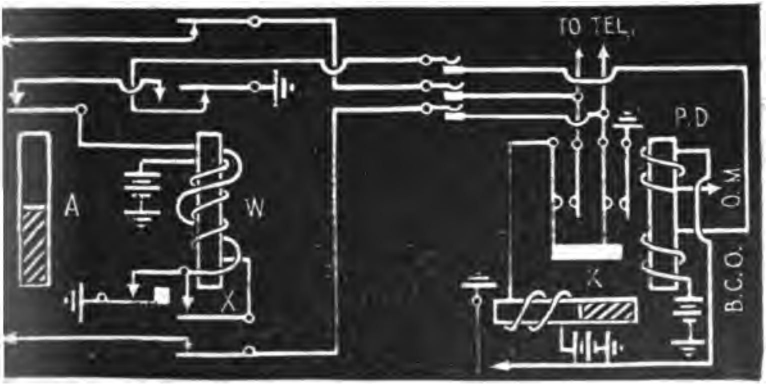
FIG. 8,441.—Master switch mechanism of line switch and diagram of trunks to first selectors. In the line switch, the notch in the head of each plunger meshes with a rocking bar or "master shaft" as it is called. A step by step device called a master switch (seen in the upper part of the figure) is connected to each pair or to each four master shafts and by means of them can swing the plungers back and forth, step by step over the banks of contact springs. The plungers are normally held in position by the master bar, which carries a feather fitted into the slots at the rear of the plunger. When the line switch operates, the plunger point is thrust into the bank, connecting the line to the connector or selector trunk, and at the same time disengaging itself from the master bar. The master switch is now automatically unlocked and begins to move under the action of the curved spring until an idle trunk is reached. When the master switch reaches the end of its stroke, the solenoid is energized and this pulls the shaft back in the opposite direction against the action of the spring.

The trip relay T, has a mechanical locking feature, which after it is once energized, will hold the springs in an operated position until mechanically released.

A section of L, is so formed as to release the springs of the trip relay T, when the master switch comes opposite the tenth trunk.



. 8,442.—Solenoid control of line switch shaft, locking mechanism and circuit. If the line witch be standing opposite, say trunk No. 8, and a plunger plunges in on the trunk, a ircuit can be traced from *release trunk ground, through master switch wiper and starting elay SR, to battery and ground*. SR, will energize and close a circuit *from ground through prings of relay SR, locking magnet ML, to battery and ground*. The locking magnet will operte to remove the retaining air from the locking segment, which now being free, to move, nder the action of the spring will swing switch wiper and plungers in front of trunk No. 7. f this trunk be idle, the associated bank contact will not be provided and relay SR, will pen and break the locking magnet circuit allowing the retaining arm to drop into the seventh lot of the locking segment. This arrests the rotation of the line switch shaft and holds the lungers opposite the seventh trunk until that trunk becomes busy. If this trunk had been usy the circuit of relay SR, would not have been opened, and the rotation would have coninued until an idle trunk was reached. A plunger cannot plunge in while the master switch s moving for during the motion the open main circuit is open at the springs of relay O. he springs of the locking magnet, when in an operated position, also close a circuit through he supervisory relay X.



G. 8,443.—Diagram of portion of a connector switch circuit illustrating *clearing the called line of attachment*. Suppose a called line found to be idle and relay W, cut the connector

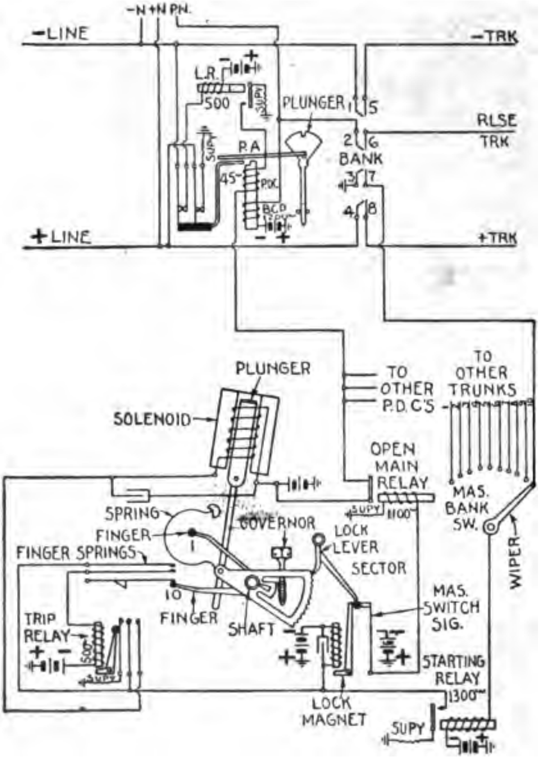


Fig. 8,444.—Line relay and master switch circuits.

There are ten sets of double contacts in the master switch bank, the lower contact being multiplied together. Each contact of the upper row is associated with one of the line switch trunks.

The switch wiper short circuits the upper and lower bank contact associated with the trunk upon which it happens to be standing.

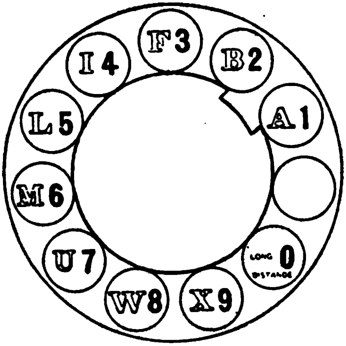
The locking magnet LM, operates to force its springs together and draw retaining arm RA, from locking segment L. Again if the retaining arm be resting against locking segment L, but has not yet fallen into a slot, it will hold the springs of relay LM, in contact. The operation of the solenoid control is explained in fig. 8,442.

Fig. 8,443.—*Text continued.*

through to the wipers. A part of the plunger circuit associated with the called line is shown at the right. When relay A, releases after dialing, a circuit may be traced from "*off normal spring ground*", *low winding of relay W, break springs relay A, break springs relay W, private wiper, through the B.C.O. of the called plunger to battery and ground.* The B.C.O. of the called plunger will clear the called line of attachments, and relay W, will operate sufficiently to close springs X. When this condition obtains, a circuit may be traced from "*off normal spring ground,*" *make springs relay W, high winding of relay W, to battery and ground.* The current in this circuit fully operates relay W. Direct ground is now placed on the private bank contact by springs of relay W, *so slowly* that the B.C.O. of the called plunger will have sufficient time to clear the called line of attachments before W, cuts the connector through to the wipers. The springs of W, are of the *make before break* type so that the B.C.O. will not be opened.

Clearing the Called Line.—When a telephone is called it is necessary that the line be cleared from battery and ground feed. This is called "clearing the line of attachments" and is illustrated and explained in fig. 8,443.

2. MULTI OFFICE SYSTEMS



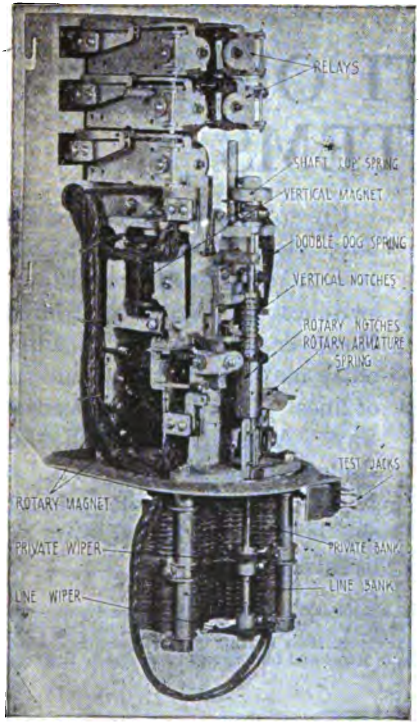
Up to this point only a 100 line, single office exchange system with 10 connector switches has been considered However, in practice, a single office may contain any number of lines. There is no limit either way. A recent single office installation at Norfolk, Va., of 11,500 lines is at the present, the largest single office in existence.

FIG. 8,445.—Multi-central station dial. On all 100,000 line systems the numbers are made up of a letter and four figures instead of five figures. With this method of numbering 26,187 would, for instance appear in the telephone directory as B-2187. When operating the calling device many subscribers will remember a letter and four figures more clearly than they will five figures.

The grouping of lines in multi-office exchange system is, with respect to the exchanges strictly according to number.

Thus, assuming 100 line units, telephones numbered 1 to 99 are wired to exchange A, those numbered 100 to 199, to exchange B, etc. At each of these exchanges is a set of *connector switches, through which connection is made with any subscriber's line which terminates at the same exchange.*

Now if a subscriber whose line terminates at exchange A, desire to talk with a subscriber where line terminals at exchange B, *he must first obtain connection to an idle connector switch in exchange B*, and in order to do this a new piece of apparatus *called a* ***selector switch*** *is necessary,* as shown in fig. 8,446.



It looks, and is very much like a connector switch; in fact the mechanism and banks are the same. Its mechanism gives the familiar vertical and rotary motion to a shaft and wipers and differs from the selector switch in the circuits and relays only.

In any multi-exchange system, the selectors *are divided into a number of classes according to the size of the group they are to choose.*

For example, in a 10,000 line system first selectors would choose the 1,000 line group, and second selectors the 100 line unit.

FIG. 8,446.—Stronger type selector with banks. *It consists of* a group and trunk choosing switch. Like the connector it comprises the usual shaft, bank, and wipers, and a mechanism whereby the shaft can be lifted and rotated step by step. Unlike the connector, however, it is a one digit switch. The vertical motion is controlled from the calling device and serves to pick out a certain group of lines. The rotary motion is automatic and picks out an idle trunk leading to that group.

The bank contacts of the selector switches are terminals of trunk lines instead of subscribers' lines.

The first or lower row of first selector bank contacts constitutes the terminals for a group of 10 trunk lines leading to second selector switches in the **1,000** section of the plant.

The second row represents another group of 10 trunk lines to second selectors in the **2,000** section of the plant, the third row represents a group of trunks leading to second selectors in the **3,000** section of the plant, etc., so that through the 10 rows of bank contacts the first selector has access to 10 second selectors in each of the 10 sections of 1,000 lines which make up a 10,000 line office.

The first selector switch used by a calling subscriber is operated *in accordance with the first digit of the number he calls.*

Suppose, for example, he is calling the number **2,543.** The impulses sent in by the first movement of his calling device will raise the shaft, and accordingly the wipers of the first selector switch two steps, placing each wiper opposite the row of bank contacts second from the bottom in its respective bank.

Now the selector switch unlike a connector switch, does not wait for the subscriber to make another turn of his dial before rotating its shaft, but the rotation is automatic and beyond the subscriber's control.

The rotation starts the instant the vertical movement is completed, and, in the particular case which is here used as an example, sweeps the wipers step by step over the row of bank contacts connected to trunks leading to the **2,000** section.

At each step of the rotation, the bank contacts on which the wipers then rest are given the busy test, and as soon as a disengaged trunk line is found the rotary movement stops and the connection is completed to an idle second selector. This is all accomplished in a fraction of a second, so that the second selector is operated by the subscriber's calling device impulses corresponding to the second digit **5,** of the number **2,543** which he is calling.

The wipers of the ***second selector*** are accordingly raised five steps and are then automatically rotated just as the first selector wipers were. The bank contacts of this second selector are the terminals of the trunks to the 10 sets of connectors which complete the connections to the line groups making up the **2,000** section of the plant. Consequently when the second selector wipers stop on an idle trunk in the fifth multiple, the calling subscriber is placed in connection with an idle connector in the **2,500** group; that is, a connector which has access to the desired subscriber's line No. **2,543.** This connector is then operated by the last two movements of the subscriber's calling device, and performs the functions of an operator in the manner already described at some length.

Fig. 8,447 illustrates this grouping arrangement and shows the connection just described from the calling telephone to a first selector, then from the second row of first-selector bank contacts to a second selector in the 2,000 section of the exchange, then from the fifth level of this second selector's bank contacts to a connector switch in the 500 group of the 2,000 section, and then through the fourth row of the bank contacts of this connector to the called telephone.

It is readily understood that by thus using a first selector to pick out a trunk to any one of ten different **1,000** sections, second selectors in each section to pick out trunks to any **100** group in each **1,000**, and then by using the connectors to complete calls to individual lines in each **100**, that connection may be made by the use of three switches from any calling telephone

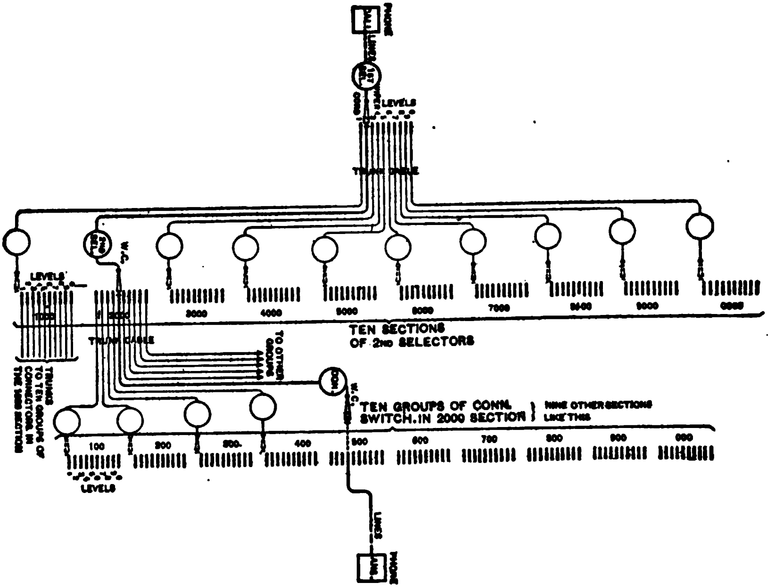


FIG. 8,447.—Diagram illustrating working of the multi-exchange system *by means of selector switches.* As shown, connection has been made by a subscriber with phone No. 2,543, by means of *first* and *second selector switches* and a connector switch, the latter located at the central station at which the line of the subscriber called terminates.

to any number from **0000** to **9,999** or in other words to **10,000** different numbers.

It will also be readily understood that by using a fourth switch, called a third-selector switch, and using numbers with five digits instead of four, that the capacity of the system will be multiplied by ten and will be 100,000 lines instead of 10,000.

In a system of 100,000 lines, **10,000** numbers are generally set aside for each main central office. Consequently on each call the first selector picks a trunk to the desired office, the second selector picks a trunk to the desired **1,000** in that office, the third selector picks a trunk to the desired **100** and the connector completes the connection to the desired line.

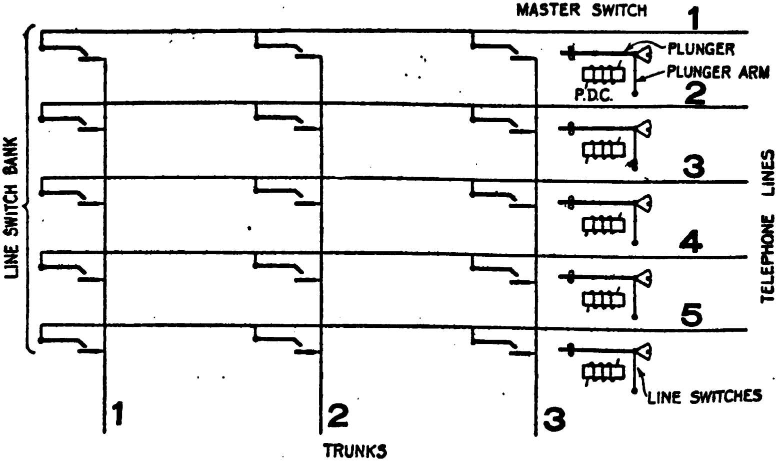


FIG. 8,448.—Diagram showing relation between the lines and the trunks at the line switch banks. Although only three trunks are shown, it must be understood that there are always ten, and the number of lines may be anywhere from 25 to 100. Assume that the position of the master switch is such that each line switch plunger is pointing opposite its set of contacts belonging to trunk No. 3. If a call be originated on say line No. 3, the plunger of that line switch will operate to close its pair of contacts on trunk No. 3, thus connecting the line with the trunk. At the same time the master switch operates to move the remaining plungers until they are resting opposite the contacts of line No. 2, (assuming that trunk to be idle). The next line switch being used will take trunk No. 2 and the rest of the plungers will take up a position opposite the next idle trunk. It must be understood that the trunk finding movement takes place from No. 10 to No. 1. The master switch does not preselect trunks in moving from No. 1 to No. 10, but passes over them without stopping.

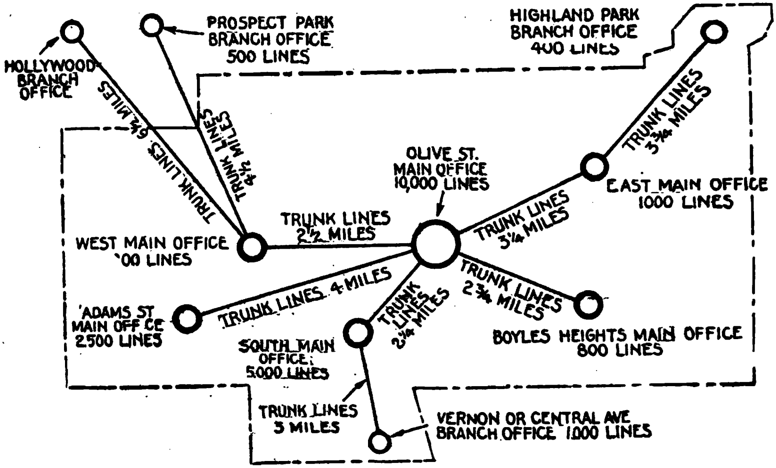
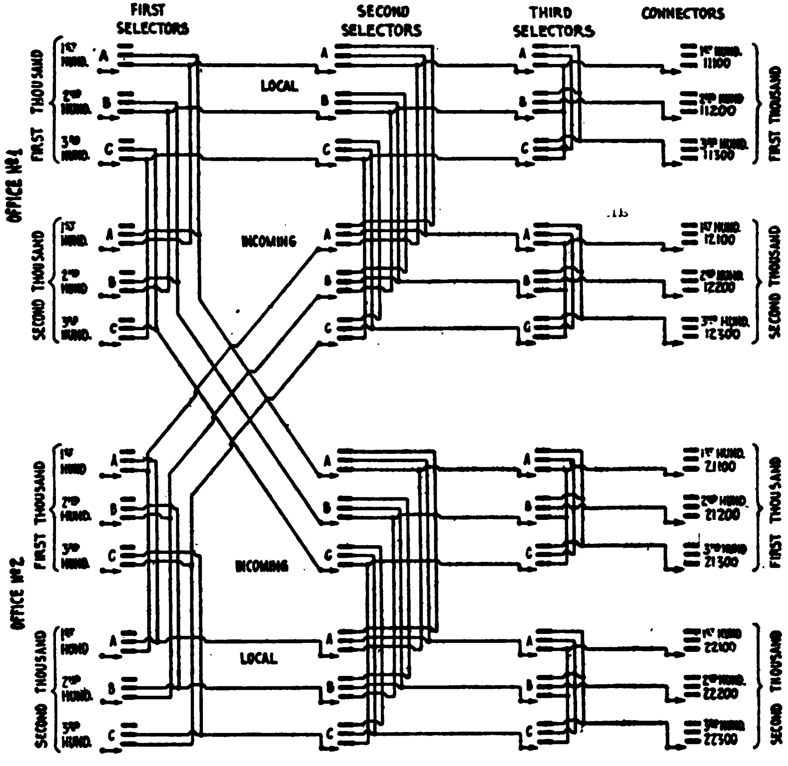


Fig 8,449.—Diagram of automatic telephone system installed at Los Angeles, Cal. As shown there are six main offices, each with an ultimate capacity of 10,000 lines. The Olive Street main office is now equipped for 10,000 lines, West for 4,000 lines, Adams for 2,500 lines, South for 5,000 lines, Boyles for 800 lines and East for 1,000 lines. The numbers in the South Office all commence with 29,000. Those in Olive Street Office all commence with 60,000 etc. South office has a branch office called Vernon; West office has two branches which are called Prospect Park and Hollywood; East office has a branch called Highland Park. The numbers in each branch office commence with the same digit as the numbers in the main office to which it connects. That is: one of the sections of 1,000 numbers are taken from the main office and are set aside for use in the branch. For example: the lines now equipped in South office are numbered from 21,000 to 25,000 and the numbers in its branch Vernon run from 29,000 to 29,999. It is ,of course, unnecessary for a calling subscriber to know to which office he is connected or to which office the party he desires to call is connected. The trunking between offices is all automatic. A subscriber, for instance, in the South office, who, on the first move of his dial turns it from the number 2, will automatically select a local trunk line to a second selector in South office. If he make the first turn from the number 3, a first selector at South office will automatically connect him to a trunk line terminating in a second selector at East office. Or, if he make the first turn from the number 6, the first selector at South Office will automatically select an idle trunk to Olive Street office, etc. Suppose, a subscriber connected to the South Office wish to call 62,127, which is an Olive Street office number. The first movement of the dial operates a first selector at South office, and extends the connection over an idle trunk to a second selector switch in the Olive Street office. The second digit 2 will operate the second selector at Olive Street office, and extend the connection to a third selector in the 2,000 section of the Olive Street switchboard. The third digit 1 will extend the connection to an idle connector switch in the 100 group of the 2,000 section. The last two digits will operate this connector switch and complete the connection to 27 in this particular 100. Suppose, again, that a South office subscriber is calling 39,143 which is in the Highland Park branch office. The first movement of the dial operates a first selector in the South office and selects a trunk to a second selector in the East Main office. The second movement of the dial raises the shaft of this second selector nine steps, and selects an idle trunk to a third selector in the Highland Park branch office. The third movement extends the connection through a local trunk in the Highland Park branch office, to an idle connector in the 100 group, and the last two motions of the dial result in the completion of the connection to 43 in that particular hundred. The time required to complete a connection and the number of machines used is independent of the number of offices through which a connection may be trunked.



INTER OFFICE TRUNKING (100,000 LINE SYSTEM)

FIG. 8,450.—100,000 line automatic telephone system. Such a system is necessarily divided up into several offices, because it is too large to be placed in one. The ideal distribution would have 10 offices of 10,000 lines each. The details of switch connections may be illustrated by using only two offices. Each office is somewhat like an ordinary 10,000 line exchange. There are 10 connectors for each 100 lines and there are 100 selectors which deliver traffic in a given thousand, consisting of 10 hundreds. These selectors are now called third selectors, although their function is exactly the same as that of the second selectors in a 10,000 line system. Back of the third selectors are other selectors whose duty it is to choose thousands. The banks of the first selectors in the 100,000 line system distribute traffic to the offices of levels. One level will be the local level, because it runs to second selectors in the same office. All the rest of the levels trunk out to other offices. All the trunks from the given level of first selector banks run to a given office and any trunk serves as well as any other. They can all be formed into one group by means of secondary line switches. This is common practice. The incoming trunks end on incoming second selectors. Their banks are multiplied to the banks of the local second selectors in such a manner as to mingle the traffic as uniformly as may be done.

Systems of 100,000 lines capacity have been installed in a number of different cities. One of the most notable is that in Los Angeles, as shown in fig. 8,449.

In multi-central installations, each line terminates at a line switch. The line switch is not under the control of the subscriber, but connects him automatically to an idle first-selector switch the instant he removes his receiver from his switch hook preparatory to making a call. The first-selector is, therefore, operated by the first impulses transmitted from the subscriber's calling device just as in the older systems. When the line switches are used, 10 first selectors for each 100 lines are generally sufficient to handle the traffic.

Each line switch (fig. 8,438) includes the line and cut off relays with which each line is equipped just as in manual practice.

Ordinarily the banks of 100 line switches are multiplied together and connected to 10 first selector trunks, but for four-party line service or extra heavy traffic, the number in one multiple is often reduced to fifty. Fig. 8,430 shows a front view of a complete line switch unit with 100 line switches and two master switches mounted. Only one master switch is used at a time the other being held in reserve. Fig. 8,431 is a rear view of the same unit showing how the 10 connector switches used for handling calls incoming to any 100 lines are mounted on the same upright as the line switches handling their outgoing calls.

While the primary object of the line switches was to reduce the cost of the switch board by eliminating 90 per cent of the comparatively expensive first selector switches, they have also simplified the central office equipment and have reduced the space required for it. Further, they have resulted in several new and somewhat radical departures in the art of building automatic telephone systems. The most important of these is the line switch district station which enables very considerable savings to be made in underground and aerial cable.

A district station is installed by placing one or more line switch units complete with connector switches in a small building at the telephonic center of a district, generally a mile or more distant from the nearest central office. The lines of all telephones in the district are brought to the district station and are there connected to the line switches. The first selectors to which these line switches are trunked remain at the nearest large central office, consequently when a district station subscriber removes his receiver from his switch hook preparatory to making a call, his line switch instantly puts him into connection by means of a trunk with a first selector switch at central office. The connector switches for handling the calls to the district station telephones are mounted in their usual places on the back of the line switch units, and are connected by trunks to the banks of second selectors, also located at the nearest central office. Thus all calls from and to the district are handled over trunks instead of over subscribers' lines.

CHAPTER 139

Wireless

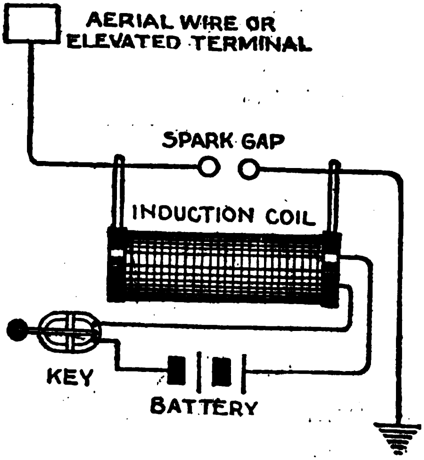


FIG. 8,451.—Electric wave method of wireless telegraphy. The theory upon which this is based assumes, that where one terminal of the oscillator system is grounded and the opposite terminal elevated as shown, the electric waves remain spherical and are propagated in a straight line, until they come in contact with the upper stratification of rarefied air, which is a conductor of electricity and therefore an insulator of electro-magnetic waves, when they are reflected back to the surface of the earth.

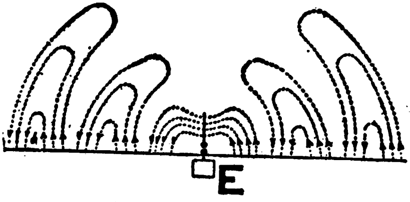


FIG. 8,452.—Electro-magnetic waves emitted by an aerial wire.

By definition, wireless telegraphy is *any system of telegraphy which successfully substitutes some medium other than wire for the connecting conductors.*

The prevailing medium is the ether, or that invisible substance which is supposed to fill all space.

The method of utilizing this medium is by *radiation*, that is, by *distributing the medium in such a manner as to produce far* ***reaching waves*** *which can be detected at distant points.*

NOTE.—***In wireless telegraphy,*** messages are transmitted by means of electromagnetic waves set up by an instrument for generating oscillations at the sending station, passing through free space, and received by a delicate detecting instrument at the receiving station. The surging of electric charges at the spark gap of the transmitting instrument causes the current to ascend the sending mast and flow out into the ether in the form of waves or vortex rings expanding in every direction: the aerial conductor at the receiving station obstructs a portion of these waves which are led into the receiving instrument, by which signals are sounded. A transmitter key controls the duration of the sparks at the spark gap, hence the waves are sent out in groups corresponding to the dots and dashes of the Morse code.

Theory of Wireless Telegraphy.—It is well known that a pebble thrown into a pond **causes** *ripples or waves on the surface of the water, which move away from the point of disturbance in concentric circles of ever increasing diameters.*

These waves represent the combined effect of two motions of the medium through which they are propagated; a vertical and a horizontal motion, both of which decrease in strength with the increase in the distance from the center of disturbance.

Evidently suitable apparatus can be devised to be operated by either of the motions, and thereby indicate the occurrence of the original disturbance. Furthermore, it is evident, that the greater the distance between the center of disturbance and the indicating apparatus, the greater must be the energy of disturbance, or the sensitiveness of the indicating apparatus.

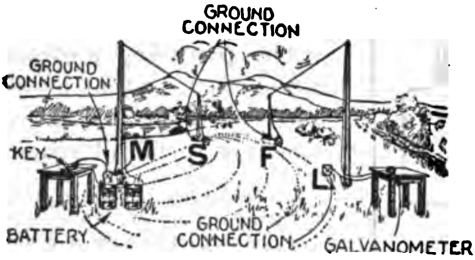


FIG. 8,453.—***Conductivity method. Earth the medium.*** Steinheil of Bavaria discovered that the earth could be utilized in place of the usual return conductor of a wire telegraph line as here shown. By placing earth plates **MS** and **LF**, connected together and having a galvanometer in circuit parallel with the first, which included a battery and a key, Steinheil found that there was enough leakage of current from one to the other to deflect the needles of the galvanometer. The dotted lines represent current in the earth.

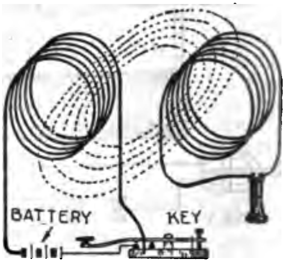


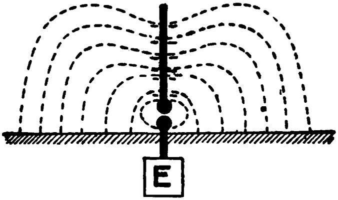
FIG. 8,454—***Inductivity method.*** By placing two coils of many turns with their axes parallel to each other and connecting in series with one a battery and key, and joining the end of the other to a telephone receiver, the make and break of the key causes the electric energy to be transformed into curved magnetic lines which link the two coils as shown, inducing in the second coil a pressure proportional to the rate of linkage. Trowbridge who experimented along these lines, believed the coils could be made to operate satisfactorily between vessels at least a mile apart.

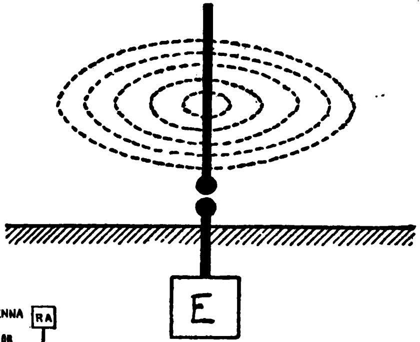
Likewise, the vibrations of a struck bell or a tuning fork are propagated through space by the air and set up corresponding vibrations in other suitable elastic bodies such as strung wires, tuning forks, glass lamps, globes, etc.

Sound waves represent the advance of a disturbance into a medium and are due to the elasticity of the medium.

Heat waves, light waves, and waves due to electric oscillations such as those employed in wireless telegraphy belong to the latter class, and differ from sound waves only in the nature of the medium by which they are propagated.

Ether waves are detected by suitable apparatus.





FIGS. 8,455 and 8,456.—Electric strains. Fig. 8,455, vertical; fig. 8,456, horizontal.

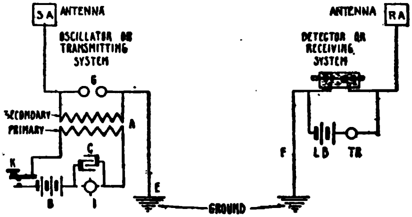


FIG. 8,457.—Diagram showing earliest form of Marconi system.

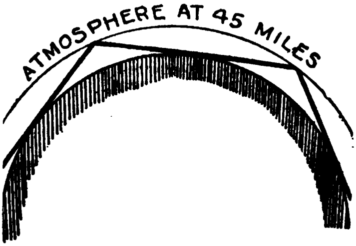


FIG. 8,458.—Reflection of electro-magnetic waves.

Thus, ether waves shorter than about $\frac{1}{64,714}$ of an inch cannot be detected by the eye, but produce effects on photographic plates. Waves ranging in length from $\frac{1}{64,714}$ to $\frac{1}{33,866}$ of an inch appear to the eye as light of different colors, the former violet and the latter red; while waves longer than $\frac{1}{33,866}$ of an inch are invisible to the eye, but produce temperature changes indicated by suitable thermometers. Likewise ether waves produced by electrical oscillations, and exceeding $\frac{1}{362}$ of an inch in length, produce no effect on photographic plates, are invisible to the eye, have no effect on thermometers, and can be detected only by means of suitable wireless apparatus such as *coherers* or other *detectors*.

Practical Wireless System.—For the successful practice of ordinary wireless telegraphy two things are essential:

1. A powerful oscillating system. 2. A sensitive detector.

As originally employed, both the oscillator and the detector were of the open circuit type, the oscillator consisting of a vertical wire, called an *aerial* or an antenna, the upper end of which was supported by a mast, and the lower end connected to the earth through a spark gap.

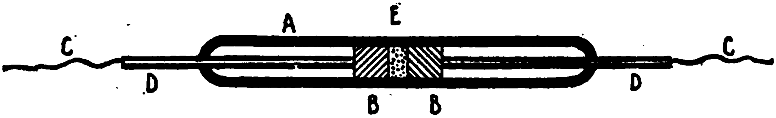
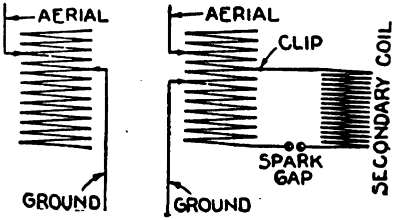
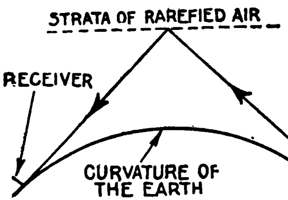


FIG. 8,459.—Branley's filing tube *coherer* or *detector*. A, is a sealed glass tube about 1½ inches long, and having a bore about 1/16 inch diameter. B,B, are metallic plugs, often made of silver, which are connected to the external wires C,C, by sealed-in platinum connections D,D. The plugs B,B, are held separated so as to leave a small gap E, about 1/50 inch wide, containing metallic powder or dust, which lies loosely in the gap.



FIGS. 8,460 and 8,461.—Oscillation transformer diagrams. ***In operation,*** the secondary coil sets up high pressure oscillations which break across the spark gap and surge through the transformer. The aerial and ground wire clips are then adjusted on the transformer helix and the wave length emitted will vary according to this adjustment.

FIG. 8,462.—Form of oscillating waves. ***The wave length,*** may be varied by increasing or decreasing the open circuit with the adjustable helix clips and by changing the closed circuit inductance in the same way. Also by altering the coupling space between the two. If they be too near together, two wave lengths will be emitted. This is desirable in emergency cases where help is needed.



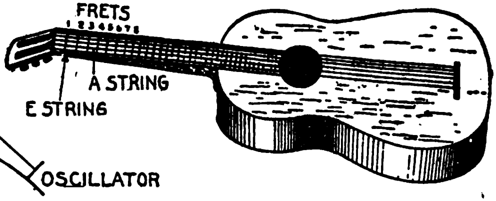


Fig. 8,463.—Electric wave reflected to the surface of the earth by strata of rarefied air.

Fig. 8,464.—Experiment with guitar to illustrate the fact that air waves, when set in motion by one string of a certain note will cause to vibrate another string tuned to the same note. In trying this experiment, to avoid troublesome stretching of strings, it will be advisable to keep about a half-tone below "concert pitch." When the A string is brought to such tension as to be in its proper relative tune with the E string, it will sound in unison with the latter, whenever the E is stopped by the finger pressing the E firmly against fret 5.

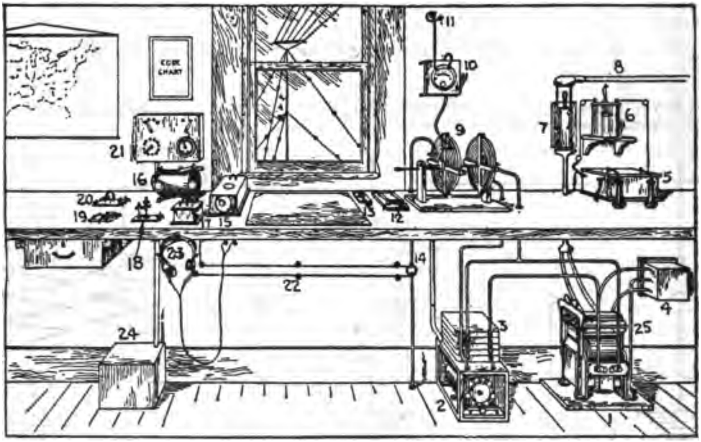
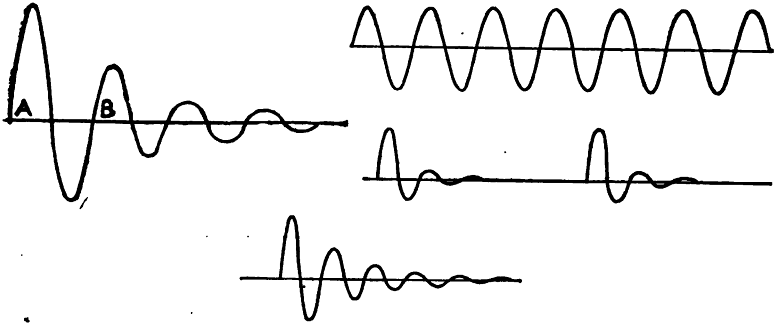


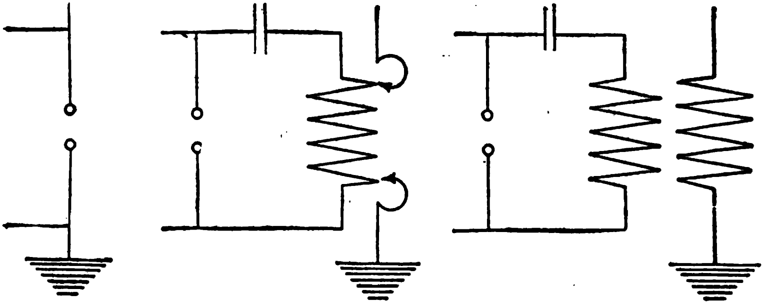
Fig. 8,465.—Amateur wireless station. 1, Thoradrson flexible transformer on slate base; 2, rotary spark gap in box with glass side and end; 3, Murdock moulded sending condenser units; 4, Clapp-Eastman kickback preventer; 5, Electro Importing Co.'s ½ kw. transformer; 6, Gernsback electrolytic interrupter; 7, 25 ampere D P S T power switch; 8, power supply, A. C. or D. C. (in conduit); 9, oscillation transformer; 10, Brandes hot wire ammeter; 11, Electrose lead-in insulator; 12, 25 ampere D P S T switch controlling current to transformer and rotary spark gap motor; 13, Marconi wireless key; 14, anchor gap in ground wire circuit; 15, Gernsback rotary variable condenser; 16, Clapp-Eastman navy type tuner; 17, fixed condenser; 18, silicon detector; 19, 10 ampere 8 P D T switch for detectors and receivers; 20, De Forest audion detector bulb; 21, battery switchboard for audion; 22, leads from anchor gap to receiving set; 23, head receiver set; 24, battery box containing battery cells for audion lamp and head telephone receivers; 25, kickback ground wire.

The capacity and inductance of the oscillator system are distributed along the entire length of the vertical wire in conformity with a law that makes the length of the electric waves approximately equal to four times the height of the antenna.

High Frequency Oscillations.—High frequency oscillating waves are best adapted for wireless telegraphy and are absolutely essential for wireless telephony.



Figs. 8,466 to 8,469.—Electric oscillations. Fig. 8,466 damped; fig. 8,467, undamped; fig. 8,468, strongly damped; fig. 8,469, feebly damped.



Figs. 8,470 to 8,472.—Oscillation circuits. Fig. 8,470, open oscillation circuit; fig. 8,471, conductively coupled oscillation circuit ;fig. 8,472 inductively coupled oscillation circuit.

With a generator having a frequency of 10,000 cycles per second and

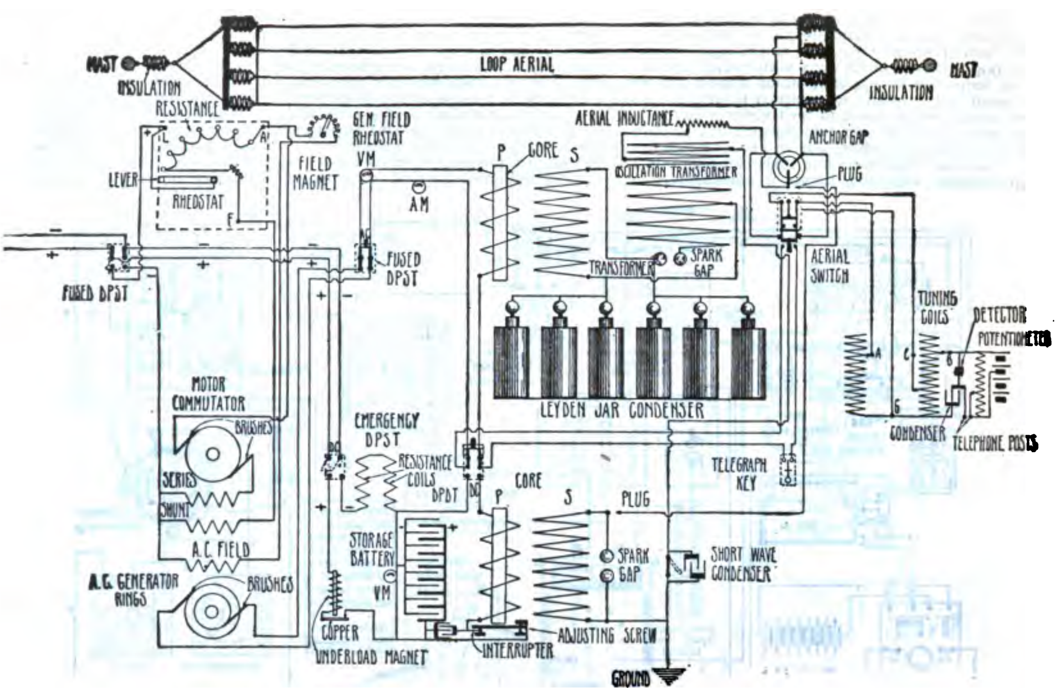


FIG. 8,473.—Diagram of Marconi system. Both transmitting and receiving equipments consist of two circuits each—open and closed. Antenna is the loop aerial type with an anchor gap and special triple blade switch. There is also an aerial inductance coil having a sliding contact by means of which the wave length of the open circuit may be altered. For efficient operation it is necessary that the closed and open circuits of each apparatus have the same time period or resonance. By throwing the antenna switch up the operator receives messages and by throwing it down messages are transmitted.

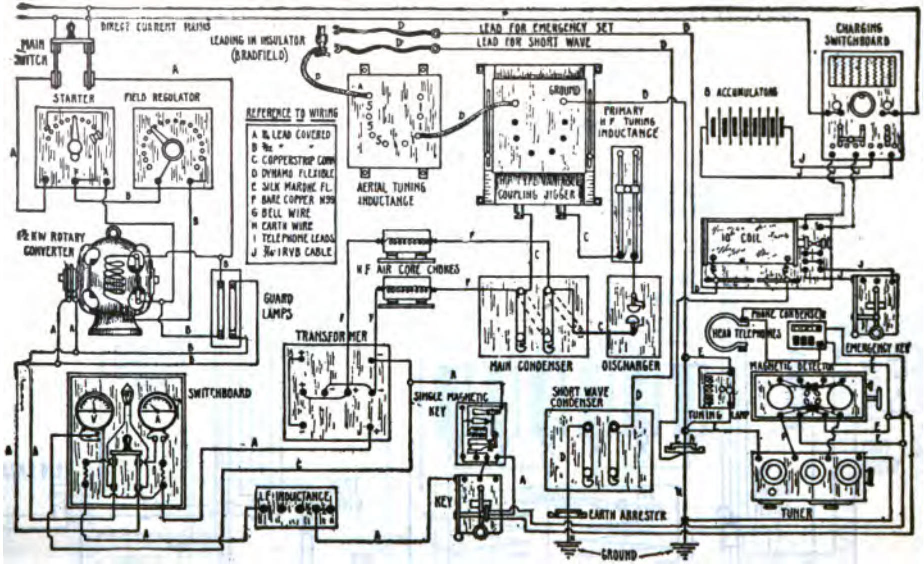


FIG. 8,474. — Marconi break-in system with parallel receiving tuner. For transmission a rotary converter supplies alternating current. *The direct current motor circuit* consists of a motor, starter and field regulator and connecting switches. The *low tension alternating current circuit* consists of primary of the transformer, special break-in key, ampere meter and impedence coil. The *high tension alternating current circuit* consists of secondary of the transformer, two air core choke coils, spark gap and condenser. The *primary high frequency circuit* consists of condenser, spark gap, primary of oscillation transformer and variable inductance all connected in series and forming a closed oscillation transformer circuit. The main condenser units are changed from parallel to series connections by throwing the double connecting blades according to the dotted lines. As shown they are in parallel for 600 meter wave length. As per dotted lines they are in series for 300 meter wave length. The *secondary high frequency circuit* consists of variable tuning inductance, secondary of oscillation transformer, antenna and ground circuit in which is interposed a special form of spark gap called an earth arrester. Across this the receiving circuit is connected. For *receiving* use is made of the magnetic detector in connection with its condensers which makes it a parallel tuner. Near this tuner is the emergency key which operates the *emergency set*. This consists of spark coil, key and storage battery. The storage battery is charged by manipulating the charging switchboard.

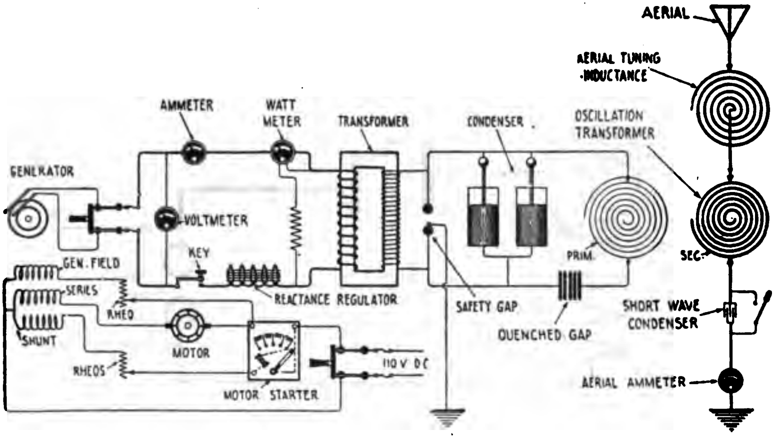


FIG. 8,475.—Fundamental circuit of modern transmitter. ***A simple explanation*** of the operation of this apparatus is given by Bucher as follows: *Direct current* at pressure of 110 volts, *enters the motor armature* through the *starting box* and sets it into rotation. The *alternator* in turn *generates alternating current* at pressures varying from 110 to 500 volts according to the design of the machine. When the *telegraph key* is *closed*, current *flows* from the *generator armature* through the *primary winding* of the *transformer* setting up magnetic lines of force which intersect or cut through the *secondary winding* inducing therein a current at pressures varying from 10,000 volts to 25,000 volts. Now the voltage and the frequency of the alternating current can be adjusted by the *generator field rheostat* and the *motor field rheostat*. ***For example:*** if resistance be added at the motor field rheostat, the motor will increase its speed and, accordingly, the frequency of the generator will be increased. This will also tend to increase the voltage of the generator. If resistance be added at the generator field rheostat, the voltage of the generator armature will be reduced and conversely if the resistance of this rheostat is decreased, the voltage of the generator will increase. The terminals of the *secondary winding* of the high voltage transformer are connected to the terminals of a *battery of condensers* where the energy is stored up temporarily in the form of *electrostatic lines* of force. When the limit of charge for each alternation of charging current has been reached, the condenser *will discharge across the spark gap through the primary winding* of the oscillation transformer, the discharge consisting of a number of *radio-frequency oscillations*. The frequency of the oscillations will decrease if *inductance* be *added* at the *primary winding*, or increase if the inductance be reduced. An increase or decrease of the capacity of the condenser affects the frequency in the same manner, *i. e.*, *a reduction of capacity will increase the frequency of the oscillations while an increase of capacity will reduce the frequency of the oscillations*. The *oscillations* flowing in the *closed circuit* are *transferred* to the *aerial circuit* through the oscillation transformer and a portion of the energy is radiated from the *antenna* in the form of *electromagnetic waves*. In a simple single wire aerial system, the wave length of this wave motion will be approximately 4.3 times the length of the oscillator. The length of the radiated wave in fact varies inversely as the frequency of the oscillation. The higher frequencies such as 500,000 and 1,000,000 cycles per second correspond to the shorter waves 600 meters and 300 meters respectively, while lower frequencies of oscillation from 30,000 to 100,000, for example; correspond to the longer waves from 10,000 meters down to 3,000 meters. If a *receiving aerial* be erected at a *distant station* and its natural time period of oscillations adjusted to the frequency of the oscillations flowing in the transmitter aerial, feeble currents will be induced in it which by appropriate devices may be heard in the *receiving telephone*. More clearly, the fluxes of the advancing wave will induce currents in the receiving aerial having substantially the frequency of the oscillations in the transmitting aerial. By appropriate devices within the station, these currents can be translated into the language of the sender.

connected to a quenched spark gap, a high frequency train of waves will be transmitted which will sound like music in a receptive device and can be heard over a greater distance than a low frequency wave because the human ear is more suceptible to high notes.

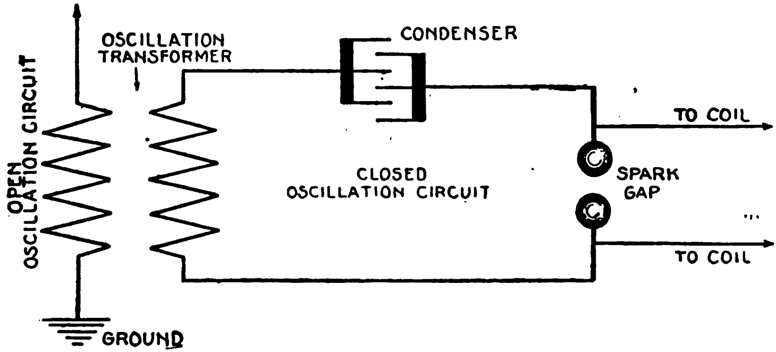


FIG. 8,476.—Tuned oscillation circuits. ***In order that*** a larger amount of energy may be delivered to the radiating aerial and to better sustain the oscillation set up in it, commercial installations have an open and a closed oscillation circuit coupled together, as here shown. The spark gap is placed in the closed circuit, as is an *adjustable condenser* formed of a Leyden jar battery and a *variable inductance coil.* Before the disruptive discharge takes place, the secondary of the inductance coil charges the battery of Leyden jars until the pressure is sufficient to produce a disruptive discharge. When the spark passes the oscillating current surges through the closed circuit. The large capacity of the Leyden jar battery permits a much larger quantity of energy to be utilized, the aerial and earth wires being connected to the closed circuit through the inductance coil as shown, the oscillations are impressed upon it when it radiates them into space as electric waves. The open circuit must be in tune with the closed circuit, so that the period of oscillation of each may be identical.

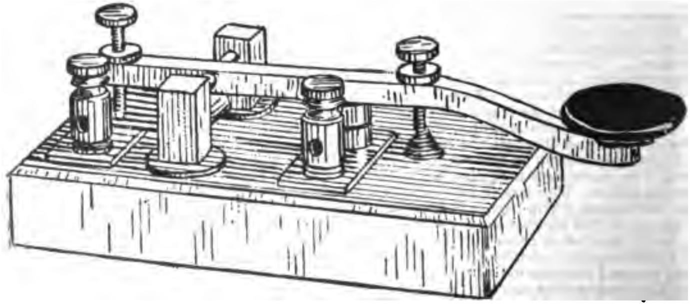


FIG. 8,477.—"Boston pattern" wireless key. ***As shown,*** the current from the lever is not conducted through the bearings but is carried by a heavy conductor direct to the binding post base. Current capacity of key, 10 to 50 amperes.

Methods of Generating Radio Frequency Current.—In order to distinguish alternating currents of the order of frequency employed in wireless telegraphy from those of a lower frequency corresponding to audible vibrations, the following arbitrary terms are in use:

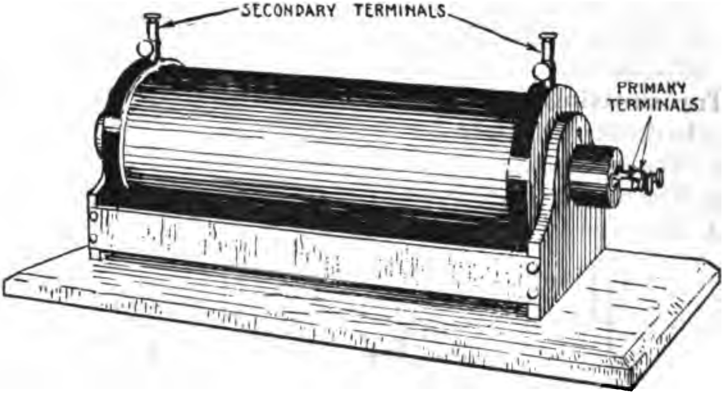


FIG. 8,478.—Open core transformer. The transformer primary coil winding is connected to the brushes of the generator by double pole single throw switch and the operation of the telegraph key. When the aerial switch handle is down and the transmitting key depressed, alternating current of about one hundred cycles per second (which is comparatively low frequency) surges back and forth through the primary coil, the secondary being wound in such ratio as to induce a pressure of between 15,000 and 50,000 volts. The current strength is one ampere.

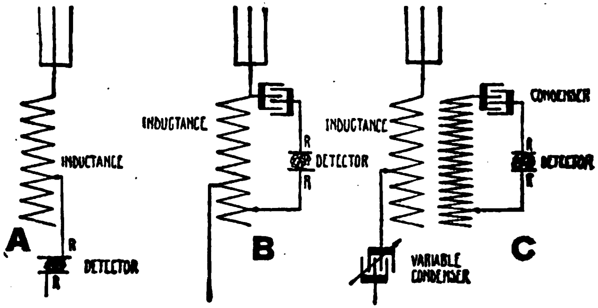
FIG. 8,479.—Aerial or antennæ switch used at Marconi stations. ***In operation,*** when thrown *down*, it is used for *sending* as it then breaks the antennæ and earth connections from the receiving tuner and completes the power circuit when the telegraph key is depressed. When thrown *up*, it connects the *receiving* tuner to the loop aerial and the ground to the G, post of the type D, tuner shown.

A.c. of frequency in excess of 10,000 cycles per second is termed a current of *radio-frequency* below 10,000 cycles per second, a current of *audio-frequency.*

A current of radio-frequency may consist of either continuous or discontinuous oscillations. *Continuous oscillations* are generated: 1, by the radio frequency alternator; 2, by some form of *d.c.* arc generator; 3, by a battery of vacuum tube bulb. *Discontinuous* oscillations are generated by the charge and discharge of a Leyden jar or battery of condensers. Electric waves set into motion by *a.c.* of constant amplitude are called continuous or undamped waves and those set into motion by discontinuous oscillations occurring in groups are called discontinuous waves. Electrical oscillations of decaying amplitude are also called damped oscillations. Damped oscillations are generated by the periodic charge and discharge of some form of condenser.

Transmitting Apparatus.—A wireless telegraph transmitter may be divided into three distinct parts.

1. The low voltage generating circuit.
2. The high voltage circuit.
3. The oscillation circuit.



FIGS. 8,480 to 8,482.—Three receiving circuits. Upon the principles of these three receiving circuits are based all of the most complicated circuits that can be devised. The open circuit is shown in fig. 8,480, the closed circuit in fig. 8 481 and the inductively coupled circuit in fig. 8,482.

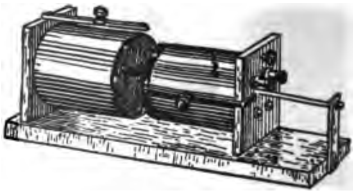
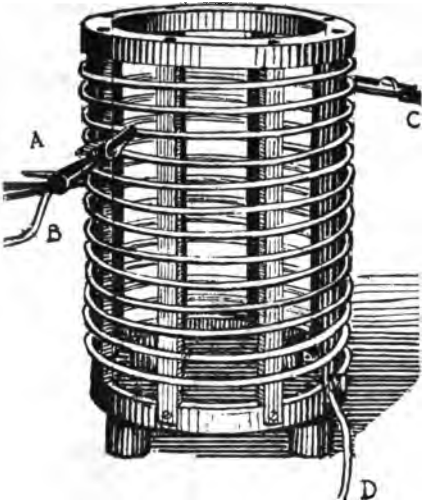


FIG. 8,483.—Loose couple receiving transformer with variable contacts.

FIG. 8,484.—Loose couple receiving transformer with variable slider. While this type of receiving tuner has the closest inductance variableness possible with any transformer, it has the disadvantage that the secondary coil cannot be inserted very far into the primary.



The low voltage current includes: 1, a source of current, 2, a regulating rheostat, 3, a telegraph key, and 4, primary winding of a transformer.

The high tension circuit consists of the secondary of the transformer and the spark gap, with or without the choke coils. If the latter be used they should consist of 8 or 10 turns of heavy wire wound in flat or pancake form. The latest forms of spark gap are those having revolving elements.

The oscillation circuits comprise 1, *open* circuit, and 2, *closed* circuits, the latter being

FIG. 8,485.—Tuning coil inductance, generally known as a "helix." This is composed of heavy wire wound on a dry wooden frame in the form of a spiral. By attaching adjustable clips to any part of the winding the inductance is changed.

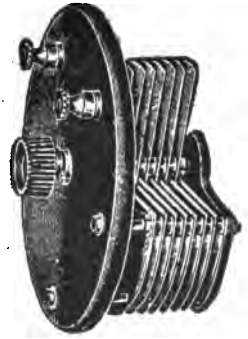


FIG. 8,486.—Mascot rotary variable condenser, the knurled hand rubber knob has an arrow head pointer to register on a celluloid scale.

FIG. 8,487.—Crystal detector. When the hard rubber knob at the top of the detector stand is turned, the needle point, which presses into the crystal is moved up or down. This allows of a variable adjustment which may be tight or loose, as desired. The spring shown helps to push the crystal up against the needle point.

made up of a spark gap, condensers, and ***tuning*** or inductance coil, usually called a *helix*.

The Receiving Apparatus.—This includes the detector and the detector circuits.

There are many ways of connecting the various parts of apparatus used for detecting wireless messages, but, reduced to their simplest forms, they are all derived from three distinct circuits. Figs. 8,480 to 8,482 show a diagram of each of these elementary circuits.

FIG. 8,488.—Peroxide of lead detector. A flat piece of peroxide of lead is clamped between a platinum surface and a flat piece of lead. Binding posts connect to these two electrodes and are marked + and —. The positive pole of a battery is connected to the platinum electrode at the binding post marked +.

FIG. 8,489.—Electrolytic detector; most sensitive except the audion and valve types. ***It consists of*** a carbon cup connected to a binding post and an adjustable standard which holds a very small hair-like platinum wire which dips into a 20% diluted solution of nitric acid. The high resistance of this acid detector is somewhat reduced by incoming wireless waves and when a telephone is shunted around it, the varying resistance is sufficient to vibrate the diaphragm but not strong enough to work a telegraph relay. When a potentiometer and battery are connected with the electrolytic detector and telephone, the sensitiveness is increased.

In fig. 4,880 no condenser should be used unless it be of high capacity. The detector must be closely adjusted and very sensitive to give the best results. The receiver is shunted around the detector.

In fig. 4,881 a low capacity condenser must be used in series with the detector, which may either be fixed or variable. The detector should also be very closely adjusted in this case to give the best results.

Vacuum Tube Detectors.—The term *vacuum tube* has become quite general, but other names such as *audion*, *vacuum valve*, *electron relay*, *Fleming valve*, *etc.*, are used for vacuum tube detection, some of them being trade names given by manufacturers to distinguish their own product.

The most important uses of vacuum tubes are: detection and rectification, amplification of signals, and generation of oscillations. A vacuum tube is sometimes called an ***electron relay***, because that is exactly what it is, that is, *it relays electrons from the filament to the plate.** The electrons thus relayed act as carriers of electricity between the filament and the plate which are separated in a vacuum. Fig. 8,490 shows what takes place

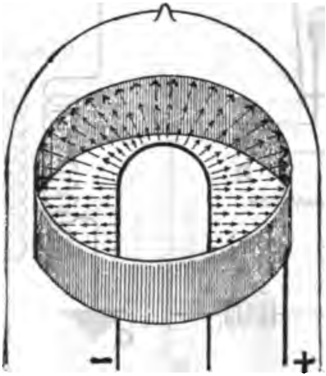


FIG. 8,490.—Fleming two element vacuum tube; view of end showing elements. ***In operation,*** as soon as the filament in any incandescent lamp is heated to a red or white heat, the filament immediately begins to emit or throw out electrons in a very rapid manner and in all directions. In the ordinary lamp, these electrons simply hit the sides of the glass bulb. If, however, a small metal band be placed around either the outside or the inside of the glass bulb and if a dry battery be connected between the filament and plate so that the negative pole of the battery is connected to the negative side of the filament and the positive pole to this metal plate, these negative electrons will be *greatly attracted to the plate* because it is of a positive nature. If the plate be made negative instead, the electrons will be repelled and will try to find other landing places.

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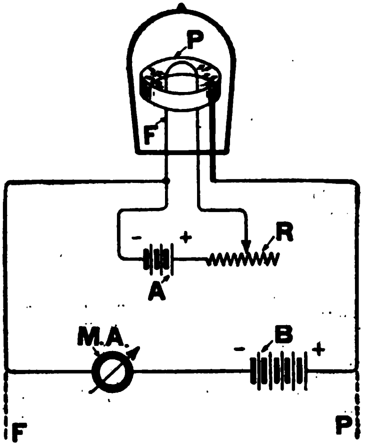
*NOTE.—An electron is the *smallest* particle of matter known to science and it is supposed to carry the smallest possible charge of *negative* electricity on its travel from one body to another. In a vacuum tube electrons act as carriers of electricity between the filament and the plate, which are separated in a vacuum.

within the inside of a vacuum tube of the Fleming two element type.*

Fleming Valve as a Detector.—Since in order to receive radio waves it is necessary to first rectify their *a.c.* nature with a pulsating *d.c.* which will operate the telephone receivers and cause a sound to be heard, the Fleming valve may be used as a detector on account of the rectifying action explained in fig. 8,492. Fig. 8,491 shows this two element vacuum tube being used as a detector of radio oscillations. Although this circuit is a very elementary one it will operate fairly well. In some cases an additional battery is used in the plate circuit with better results.



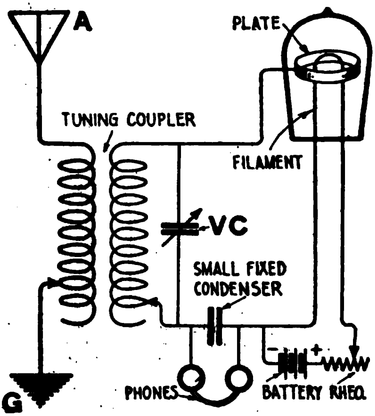


FIG. 8,491.—Simple form of Fleming two element valve and application of direct current. F, is a filament heated to incandescence by the battery A, the current being controlled by the rheostat R. If a battery B, be connected as shown in series with a milli-ammeter M. A. it will indicate that a minute current is capable of passing through the space separating the filament and the plate in one direction only, that is for the plate to the filament. If the polarity of the battery be reversed no current will pass through the system. Accordingly the valve is a *rectifier*. If alternating current be substituted for battery B, corresponding halves of each cycle of the current will pass while the other halves will not pass. This rectifying action of the valve is utilized to rectify the incoming oscillations of a radiotelegraph receiving system.

FIG. 8,492.—Fleming valve used as a detector in a radio receiver and elementary circuit. The action of this circuit is a rectifying one, the incoming radio oscillations which represent the signals are rectified where but one-half of their alternations (the positive side) is permitted to pass through to the filament circuit and thence to the phones.

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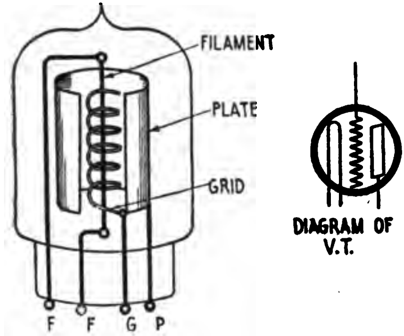
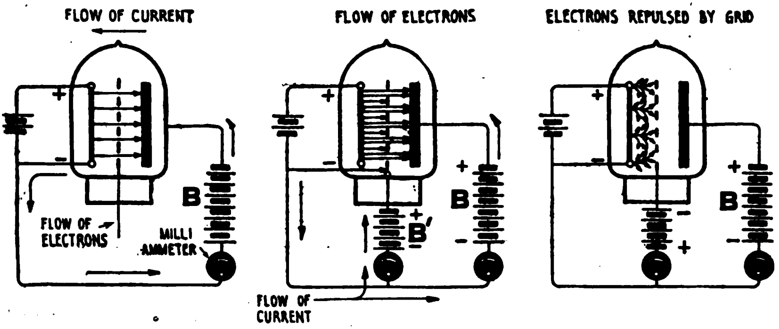
*NOTE.—The term *two element* means simply a filament and a plate. The three element vacuum tube is the one employing filament, plate and gird.



Three Element Vacuum Tube.—De Forest conceived the idea of introducing an auxiliary electrode in the ordinary valve of the Fleming type. This electrode placed between the filament and the plate is known as the grid and is composed of a little solenoid surrounding the filament as shown in fig. 8,493. It is sometimes made in the shape of a ladder placed on both sides of the filament as in some transmitting tubes, but its purpose is the same in all cases. The operation of the three element vacuum tube is explained in figs. 8,494 to 8,496.

Fig. 8,493.—View of three element vacuum tube showing parts and diagram of same.



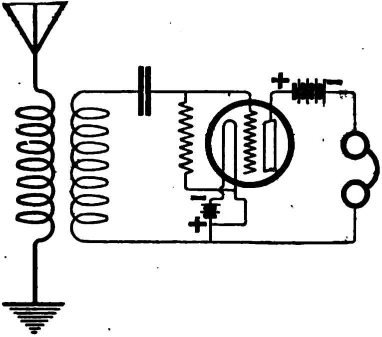
Figs. 8,494 to 8,496.—Diagrams illustrating the operation of the three element vacuum tube. As before explained a plate filament circuit is secured by the electrons traveling *from the filament to the plate*, since they are attracted by the plate *positively* charged, although the current from the battery B, flows in this circuit *from the plate* to the filament. The electrons thus act as a conductor. If the gird be connected as in fig. 8,495, including in this circuit a battery and a milli-ammeter, a current will flow in the gird circuit because a certain number of electrons are stopped by the positively charged grid which allows the current of the battery B' to flow in the grid filament circuit. Now if the polarity of the grid be changed as in fig. 8,496, the flow of electrons from the filament, when the grid is negative is repulsed, for in this case the electrons are negatively charged. Accordingly, the current from the plate, having no path, is suddenly stopped. Evidently then the grid *acts as an automatic interrupter*.

By properly connecting a three element vacuum tube in a receiving circuit, it may be used as a detector, its operation as a detector being shown in fig. 8,494.

Amplifier.—A so-called amplifier is simply a type of trans-

former the object of which is to strengthen the radio signals so as to make possible the reception of signals from very distant stations, which otherwise would be inaudible. The method of connecting an amplifier in the circuit is shown in fig. 8,499.

FIG. 8,497.—Professional type of audion detector. It is provided with two super-sensitive audion bulbs, high voltage local battery, potentiometer switch graduated to show voltage at any point, switch to change from one bulb to the other, and rheostat to change brilliancy of filament. This detector is used by the U. S. Army and Navy, and is furnished in oak and hard rubber; size, 9¼ by 9 by 7 inches. Three dry cells to light filament are necessary.



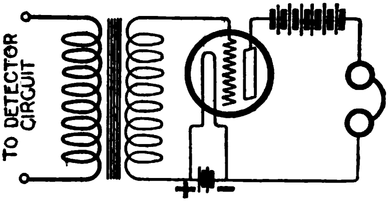
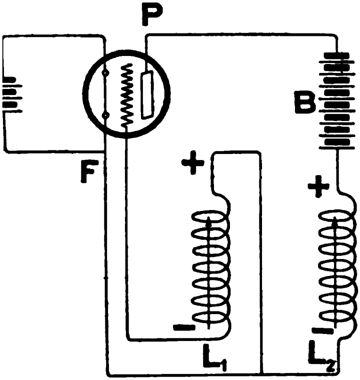


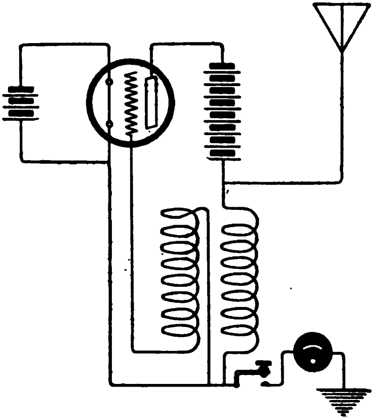
FIG. 8,498.—The three element vacuum tube used as a detector and diagram of connections. In order to make the tube operate at all times as a rectifier of oscillations a *grid condenser* and *grid leak* must be placed in the grid circuit. Only alternating current can pass through the condenser. When the grid is positive, electrons are drawn over it, but when it is negative, the electrons are repelled, thus for each succeeding half oscillation, electrons are drawn to the grid, placing a charge in the grid condenser which is negative on the grid side. Since an increasing negative charge on the grid acts to reduce the plate to filament current, then, while a group of oscillations are rectified, the telephone current is reduced, but the gird leak operates to slowly discharge the condenser and allow the grid and plate to come back to their normal state. These variations which occur at each wave train causes the diaphragm of the telephone receiver to vibrate.

FIG. 8,499.—Diagram of single stage amplifier and connections. ***In operation,*** when the rectified current from the detector circuit is applied on the primary of the transformer a corresponding voltage is induced in the secondary. This voltage charges the pressure of the grid and this opens and closes the plate filament circuit. These impulses in the plate filament circuit, make the telephone diaphragm vibrate with a great amplitude for the current interrupted is of greater intensity owing to the higher voltage of the battery used in the amplifier. If, instead of the telephone, the primary of another amplifier be connected in the plate circuit, the same process will be reproduced as a *second stage* of amplification, where the secondary of this transformer is connected to the grid of the second vacuum tube, but with a still much greater intensity.

y repeating the process several times (two and three stage nplification), communication may be extended to stations at ill more remote points.

Regenerative Amplification.—It has been shown by Armrong that amplification similar to that obtained with several ages may be secured with a single tube. Instead of feeding ıe voltage of the secondary of a transformer into the grid rcuit of a second tube used as amplifier, it is fed back into the



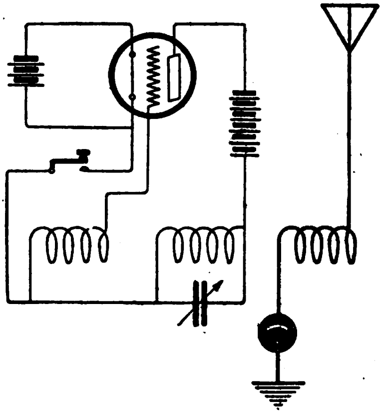


IG. 8,500.—Typical oscillating circuit in which sustained oscillations are produced by a vacuum tube. *In operation,* the battery B, current flows suddenly in the circuit PFL_2, when the filament is lit up, but this current flowing through coil L_2, induces a current in coil L_1, which is connected to the filament and the grid. This induced current flows as shown by the arrow, thus impressing a negative pressure on the grid which at this negative pressure stops the electrons flowing from the filament to the plate. The current from the battery B, travelling from the plate to the filament is stopped because the electrons cease to flow. At this point which corresponds to a break in the plate circuit, a current flowing in the other direction being induced in the grid coil L_1, the grid is made positive and *helps* the electrons to reach the plate and the same phenomenon is reproduced, keeping in the circuit oscillations of constant amplitude

IG. 8,501.—Elementary circuit of a C. W. transmitter illustrating its principle. If a capacity be connected to the circuit in which sustained oscillations are produced, a current will flow in this circuit. An areial and ground may therefore be used as a capacity and undamped signals sent by connecting or cutting out this capacity by means of a key as shown. *In practice,* to avoid the production of unused oscillatory current during the time no signals are sent, the key is placed at such a point in the circuit that the vacuum tube oscillates only when the circuit is closed. In order to keep the wave length constant, a condenser replaces the aerial, the latter being only coupled to the oscillatory circuit.

grid circuit of the detector tube so as to increase the voltage acting upon the grid. This results in an increased amplitude of the plate current alternations, which likewise being fed back into the grid circuit increases the voltage operating upon the grid.

One form of the so called feed back circuit for rectifying and amplifying damped oscillations is shown in fig. 8,503.



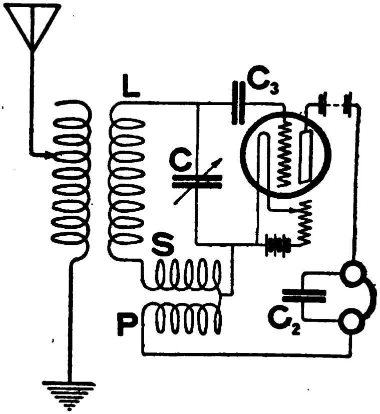


Fig. 8,502.—Practical circuit of an undamped wave transmitter. The aerial is coupled to the oscillating circuit.

Fig. 8,503.—Typical Armstrong feed back or "regenerative" circuit. ***The operation*** of the circuit used as a receiving device, is the same as that of a condenser in the grid lead. The condenser C_1, is merely to provide a path of low impedance across the phones for the high frequency oscillations. The coils P and S, constitute the feed back by means of which the oscillations in the tuned circuit are reinforced. The mutual inductance between S and P, must be of the proper sign so that the back pressure aids the oscillations instead of opposing them. If the coupling between coils P and S, be continuously increased and the values of L,S and C, and the resistance of this circuit be suitable within certain limits, the pressure impressed back by the coil P, into the oscillatory circuit at any instant will become greater than that required to just sustain the oscillations in the circuit. In this case any oscillation, however small in the circuit LSC, will be continuously built up in amplitude until a limit determined by the characteristics of the tube and circuit is reached. In other words, the tube self-generates *a.c.* of a frequency determined by the natural frequency of the oscillatory circuit, permitting the reception of undamped waves by the best method.

Codes.—There were formerly two codes used by commercial companies: the Morse code and the Continental code. The former is seldom used today and the latter has been made universal and called by the radio convention the International Morse. It is sometimes called the Continental Morse. This International Morse code differs from the American Morse; the Naval code was used officially by the U. S. Navy till Nov. 16, 1912.

Whatever be the speed at which signals are sent, the following rules must be remembered and strictly adhered to:

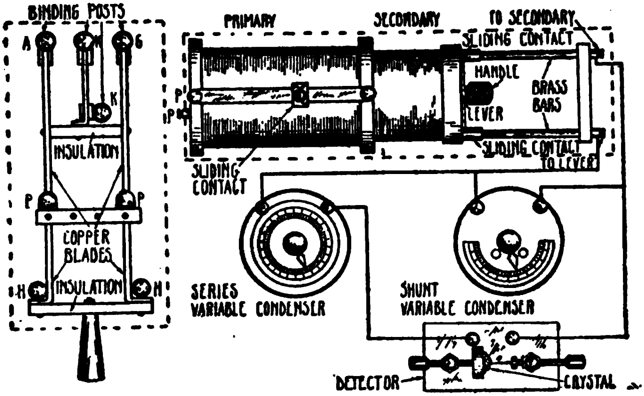


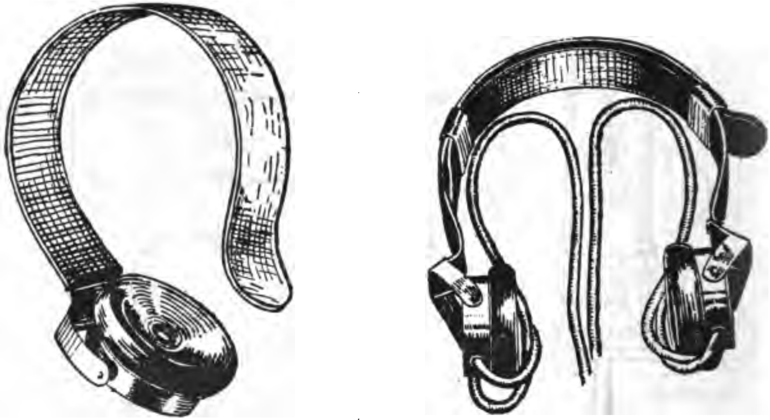
FIG. 8,504.—Diagram showing inductively coupled receiving tuner and connections. A variable condenser is connected in series with the detector and secondary coil and another variable condenser connected in parallel with this receiving circuit. The primary binding posts marked P,P, are connected to the upper posts of the switch which are marked the same. A variable capacity is, however, connected in shunt around the secondary inductance. This gives most accurate tuning by establishing absolute syntony or resonance. Capacity and inductance are directly opposite in their effects upon either a sending or receiving circuit when the capacity and inductance are connected in parallel. If the value of one be decreased, the value of the other is increased because the oscillating pressure does not always keep in step with the current. Where there is too much inductance in the circuit, the current will lag behind the voltage, and where there is too much capacity, the pressure will lag behind the impulses of the current. Perfect resonance in receiving is therefore accomplished by varying both the inductance and the capacity.

1. A dash is equal in length to three dots.
2. A space between two elements in a letter is equal in length to one dot.
3. The space between letters in a word is equal in length to a dash.
4. The space between words in a sentence is equal in length to five dots.

Radio Telephony.—Various experiments have been made from time to time to make wireless telephony a practical success, and for distances up to several thousand miles it has been successful.

In many respects the wireless telephone resembles the wireless telegraph, but the actual operation is quite different.

With wireless telegraphy the key is depressed and a cycle of transformation produced whereby a wave motion is set up in the ether, but this wave motion is inadequate for wireless telephone transmission owing to its periodic damping character. The human voice, or sound waves produced thereby, range from 5,000 to 10,000 variations a second, and if it be attempted to impress these on a damped oscillation wave, the periodic character would destroy all characteristics of speech.



FIGS. 8,505 and 8,506.—Single and double wireless receivers. These are not necessarily different from any head telephone or watch case receiver except that they are constructed so as to be most sensitive. The thinnest ferrotype diaphragms are used and the smallest copper wire. Where two are used they are connected in parallel and their cases held by a leather head band.

Hence, it is necessary to produce a sine wave, or one that will remain constant and undamped, for wireless telephony, on which the voice can be impressed, the break being sufficiently rapid to keep synchronous with the vibrations of the human voice.

Three practical methods have been used for wireless telephony by the use of:

1. Arcs

Obsolete.

2. High frequency alternation

Extensively used, being the most practical and adopted for almost all new powerful stations.

3. Vacuum tubes

The speech is generally impressed upon the grid and the variations of pressure cause the plate current to vary accordingly, reproducing the variations of the speech in the carrier wave. A simple radio telephone using one vacuum tube is shown in fig. 8,507.

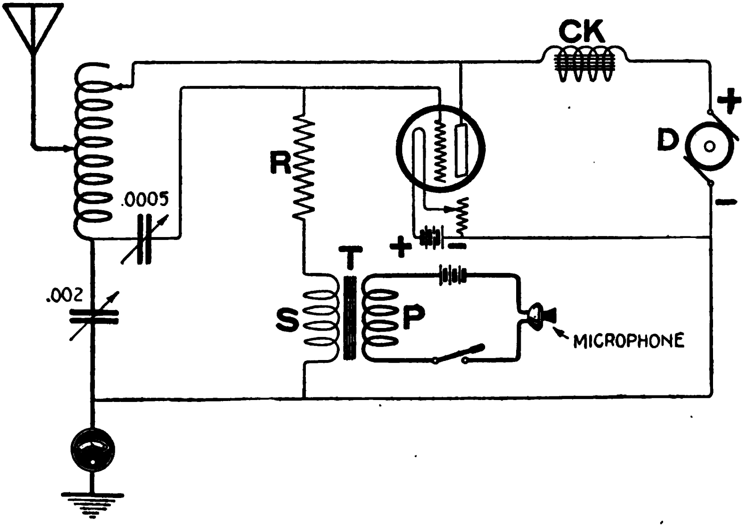
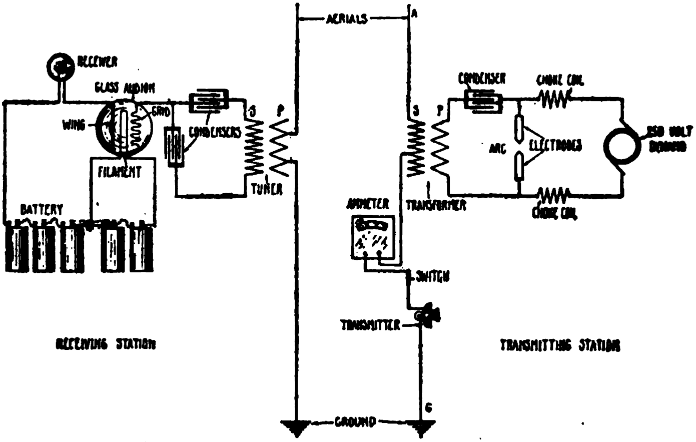
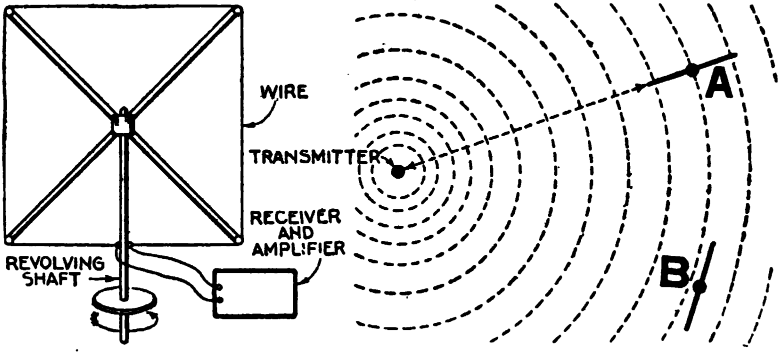


FIG. 8,507—Simple radio telephone using one vacuum tube. R, carbon, variable resistance of about 20,000 ohms; T, transformer; CK, choke coil; D, source of high pressure direct current. The tube is used as an oscillator and the variations of current caused by the voice in the microphone circuit are applied on the grid through a transformer amplifying the variations of pressure. *In operation*, the pressure of the grid being varied, causes the plate current to vary accordingly, thus producing phone variations in the amplitude of the oscillations produced and radiated by the aerial.

Radio Direction Finder.—The operation of this instrument is based on the fact that *when a closed circuit is used as an aerial,*



Figs. 8,508 and 8,509.—Diagrams showing receiving and transmitting wireless telephone stations. The dynamo supplies direct current to the transmitting arc which produces high frequency oscillations in the transformer. A telephone transmitter and hot wire ammeter are connected between the ground and the transformer secondary coil. By talking into the telephone transmitter undamped oscillating waves are transmitted and recorded in the audion receiver. By placing the telephone receiver to the ear the sounds produced in the telephone transmitter can be heard.



Figs. 8,510 and 8,511.—Radio direction finder and plan showing operation. In fig. 8,511 the loops at position A, receive maximum energy for minimum lines of force to pass through, while at position B, no current is induced, since no lines of force can pass through.

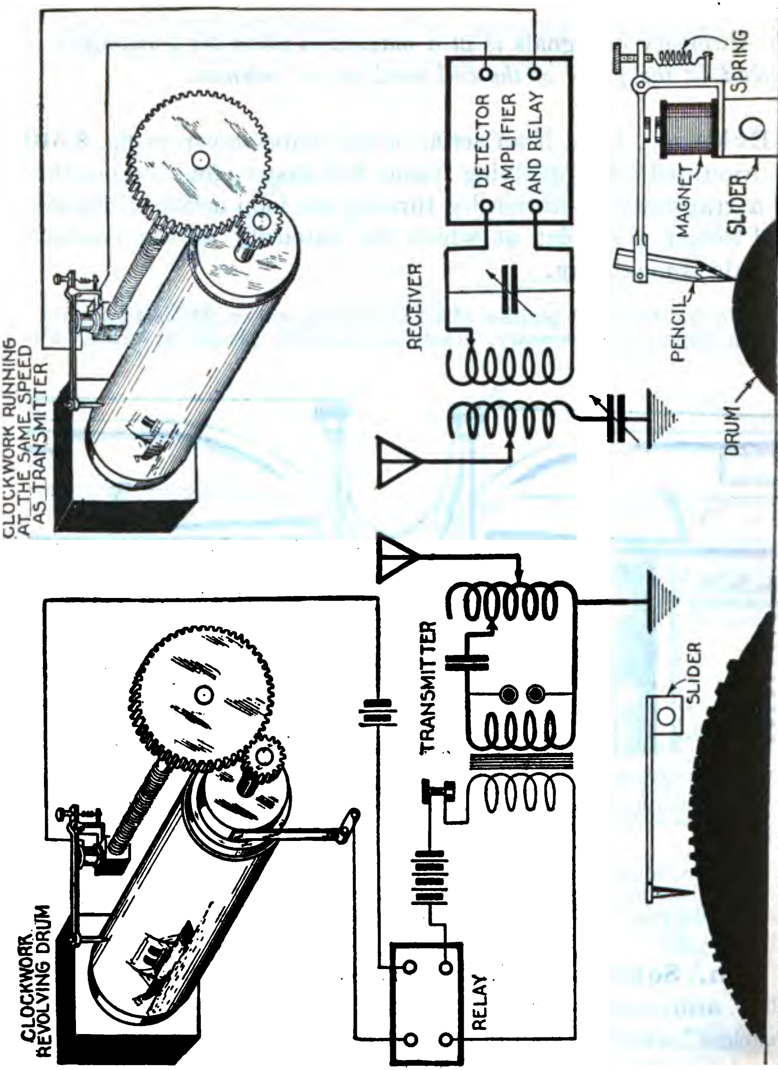
the intensity of signals *is at a maximum when the transmitter is placed in the plane of the coil used as an antenna.*

Evidently, then, if an aerial of the shape shown in fig. 8,510 be mounted on a revolving frame, it is easy to find the position of a transmitting station by turning the loop aerial on its axis and noting the point at which the intensity of the received signals is maximum.

To find the exact position of a transmitting station, at least two direction finders are necessary. They are generally placed far apart. For instance, when a ship sends a message, each of the compass stations take a bearing and send it by radio to the ship. It is then possible to determine the exact location of the ship by drawing two lines on the map.

FIG. 8,512.—Train dispatching by wireless, showing the way the aerial wires are strung from car to car, which may easily be disconnected. The ground connection was a problem solved by connecting it to the frame of the trucks and sending the ground current to the rails through the wheels.

Gen. Squier's "Wired Wireless."—Gen. Squier of the U. S. army some years ago gave to the public a system of "wired wireless" which he had developed whereby it is possible to telegraph or telephone on a single wire for any distance.



Figs. 8,513 to 8,516.—Method of sending pictures and writing by radio, as described in the accompanying text.

The wire is like a single wire aerial connected to a high frequency generator. Since high frequency current travels on the surface of a wire there is practically no resistance to the circuit and telephone conversation may be carried on over an unlimited distance providing a single wire connect the two stations.

It is also possible to use a bare wire instead of a highly insulated cable through the water, using different wave lengths, several conversations may be transmitted on the same wire without interference.

Although this has been developed into a duplex telephone system, it is hardly adaptable to the commercial telephone system of to-day and so has not been used by the public. It offers a field for new inventions and improvements in the electrical industry.

Pictures and Writing by Radio.—A picture to be sent by radio is first photographed through a screen, and covered with an insulating film which fills only the space between each little dot of the halftone reproduction. This reproduction is then fixed on a drum revolving slowly and in synchronism with a similar one at the receiving station.

A sharp pointer in contact with the reproduction moves slowly along the drum while it revolves as shown in figs. 8,513 to 8,516, thus covering the whole surface of the photograph and closing the circuit of the transmitter when the stylus comes in contact with a spot which is not insulated. At the receiving station the same apparatus is used, but a pencil is fixed on the arm moving along the drum which is there covered with a white paper. Evidently for each dot received, the pencil makes a dot on the white paper, thus reproducing the picture.

CHAPTER 140

Motion Pictures

The property of vision upon which moving picture projection is based is called the *persistence of vision*, or "optical inertia." It is that property of the eye by which vision remains or ***persists*** *for a short interval after the thing viewed has vanished*.

Owing to the persistance of vision, when two views are seen with an interval of not more than one fiftieth of a second between the two, the eye blends the two and accordingly does not appreciate the interval of darkness which has occurred between the two, as is demonstrated in moving picture projection.

Motion Picture Machines.—The term motion picture machine is the proper name of the apparatus used in projecting motion picture film upon a screen; the use of such expressions as projector, graphoscope, etc., should be avoided.

The function of a moving picture machine, as stated, is to project motion pictures upon a screen, in distinction from a motion picture camera used for motion picture photography. Some of the "coined expressions" are both ill advisedly and erroneously used.

A motion picture machine may be said to consist of:

1. An optical system, comprising

   a. Source of light;
   b. Lens {condenser; objective.

2. Intermittent film feed system, comprising

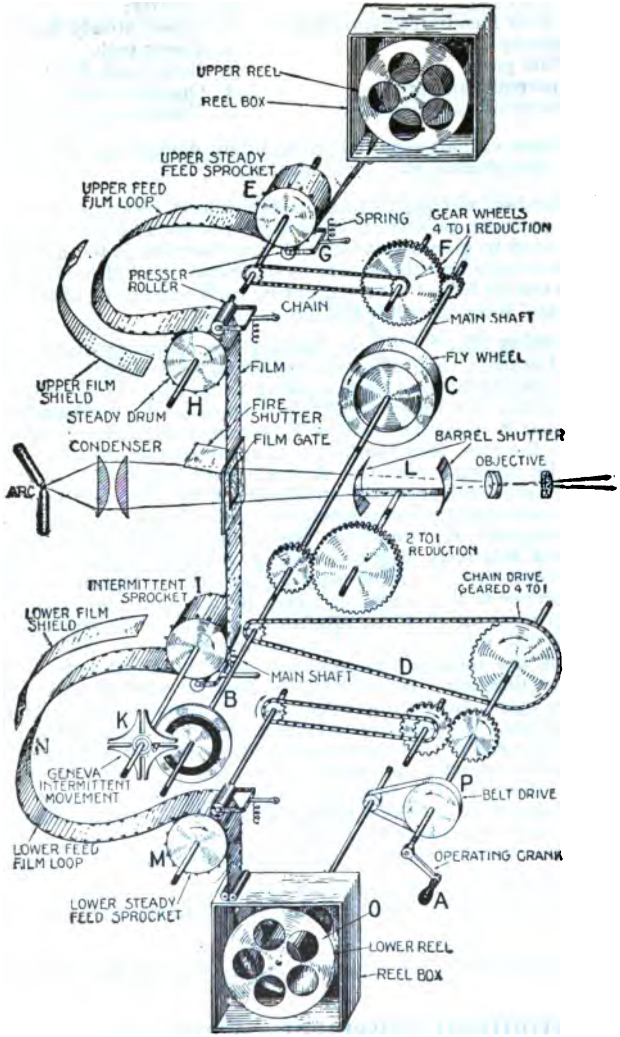


Fig. 8,517.—Elementary moving picture machine without case, showing essential parts.

a. Upper reel;
b. Upper steady feed sprocket;
c. Steady drum;
d. Film gate;
e. Intermittent sprocket;
f. Intermittent movement;
g. Shutter;
h. Lower steady feed sprocket;
i. Lower reel;
j. Lower reel drive;
k. Operative crank and drive;
l. Numerous presser rollers.

Besides these various essential parts, safety devices such as, fire shutter, fire valves, film shields, etc., are provided.

The elementary moving picture machine shown in fig. 8,517 is so drawn that every part can be seen; it does not represent any particular machine but is intended to give a clear idea of how the film is fed across the film gate intermittently and the synchronous operation of the shutter whereby the light is cut off from the screen during each movement of the film, with alternate "on" intervals while the film is at rest.

In operation (fig. 8,517), by turning the operating crank A, counter clockwise, the main shaft B, is driven through the 4 to 1 reduction chain drive D, a steady turning motion being caused by the fly wheel C, this in turn operates the upper steady feed sprocket E, through the 4 to 1 reduction gear F, thus the teeth of E, sprocket which mesh with the perforations in the film, feed the film at a constant rate, the film being held against E, by pressure roller G. A film loop or length of loose film is thus maintained between E, and the steady drum H. The film is fed past the film gate intermittently by the intermittent sprocket I, operated by the Geneva movement K, the latter producing a quick quarter turn of I, followed by a relatively long rest during which the main shaft B, makes one revolution. The barrel shutter L, by a 2 to 1 gear with the main shaft and proper timing, operates to cut off the light rays from the screen during each movement of the intermittent sprocket I, and to admit the light during the intervals that I, remains stationary. The synchronous operation of the intermittent sprocket and the shutter is very clearly shown in the diagram. A lower steady feed sprocket M, which operates at the same speed as the upper sprocket E, maintains a lower feed film loop N, and feeds the film to the lower reel O. Because of the increasing diameter of the roll of film due to winding the film on reel O, the velocity of rotation of O, must be allowed to vary; this is accomplished by means of the belt drive P, the belt permitting slippage below the maximum speed. *It should be carefully noted* that the total revolutions made by each of the three sprockets E, I, and M, is the same, the only difference being that *the motion of* E, *and* M, *is constant while that of* I, *is intermittent.*

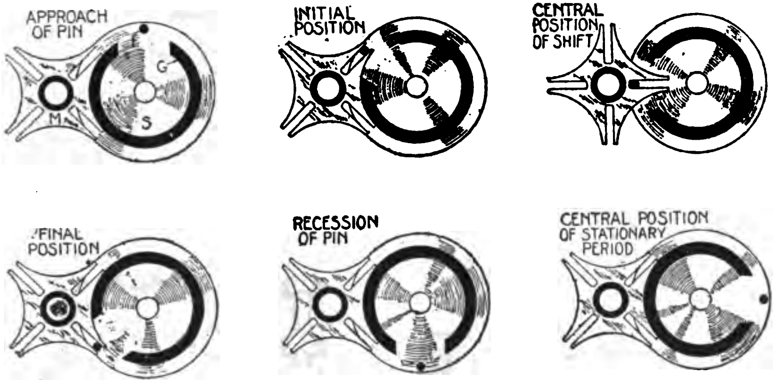
The object of the upper and lower feed loops is to lessen the inertia of the film by reducing the length of film subject to the sudden intermittent motion.

The film gate guides the film so as to prevent any lateral motion.

The Intermittent Movement.—Various devices have been introduced for producing the intermittent movement necessary in projecting motion pictures.

The movement consists essentially of an intermittent sprocket and intermittent gear.

The sprocket is a cylinder with teeth at each end, or for very light construction, it may consist of two hubs provided with teeth and properly spaced on a shaft to take the film. The teeth mesh with perforations of the film and thus secure a positive movement.

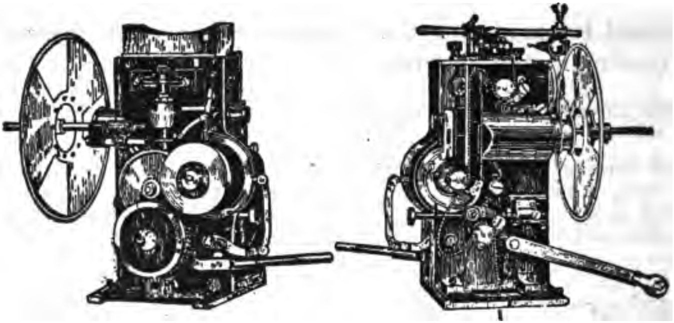


Figs. 8,518 to 8,523.—Operation of Geneva movement shown progressively. ***It consists of*** **a maltese cross M, and a disc S, provided with a pin F, and circular guide G.** ***In operation,*** **the pin disc S, is in continuous motion and the pin is so located that it enters one slot of the cross M and carries it along with it, thus causing one-quarter revolution. The circular guide G, is cut away sufficiently to allow the cross to make a quarter revolution, but when it registers with the cross it holds the latter securely until the pin rotates around to the next slot.**

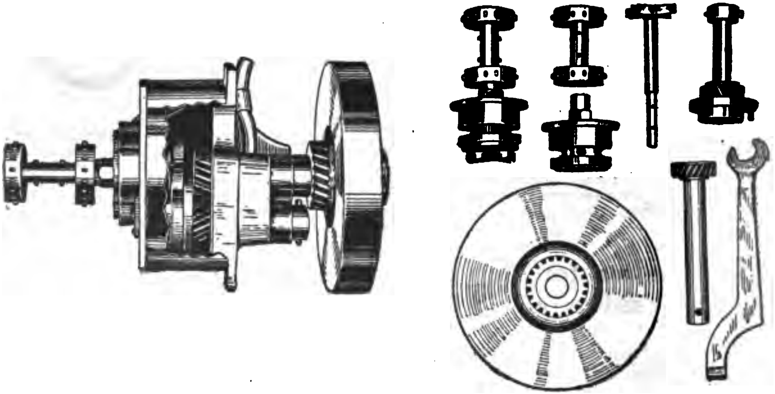
Illumination for Picture Projection.—Both gas and electricity are used to produce illumination for motion picture projection.

The electric arc is universally employed wherever electric current is available, but in many rural districts where electricity cannot be obtained, gas is used and gives satisfactory results.

The Electric Arc.—The only modification of the ordinary arc



Figs. 8,524 and 8,525.—Simplex motion picture machine. Fig. 8,524 shows the right side with film covers and upper magazine fire valve removed from the top. The valve consists of one large steel roller and two smaller ones which are set at an angle of 45 degrees. They bear against the film top and bottom, and protect the reel from fire. Fig. 8,525 shows also the revolving shutter and shutter mechanism. The three wing shutter shown is used with direct current, but on A. C. circuits of 60 cycles or less, a two wing shutter is recommended as it does not intercept the light periods in step with the alternation of the arc. A three wing shutter used with alternating current is liable to get into synchronism with the alterations of the arc and cause a wavy effect in the light similar to a bad flicker. The shutter may be set during operation by turning the knurled knob located alongside the framing handle, thus avoiding ghosts or white streaks. Fig. 8,525 shows clearly the path of the film through the machine.



Figs. 8,526 to 8,534.—Construction details of an intermittent sprocket and intermittent movement. Fig. 8,526, intermittent sprocket and intermittent movement with case broken to show interior; figs. 8,526 to 8,534. parts. The intermittent movement is of the Geneva type arranged to run in oil. The case is in two pieces, consisting of box and screw cover, as shown in fig. 8,526. "Framing" of the film is accomplished by advancing or retarding the intermittent movement by a device for turning the intermittent box forward or backward. The revolving shutter synchronizes automatically by a cam system.

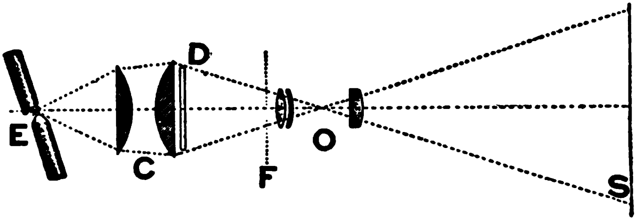
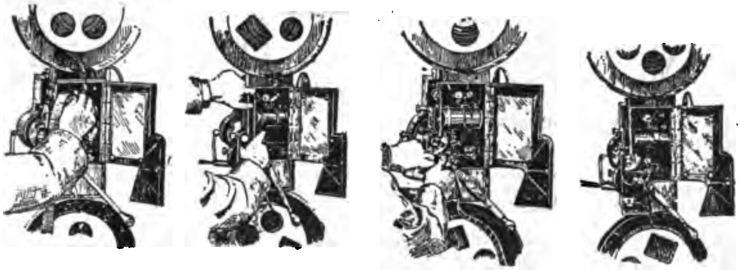
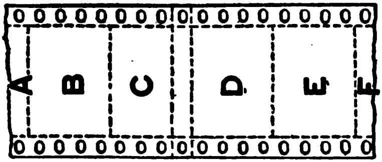


FIG. 8,535.—**Diagram showing various lenses of a motion picture machine, illustrating the principle of optical projection. E, is the arc light; C, condenser; D, slide; F, film; O, objective; S, screen.**



FIGS. 8,536 to 8,539.—***Threading. To thread,*** a typical motion picture machine, form upper loop (fig. 8,536); thread film through film loop (fig. 8,537); form lower loop and thread film over lower feed sprocket (fig. 8,538); insert film through fire valve and fasten film to lower reel, thus completing the operation (fig. 8,539).



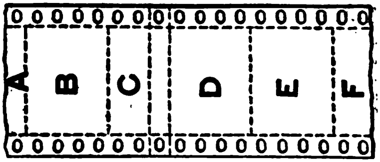
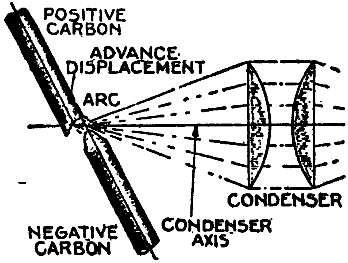


FIG. 8,540.—Splice, in frame. The picture C, has four holes at the side, just as have the pictures A,B,D,E, etc., and when that film is passed through the film gate and intermittent mechanism, the framing will be preserved, because mechanically the film is the same in distribution of pictures and of sprocket holes as though no splice had been made. The difference is found in the "jump" of the pictures when one or more pictures have been omitted, but the "frame" will not be disturbed as the splice passes.

FIG. 8,541.—Splice out of frame. The picture C, has but three holes at the side. Hence, when the picture B, is pulled out of the film window and C, is pulled in, the intermittent sprocket pulling down four holes will pull into the film window the three-quarter picture C, and also the top quarter of the whole picture D. At the next shift, the intermittent sprocket pulls down another four holes, pulling into the film window the remaining three-quarters of D, and the top quarter of E, etc. This continues until the operator notices the screen and frames with his lever. This is called a splice "out of frame" because the splice throws the picture out of frame in passing.

required to adapt it for use in the optical lantern is to ***make it as much one sided as possible***, that is to say, to so arrange it that *as much of the light as possible will be thrown toward the condensers*.

Either *d.c.* or *a.c.* may be used for the arc. For *d.c.*, the positive pole is connected to the upper carbon of the lamp and the negative pole to the lower carbon.



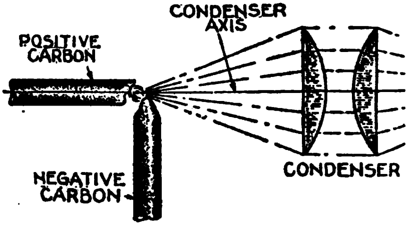
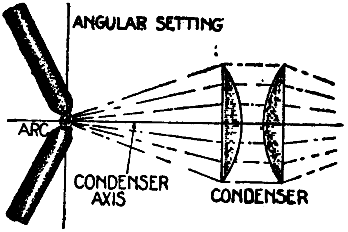


Fig. 8,542.—Motion picture arc for direct current. ***The advance displacement,*** say one-eighth inch, causes the upper carbon to burn with a diagonal end containing the brilliant crater and the light is accordingly thrown toward the condenser.

Fig. 8,543.—Stereopticon arc for direct current. ***This setting*** does not give as brilliant an arc as fig. 8,542, when a long arc is used, but for a short arc the carbons become so near that an arc of more brilliancy than fig. 8,542 is obtained.



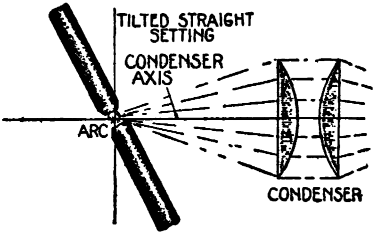


Fig. 8,544.—Arc setting for *a.c.* arc with cored carbons.

Fig. 8,545.—Tilted straight setting for *a.c.* arc carbons.

To adjust carbons for *d.c.* motion picture arc, they are placed end to end in a straight line except that the axis of the lower one is slightly in advance of that of the upper one as in fig. 8,542. To bring the maximum light upon the condensers the carbon must be inclined about 25°.

A difficulty with *a.c.* arcs is that two craters are formed and if the light from both is to be used, a very careful setting and adjustment is necessary to avoid poor illumination and a double spot at the center of the screen. Cored carbons are used for *a.c.* arcs.

For angular settings the angle of the carbons varies with the amount of current used, and the size and quality of the carbon.

The proper angle is secured by "rocking" the carbons while watching the screen till the best illumination is secured.

The light is centered by moving the arc in a direction opposite to that in which it is desired to move the bright spot on the screen.

There are four lamp adjustments: 1, vertical, 2, lateral, 3, focusing, and 4, feed.

The arc is started or struck by turning the proper knob to bring the carbons together, then reversing to draw them apart until the proper arc is secured. The feeding of the carbon is gauged by observation through a peep hole in the lamp house, or by the sound produced by the arc.

Fig. 8,546.—The arc controller or device designed to control the rate of feed of the carbons of an arc lamp, with the object of maintaining at all times a predetermined size of arc. *It consists of* the controller proper, direct coupled to a fractional horse power motor. There are two shafts, primary and secondary. The former, which is direct coupled to the motor, carries governor parts, and rotates constantly at the motor speed. The secondary, to which the telescope rod is geared, remains idle until the speed of the primary shaft exceeds the point of adjustment. The adjustment for any preferable size of arc is made with a brass adjusting nut upon a rod projecting from the cover of the controller.

Auxiliary Apparatus.—Various devices are necessary for the proper and safe control of the electric arc used in motion picture projection.

Each installation will require proper fuses and switches, rheostats, etc., in accordance with the Underwriters' regulations.

Film.—This is made of celluloid, being similar to the film used in ordinary cameras, excepting that it comes in long strips, one thousand or more feet in length.

The size of each picture on the film is 11/16 inch high by 15/16 inch wide. The film is 1 3/8 inch wide which leaves a margin on each side of the pictures for the holes which mesh with the sprocket teeth. These holes are about 3/16 inch apart. At present there is no standard as to the spacing of the holes, but as in other lines, the makers will sooner or later adopt a standard.

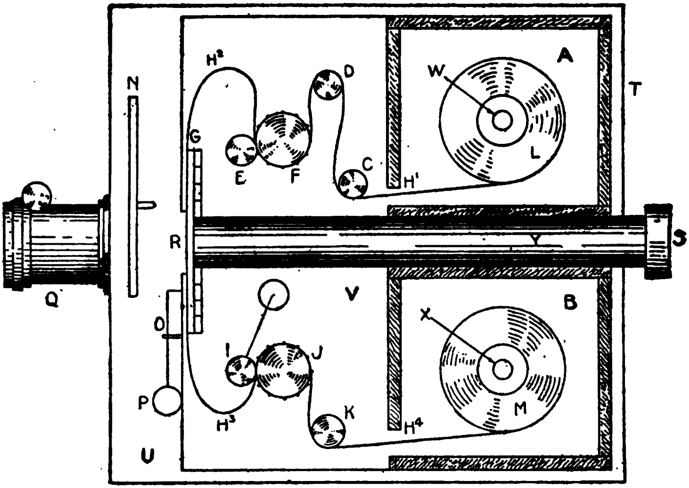


FIG. 8,547.—Diagram of motion picture camera showing the essential parts. Cameras are built for various numbers of picture per turn of the crank; four, six, and eight are common. An eight picture camera should be run at a speed of almost one hundred turns per minute. To operate at this speed, get a watch ticking 300 ticks per minute and learn to count one, two, three; one, two, three, etc., just as fast as the watch ticks, turning the crank one revolution for every one, two, three counted; that is to say, one revolution per every three ticks of the watch.

The film is treated with glycerine to keep it pliable, and delay drying out. *Because of its inflammable character film must always be kept in fire proof enclosures.* Film is repaired usually by cutting out the defective part and splicing the ends together.

Cameras.—Apparatus for taking motion pictures differs in many ways from ordinary cameras. Fig. 8,547 is a diagram showing the essential parts of a motion picture camera.

There are three compartments: 1, a front compartment U, containing a rotating shutter N, pin mechanism OP, and other parts not shown; 2, a compartment V, containing the film mechanism and magazines, and 3, a compartment on the opposite side containing mechanism communicating with the spools in the magazines, with the sprocket wheels, and the points in the first compartment.

The two magazines A,B, consisting of light boxes, fit into the back portion, and carry reels, W,X, on which the film is wound.

In operation, the roll of unexposed film L, which passes out of a small aperture H^1, at the corner of the top magazine A, around guide rollers C, D, engages by its perforations with the sprocket wheel F, to which it is kept by the roller E. The film forms a loop at H^2 and passes downward through the guide grooves made in the gate G.

Continuing, it passes out past the bottom of the gate, forming a second loop H^3, and then passes between a spring roller I, and sprocket J, under the guide roller K, and enters at H^4 the lower magazine B, when it is wound up on the bobbin X.

The sprocket wheels rotate continuously drawing the film from the supply at L, and taking it up at M.

The motion of the film in the gate G, however, is intermittent. During the period of rest, a surplus loop of film forms at H^2, which is then pulled down through the gate by the action of the pin O, engaging with the perforations.

The whole mechanism is so arranged and geared together that, *while the film is being* ***shifted,*** *the light is* ***excluded*** *from the lens, and admitted during the stationary periods.*

A long tube V, extends through the center of the camera, and is provided with a detachable cap at S. This tube forms the sight hole for inspecting the image on the film, prior to exposure.

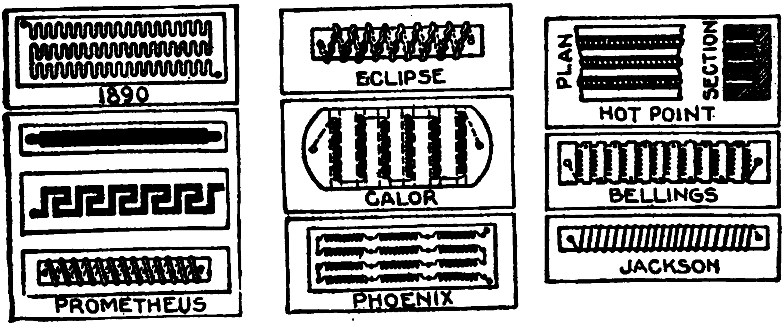
The gate G, is a kind of hinged door with an aperature in it, and its function is to keep the film flat and vertical during exposure and also to act as a channel or guide.

After taking a subject, the operator presses a button, and in so doing punches a hole in the film at a point just above the gate, thus indicating the end of the subject and beginning of the next subject.

CHAPTER 141

Heating

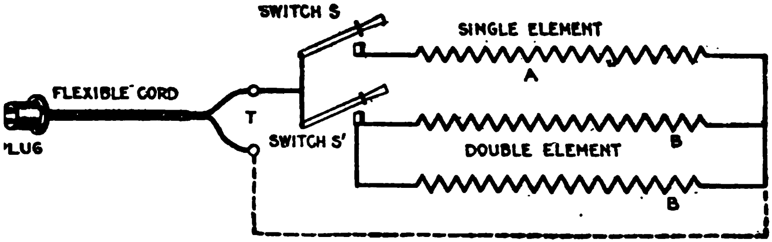
Production of the Heat.—For domestic and some industrial purposes, heat is produced by electricity *by forcing it through resistance wires*, raising the temperature of the latter, and applying the heat thus generated to the articles to be heated.



Figs. 8,548 to 8,558.—Various types of electric heating unit.

Heating Units.—The term heating unit is given to *that portion of a cooker or heater which gives out the heat* for warming an oven or hot plate or for raising the temperature of a room.

It consists of some material which is more or less a bad conductor of electricity, and when current is taken through it, by making it form a portion of an electrical circuit, it becomes hot owing to the resistance it



IG. 8,559.—Arrangement of internal circuit for heaters giving three heating values. *In the diagram* A, represent one third of the heating circuit; BB, two thirds. With switch S, on, one-third of full heat is given; with S', two-thirds, while with both S, and S' on, the heater works with full power. At T, are two terminals to which the ends of the flexible cord from the plug are secured.

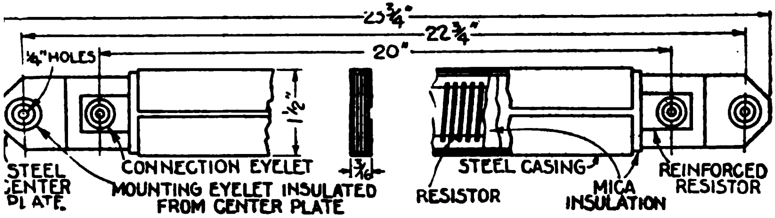
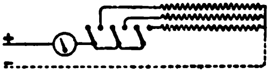
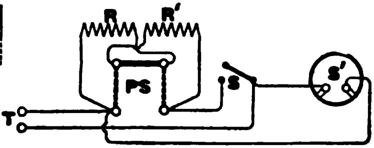


Fig. 8,560.—C-H "space" heater unit. The resistance material is insulated in sheets of mica and enclosed in a protecting sheath of steel. The heater is flat like an ordinary ruler, it size being 1½ X 3/16 X 24 ins. When mounting in frames, the heaters are spaced 1½ ins. apart sufficiently to allow a free circulation of air. On 440 volt circuit the units are connected up in pairs in series, as many pairs being used as are required.





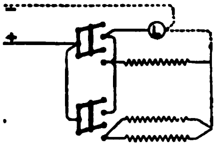


Fig. 8,561.—Arrangement of internal circuits for heaters in which each resistance section is controlled by a separate switch.

Fig. 8,562.—Internal connections of a cooker. T, terminals; PS, parallel or series switch; S, ordinary switch; S', two pin socket for plug connection; R,R', resistance sections. Current is turned on or off from R, R' at S, while PS, puts R and R' either in parallel or series. S', allows of the attachment of an auxiliary heater. This arrangement is applicable to other types of heater, and S', would then generally be omitted.

Fig. 8,563.—Arrangement of two circuit heater with pilot lamp L. When either switch is put on, L lights up. The top switch controls one-third of the heater resistance, and the bottom switch two-thirds.

sets up to the current. In order to meet the varied conditions of ser there are numerous forms of resistor or heating unit, and these may classified as:

1. Exposed coils of wire or ribbon open to air and wound around ins lating material;

2. Wire or ribbon in the form of coil or flat layer embedded in enamel, asbestos, mica, or other insulators:

The following are the principal heating elements used:

The Eclipse element consists of high resistance ribbon crimped to give greater length and free air space, wound over mica strips with the ends conne to heavy eyelet terminals.

FIG. 8,564.—Two Apfel's heating units (2 kilowatts) connected in series (220-250 volts) presenting 12 sq. ft. of radiating sur face.

The Calor element has a ba of fireclay with grooves into wh spirals of fine high resistance wi are placed.

The Phoenix element h spiral wire coils held lightly a short intervals by procelain ins ators mounted on a suitable bas

The hot point element made up of nichrome wire or r bon, wound lightly around th strips of mica, then further co ered with a thin mica coveri and inserted very tightly in grooves or slots made in the b plate or iron base to receive th finished strips.

FIG. 8,565.—Method of attaching Apfel heating unit to a partition, showing wiring, direct-ing plate, insulators and wire screen over connections.

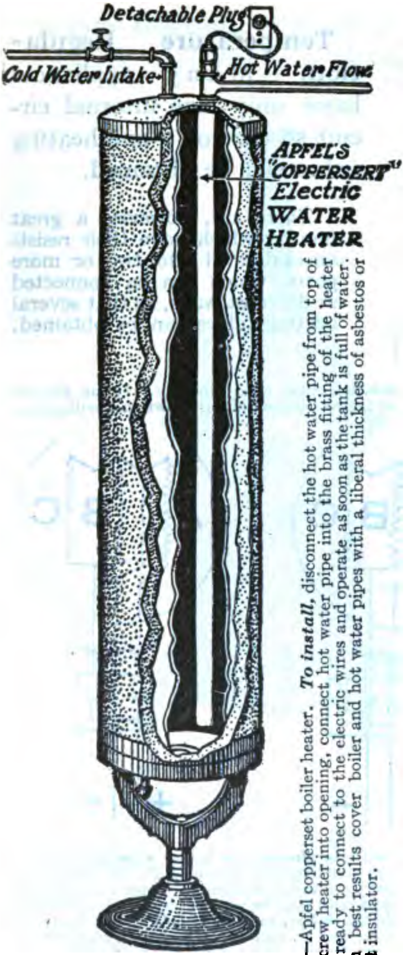


FIG. 8,566.—Apfel copperset boiler heater. *To install,* disconnect the hot water pipe from top of boiler. Screw heater into opening, connect hot water pipe into the brass fitting of the heater and it is ready to connect to the electric wires and operate as soon as the tank is full of water. To obtain best results cover boiler and hot water pipes with a liberal thickness of asbestos or other heat insulator.

The Belling element consists of a fire clay strip with spirals of nichrome wire stretched across the width of the base, notches being provided in the base for receiving the ends of the spiral and holding them tightly in position in the manner shown.

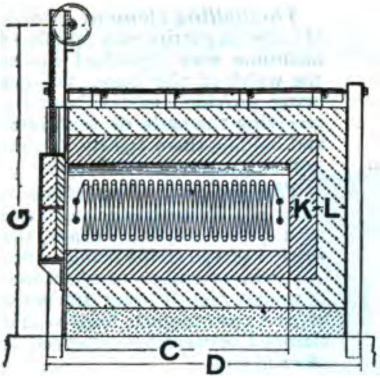
The Jackson element has a different class of fire clay base with quite a smooth surface, the section of the strips being a flat oval wire or ribbon of nichrome, is wound tightly over the strip in one continuous length and clamped between heavy terminals at each end.

The Tricity elements consists of nichrome ribbon wound over thin mica and clamped between thin sheets of mica and metal. The method of winding provides for uniform distribution of heat at any loading.

The Bastian or Quartzalite element consists of a spiral of nichrome wire or ribbon coated with a film of oxide insulation. The spiral is held in or on a tube of quartz. The turns of the spiral may be close together without fear of short circuit. This gives it a "hot rod" appearance.

NOTE—***Coffee and Cocoa Dryers.***—The coffee and cocoa trade has applied electric heat to its small desiccating or drying cabinets: A dryer 3½ ft. by 5 ft. requiring a temperature of 150 degrees, requires abont 74 watts per cu. ft. when properly jacketted. The beans are particularly susceptible to the odors arising from combustion, hence the advantage of electric heat. For drying kills, 4 watts per cu. ft. are recommended.

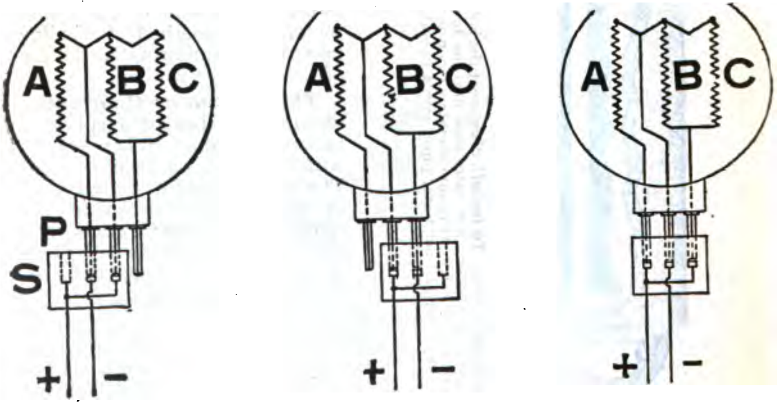
NOTE—***Soldering and branding irons.***—It is more economical to operate electric soldering irons heated by current costing 5¢ per *kw. hour,* than by gas at $1.00 per 1,000 cu. ft. Heaters of 110 watt capacity are made, into which a soldering iron is thrust, thereby doing away with the connecting handle cord.



Temperature Regulation. — Many appliances have only one internal circuit so that only one heating value can be obtained.

There are, however, a great number which have their resistances divided into two or more parts, which can be connected in different ways, so that several heating values can be obtained.

Fig. 8,567.—Hagen electric furnace for heat treating small steel products. It can also be used as a carbonizing furnace. The location of the resistance units is shown in the diagram.



Figs. 8,568 to 8,570.—Internal circuits of heater. *As shown* the heater wires are divided into three sections; A, B, and C, connected to the external terminals P. A three hole socket S, has one conductor of a twin flexible cord connected to the two outer sockets, and the other to the middle socket. The socket piece may thus be put on the pins in three different ways, as shown in the three figures. In fig. 8,568, section A, only of the heater is in circuit; in fig. 8,569, sections B and C, are connected, and in fig. 8,570, all sections are in circuit. The signs + and − in each figure indicate the heater end of the flexible cord, the other terminating in a plug connection or switch plug on the wall. In some apparatus, a three or four hole socket is made to fit a corresponding number of pins in one position only, and is connected through a triple or quadruple flexible cord to a two or three way switch adjacent. The various degrees of heat are then obtained by altering the position of the switch.

Room Heating.—Only in a comparatively few instances is electricity employed to advantage in the heating of rooms, such

FIGS. 8,571 to 8,577.—Schaar universal electric heater with simple attachments, adapting it to the various laboratory operations for which the Bunsen burner has been used. The construction is such that the heat is concentrated at the upper and central portion of the heater, by radiation and convection, the heated air striking and surrounding the object to be heated. Crucibles and test tubes are so placed within the heater that they are heated on the sides and bottom by direct radiation. The heater coils are so arranged that any liquid spilled upon the heater falls through without injury to them. Current consumption 6.8 amperes at 110 volts on high, and 4 amperes on low. Attachment **A**, inserted in the heater from the top, will hold from one to four test tubes. The gauze **B**, is of special form for the support of round bottom flasks and evaporating dishes, and is placed in the top of the heater together with the device shown in fig. 8,571. Beakers and other flat bottom apparatus are heated in a similar manner, using the flat gauze **C**. The nichrome triangle **D**, inserted in the top of the heater, supports crucibles in position to receive the most intense heat. For reduction experiments attachment **E**, is placed over the heater, reduction tube allowed to rest in the slots, and the asbestos plate placed over the top. Copper oxide is thus readily reduced by hydrogen. By placing attachment **F**, over the flask, shown in fig. 8,571, the heat is conserved so that the time of boiling is considerably reduced.

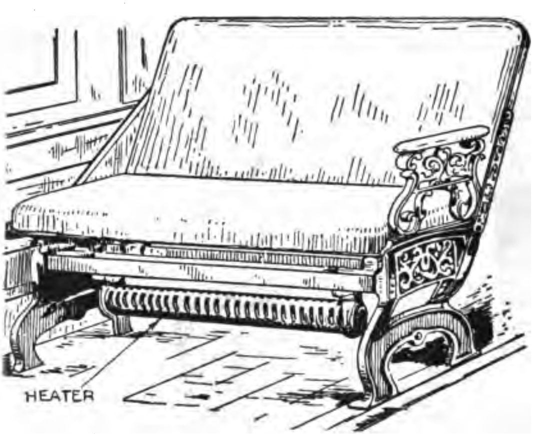


FIG. 8,578.—Underseat method of car heating; view showing seat and placement of heater. At the Montreal meeting of the American Street Railway Association some years ago, Mr. J. F. McElroy read an exhaustive paper on the subject of car heating, from which the following abstracts are taken: *In practice* it is found that 20,000 *B.t.u.* (*per hr.*) are necessary to heat an 18 to 20 ft. car in zero weather. When the outside temperature is 12½° Fahr., only 16,000 *B.t.u.* are required, etc., which shows the necessity of having electric heaters adjustable. The amount of heat necessary in a car to maintain a given inside temperature depends on: 1, the amount of artificial heat which is given to it; 2, the number of passengers carried. The average person is capable of giving out an amount of heat in 24 hours which is equal to 191 *B.t.u.* This is evidently an error, as Kent says that a person gives out about 400 heat units per hour, and tests by the Bureau of Standards show approximately the same (413) for a person at rest, and about twice that for a man at hard labor (835).

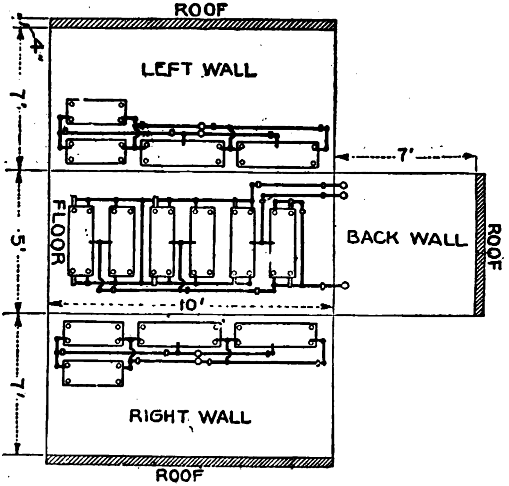


FIG. 8,579.—Arrangement of heater units in a core baking oven. By doubling up the heaters near the door, radiation losses at that point are taken care of.

practice being confined chiefly to intermittent auxiliary service in offices and dwellings, ticket booths, etc.

The electric energy required to heat an ordinary sized room when the outside air is near the freezing point ranges from about 1 to 2 watts per cu. ft.

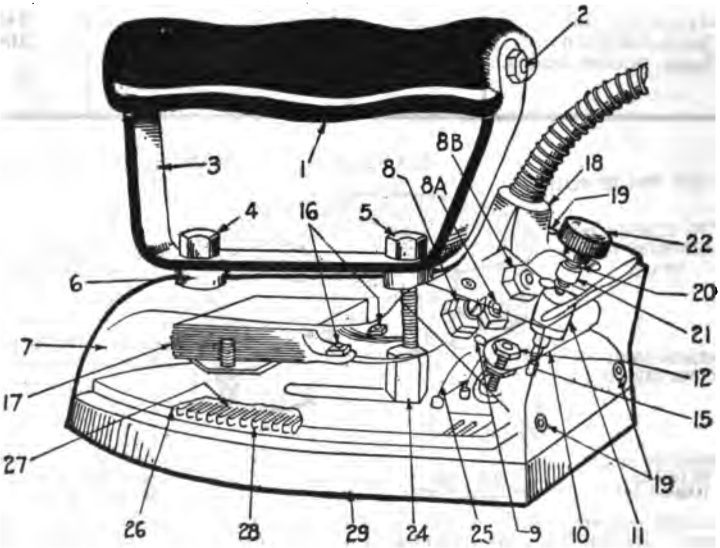


FIG. 8,580.—Dover electric iron with automatic control adjustable for any temperature between 300 and 600° Fahr. The control of thermostat consists of a bar of thermostatic metal through which passes a brass screw tipped with platinum and a bar of spring metal through which passes a brass screw tipped with platinum; these two points coming together make the contact. The make and break of current is accomplished by the bar of thermostatic metal, which when heated, expands and curves downward (the upper bar being stationary), thereby breaking the circuit. As the iron cools, the thermostatic bar contracts and makes contact. A condenser is provided to prevent any arcing at the contact points when the circuit is broken. ***The parts are:*** 1, handle; 7, hood proper; 10, tension spring; 11, insulated cap; 14, headless screw with platinum point; 15, thermostat; 17, condenser; 18, feed cord receiver; 20, regulator screw; 22, regulator spring; 28, resistance coil; 29, wiring face.

The following table shows the loss of heat per sq. ft. of window and wall surface, for one degree Fahr., difference of inside and outside temperature, the loss being expressed in heat units per hour.

Loss of Heat per Sq. Ft. of Surface

Kind of Surface	B. t. u. per hour	Kind of Surface	B. t. u. per hour
4 in. brick wall	68	Window, single glass	.776
8 in. brick wall	46	Window, double glass	.518
12 in. brick wall	32	Skylight, single glass	1.118
16 in. brick wall	26	Skylight, double glass	.621
20 in. brick wall	23	Ceilings, fire proof	145
Floors, fire proof	124	Ceilings, wooden beams	.104
Floors, wooden beams	683	Ordinary wooden wall, lathed and plastered	.1

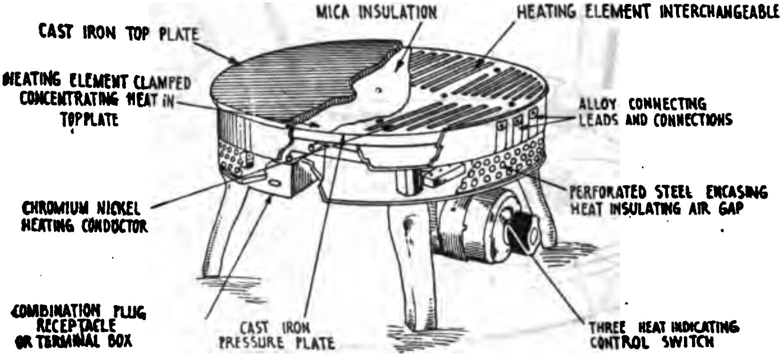


FIG. 8,581.—American electric disc stove. Adapted to laboratory and other industrial purposes. The maximum surface temperature is 750° Fahr.

Example.—What will be the loss of heat per hour in a single room wooden structure when the temperature inside is maintained at 70° Fahr., while the outside is at 32°. Size of room 10 × 10 × 10, having three 3 × 6 windows. Here all surfaces must be considered.

Area of windows = 3 (3 × 6) = 54 sq. ft.
Area of walls = 4 (10 × 10) — 54 = 364 sq. ft.
Area of floor = 10 × 10 = 100.
B.t.u. lost through windows = (70 — 32) × .776 × 54 = 1,592.4
B.t.u. lost through walls = (70 — 32) × .1 × 346 = 1,314.8
B.t.u. lost through floor = (70 — 32) × .083 × 100 = 315.4

Total loss of heat per hour........................ = 3,222.6 *B.t.u.*

Water Heaters.—These devices are made in a variety of form to suit different conditions. The various methods of heating water may be classed.

1. With respect to capacity, as

    a. Non-storing;
    b. Storing.

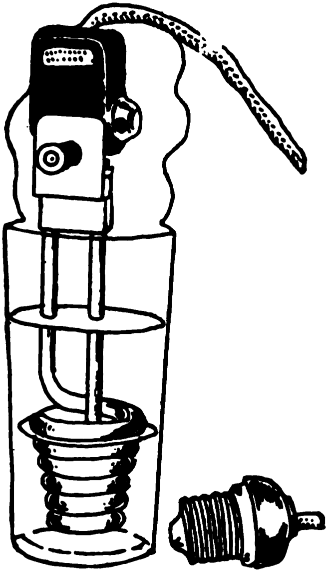
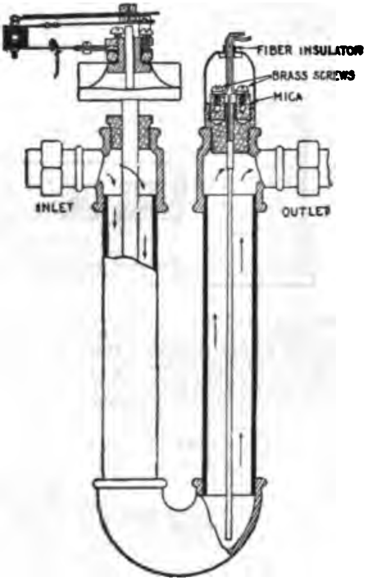


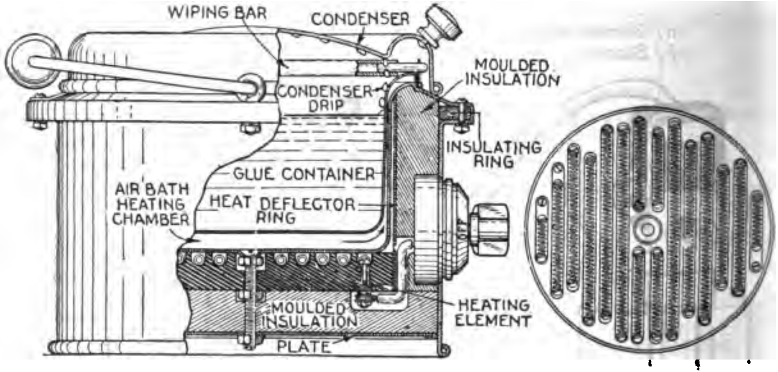
FIG. 8,582.—Simplex immersion heater.



FIGS. 8,583.—Sectional view of Good Housekeeping electric water heater designed to be connected on the circulation pipe of a kitchen boiler or other storage vessel for hot water. There is a resistance coil using 750 watts per hour (or greater consumption if desired, depending on the hot water requirements). The water is circulated from the bottom of the storage tank through the inlet in the water heater around the heating coil and through the outlet into the top of the storage tank. *In operation,* when all the water in the tank has been heated and the hot water circulates through the inlet of the water heater around the copper tube, the expansion of the liquid in the copper causes the diaphragm to buckle from convex to concave, which turns off the electricity, thus no current will be used until the water in the tank has cooled sufficiently to reduce the pressure, thereby allowing the diaphragm to buckle back and the circuit to be closed. When hot water is drawn from the top of the tank, cold water will replace it through the inlet around the copper tube reducing the pressure, the diaphragm will buckle back thereby closing the circuit, and only sufficient electricity is used to bring the temperature of the cold water up to the predetermined temperature of about 180° Fahr. in the bottom of tank.

2. With respect to the heating element, as
   - *a*. External element;
   - *b*. Immersed element.

The so called "instantaneous" is an example of the non-storing class and



Figs. 8,584 and 8,585.—Mabey electric glue pot. It is spun from aluminum and operates on dry heat, that is no water is used. Fig. 8,585 shows detail of the heating element. The current is controlled by a three heat indicating switch, marked *Full*, *Medium*, *Low*. Full heat is used only for melting the glue. Medium heat is used for maintaining proper working temperature when the lid is up and the glue in use. When the lid is down and the pot closed Low Heat will hold the glue at correct working temperature.

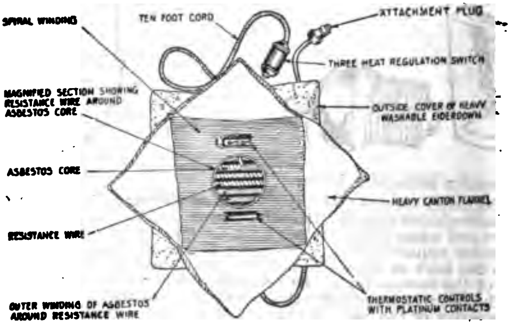


Fig. 8,586.—American electric warming pad. ***It consists of*** a flexible heating element with an outer cover of eiderdown which is removable and washable, so that the pad may always be kept in a sanitary condition. The pad is arranged for three heats, which are regulated by means of a switch so designed as to be easily operated in the dark, the sense of touch enabling the user to change from one heat to the other. It also contains two thermostats to prevent overheating.

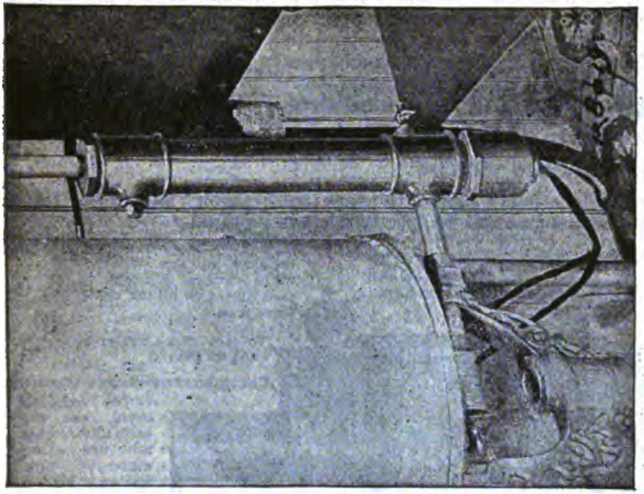


FIG. 8,588.—Westinghouse bayonet water heater as attached to range boiler.

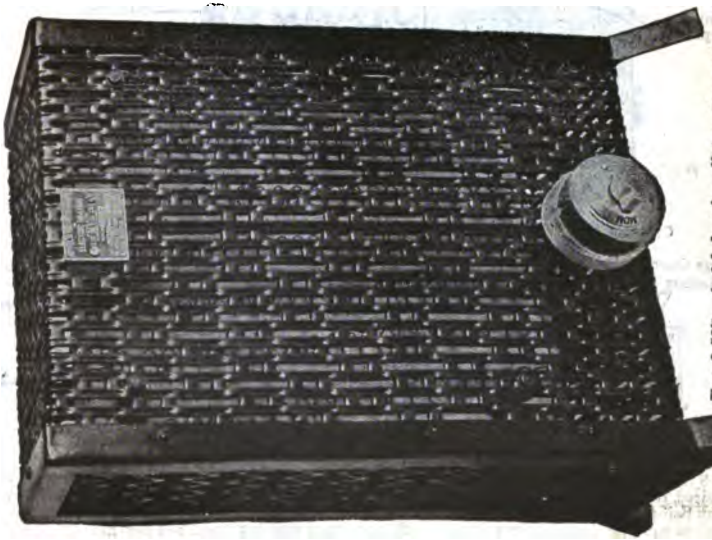


FIG. 8,587.—Apfel electric radiator. ***It consists of*** an assembly of "heat feet" units (as shown on page 4,278-918), in a perforated metal frame.

consists of a heating element and coil of pipe through which water passes, the rate of flow, and consequently the temperature being controlled by a valve. Nothing can be more ridiculous than to call these affairs "instantaneous" heaters, as no physical change takes place instantaneously.

Wiring for Heating and Cooking.—The use of electricity for such service in addition to lighting, ***necessitates** the installation of suitable extra outlets*.

The proper location of such outlets are matters which should be attended to by some one competent to specify what is required.

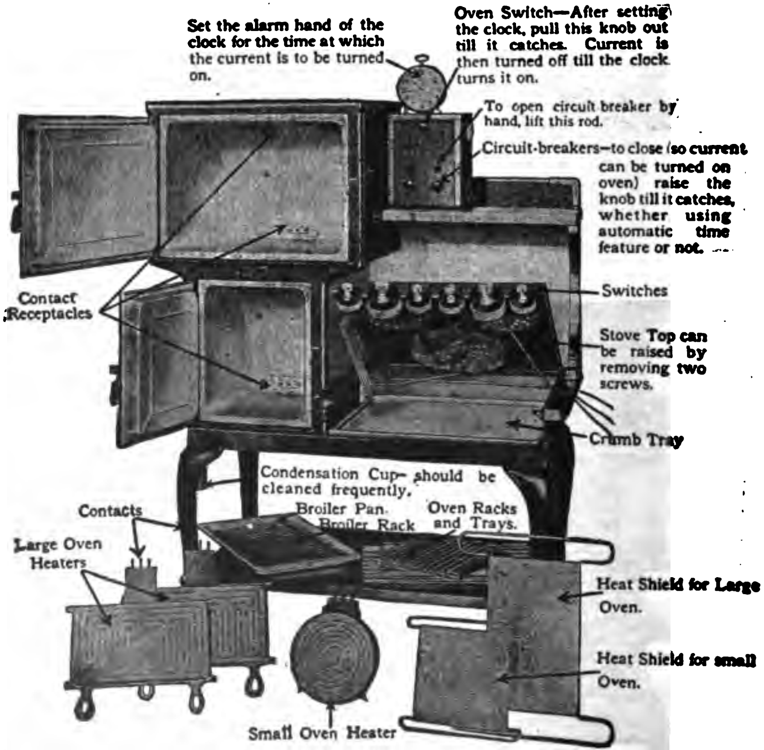


FIG. 8,589.—Westinghouse electric range. *In operation*, current brings the oven up to the desired temperature, after which the corking is carried on by stored heat, no further current being required. The stove top banners are not provided with automatic control, but each is equipped with a three heat switch, a turn of which gives a red hot heat.

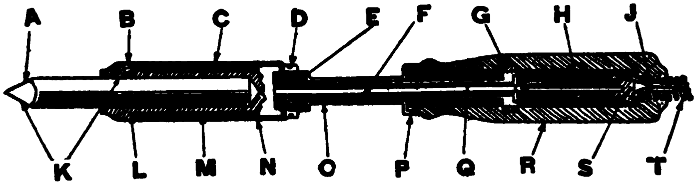


FIG. 8,590.—American electric soldering iron. The element core and the shank of the copper tip are heat treated and will not readily corrode or oxidize. The heating element of nickel chromium ribbon, insulated with mica, is kept in intimate contact with the core by means of a compression winding. This prevents overheating of the element. Copper tips are of standard size drawn copper rod, ⅜, ⅝, and ⅞ ins. respectively in diameter. As the tip wears away it is possible to withdraw it from the core and most of the tip may thus be utilized. The ratings are: ⅜ tip, 100 watts; ⅝ tip, 200 watts; ⅞ tip 300 watts; made for various pressures from 32 to 250 volts. A, copper tip; B, set screw; C, steel shell; D, assembly nut; E, threaded core projection; F, insulated wires; G, nut; H, connector assembly; I, conductor cord; J, heating element extension; K, core; L, chrome nickel heating element; M, compression winding; N, shank; O, ferrule; P, insulated wires; Q, wood handle; R, strain block; S, protecting spring.


FIGS. 8,591 and 8,592.—Burners for Westinghouse electric range. Fig. 8,591, small oven burner; fig. 8,592, large oven burner. All burners are of the radiant type. ***In construction,*** all wires are laid in deep grooves of a moulded porcelain brick that will not crack under extreme heat. The coils are so arranged that they cannot creep up when heated and come in contact with the cooking vessels. Perforations are provided to allow any liquid which may be spilled on the burner to pass through.

CHAPTER 142

Soldering

A knowledge of soldering and brazing is useful to the electrician, and the acquirement of proficiency in these operations will be found of value.

Solder.—The word solder is a name for *any fusible alloy used to unite different metal parts.*

In electrical engineering the solder used is practically always an alloy of tin and lead. As the electrical conductivity of such an alloy is usually about one-seventh that of copper, the best joint between copper conductors is made *by bringing the copper surfaces as close together as possible and using a minimum of solder.*

There are two general classes of solder: ***soft*** *and* ***hard.***

Soft solder is composed of lead and tin. Sometimes other metals are added to lower the melting point.

Hard solder is composed of copper and zinc, or copper, zinc, and silver. Hard solder in general is sometimes erroneously called ***spelter.***

To increase the fusibility of a solder, add a small portion of bismuth.

Soft solder melts at a low temperature compared to hard solder which melts at a red heat.

Soft Solders.—These consist *chiefly of tin and lead,* although other metals are occasionally added to lower the melting point.

Those containing the most lead are the cheapest and have the highest melting point. According to the tin content they may be classed as 1, common or plumber's; 2, medium or fine.

Common or plumber's solder consists of one part of tin to two parts of lead, and melts at 441° Fahr. It is used by plumbers for ordinary work, and occasionally for electrical work where wiped joints are required, for instance, in large lead covered work. Medium or fine solder consists of equal parts of tin and lead, or *half and half*, and melts at 370° Fahr. This solder is always used for soldering joints in copper conductors, and for soldering lead sleeves on lead covered wires.

Melting Points and Hardness of Tin Lead Solders

Percentage		Melting Temp. Deg. F.	Brinell Hardness Test	Percentage		Melting Temp. Deg F.	Brinell Hardness Test
Tin	Lead			Tin	Lead		
0	100	618.8	3.9	60	40	368.6	14.6
10	90	577.4	10.1	66	34	356.0	16.7
20	80	532.4	12.16	70	30	365.0	15.8
30	70	491.0	14.5	80	20	388.4	15.2
40	60	446.0	15.8	90	10	419.0	13.3
50	50	401.0	15.0	100	0	466.0	4.1

In the table which follows will be found the proper solder and flux to use with various metals.

Soft Solders and Fluxes for Various Metals

Metal to be Soldered	Flux	SOFT SOLDER					
		Tin	Lead	Zinc	Aluminum	Phosphor tin	Bismuth
Aluminum	Stearin	70		25	3	2	
Brass	Chloride of zinc, rosin, or Chloride of ammonia	66	34				
Gun metal		63	37				
Copper		60	40				
Lead	Tallow or rosin	33	67				
Block tin	Chloride of zinc	99	1				
Tinned steel	Chloride of zinc or rosin	64	36				
Galvanized steel	Hydrochloric acid	58	42				
Zinc	Hydrochloric acid	55	45				
Pewter	Gallipoli oil	25	25				50
Iron and steel	Chloride of ammonia	50	50				
Gold	Chloride of zinc	67	33				
Silver	Chloride of zinc	67	33				
Bismuth	Chloride of zinc	33	33				34

Hard Solders.—The various solders known as "hard" solders are used for joining such metals as copper, silver and gold, and such alloys as brass, German silver, gun metal, etc., which require a strong joint, and often a solder the color of which is near that of the metal to be joined.

The following table gives the various hard solders, proper flux, and metals for which they are suited.

Hard Solders and Fluxes for Various Metals

Metal to be soldered	Flux	HARD SOLDER			
		Copper	Zinc	Silver	Gold
Brass, soft	Borax	22	78		
Brass, hard	Borax	45	55		
Copper	Borax	50	50		
Gold	Borax	22		11	67
Silver	Borax	20	10	70	
Cast iron	Cuprous oxide	55	45		
Iron and steel	Borax	64	36		

Miscellaneous Solders.—In addition to the solders already given, there are a number that are of value for various purposes.

Very Hard Yellow Solders.—The following formulæ make excellent hard solders for all purposes where a high melting point is required:

No. 1. Copper, 58 parts; zinc, 42 parts. *No. 2.* Sheet brass, 85.42 parts; zinc, 13.58 parts. *No. 3.* Brass, 7 parts; zinc, 1 part. *No. 4.* Copper, 53.3 parts; zinc, 43.1 parts; tin, 1.3 parts; lead, .3 part.

The hardest solders are given first. The following four have lower melting points than those above, and are more suitable where it is desired to solder brass alone.

No. 5. Brass, 66.66 parts: zinc, 33.34 parts. *No. 6.* Brass, 50 parts; zinc, 50 parts. *No. 7.* Brass, 12 parts; zinc, 4 to 7 parts; tin, 1 part. *No. 8.* Copper, 44 parts; zinc, 49 parts; tin, 3.2 parts; lead, 1.2 parts.

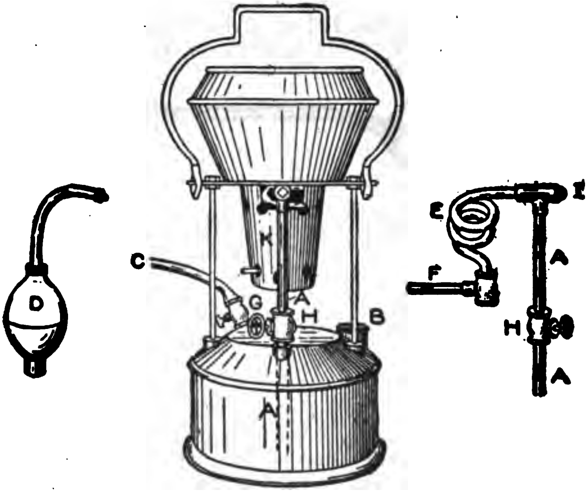
Silver Solders.—These are not, as might be inferred from the name, employed only for the purpose of joining silver, but because of their great strength and resistance are used for many other metals. Like all other solders, they may be divided into the two groups: hard, and soft. Silver solders are usually employed in the shape of wire, narrow strips, or filings. The following are especially adapted to soldering silverware.

Hard Solders

No. 1. Copper, 1 part; silver, 4 parts. ***No. 2.*** Copper, 1 part; silver, 20 parts; brass, 9 parts. ***No. 3.*** Copper, 2 parts; silver, 28 parts; brass, 10 parts.

Soft Solders

No. 4. Silver, 2 parts; brass, 1 part. ***No. 5.*** Silver, 3 parts; copper, 2 parts; zinc, 1 part. ***No. 6.*** Silver, 10 parts; brass, 10 parts; tin, 1 part.



Figs. 8,593 to 8,595.—Plumber's gasoline furnace, adapted to heating soldering pots and copper bolts. ***In construction,*** the gasoline supply for the blast passes through AA, and is provided with valve H, and clean out plug I. The lower end of the supply extends nearly to the bottom of the reservoir. The gasoline passes through coil E, which is partially filled with wire, usually a scrap of small wire cable, to prevent flame running back into the reservoir. The fuel issues from a single small hole at F, which is turned so that the flame will impinge on the coil. Air pressure on top of the gasoline in the reservoir is necessary to make a blast. The air cock is shown at G. For ordinary purposes sufficient pressure can be obtained by blowing air in the hose at C with the lungs, but for a short blast, a bulb containing check valves, shown at D, is used to increase the pressure. The filling plug is at B. ***To light the furnace,*** valve H, is opened and some of the gasoline allowed to play on the coil, from which it falls back into the bottom of cup K. Admit about two tablespoonfuls to cup, close H, and light the gasoline through one of the holes in K. When coil is sufficiently heated, gas instead of liquid will come from the end F, forming a blast which increases in intensity as E. becomes hotter. The strength of the blast is regulated by valve H.

The following silver solders are suitable for cast iron, steel and copper:

No. 1. Silver, 10 parts; copper, 10 parts. *No. 2.* Silver, 20 parts; copper, 30 parts; zinc, 10 parts.

In addition to the various silver solders already given, two other formulæ should be included as follows:

No. 1. Yellow brass, 70 parts; zinc, 7 parts; tin, 11½ parts. *No. 2.* Silver, 145 parts; brass (3 copper, 1 zinc), 73 parts; zinc, 4 parts.

Miscellaneous Silver Solders

Solder for silver plated work: No. 1. Fine silver, 2 parts; bronze, 1 part. *No. 2.* Silver, 68 parts; copper, 24 parts; zinc, 17 parts.

Solder for silver chains: No. 1. Fine silver, 74 parts; copper, 24 parts; orpiment, 2 parts. *No. 2.* Fine silver, 40 parts; orpiment, 20 parts; copper, 40 parts.

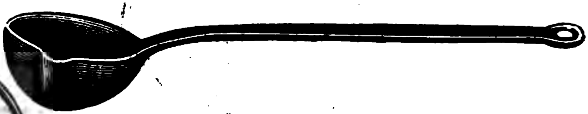


FIG. 8,596.—Ladle for removing solder from soldering pot and for pouring same in making wipe joints, etc.

FIG. 8,597.—Soldering pot.

Resoldering silver solders: These silver solders are for resoldering parts already soldered. *No. 1.* Silver, 3 parts; copper, 2 parts; zinc, 1 part. *No. 2.* Silver, 1 part; brass, 1 part; or, silver, 7 parts; copper, 3 parts; zinc, 2 parts.

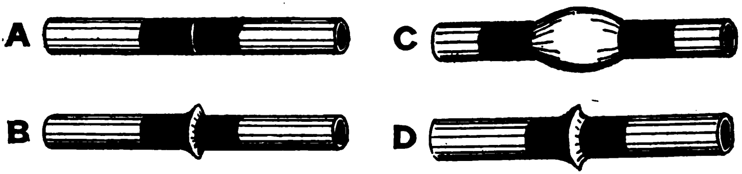
Readily fusible silver solder for ordinary work: Silver, 5 parts; copper, 6 parts; zinc, 2 parts.

French solders for silver: No. 1, for fine silver work: Fine silver, 87 parts; brass, 13 parts. *No. 2,* for work 792 fine: Fine silver, 83 parts; brass, 17 parts. *No. 3,* for work 712 fine: Fine silver, 75 parts; brass, 25 parts. *No. 4,* for work 633 fine: Fine silver, 66 parts; brass, 34 parts. *No. 5,* for work 572 fine: Fine silver, 55 parts; brass, 45 parts.

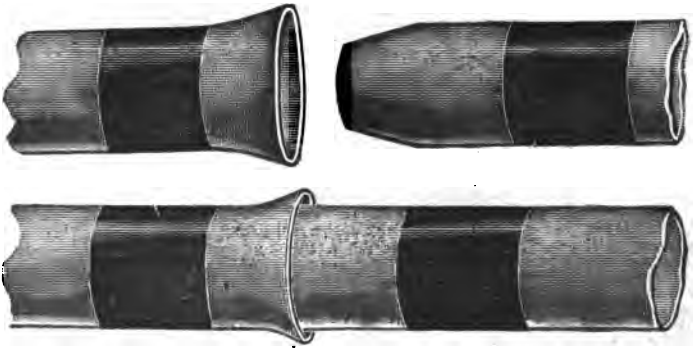
German Silver Solders.—German silver is a very hard alloy of copper (50 to 60%), nickel (15 to 25%), and zinc (15 to 20%). A German silver containing 1 to 2% of tungsten is called *platinoid*. These alloys have a high electrical resistance, platinoid being higher than the other varieties of German silver; the resistance increases uniformly between 32° and 212° Fahr.

German silver solders possess considerable strength, and are often used for soldering steel. The color is very similar to that of steel.

In preparing German silver solders, the copper is melted first, and then the zinc and nickel added simultaneously.



FIGS. 8,598 to 8,601.—Various joints. Fig. **A**, ***butt joint*** made by squaring the ends, tinning one, and sweating the other to it by heating with torch; this is a comparatively weak joint. Fig. **B**, ***blow joint***; fig. **C**, ***copper bit joint,*** the only difference between these is that the solder is floated by a torch in fig. **B**, and by a bit in fig. **C**, the latter joint being heavier than the former. Fig. **D**, round wiped joint.



FIGS. 8,602 to 8,604.—Round wiped joint; preparing the pipe ends. These ends to be united are sawed squarely across, to make the joints true with the pipe. It is usual to prepare the female end first, as shown in fig. 4,431. The end is flared or belled out with a *turn pin*, which is a taper boxwood plug, so that the pipe is enlarged a quarter of an inch. The cup thus formed serves to retain the solder. The internal and external surface must be shaved or scraped bright and clean with a *shave hook*, a small tool with a heart shaped blade set at right angles to its stem or handle. Immediately after a little tallow is applied to the parts to preserve them from the oxidizing action of the atmosphere, which would otherwise tarnish the surfaces, and form a film to which the solder cannot adhere. The male end of the pipe is tapered off with a rasp, as shown in fig. 4,432, cleaned with a shave hook and "touched" as before; the two pieces are brought together as in fig. 4,433, and are then ready for the joint.

Soft German Silver Solders

No. 3. Copper, 4.5 parts; zinc, 7 parts; nickel, 1 part.

No. 4. Copper, 35 parts; zinc, 56.5 parts; nickel, 8.5 parts.

The following No. 5 formulæ given by Kent is similar to *No. 4.*

No. 5. Copper, 38 parts; zinc, 54 parts; nickel, 8 parts.

Hard German Silver Solders

These solders, sometimes called steel solders, contain a large proportion of nickel and are very strong. They require a very high heat for melting, and usually cannot be fused without the aid of a bellows or blast.

No. 1. Copper, 35 parts; zinc, 56.5 parts; nickel, 9.5 parts. *No. 2.* Copper, 38 parts; zinc, 50 parts; nickel, 12 parts.

Gold Solders.—The hard solder or gold solder which the jeweler frequently requires for the execution of various works, not only serves for

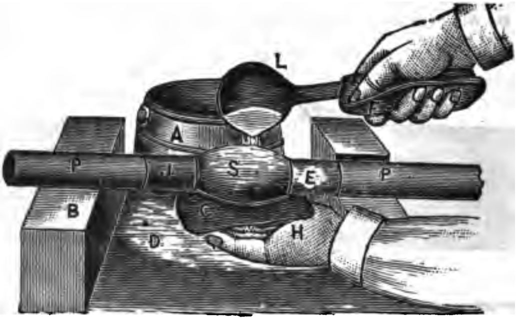


FIG. 8,605.—Method of wiping a horizontal joint. The *cloth* used for wiping is a pad of moleskin or fustian about four inches square made from a piece twelve inches by nine, folded six times, and sewed to keep it from opening; the side next the pipe is saturated with hot tallow when used. If the lead has been brought to the heat of the solder, and the latter properly manipulated and shaped while in a semi-fluid or plastic condition, the joint gradually assumes the finished egg shaped appearance. In making the joint a quantity of solder is taken from the pot by means of the ladle, the solder being previously heated so hot that the hand can be kept within two inches of its surface. The solder is poured lightly on the joint, the ladle being moved backwards and forwards, so that too much solder is not put in one place. The solder is also poured an inch or two on the soiling, to make the pipe of proper temperature. Naturally the further the heat is run or taken along the pipe, the better the chance of making the joint. The operator keeps pouring and with the left hand holds the cloth to catch the solder, and also to cause the same to tin the lower side of the pipe, and to keep the solder from dropping down. By the process of steady pouring the solder now becomes nice and soft and begins to feel shaped, firm and bulky. When in this shape and in a semi-fluid condition the ladle is put down, and, with the left hand, the operation of wiping, as illustrated, is begun working from the soiling towards the top of the bulb. If the lead cool rapidly, it is reheated to a plastic condition by a torch, or a heated iron. When the joint is completed, it is cooled with a water spray, so that the lead shall not have time to alter its shape.

soldering gold ware, but is also often employed for soldering fine steel goods, such as spectacles, etc. Fine gold is only used for soldering articles of platinum. The stronger the alloy of the gold, the more fusible must be the solder. Generally the gold solder is a composition of gold, silver, and copper. If it is to be very easily melted, a little zinc may be added. The shade of the solder is regulated by varying the proportions of silver and copper.

No. 1. For 18 carat gold: Gold (18K), 9 parts; silver, 2 parts; copper, 1 part. *No. 2.* For 16 carat gold: Gold (16K), 24 parts; silver, 10 parts; copper, 1 part. *No. 3.* For 14 carat gold: Gold (14K), 25 parts; silver, 25 parts; brass, 12½ parts; zinc, 1 part.

Aluminum Solders.—In soldering aluminum it is necessary previously to tin the parts to be soldered. This tinning is done with the iron, using a composition of aluminum and tin. A pure aluminum soldering bit should be used. To prepare an aluminum solder, first melt the copper, then add the aluminum gradually, stir well with an iron rod, next add the zinc and a little tallow or benzine at the same time. After adding the zinc do not heat too strongly.

FIG. 8,606.—Method of wiping a vertical joint. A small piece of cardboard cut open is placed under the joint to catch excess solder, or as shown, a lead flange cut open is placed around the pipe and held in place by twine.

Novel's solders for aluminum as given by Kent are as follows:

Tin 100 parts, lead 5 parts; melts at 536° to 572° Fahr.
Tin 100 parts, zinc 5 parts; melts at 536° to 612° Fahr.
Tin 1,000 parts, copper 10 to 15 parts; melts at 662° to 842° Fahr.
Tin 1,000 parts, nickel 10 to 15 parts; melts at 662° to 842° Fahr.

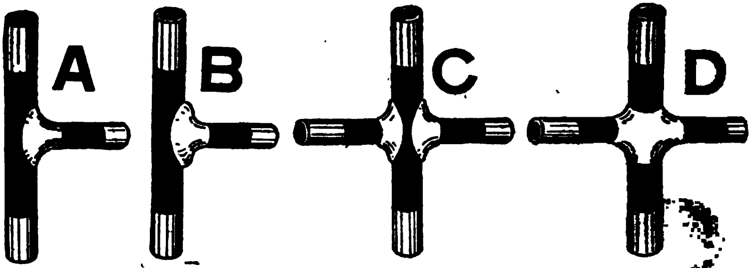
Novel's solder for aluminum bronze: Tin 900 parts; copper 100 parts;

bismuth 2 to 3 parts. It is claimed that this solder is also suitable for joining aluminum to copper, brass, zinc, iron and nickel.

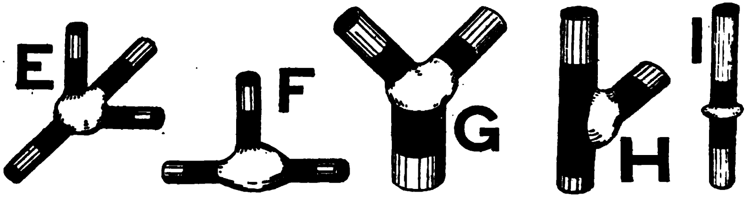
Soldering Fluxes.—The word *flux*, means a *substance applied to a metal to make solder flow readily on its surface.*

The action of a flux is largely that of cleaning the surface, and of reducing any oxide on the surface to the metallic state.

If a piece of sheet copper be carefully cleaned by means of emery cloth and heated over a gas flame, the surface will be seen to tarnish rapidly and assume a dark brown appearance. A small piece of resin dropped on the surface will melt, and when the liquid runs, the initial brightness of the surface will be found to reappear.



Figs. 8,607 to 8,610.—Various wiped joints. Fig. **A**, ***branch joint with concave neck;*** fig. **B**, ***branch joint with swell neck,*** this style is much more difficult to wipe than the one shown in fig. **A**; fig. **C**, ***double branch cross,*** this style looks well and is very easy to wipe because one branch may be wiped at a time by protecting the first with chalk or paste; fig. **D**, ***regular cross joint,*** more difficult than the double branch because there are four edges to take care of at one heat.



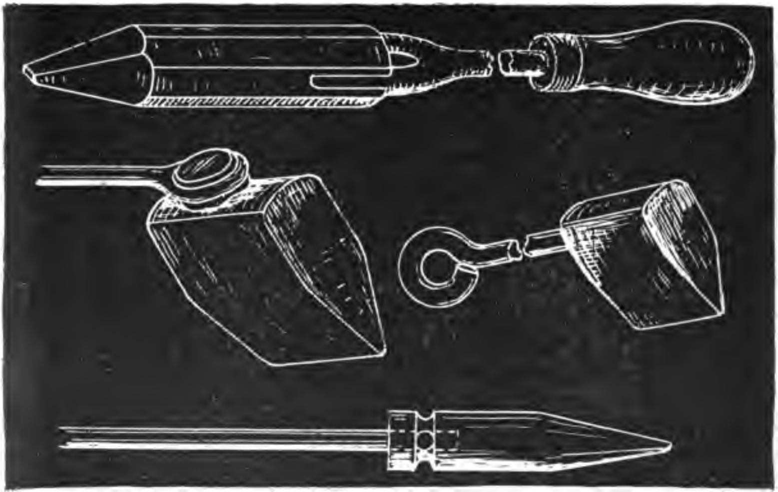
Figs. 8,611 to 8,615.—Various wiped joints. Fig. **E**, ***angle cross,*** a joint more difficult to make than the regular cross; fig. **F**, ***combination branch and round joint,*** sometimes made where it is most convenient to have a branch joint come at a point where two ends of the supply line must be joined; fig. **G**, ***V joint,*** generally used on telephone branch cables; fig. **H**, ***so-called Y joint,*** usually made on lead waste pipe; fig. **I**. ***common flange joint.***

There are a number of flux suitable for various kind of soldering, but pine amber resin is the best for electrical work as it does not cause corrosion. A corrosive flux, such as zinc chloride solution (killed spirits) should be strictly excluded from any electrical work. The nature of the solder often determines the flux. According to Haswell, the proper fluxes to use are as follows:

For iron, use borax
" tinned iron, use rosin
" copper and brass, use sal-ammoniac

For zinc, use chloride of zinc
" lead, use tallow or rosin
" lead and tin, use rosin and sweet oil

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a point or edge and fastened to an iron rod having a wooden handle. The various types of bit are shown in the accompanying cuts.



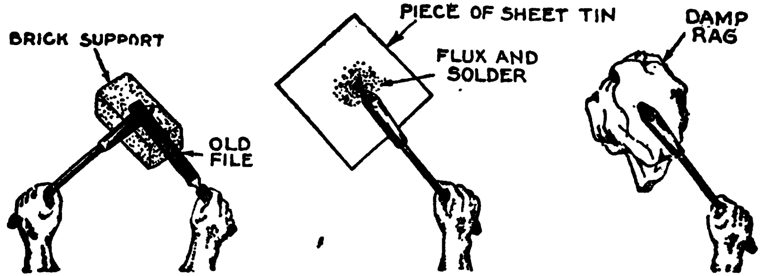
FIGS. 8,616 to 8,619.—Various soldering bits, or so-called "irons." Fig. 8,616, ordinary edge bit; figs. 8,617 and 8,618, hatchet bit; fig. 8,619, pointed bit.

Tinning the Bit.—Preliminary to soldering, the bit must be coated with solder, this operation being known as "tinning."

The operation of tinning the bit is shown in figs. 8,620 to 8,622. Once a soldering bit has been well tinned care should be taken not to overheat it. If the bit at any time reach a red heat it will be necessary to repeat the whole tinning process before it is fit to be used again. **No good work *can be done with an untinned or* badly tinned bit.**

Soft Soldering.—The theory of soft soldering is that: *as the solder adheres to and unites with the surface of the copper when the bit is tinned, so will it adhere to and unite the surfaces of the metals to be soldered.*

Soft soldering, as well as hard soldering, or brazing, consists in welding together two or more pieces of similar or dissimilar metals by means of another metal of lower melting point.



Figs. 8,620 to 8,622.—"Tinning" the bit. Fig. 8,620, cleaning bit by filing working surfaces with an old file; fig. 8,621, rubbing the bit on the flux and solder, which may be conveniently placed on a piece of sheet tin as shown; fig. 8,622, removing surplus solder by giving each side of the bit a quick stroke over a damp rag.

In order to successfully solder wire joints, the following instructions should be followed:

1. Clean and tin the bit as shown in figs 8,620 to 8,622.

2. Heat the bit in the fire until it reaches the right temperature. Do not try to solder a joint with a bit so cool that it only melts the solder slowly, nor with one so hot that it gives dense clouds of smoke when in contact with rosin. Burned rosin must be regarded as dirt.

3. Remove the bit from the fire and hold it, or preferably support it on a brick or block of other material which does not conduct heat readily.

4. Wipe the surface clean with a rag. Apply solder until a pool remains on the flat surface, or in the groove, if a grooved bit be used.

5. Sprinkle with rosin, lay the joint in the pool of solder and again sprinkle with rosin.

6. Rub the joint with a stick of solder so that every crevice is thoroughly filled.

7. Remove the bit, and lightly brush superfluous solder from the bottom of the joint. See that no sharp points of solder remain which may afterwards pierce the insulation.

When the joint is first placed on the bit, the solder should run up into the joint. This will occur only when the joint is well made and thoroughly cleaned, and if the workmanship be perfect it is even possible to fill the joint completely by feeding in solder below the joint as it melts and runs up into the joint.

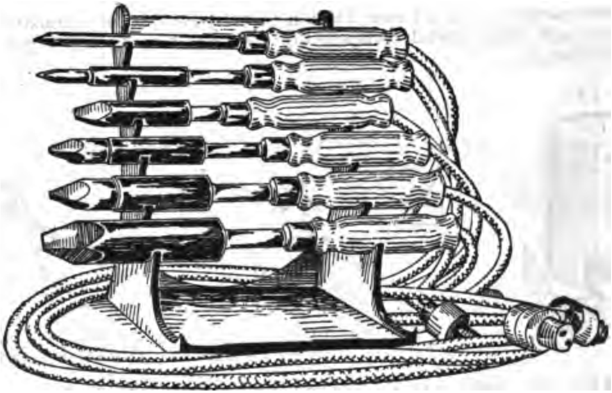


Fig. 8,623.—Nest of electric soldering bits, showing various forms and sizes.

A well soldered joint should present a smooth, bright appearance like polished silver. Wiping the joint before it cools destroys this appearance, and is also liable to produce roughness, which is detrimental to the insulation.

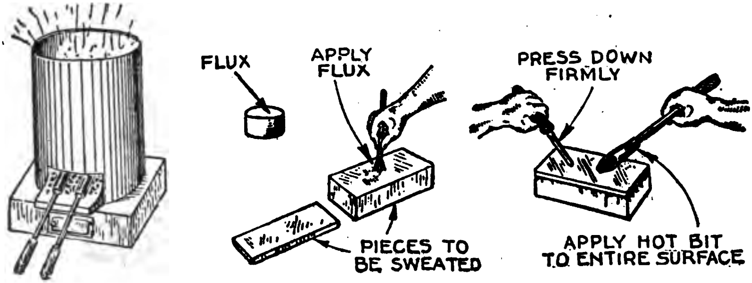
In order to prevent the insulation on the wire near the joint being damaged, the process of soldering should be carried out as quickly as possible, and for this reason the tendency to burn the insulation is less with a *hot* bit (a quick bit) than with a cooler one.

Sweating.—In this operation the *surfaces are cleaned, heated, and covered with a film of solder.*

The soldered surfaces are then placed together and heated by passing the bit over the outside surface until the solder melts and unites the two surfaces.

Babbitting Boxes.—Although some special machines are provided with ball bearings, most dynamos and motors have plain babbitted bearings, accordingly electricians and repair men should know how to babbitt a box should occasion arise for such operation.

Of the various so-called anti-friction metals, Babbitt is extensively used. This is a soft white metal composed of 50 parts tin, 2 parts copper and 4 parts antimony.



Figs. 8,624 to 8,626.—*Sweating.* When two surfaces are to be united by sweating, first see that the surfaces are perfectly clean, then flux as in fig. 8,625. Put a piece of tinfoil over one surface and the other surface on top. They should be held firmly together by a clamp or other means and heated as in fig. 8,626 by a hot bit, or if the metal have considerable thickness by a torch, until the solder melts. When cool, the surfaces will be found to be firmly united.

At the beginning this proportion was used for all purposes, but it has been found that there is no one composition that will bring equally good results in all kinds of machinery, hence are given the following different proportions:

Babbitt metal for light duty is composed of 89.3 parts of copper, 1.8 parts of antimony, 8.9 parts of lead.

Babbitt metal for heavy bearings is composed of 88.9 parts of copper, 3.7 parts of antimony, 7.4 parts of lead.

Lead and antimony have the property of combining with each other in all proportions without impairing the anti-friction properties of either, the antimony hardens the lead, and when mixed in the proportions of 80 parts lead, by weight, with 20 parts antimony, no other known composition of metals possesses greater anti-friction or wearing properties or will stand a higher speed without heat or abrasion.

The operation of babbitting a box should be done in accordance with the following instructions to obtain good results.

1. Avoid overheating the babbitt, as this is destructive to the qualities of the metal and also entails a considerable loss on account of the dross or scum that has to be skimmed off the ladle.

To ascertain the proper temperature, the time honored test is to try it with a dry pine stick. The temperature should be such that the stick will char without catching fire. Cover the metal with powdered charcoal and put in the ladle a lump of sal-ammoniac.

Of course, it is sometimes necessary to heat the babbitt hotter than this to insure its running to all parts of the box when the section to be filled is thin, but if possible, in such cases, the box should be warmed up to prevent excessive chilling of the metal.

2. If the box is to be babbitted with the shaft in position for a mandrel, be careful to get the shaft properly lined and central in the box.

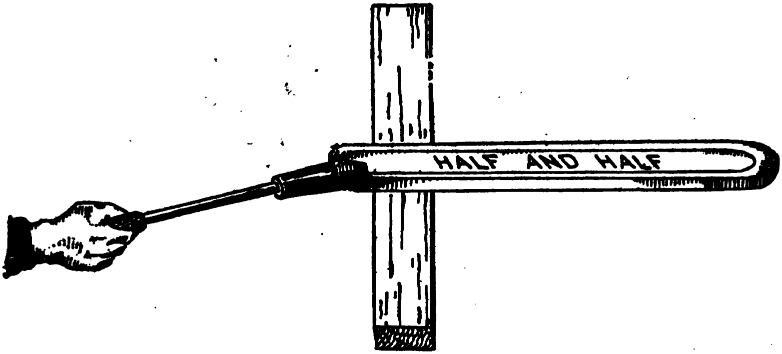
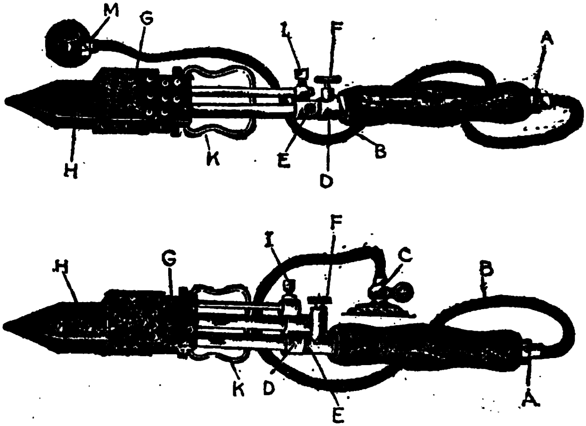


FIG. 8,629.—Picking up solder with a hot bit. This is the proper method for small work. Rest the bar of solder on some support as a brick or piece of wood and touch it with the end of the hot bit. Some of the solder will melt and remain on the bit. It is then transferred to the part to be soldered, and if the surfaces be in proper condition and fluxed when the bit touches the surfaces, the solder will leave the bit and cover the surfaces. ***In picking up solder*** from the stick, care should be taken not to leave the bit in contact with the solder too long or some of it will drop off. The larger the bit and area tinned, the more solder will the bit hold.

To hold it in position use an outside support if convenient, but if not, small pieces of lead hammered to the right thickness may be used to hold it at the proper height and in a central position. ***It is not good practice,*** however, to use the shaft for the purpose of casting the bearings, especially if the shaft be of steel, for the reason that the hot metal is apt to spring it; the better plan is to use a mandrel of the same size or a trifle larger for this purpose. For slow running journals, where the load is moderate, almost any metal that may be conveniently melted and will run free will answer the purpose. For wearing properties with a moderate speed there is probably nothing superior to pure zinc, but when not combined with some other metal it shrinks so much in cooling that it cannot be held firmly in the recess, and soon works loose.

3. The shaft should be smoked or greased so that the babbitt will not adhere to it.

4. The ends of the box should be stopped with clay or cardboard washers cut to snugly encircle the shaft and held to the face of the box, to prevent the babbitt escaping.



FIGS. 8,630 and 8,631.—Kageman self-heating gas soldering bit for bench work. Fig. 8,630 single torch; fig. 8,631, double torch. Any shape or weight of copper point for any class of work may be easily substituted by means of a set screw I. One end of a flexible tubing is attached to the nozzle or male screw near the handle A, and the other end is connected to the gas main M. (Five-eighths main preferred.) Before lighting, close the Bunsen holes E by means of the air slide D, open the governor F, turn on gas main M, light near copper point at G, and gently open Bunsen holes by means of slide D. If flame appear within chamber E, turn off gas, slightly close holes by means of slide D, and light again. Shut off gas at main cock M. Where the gas main is already installed it is advantageous to bore a hole in the bench near the wall, connect a flexible metallic tubing to the gas main, pass tubing through the hole and fasten tubing to the underside near the outer edge of the bench. In that way the hose will hang freely and will hardly be noticeable. The soldering iron can be used away from the bench at any desired distance, depending upon the length of the tubing. The double torch, fig. 8,631, has two burner tubes generating two short but intensely hot blasts. The double flame is intended to heat heavy coppers quickly, and when the desired temperature is reached one flame is shut off by a half turn of the governor, the remaining flame keeping the point at a steady temperature throughout the day. For smaller coppers one flame is sufficient. When a large heating power is required it is often desirable to use both blasts throughout the day.

NOTE.—***Cast iron soldering.*** A new process consists in decarbonizing the surfaces of the cast iron to be soldered, the molten hard solder being at the same time brought into contact with the red hot metallic surfaces. The admission of air, however, should be carefully guarded against. First pickle the surfaces of the pieces to be soldered, as usual, with acid, and fasten the two pieces together. The place to be soldered in now to be covered with a metallic oxygen compound, and any one of the customary fluxes, and heated until red hot. The preparation best suited for this purpose is a paste made by intimately mingling together cuprous oxide and borax. The latter melts in soldering and protects the pickled surfaces, as well as the cuprous oxide from oxidation through the action of the air. During the heating the cuprous oxide imparts its oxygen to the carbon contained in the cast iron and burns it. Metallic copper separates in fine subdivision. Now apply hard solder to the place to be united, which in melting, forms an alloy with the eliminated copper, the alloy combining with the decarburized surfaces of the cast iron.

Liners made of cardboard should be inserted between the halves of the box and should touch the shaft on each side so that the box can be divided without trouble after the pouring is completed.

5. A small hole at one end will be sufficient to insure the lower part filling properly.

6. With a large box and shaft, it is best to pour the lower part first and then the upper one.

7. Care should be taken that there is no water or dampness in the box, as serious consequences may follow if this precaution be neglected.

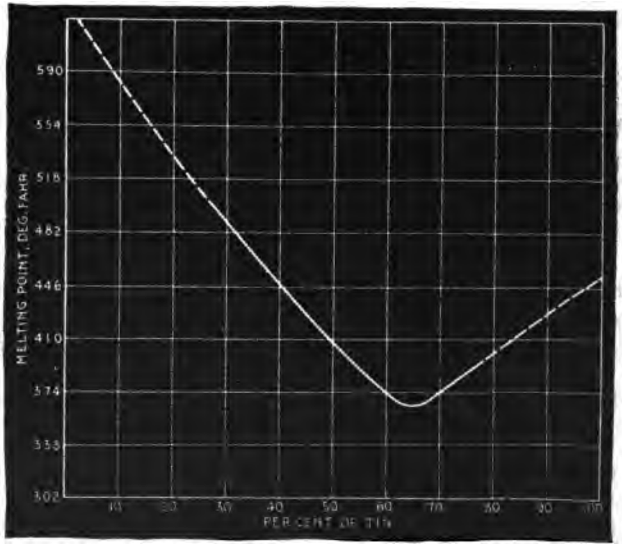


Fig. 8,632.—Characteristic curve showing the melting points of *tin lead* solders, according to the Smithsonian Institution tables. Authorities differ as to the exact values.

A rusty box is likely to throw the babbitt, as water will be liberated when the hot metal is poured on it. A small lump of rosin dropped in the ladle just before pouring increases the fluidity of the metal somewhat and reduces the liability of the babbitt to explode when the interior is slightly damp, although no risks should be taken in this direction.

8. If the oil hole be used to pour through, it will be necessary to drill it out and cut the oil grooves after the box is taken apart.

9. If the babbitt be poured from the side, a plug of pine wood can be inserted in the oil hole down to the shaft to keep it clear.

10. The shaft is sometimes wrapped with a stout cord laid in a spiral direction to get the proper oil runs, but it is usually better to cut them afterwards with a round nose chisel.

CHAPTER 143

Brazing

The art of *uniting metals by means of a* ***hard solder*** is called *brazing*.

Originally, as its name implies, brazing was devoted to the union of brass or other copper alloys.

The theory of brazing is *the melting of a low fusing metal against the metals to be united while they are in such a condition of cleanliness* ***and temperature*** *that the metal welds itself to them*.

Brass filings have been generally replaced by *spelter*, which is a composition of about equal parts of copper and zinc; this is used for brass work. For tubes, a composition of 8 parts of brass tube filings to 1 of zinc is used.

Brass or gun metal united by this process will produce a joint as hard as the metal pieces united.

Iron and steel, especially small pieces of finished work, may be united by the same means. The process of brazing consists essentially of; 1, cleaning the parts to be brazed; 2, applying the hard solder and flux; 3, heating.

The work is first carefully cleaned with acid, and some fine spelter is mixed with borax to form a flux, a little water being added to make a paste. The compound is placed between the parts to be united, as much surface as possible being brought in contact, the two being held firmly together, in the case of small pieces by tongs, and heated until the flux and spelter are melted, the parts being held together until the spelter unites with the metal and solidifies.

Sometimes the work cannot be easily gripped, and so, after inserting the spelter and borax as before, the parts are bound with iron wire and placed in a clear coke fire until the operation is complete. The superfluous metal around the joint will in each case need to be removed by means of the file.

There are various methods of brazing, such as

1. Butt brazing;
2. Lap brazing;
3. Dip brazing;
4. Muffle brazing.

The names are self-defining. Thus in ***butt brazing*** the two pieces to be brazed are placed ***butt to butt;*** in ***lap brazing,*** the ends are overlapped; in ***dip brazing*** the parts are dipped into molten solder until the parts are heated sufficiently to be united by it; in ***muffle brazing,*** a tube or ***muffle*** is used to enclose the parts to be brazed.

Heating Methods in Brazing.—On account of the higher

FIG. 8,633.—Ordinary mouth blow pipe.

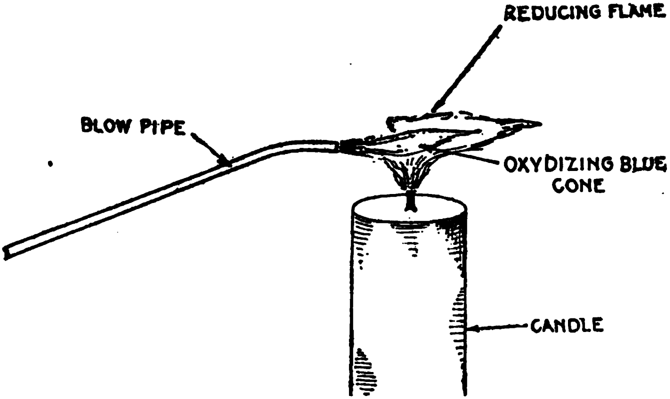


FIG. 8,634.—Method of using the mouth blow pipe. This is for small work, though the intensity of the heat thus produced is very great, the volume of flame is small. On some blow pipes a ball or enlargement is made at A, to catch any moisture or saliva, thus increasing the efficiency of the instrument. The torch as shown, gives two flames as follows: ***1, oxydizing flame,*** commonly caused by the chemical union of oxygen with another substance, if more oxygen be supplied than is needed for perfect combustion, the free oxygen in excess makes an oxydizing flame, one that rusts or burns the metal. A flame may be oxydizing in one place and reducing in another; ***2, reducing flame,*** defined as a flame in which the fuel is in excess of the oxygen necessary for perfect combustion. *The tendency of such a flame is to draw some oxygen from the burned parts of the metal.* It prevents burning within its radius.

temperature required in brazing, *a flame is generally used instead of a heated bit.*

For small work a blow pipe or torch is used, and a forge for large work. A torch alone is ordinarily insufficient as the heat must be put where it is needed and held there. This is usually done by building around the work with charcoal which becomes incandescent from the heat of the gasoline flame, and also gives off some heat from its own combustion.

If the article to be brazed be very small, it can be placed bodily in a hole scooped in a bit of charcoal as shown in fig. 8,638.

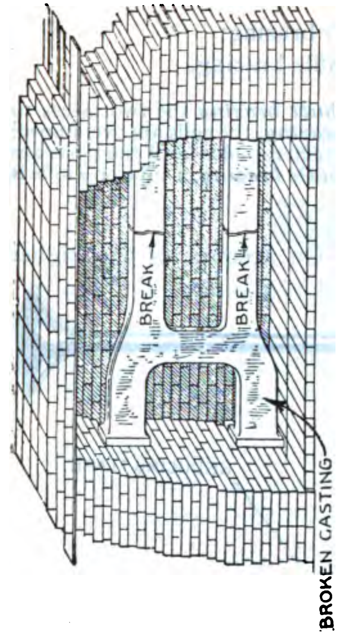
In brazing in the smith's forge it is well to hold the work high up, that is, so that it does not rest on the coal.

Moreover the work is kept suspended between banks of incandescent fuel so that the heating will be as near uniform as possible.

A charcoal fire should be used, but if bituminous coal be used, coke enough of it to do the work, as the sulphur in the soft coal is to be avoided where good brazing is desired.

A gas furnace is very desirable for brazing.

An air blast is necessary as in the forge but a comparatively small blower will suffice.



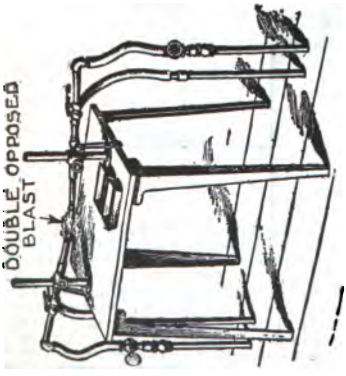


FIG. 8,635.—Double opposed torch brazing furnace without fire brick.
FIG. 8,636.—Quickly constructed furnace for brazing; view showing broken casting in position ready for brazing.

Brazing of Copper.—For coppersmith's work the joints are prepared either by *thinning* or *cramping*.

The first process consists simply of scarfing the edges to a long bevel, and is used for heavy material only. The second, a necessity for lighter

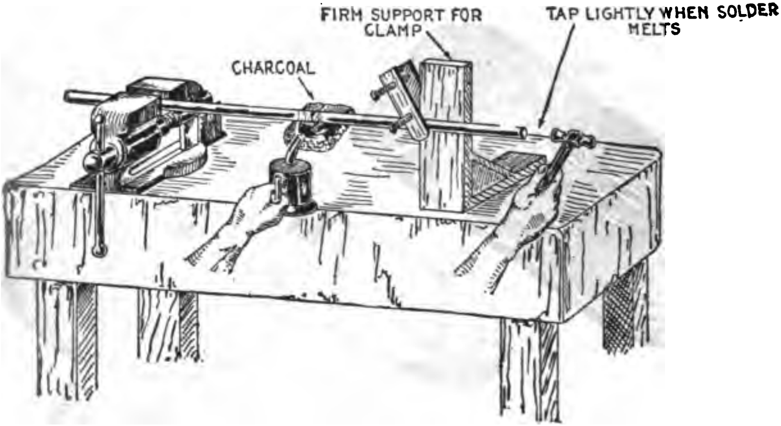


FIG. 8,637.—Butt brazing two lengths of small pipe. After cleaning the ends to be brazed and fluxing, they are clamped in position butt to butt using a vise and clamp as shown, or other means. A little brazing solder is sprinkled over the joint and heat applied. When the pieces are hot enough to melt the solder, it must flow into the joint, butt brazing the two pieces. By giving one of the pieces a slight tap on the end, when the solder melts, the surplus solder is squeezed out, making a good and firm joint. If the pipes be large or of considerable length, the heat is quickly conducted away, necessitating a charcoal backing or more adequate means of heating.

Table of Brazing Solders

Description	Copper	Zinc	Tin	Lead
Coppersmiths' strong spelter............	75	25		
Coppersmiths' spelter..................	58	42		
Ordinary refractory spelter.............	50	50		
Hard white solder......................	57½	28	14½	
Half white, easily fusible..............	44	50	4½	1½
Spelter, readily fusible................	33⅓	66⅔		

work, is rather more elaborate; notches are cut at a slight angle into one of the edges to be united, and the teeth thus formed are bent alternately to left and right. The edge of the other piece is thinned and inserted between the cramp, so that alternate pieces come on opposite sides of the thinned edge supporting it.

Copper joints to be brazed are cleaned by covering the parts with a strong brine made from salt and water; they are then heated to a cherry red and plunged into clean fresh water. which also has the effect of

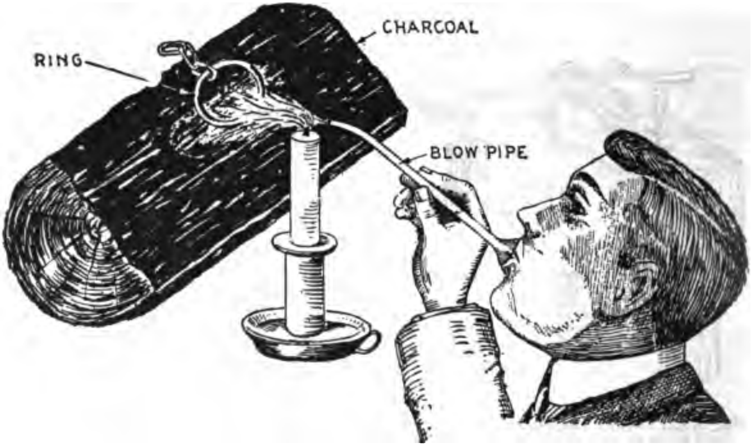


Fig. 8,638.—Brazing a small chain link in charcoal with a blow pipe. Place the broken link in a small hole scooped in the charcoal and heat with the candle flame and blow pipe after applying the solder and flux.

Miscellaneous Brazing Solders

PERCENTAGE				Characteristics	Color
Copper	Zinc	Tin	Lead		
58	42			Very strong	Reddish yellow
53	47			Strong	Reddish yellow
48	52			Medium	Reddish yellow
54.5	43.5	1.5	0.5	Medium	Reddish yellow
34	66			Easily fusible	White
44	50	4	2	Easily fusible	Gray
55	26	15	4	White solder	White

annealing the copper. Scouring follows with clean water and sand rubbed on with a wad of tow.

The brazing mixture is made of borax and spelter in equal parts, with water, and is preferably made a day or two previously. The prepared

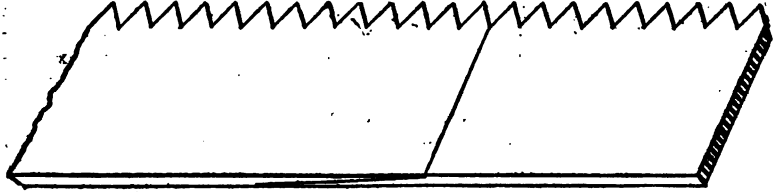


FIG. 8,639.—Method of lap brazing a band saw. ***In making the lap,*** the two ends are chamfered by filing to make an accurate joint as shown. Silver solder is generally used, it being applied between the two surfaces, or the surfaces are coated with borax and the solder allowed to flow into the joint from the edges. After firmly clamping the parts in position, the solder is laid over the joint, or it may be placed between the two pieces to be united. When the heat is applied, the solder melts and the two pieces must be squeezed tightly together to force out surplus solder. Silver coins contain 10 per cent. of copper and make a good hard solder. When using a coin, pound it until very thin and then place between the two surfaces to be brazed.

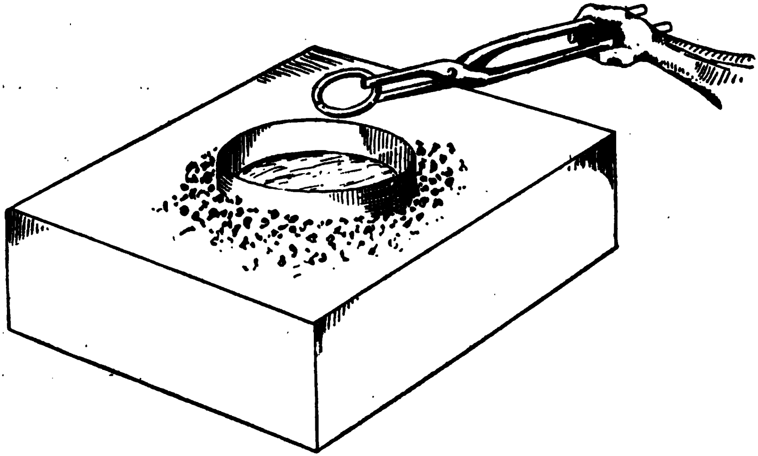


FIG. 8,640.—Brazing by immersion or dipping. The brazing solder is melted in a pot on the coal fire, as shown, or better in a gas furnace, flux being placed on top of the solder. ***In brazing,*** hold the object first in the flux a little while to heat and coat the article with a film of flux. Then, when it is lowered into the solder, the latter will flow in the joint and firmly attach itself. Before dipping, the article to be brazed is coated with a special anti-flux graphite, covering all the surface except that which is to be brazed. The layer of flux in the pot may be kept from ½ inch to 2 inches deep.

portions of the article to be jointed are placed together and fastene if for a pipe, by being bound with iron wire. The over lapping edges are closed by means of a mallet on a stake or mandrel.

The mixture is then laid evenly along the joint, and the pipe or othe article placed upon a clear coke fire, the temperature of which is easi regulated. Presently, the borax fuses and forms into *drops*, and th the solder melts, which is indicated by blue fumes from the zinc. Pr ably it will be necessary to sprinkle a little more powdered borax, a the pipe may have to be tapped with a mallet or hammer to cause th lapped parts to open slightly and permit of the solder flowing readi between them. Salt is often strewn on the surface immediately a the solder has run, to kill the borax, as it would leave a hard scale interfer with future filing.

FIG. 8,641.—Brazing the joint of a pair of tweezers. The surfaces to be brazed are clea some of the spelter applied to each surface, and the pieces tied together with a fine wire and heated sufficiently to melt the spelter. The heat may be applied with a b pipe or by holding the pieces in a pair of hot tongs. When the spelter is melted the p is cooled and the iron wire is taken off. When the pieces are clamped in hot tongs, th wire is sometimes omitted, the pieces being placed in their proper relation and the depended on to keep them there, or stops may be arranged to determine the location o pieces.

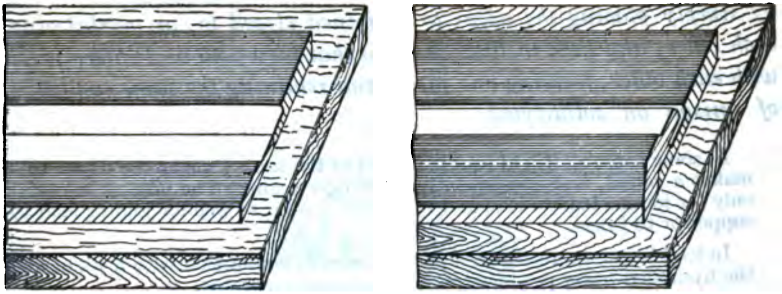
All flanges to be brazed to copper pipes must be of copper or wha known as brazing metal, 98 copper to 2 of tin, as gun metal flanges wo melt before the spelter ran.

The hole in the flange is slightly tapered, and the end of the pipe al to form a clearance in which the spelter may flow, a countersink be also formed in the face side of the flange, and the pipe slightly ope to fit it.

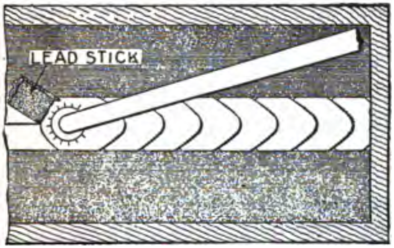
After the mixture is placed in the joint and the parts put togeth the countersink is stopped with clay, to retain the solder. The p is then slung vertically over the fire, with the flange underneath, a the previous process carried out.

It will frequently be necessary to close the pipe with a clay tam or a wooden plug to prevent the heat going up it. Projections fr flanges are protected from the fire by means of a covering of clay.

Lead Burning.—This process, sometimes erroneously cal autogenous soldering, consists of *joining pieces of lead toge*



Figs. 8,642 and 8,643.—Preparation of butt and lap seams for lead burning. Fig. 8,642 shows the edges of a butt seam placed together on a piece of flat board, and the seam shaved ready for burning. The width of the shaving is governed by the thickness of the lead to be joined. For 5 lb. lead the rear should be about 3/8 inch wide, that is the edge of each piece should be shaved to a width of 3/16 inch. Fig. 8,643 shows a lapped seam ready for burning. The face of the under side is shaved the width of the seam, and the over lead on the under side, as well as on the upper face, the width being a little less than the width of the seam for butt burning. The shaving is done with an ordinary shave hook and straight edge. To burn either of these seams, first regulate the gas and air cocks or the gas and oxygen cocks of the generator as the case may be, so as to obtain a "hard solid flame."



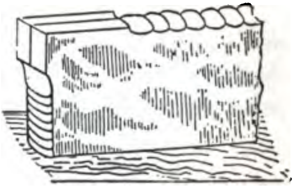


Fig. 8,644.—Lead burning. 1, Butt seam. For flat butt burning the end of a stick of lead should be held on the seam so as to be melted at the same time as the other lead. Before beginning to burn the seam, a stick of lead should be held in the hand and the flame made to play upon it so as to ascertain the hottest part of the flame to apply to the seam. If the flame tarnish or smoke the lead stick, more air or oxygen should be burned in, but if the lead turn to a silvery brightness, when the flame impinges, the heat will be right and the part of the flame to be used will be ascertained. Now tack the two ends of the seam by melting little beads on them to hold the pieces in position. The burning can now be started, beginning being made at the right hand end. The flame is lifted immediately when the metal begins to flow and reapplied at a distance of from 1/8 to 1/2 inch, according to the thickness of the lead being joined together, giving the appearance as shown. During the process of burning, the sheet lead will be expanded when the heat is applied, and being a poor conductor, the heat is not distributed to the adjoining sides of the seam, hence the heated parts will rise up and leave hollow spaces underneath. When this happens, leaving places where the lead does not rest in the board the lead melts more readily, with the result that a hole is made, through which the molten metal will flow. To prevent this, the lead should be held down with the end of the stick of feeding lead, which is held in the left hand.

Fig. 8,645.—Edge burning. In this case no feed lead is necessary, but a slight jar has to be given to start the first bead on either the vertical or the horizontal seam.

by simply placing the edges to be joined closed to, or overlapping each other, and then melting them so that they flow and intermingle with each other, forming one piece, and retaining the same condition of unison on solidifying.

In some cases a strip of lead is melted at the same time as the edges; this makes a raised, and consequently a stronger seam. The process is used only for joining lead to lead and would not answer so well for joining lead to copper or to brass.

In lead burning, a hydrogen flame is used in connection with a jet of air, the hydrogen being produced in a machine or generator.

For joining lead sheets together by burning, it is essential that the pieces touch or overlap each other when in the horizontal position, and overlap when in either slanting, upright, or overhead positions. It is not necessary to *soil* the sides of the seams, because the lead will flow only when it is directed by the flame jet. No fluxes are necessary.

CHAPTER 144

Welding

The art of *forcing two pieces of metal into union by means of eat and pressure*, is known as ***welding.***

Until the introduction of electric welders, it has always been a difficult process, requiring considerable experience and skill of hand and eye. Not only must the temperature of the heated iron be properly judged for a successful weld, but the metal itself must be protected from the effect of the oxygen in the air.

Oxidation of Iron.—If a piece of iron be heated in contact with air, it will absorb oxygen from the air, thus forming a scale of oxide of iron on the surface. The hotter the iron, the more rapidly will the scale form.

Oxide of iron prevents welding because it lies between the two surfaces to be united and prevents them coming into contact.

Methods of Preventing Oxidation.—There are two methods used in welding to prevent the formation of oxide of iron, and both methods are based upon some means of protecting the hot iron from the oxygen in the air.

Oxidation may be prevented by using: 1, a reducing fire, or, 2, a protective coating. A reducing fire is one in which all the oxygen is consumed in the combustion. In practice this is accomplished by having a closed thick bed of fire for the air to pass through before coming in contact with the iron and by maintaining a moderate blast.

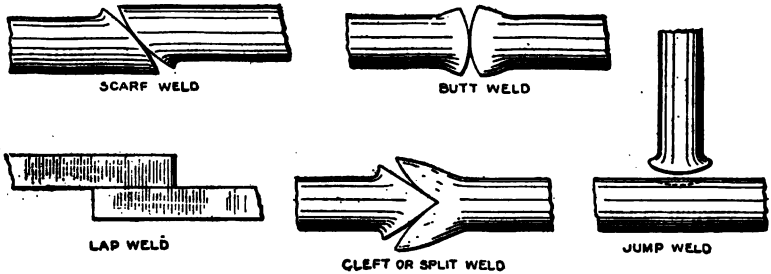
A protective coating, called a *flux* is a substance containing no oxygen, which is applied to the heated metal, and which possesses certain qualities which prevent oxidation.

Fluxes.—The usual composition of fluxes for the various metals are as follows:

Cast Iron.—Equal parts of carbonate and bicarbonate of soda to which is added 10 to 15 per cent. of borax and 5 per cent. of precipitated silica. Ordinary table salt may also be used.

The flux should be used only when the metal does not run freely, and then only sparingly.

Too much causes the metal to harden so that it cannot be machined.


SCARF WELD

BUTT WELD

LAP WELD

CLEFT OR SPLIT WELD

JUMP WELD

FIGS. 8,646 to 8,650.—Various welds. Fig. 8,646, ***scarf weld.*** In this weld *the two pieces are chamfered*, that is beveled. If the iron be of uniform thickness it is first upset at the point where the weld is to be made to make it a little thicker, then it is scarfed. To scarf, the upset end is thinned down, generally with the peen of the hammer, drawing it out thin at the point and crowding the metal together at the stick. The faces to be welded are given a crown shape to facilitate squeezing out of the slag as the weld is closed. Fig. 8,647, ***butt weld.*** This is *an end to end weld.* Usually the two pieces are upset a little at first, and then ends welded together. They are hammered on end to bring them together, and as this tends to upset the pieces some more, they are drawn out to the required size after the weld has been made. In preparing the ends, the surfaces to be welded are made convex as in the scarf weld, in order to allow the slag to work out. Fig. 8,648, ***lap weld:*** a weld in which *the faces of the two pieces overlap.* When the faces are not crowned or rounded, care should be taken to begin hammering at the center and work outward to force out all the slag. Fig. 8,649, ***cleft or split weld:*** *a "tongue and groove" form of weld.* One of the pieces after upsetting on the end to gain width, is split in the center making a V shaped groove the other piece is chamfered on both sides bringing it to a point to form a V tongue to fit the groove. In welding the two pieces they are "stuck" together by hammering on the end, and then on the sides of the groove piece to close the weld. The V groove should not have straight sides but slightly rounded as shown so that the slag may be forced out in closing the weld. Fig. 8,650, ***jump weld.*** *A weld formed by bringing the ends of a bar together* and *jumping them upon the anvil, or with a heavy hammer.*

Steel.—Borax, boracic acid, sodium chloride (salt). It is used only when the metal will not run.

Mild Steel and Wrought Iron.—Same as for steel, used sparingly or not at all.

Copper, Brass, and Bronze.—Same as above. When used for brass make a paste with a little water.

Aluminum.—Flux consists of: 15% lithium chloride; 45% potassium; 30% sodium; 7% potassium fluoride; 3% bisulphate of potassium. Another flux for aluminum is plain borax.

Various Welds.—These may be classified according to the way the ends are formed prior to making the weld, as

1. Scarf weld;
2. Butt weld;
3. Lap weld;
4. Cleft or split weld
5. Jump weld;
6. Glut weld.

In addition, there are two processes, known as: 1, fagoting, and 2, building up. Fagoting consists in assembling a quantity of iron junk such as old bolts, pieces of chain, turnings, and other scrap iron, and forging the mass into a billet or slab.

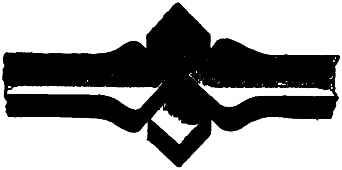


FIG. 8,651.—***Glut weld.*** *A weld in which the ends of the two parts are tapered down, and the angles filled with wedges of iron*, the whole being welded together while checking the length with a trammel, excess material being subsequently cut away. This type of weld is generally used in repair work where it is necessary to maintain unchanged the length of the broken part.

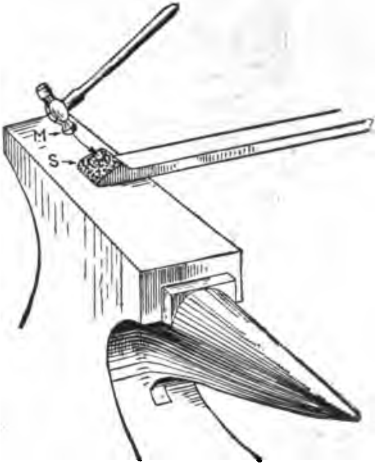


FIG. 8,652.—Making a scarf for a scarf weld. To do this, the upset end is thinned down, generally with the peen of the hammer, drawing it out thin at the point and crowding the metal together at the stock by drawing the hammer as shown at M. The faces to be welded should be rounded as shown at S, so that the pieces first come in contact at the center, in order to give the slag and impurities an opportunity to squeeze out as the weld is being closed.

Building up is the process of making a multi-piece forging.

NOTE.—It will be noticed from the illustration of the various weld that *the surfaces are in most cases rounded or curved.* This is done so that when the heated ends are brought together they will unite first in the center. Any slag or dirt which may have adhered to the heated surfaces *will then be forced out as the welding proceeds from the center outward.* When making a lap weld, the hammering should begin at the center in order to work all the slag out, as the faces in this case are not rounded.

Forge Fuels.—Several kinds of fuel, such as, charcoal, coal, coke, and gas are used for heating metal in welding. Perhaps bituminous coal is mostly used, though for general work coke is considered the best.

Welding Methods.—The various systems of welding may be classified: 1, with respect to the method of working, as

a. Hand welding. *b.* Machine welding.

2. With respect to the treatment of the metal, as

a. By hammering. *b.* By fusing (autogenous).

FIG. 8,653.—*Fagoting.* The pile is started with a flat piece of iron, generally fagoted up of small pieces and the pieces of scrap iron piled on top of this, making a firm rectangular pile with large pieces around the outside and small pieces in the center, or the flat piece on the board may be omitted. It is then heated in a furnace and welded under a steam or a machine hammer.

3. With respect to the method of heating, as

a. By forge fire.
b. By blow pipe.
c. By combustible melting.
d. By electricity.

Blow Pipe Welding.—This method consists in *uniting the* *metal pieces by means of a blow pipe flame* of appropriate temperature with the addition of metal of the same composition, the joint thus obtained is called autogenous.

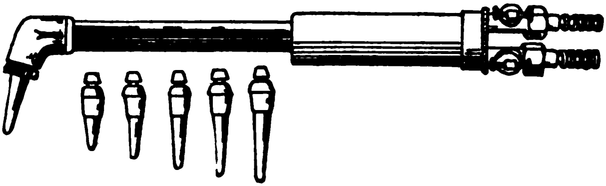
First oxy-hydrogen was used, in the blow pipe, then oxy-acetylene, and later, oxygen and coal gas, and oxygen and benzol, etc.

The temperature of the oxy-hydrogen flame is approximately 4,000° Fahr., and the oxy-acetylene flame, 6,300°.

In making an autogenous weld, the torch should be given a rotary motion, accompanied by a slight upward and forward movement with each rotation.

FIGS. 8,654 and 8,655.—Correct shapes for jump and lap welds.

FIGS. 8,656 and 8,657.—Incorrect shapes for jump and lap welds

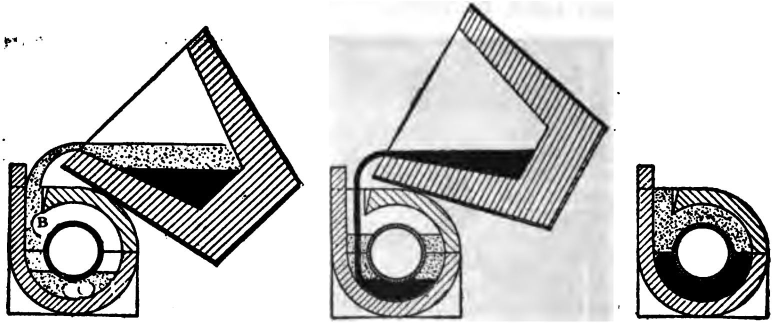


FIGS. 8,658 to 8,663.—Davis-Bournonville oxy-acetylene blow pipe, or "torch." Both gases being admitted to the mixing chamber at appreciable pressure, and at right angles to each other, the maximum of molecular contact of the two gases is secured. The working pressure of both gases are controlled by regulators on the tanks. The type of torch shown, the "positive mixture torch," is for light, medium or heavy welding.

This movement assists in blending the metal and reduces the liability of local overheating. It is desirable to keep the metal surrounding the spot operated upon to a fairly high temperature to prevent excessive conduction of heat away from this spot.

When fusion occurs, new metal should be added from a "weld rod" of suitable composition.

The surface should be thoroughly fused before adding metal from the welding rod, and the latter should be held close to, or in contact with, the surface.

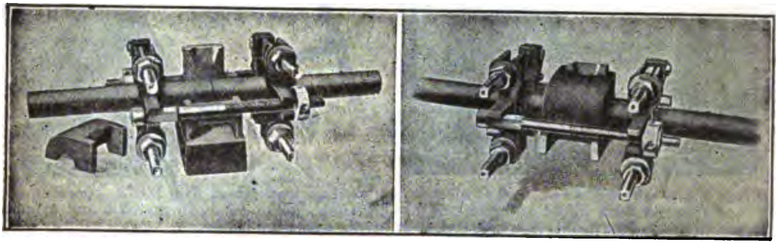


Figs. 8,664 to 8,666.—Thermit pipe welding operation. Fig. 8,664, slag flowing into mould and coating inside of pipe and inside of mould. Fig. 8,665, slag in mould and steel following, displacing slag in bottom part. Fig. 8,666, both slag and steel in mould but steel separated from pipe and mould by film of slag. In making a butt to butt thermit pipe weld, the pipe ends are first faced very accurately and are then held tightly together by means of clamps. A cast iron mould is then placed around the pipe ends and the proper amount of thermit ignited in a small flat bottom crucible or ladle. As soon as the thermit reaction is over (about ½ minute), the contents of the crucible are poured into the cast iron mould. The liquid alumina or slag which floats on top of the molten mass in the crucible, naturally goes into the mould first and covers the inside of the mould and the outside of the pipes with a protective coating which prevents the superheated liquid steel, which flows in afterwards, coming in contact with either. The heat of the entire mass, however, serves to bring the pipe ends up to a welding temperature at which time they are squeezed together by means of the clamps and a butt weld effected. The entire thermit mass can then be knocked away from the pipes and nothing will stick to either the pipe or the mould. A slight upset will be observed on the outside of the welded pipe but the inside diameter is in no way affected.

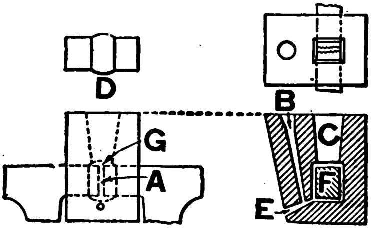
Thermit Welding.—This process consists in *pouring superheated thermit steel around the parts to be united.*

This thermit steel is produced by the chemical reaction between finely divided aluminum and iron oxide when ignited. This reaction when started in one spot continues throughout the entire mass, without the supply of heat or power from outside and produces superheated liquid steel and superheated liquid slag (aluminum oxide) at a temperature of approximately 5,400° Fahr.

From 30 seconds to one minute is sufficient time to bring into reaction almost any amount of thermit. The thermit steel when poured into a mould surrounding the ends of the sections to be united dissolves the metal with which it comes in contact and amalgamates with it to form a single homogeneous mass when cooled. It is necessary, however, in all cases to preheat the sections before pouring the thermit steel, as otherwise they would exert a chilling effect on the incoming metal and prevent successful fusion.



FIGS. 8,667 and 8,668.—Thermit pipe clamps and mould. Fig. 8,667, pipes held in clamps. Mould partly assembled for thermit welding. Fig. 8,668, mould fully assembled ready for weld.



FIGS. 8,669 to 8,672.—Mould for thermit welding of locomotive frame that has been broken between the pedestals at A. The mould surrounding the broken part should be so arranged that the molten thermit will run through a gate to the lowest part of the mould and rise through into a large riser. In the mould here shown the thermit is poured through gate B, and rises into space C, after passing through and between the ends of frame F. The mould must allow for a reinforcing band or collar of thermit steel to be cast around the ends to be welded. Space G, for forming this collar, and the opening between the frame ends must be filled before ramming up the mould. Yellow wax is ordinarily used for this purpose. The shape of this band or collar should be as indicated by the view of the completed weld at D. The thickest part is directly over the fracture and the band overlaps the edges of the break at least one inch. Pattern for the riser, pouring and heating gates can be made of wood. The riser C, should be quite large because the steel that first enters the mould is chilled somewhat by coming into contact with the metal, even when pre-heated. This chilling effect is overcome by using enough thermit steel to force the chilled portion up into the riser and replacing it by metal which has practically the full temperature received during reaction. The mould must be of a refractory material owing to the intense heat. When the mould and box are filled and tamped, the wooden runner and riser patterns are withdrawn. The mould is then ready for pre-heating and the drying operation, which causes the wax matrix to melt and run out.

The essential steps of the operation, therefore, are to clean the sections, and remove enough metal to allow for a free flow of thermit steel, then surround them with a mould, preheat by means of a gasoline torch, ignite the thermit in the crucible suspended over the pouring gate of the mould, and then pour the thermit steel.

Figs. 8,673 and 8,674.—C and C electric arc welding apparatus. Fig. 8,673, operator with one type of head shield and combination electrode holder for both metallic and graphite electrodes. Fig. 8,674, graphite electrode holder and hand shield.

Electric Welding.—All systems of electric welding are based upon the principle of causing a current of electricity to pass through a high resistance, thereby generating heat.

There are, however, important differences in the manner in which the heat so generated is applied to the welding of metals.

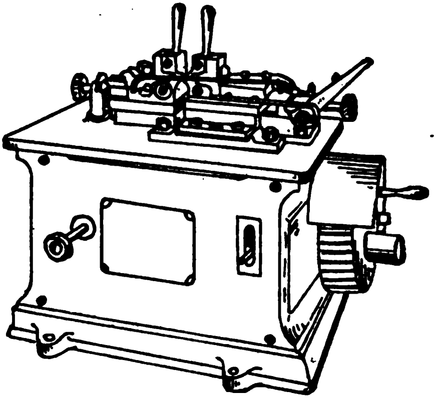
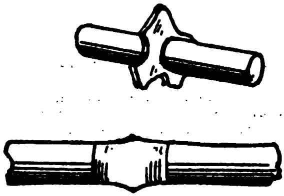


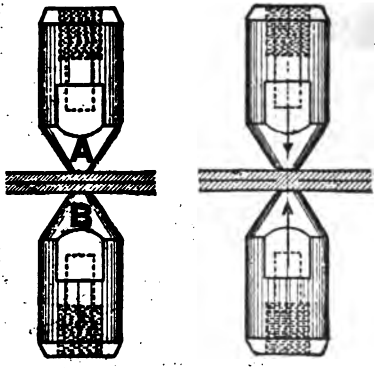
Fig. 8,675.—Thomson welder. Portable, pressure and cut out, mercury slide, with regulator and automatic break switch. Copper wire No. 23 to No. 15. Power 1.5 *kw*. Time, fraction of second. ***To operate,*** move lever at right to position shown; hold back levers at center and insert wire; return lever at right to opposite position; press button and the weld is made.

Thomson Process.—In this method a current of electricity heats the abutting ends of the two objects which are to be welded, these being pressed together by mechanical force, and so arranged with the electric current that there is great and rapid accumulation of heat at the joint, in consequence of the greater relative conductivity of the rest of the circuit.

Zerner or Electric Blow Pipe Process.—In this method, *an electric arc is drawn between two carbon electrodes.* This arc is then caused to impinge upon the metal surfaces to be welded by means of an electromagnet. The arc is pointed to concentrate the heat, and the metal is fused around its point of contact with the arc.



Figs. 8,676 and 8,677.—Flash weld, and upset weld. ***A flash weld*** is generally used on stock that is wide and thin; where it is rectangular in shape, and where it is not possible to have the welding faces cut square and true. ***An upset weld*** is used in all cases where the weld is to be hammered, using the heat generated in the welding. Also for small rods or rings where it is not necessary to have a uniform thickness of stock. On brass or copper a flash weld is made. Three times the diameter of stock between the dies should be allowed on brass and four times on copper, but only once the diameter of stock is actually taken up in the weld.



Figs. 8,678 and 8,679.—***Spot welding.***—This is *the process of joining or fusing together electrically two or more metal sheets or parts without any preparation of stock.* ***In welding,*** two electrodes, or welding points, A and B, fig. 8,678, are brought to bear on the plates where it is desired to make the weld and a heavy current at a low electrical pressure is passed through the electrodes. The metal plates, as they are much poorer conductors of electricity, offer so great a resistance to the flow of current that they heat to a molten state, and then, by applying pressure on the electrodes, the metals are forced together and the weld is made, as shown in fig. 8,679.

This method is applicable to a rather limited range of small work, such as welding small steel and brass castings, plates, tubes, tanks, etc.

Bernados Process.—*The metal to be welded is connected to one pole of an electric circuit.* When iron or steel is being welded, for which a high temperature is needed, the metal is made the positive and the carbon the negative. In the case of lead, or any metal requiring a comparatively low temperature, this polarity is reversed.

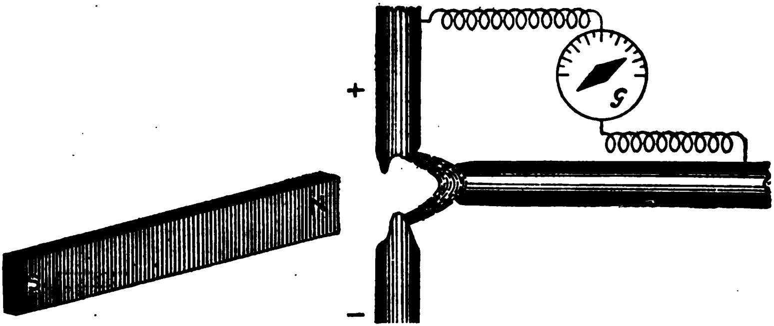
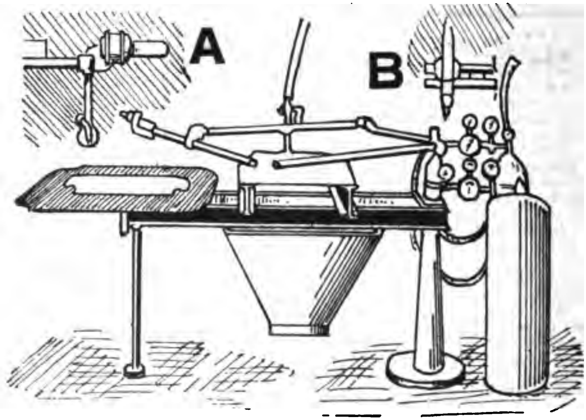
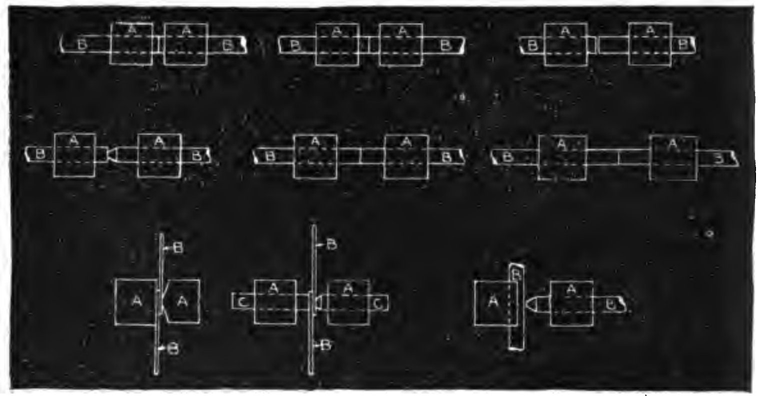


FIG. 8,680.—Electric blow pipe. ***It usually consists of*** two carbon rods, to each of which one pole of the electric circuit is connected, and an electromagnet energized by a shunt current is suspended over the arc. When the current is turned on a strong magnetic field is formed which produces a blow lamp effect on the arc, and by placing the article to be welded or brazed at varying distances from this flame, the heat can be regulated.



FIGS. 8,681.—Davis-Bournonville oxygraph. At A, is shown a motor rheostat and tracing device; at B, the cutting torch. The oxygraph is seen below. This machine will cut steel up to six inches in thickness, at the rate of three to twelve inches per minute, a larger size cutting up to 18″ in thickness, and another modification, for circle or straight line cutting only, taking in armor plate up to 24″ thick. It has an electrically propelled rolling tracer, which is guided along the lines of a drawing, and the cutting flame will make an exact reproduction in one machine of one-half the dimensions, in another of the exact size of drawing. Steel can be cleanly and smoothly cut at short angles and of any irregular shape. The machine is desirable for die makers, blanking out connecting rods, crank shafts, etc. The motor can be connected to a lighting circuit or to a battery. The automatic uninterrupted feed adapts the machine to quantity work, and to all work where accuracy, as well as smoothness of cutting surfaces, or roughing out close to the required finished surface are essential.



FIGS. 8,682 to 8,690.—General hints on electric welding. ***Cast iron*** cannot be commercially welded, as it is high in carbon and silicon, and passes suddenly from a crystalline to a fluid condition when brought up to the welding temperature. ***Iron or steel.*** It is necessary to keep the temperature below the melting point to avoid injury to the metal, and consequently considerable pressure is required to make the weld. The stock should be placed in the dies as shown in fig. 8,682 for a flash weld, and as shown in fig. 8,683 for an upset weld, A representing the dies, and B, the stock to be welded. ***High carbon steel*** can be welded, but must be annealed after welding to overcome the strains set up by the heat being applied locally at one place. Good commercial results are hard to obtain when the carbon runs as high as point 75 or above, and can only be done by an experienced operator. When below point 25, the operator can always be sure of making a good weld. To weld high carbon steel to low carbon steel, the stock should be clamped in the dies as shown in fig. 8,684, with the low carbon stock extending considerably further out from the dies than the high carbon stock. ***Nickel steel.*** This welds readily, and a small percentage of nickel materially increases the tensile strength of the metal. ***Iron to copper.*** These metals can be welded to each other, but it will be found necessary to reduce the cross section of the copper as shown in fig. 8,685. ***Copper and brass.*** When welding copper and brass the pressure must be less than when welding iron. The metal is allowed to actually fuse or melt at the juncture, and the pressure should only be sufficient to force out the burnt metal. This burnt portion being forced out, accounts for the good results obtained in welding these metals. The current must be cut off the instant the ends of the metal begin to soften. This is done by using an automatic switch which opens at any predetermined point. The sliding head is actuated by either a spring or weight to force the heads together as soon as the metal softens, and this automatically operates the switch. As copper and brass are good conductors of the electric current, a larger volume of current at lower secondary voltage is used and the sliding heads are arranged to move with the least possible friction. The dies should be set apart approximately three times the diameter of the stock for brass and four for copper. See figs. 8,686 and 8,687. A, represents the dies, and B, the stock to be welded. The welds when properly made will stand the strain of the rolling or drawing process to reduce them to a smaller size. ***Spot welding.*** To weld two pieces of sheet steel at one small place or spot is called spot welding. For convenience of handling the stock this is usually done in a machine with vertical clamping dies. Where the size and shape of the pieces to be welded will admit, the work can be done in a butt welder equally as well. In this case one of the dies is slightly pointed and the stock welded between the dies as shown in fig. 8,688. Another way is shown by fig. 8,689, where two pieces of copper rod C, one of them slightly pointed, are clamped in the dies A. If galvanized iron is to be welded it will be found necessary to use two pointed dies instead of one flat and one pointed. ***Jump welding.*** This is for light stock only and the best results are obtained by slightly pointing one of the pieces as shown in fig. 8,690. The other piece is held with a portion extending outside the die, then bring them together, turn on the current and weld quickly.

This process is especially adapted to the filling up of blow holes, cracks, etc., in steel castings.

Slavianoff or Modified Bernardos Process.—In this method, *an electrode which is of the same material as the metal to be welded is used instead of a carbon electrode.*—This change is made so as to prevent the hard welds which sometimes result with the Bernardos or Zerener processes, owing, principally, to the transfer of carbon from the electrode to the weld. A direct current of about 130 amperes and 24 to 26 volts across the arc is adapted for this process.

Hoho and Lagrange Process.—The apparatus used usually consists of a lead lined wooden tank, filled with an electrolyte of any conducting liquid solution, either alkaline or acid.

The positive pole of a dynamo, giving usually about 200 volts, is connected directly to the inner leaden sheath. The bar of steel or other metal to be heated, is connected to the negative pole and plunged into the bath.

Directly the bar touches the liquid, electrolysis is set up and the water splits up into its component parts, the oxygen going to the leaden sheath and the hydrogen clinging to the metal, forming a complete gaseous envelope around it, and thus preventing the metal actually touching the solution. Here again, a high resistance to the flow of current is offered by the hydrogen sheath, and the electric energy is transformed into heat.

It is difficult with this process to control the temperature, but some practical applications have been made, one of the most successful being the annealing of wire by passing it rapidly through the solution.

A modification of the system consists in replacing the liquid by powered carbon or charcoal, the article to be heated forming one pole, and the carbon, the other pole. When the article touches, or is inserted in the powdered carbon, the resistance of the latter and its poor contact with the metal generate heat which is conducted to the object.

CHAPTER 145

X-Rays

These rays, discovered by Roentgen were called X-rays because of their unknown real nature.

Some scientists have regarded X-rays as light rays of very small wave length, but the sounder theory seems to be that they are instantaneous impulses produced by the impact of electrons upon the anti-cathode. They may be likened to the sound waves produced by rain drops on the roof, not of a definite pitch. The velocity of X-rays is probably the same as that of Hertzian waves.

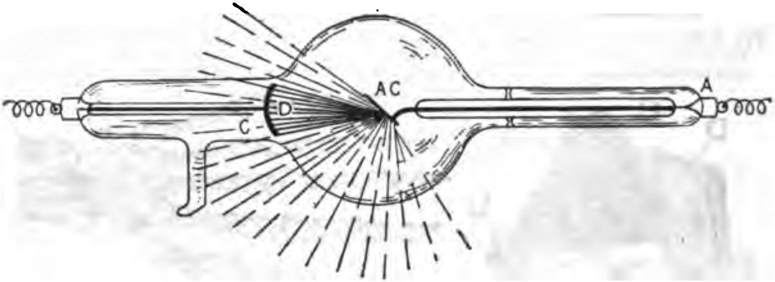
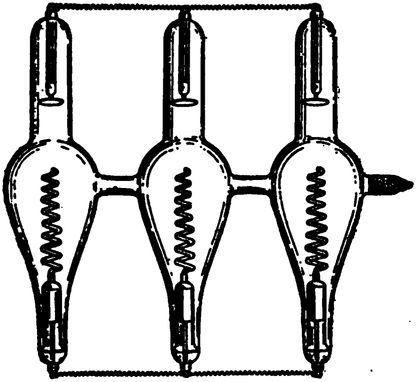


FIG. 8,691.—Single focus X-ray tube. ***In this tube,*** the copper wire A, is the ***anode***, the cup shaped aluminum plate C, the *cathode*, and the thin plate of platinum foil A,C, is the *anti-cathode*. The copper wire connecting the anode with the anti-cathode, makes the latter the anode. ***In operation,*** the cathode rays represented by the dark cone D, converge onto the inclined surface of the anti-cathode, so that the latter becomes a *point source of X-rays*, the rays being radiated in all directions as shown by the broken lines. The anti-cathode is made of platinum so as to enable it to resist the powerful heating effects of the concentrated cathode rays.

The exact nature of the X-ray is still under discussion. The most commonly accepted explanation is that it is a disturbance of the luminiferous either similar to visible light, but having much shorter wave length than ultra-violet light.



The apparatus necessary for the production of X-rays consist of a vacuum tube, a battery, and an induction coil with interrupter.

If an electrical discharge be passed through a vacuum tube exhausted to a Crookes vacuum (much higher degree of exhaustion than in the tubes of Hillorf, Geissler and Lenard X-rays are produced whenever the cathode stream is arrested by the walls of the tube or metallic objects therein.

The cathode stream is believed to be a discharge of negatively charged electrons from the surface of the cathode.

Fig. 8,692.—Scheidel-Western triple valve tube. The valve tube is used as an accessory to the X-ray coil for eliminating any reverse current. It assists in obtaining greater definition in the radiograph, and by eliminating the heat rays prolongs the life of the X-ray tube.

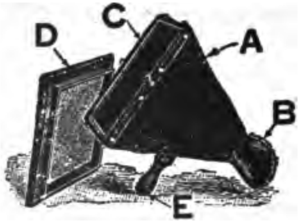


Fig. 8,693.—Fluorscope. ***This device consists of*** a light tight box A, provided with an aperture for the eyes at B, and an opening C, at the opposite end for the fluorescing screen D. The latter consists of a piece of paper or cardboard coated with platinum-barium cyanide crystals, which fluoresce under the action of X-rays. When such a screen is held against the face by means of the handle, and the aperture B, pressed tightly around the eyes so as to exclude all outside light, and the screen placed near an active X-ray tube, the former will fluoresce with a greenish yellow light.

Fig. 8,694.—X-ray fluorescent shadow of the bones of the hand and wrist. If a hand, for instance, be placed between the screen and the tube of the fluorscope (fig. 8,693) the X-rays will pass through the fleshy parts and impinging on the screen will cause it to fluoresce, but, being intercepted by the bones, will not affect the screen, thus leaving thereon a shadow picture of the bones as shown. It is immaterial whether the screen be placed in the holder box with the crystal coated, or opposite side turned to the eye aperture.

Fluorescing Screens.—Examination of objects, such as the bones of the hand, foreign bodies in the system, etc., are made with the aid of a *fluorescing screen* or *fluroscope.*

The intensity of the illumination produced by the fluorescence on the screen rapidly diminishes with the distance of the screen from the tube; therefore, in order to obtain a maximum illumination and consequently a sharply defined shadow, the screen should be held close as possible to the source of X-ray, and the hand close to the screen.

Radiographs.—A picture taken upon a photographic plate by means of X-rays is called a radiograph.

To take a radiograph, replace the fluorescent screen of the fluoroscope by a suitable photographic plate, give it the proper exposure and develop as in photography.

Radiographs may be made on photographic paper, films, or glass plates. For best results, however, specially prepared X-ray plates with double coating should be used.

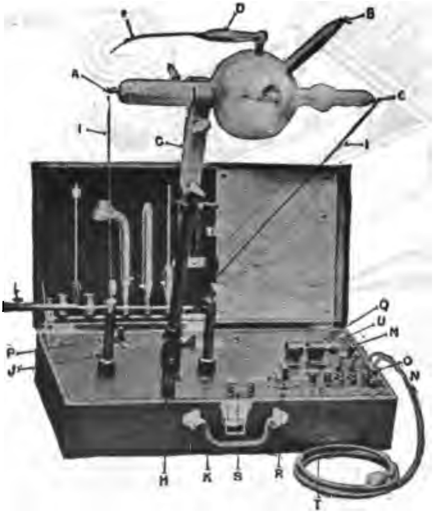


FIG. 8,695.—Scheidel-Western suit case portable coil. ***The parts are:*** A, cathode; B, anode; C, assistant anode; D, regulating chamber; F, regulating adjuster; G, tube holder; H, tube holder socket; I, connection tapes; J, left hand terminal post; K, right hand terminal post; L, regulating rod; M, main line switch; N, connecting cord; O, connecting cord sockets; P, selector switch; Q, interrupter spark gap; R, controller switch; S, D'Arsonval; T, cautery and diagnostic lamp; U, sinsuoidal current. Any electric lighted diagnostic instruments may be used with this coil. The sinusoidal current for inducing muscular contraction without pain is applied by means of metal or moist electrodes, connections being made to the two binding posts marked *sinusoidal*.

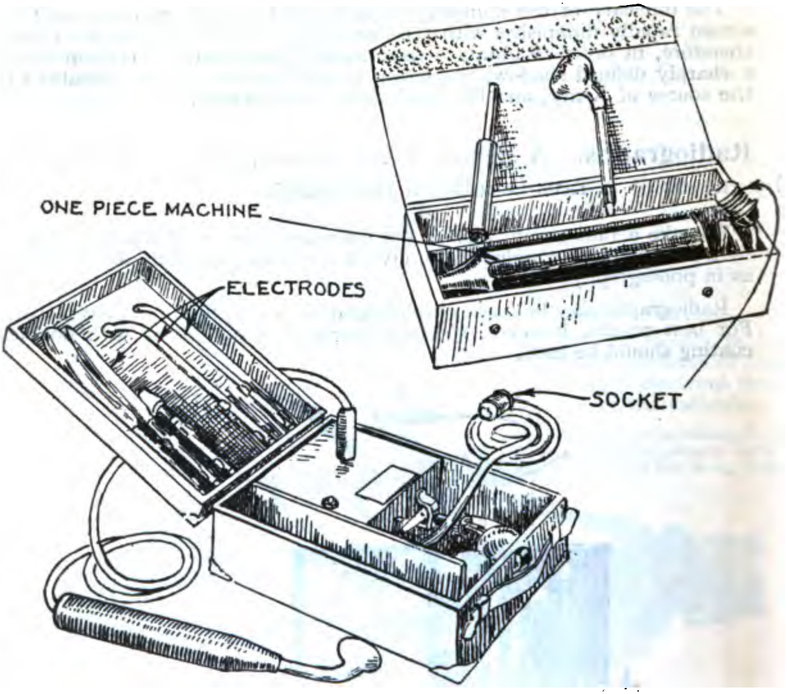


Fig. 8,696.—Rogers violet ray high frequency generator with case and electrodes. The generator is equipped with coils wound to produce very high voltage and oscillation and generates considerable heat. It operates on either *a.c.* or *d.c.* ***Operating instructions:*** 1, connect the generator to any *ordinary* lamp socket, 110 volts, either *a.c.* or *d.c.* 2, Place the general applicator (No. 1) in the handle of the generator by gently pressing it into place until it rests solidly in the socket. 3, Regulate the strength of current by turning the adjusting screw on the machine. Turning to the right increases strength. Turning to the left decreases strength. Test the strength of current by placing the electrode about ¼ inch from the back of the hand, and if too severe, reduce until proper effect is attained. 4, Apply the electrode to the surface of the area to be treated, increasing the current as the tissues become accustomed to the spark, and use in this manner for five to ten minutes, or until relief is obtained. Use several times daily if desired. 5, Good results are obtained after above application by letting patient hold No. 12 metal electrode in one hand and have a second person massage the diseased area directly on the skin with light pressure. In this way the current is drawn through the tissues to afflicted parts. It is well to apply either talcum powder or high frequency lubricant on all areas where the surface electrode is to be used in contact with the skin, as it renders the surface smooth and prevents the electrode from sticking. In some conditions the first few treatments may apparently aggravate the condition, but this will soon disappear and relief will be afforded.

Fig. 8,697.—Rogers type R violet ray one piece high-frequency generator. The heat is dissipated by air cooling system consisting of open ducts running the length of the handle.

CHAPTER 146

Electro-therapeutics

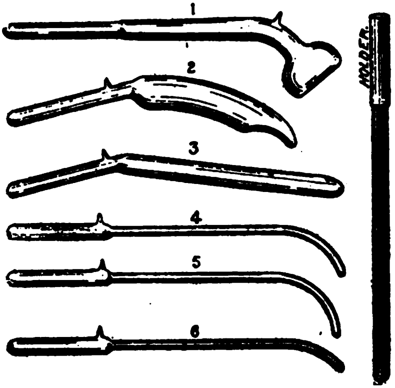
By definition electro-therapeutics is *the treatment of disease by electricity;* it embraces the laws, principles and doctrines of such treatment.

Electricity is of special value in the treatment of various forms of nerve lesion, thus giving a distinct place in the practice of every reputable physician.

The kinds of electricity used may be classed as

1. Static;
2. Current;
3. Radiant.

FIG. 8,698.—Toepler-Holtz influence machine. *In operation,* increasing the distance between the knobs of the discharging rods will give an increase of pressure attended by a diminished frequency of discharge. *The effect of the Leyden jars* is to diminish the electrostatic resistance between the main terminals of the machine, thereby enabling a given voltage, to accumulate a greater charge between the terminals.



Figs. 8,699 to 8,705.—High frequency electrodes for treatment of diseased parts. The set comprises suitable tubes for vaginal, rectum, throat, nose, and general application, and an insulated universal holder.

Such terms as ***galvanic electricity*** (produced by means of a primary battery), and ***faradic electricity*** (produced by secondary induction coils), are commonly, though ill advisedly, used by the medical profession.

Induction Coils.—These are employed chiefly for the application of currents of varying voltage, strength, frequency and wave form directly to the patient, and for supplying the high frequency current required for the operation of vacuum tubes.

High Frequency Apparatus.—This is used for therapeutic or radiographic purposes, and includes various forms of alternators producing directly frequencies up to 10,000 cycles per

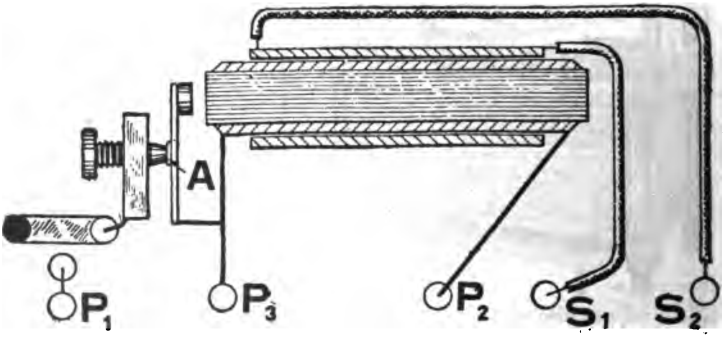


Fig. 8,706.—Diagram showing connections of a medical induction coil. P_1 and P_2, are the terminals of the primary circuit (including vibrator). S_1 and S_2, those of the secondary coil. The terminal P_3, is connected to the vibrating spring or interrupter A.

second; powerful induction coils charging condenser, which produce high pressures through the discharging circuit, in a manner similar to that of influence machines through the medium of Leyden jars; and suitable influence machines.

Interrupters.—For the successful operation of an induction coil, the current must be rapidly interrupted. There are various methods of interrupting the current which may be classed as: 1, magnetic, 2, electrolytic, and 3, mechanical.

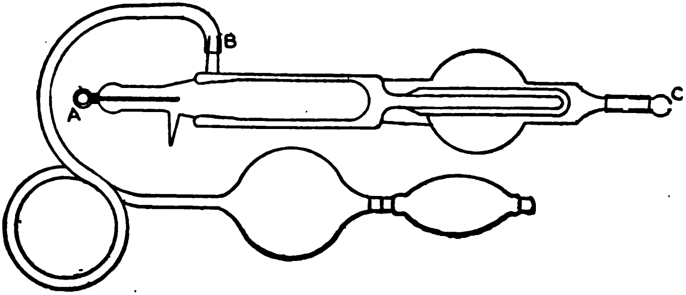


FIG. 8,707.—Columbia ozone generator. ***In operation,*** a current of air passes through the high frequency discharge and through a reservoir containing oils of eucalyptus and pine needles. The vapor is inhaled by the patient and is said to have an oxydizing and antiseptic effect; desirable in treatment of diseases of the respiratory organs.

FIGS. 8,708 and 8,709.—Wehnelt electrolytic interrupters. Fig. 4,617, 3 point interrupter; fig. 4,618, 1 point interrupter. In the multi-point type two or more anodes can be used at one time in parallel, thus more current can be passed through the primary.

Rectifiers.—The physician whose office is supplied with alternating current finds it necessary upon the installation of a wall plate to put in some device to change the alternating current to a direct current possessing the proper proportions for use in galvanic application. Alternating current may be changed into direct current by means of: 1, rotary converters, or 2, rectifiers.

Both are satisfactory, but the converter is much more expensive to install.

Currents used in Electro-therapeutics.—Many kinds of electric current are used, to secure different effects, all of which may be classed as

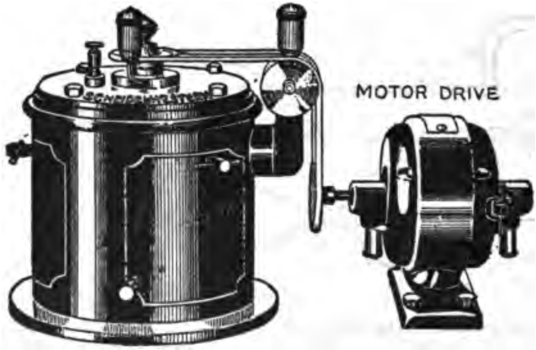
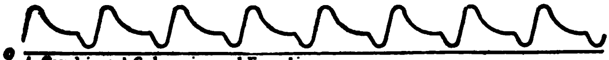


FIG. 8,710.—Scheidel-Western mercury turbine or *mechanical interrupter*. When an induction coil is used with direct current for considerable periods for X-ray treatment, for fluoroscopic work, or for operating a resonator, a mechanical interrupter will be found more desirable than the electrolytic type. If an electrolytic interrupter be used for such work, the solution heats by continual use, the rate of interruption varies and there is considerable wear on the platinum points.

FIG. 8,711.—Scheidel-Western anti-acid interrupter. In this type of interrupter an alkaline solution is used. By using an aluminum plate in place of the lead plate, it acts as the alternating current both as a rectifier and an interrupter.

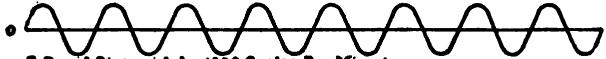
1. Direct; 2. Intermittent; 3. Alternating, or some modification formed by combination.

The apparatus used permits of many modifications. Usually a dial selector switch is provided by means of which any of the currents may be obtained, thus producing various changes, as: frequency control; primary faradic wave; secondary faradic wave, interrupted galvanic wave; combined galvanic and faradic wave, etc.

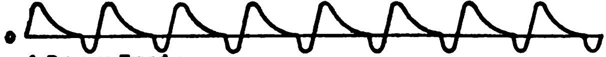


1. Combined Galvanic and Faradic

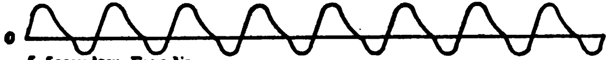
2. Combined Galvanic and Sinusoidal 1800 Periods Per Minute



3. Rapid Sinusoidal 1800 Cycles Per Minute



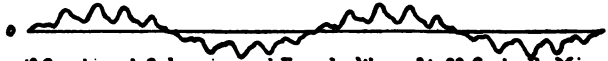
4. Primary Faradic



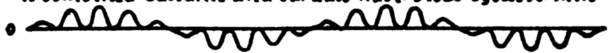
5 Secondary Faradic

6 Galvanic

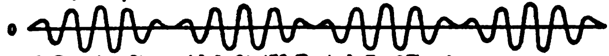
7. Interrupted Galvanic 3 to 88 Interruptions Per Minute.
8. Diagnostic Lamp.
9. Cautery.



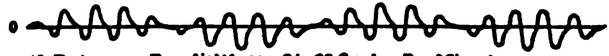
10 Combined Galvanic and Faradic Wave 3 to 88 Cycles Per Min



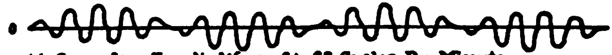
11. Superimposed Wave 3 to 88 Cycles Per Minute



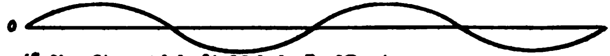
12. Surging Sinusoidal. 6 to 176 Periods Per Minute



13. Primary Faradic Wave 3 to 88 Cycles Per Minute.



14 Secondary Faradic Wave 3 to 88 Cycles Per Minute



15. Slow Sinusoidal. 3 to 88 Cycles Per Minute

16. Interrupted Galvanic Wave 3 to 88 Interruptions Per Minute.

IGS. 8,712 to 8,725.—Modalities of the McIntosh universalmode. In addition to the sixteen illustrated, the following are also available: 17, mechanical vibratory massage; 18, nasal drilling to remove obstructions; 19, electrically heated air; 20, pneumo-massage of tympanum, eye or skin; 21, spraying of liquids or powder blowing in nose or throat work; 22 vaporizing or nebulizing of oils; 23, deep suction suitable for aspirating in congested sinuses; 24, Bier's hyperemia.

The Selection of Electrodes. — Neis-wanger is partial to copper, Massey holds fast to zinc, and Martin is a strong ad-vocate of platinum

The matter really resolves itself to the question: "Shall the particular electrode be

FIG. 8,726.—Dr. Rice's epilation set comprising electrodes necessary for epilation according to the method introduced by Dr. May Rice of Chicago. The set contains: Face anes-thetizer; lip anesthetizer; needle holder with magnifying glass; forceps; hand spongio electrode; bulbous pointed epilater needles; broaches for growths.

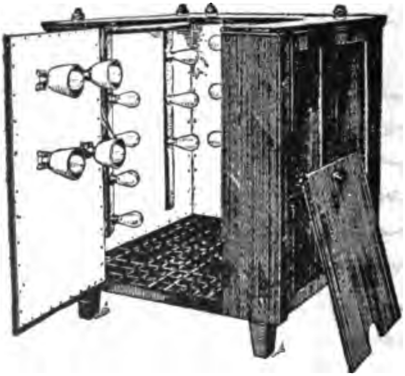
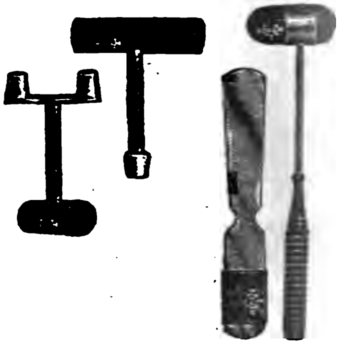


FIG. 8,727.—Columbia electric light bath cabinet. *In using*, it should be noted that the [illegible] light giving the thermal rays, acts as a nerve stimulant, having a special effect on the sympathetic nervous system, and through this on all functions of the animal economy. Used as a general tonic. this is the most satisfactory color and valuable in contusions, bruises sprains, etc. The green light contains the luminous rays and acts as a mild sedative. [illegible] light, containing the chemical or actinic rays, is a more pronounced sedative, diminishing pain, rectifying metabolism and is a local anesthetic.



FIGS. 8.728 to 8,731.—Dr. Abrams' reflex set for the physician who desires to test the [illegible] of concussion according to Dr. Abrams' method. The hammer, for evoking vertebral reflexes, is called a *plexor*. It is employed for diagnostic purposes and as a concussion apparatus in spondylotherapy. Many use it exclusively to attain their therapeutic results. *The pleximeter* is of metal, covered at one end with rubber and is employed concurrently with the plexor. *The single pronged instrument* is used for demonstrating areas of paravertebral tenderness. Better than the fingers. *The two pronged instrument* (radicularpressor) is employed for making bilateral pressure on the roots of the spinal nerves at their exit from the intervertebral foramina.

soluble or insoluble?" Copper is a very serviceable, all round metal, and can occasionally be replaced by zinc or iron; but nickel plated instruments are in a class of their own, and are unexcelled for certain special applications.

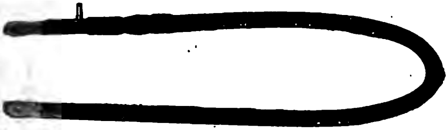


FIG. 8,733.—Dr. Rice's rectal electrode.

FIG. 8,732.—Johnson's hydro-electric rectal tube.

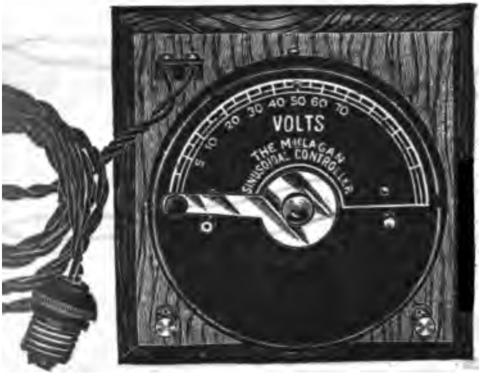
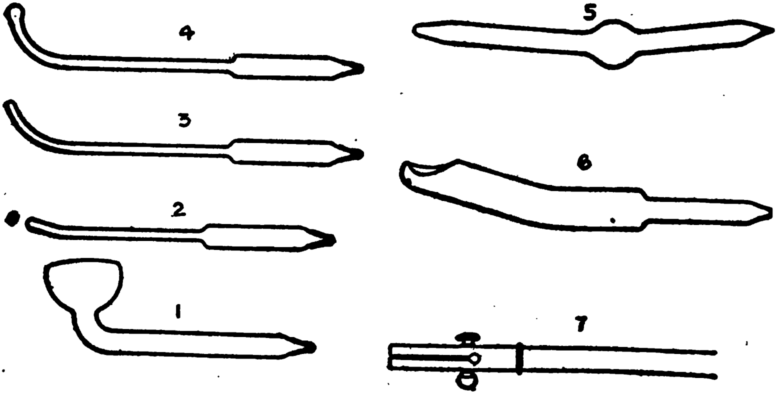


FIG. 8,734.—MacLagan sinusoidal controller for securing a rapid sinsuoidal current for connection with 110 volt, alternating current circuit. The apparatus consists of a current controller or rheostat wound with a fine quality of resistance wire controlled by a lever which permits of a gradual increase or decrease of the current strength absolutely without shock. The rapid sinusoidal is desirable in constipation and other gastro-intestinal disorders. In sciatica, lumbago and neuritis it is of great value. This current can be used to elicit the reflexes according to Abrams by applying one electrode to the spinal center and an indifferent pad at the sacrum. At the seventh cervical the heart and aorta are contracted; at the fifth dorsal the pylorus is opened, discharging contents of stomach into duodenum; the twelfth dorsal contracts the prostate; at the seventh and eighth dorsal the abdominal muscles are contracted; and at the second lumbar the uterus and ovaries are contracted.

FIG. 8,735.—McIntosh monomotive rheotome, for interrupting galvanic, faradic, or sinusoidal current for therapeutic application. The range of interruption is from 20 to 400. *The instrument consists of* a clock work mechanism with platinum tipped contact, and is wound up with a key, running 45 minutes with a single winding. *In connecting,* it is placed in series between the patient and battery or other apparatus. *In adjusting,* the lever is turned to the frequency desired.

Galvanic Therapy.—The importance of the galvanic current in gynecology, rectal work, urology and for cosmetic purposes is recognized by all engaged in these branches of practice. The galvanic current possesses the following properties:

Positive Pole	Negative Pole
1. Oxygen;	1. Hydrogen;
2. Acid;	2. Alkaline;
3. Will stop bleeding;	3. Increases bleeding;
4. Sedative;	4. Produces hypersensitiveness;
5. Hardens tissues;	5. Liquifies and disintegrates;
6. Is an acid caustic and the resultant cicatrix is hard and unyielding;	6. Is an alkaline caustic and the resultant cicatrix is soft and pliable;
7. Is a vaso constrictor.	7. Is a vaso dilator.



Figs. 8,736 to 8,742.—Columbia vacuum electrodes. 1, surface; 2, nasal; 3, urethral; 4, throat; 5, rectal; 6, vaginal; 7, handle.

Fig. 8,743.—Neiswanger's perforated copper ball electrode for galvanic current. May be used as an irrigating electrode.

Sinusoidal Therapy.—The value of the sinusoidal current has been proven in many chronic nervous and muscular conditions not amenable to drug therapy, such as atonic constipation, prostatic hypertrophy, splanchnic engorgement, locoataxia, anterior poliomyelitis menorrhagia, prolapsed ovaries and many other cases.

The sinusoidal current increases the elimination of urea, sulphates and phosphates in the urine. Indican, if present, is at first increased, or if not found before, frequently appears after administration of the current. After a number of treatment it is much less evident, as it is looked upon as the product of proteid putrefaction. The inference is that the sinusoidal current tends to lessen toxic intestinal products through improved intra-abdominal circulation. In general terms, it may be said that the sinusoidal current is employed in all cases where faradism is ordinarily employed, following essentially the same technique

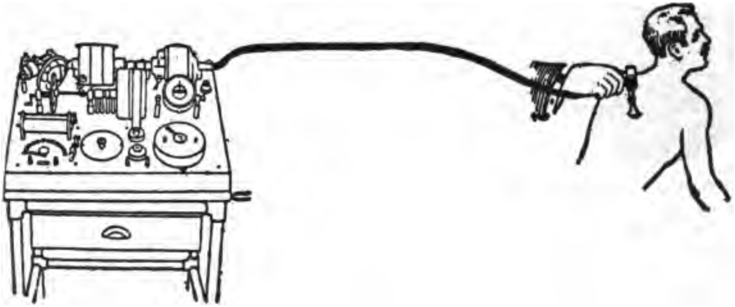


FIG. 8,744.—McIntosh apparatus showing application of ***mechanical vibration.*** The effects claimed for mechanical vibration are: 1. Cardic activity is regulated. Blood pressure may be lowered reflexly. It may be raised also. 2. Contracts arterial blood vessels. If prolonged, dilation results. Pulse rate may be lowered. 3. It induces many reflex effects as well as motor, sensory, secretory and vaso-motor effects. It lessens and removes hyperactivity of nerves. It diminishes pain and relieves congestion not due to organic conditions. 4. Diminishes and relieves muscular pain and stiffness. It can relax tense muscles and cause relaxed and athrophied muscles to become firm and increase in size. It tones up cardiac muscles. 5. Reflexly induces contraction of the lungs. Relieves pain and dysponea. Improves respiration. 6. Diminishes size of glands, directly and reflexly. 7. Contracts or dilates the liver, stomach and spleen. 8. Diminishes irritability of the bladder when not due to organic conditions. 9. Induces peristalsis. 10. Increases or diminishes lymphatic circulation according to the vibratory friction given, centripetal or centrifugal. 11. Assists in diminishing intraocular tension. 12. Lessens nasal hyperemia. 13. Suction vibrations are valuable in removing pus from a boil, etc.

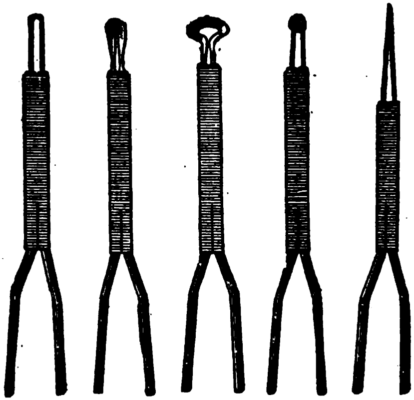
Mechanical Vibration.—This is a remedial agent of proven value. Massage is one of the oldest forms of physical therapy, in fact it is almost as old as medicine itself.

FIG. 8,745.—McIntosh universal cautery transformer.

Electro - Cautery. — This treatment utilizes the heating effect of the electric current for surgical purposes. Various forms of cautery knife are used.

They consist of suitably shaped platinum wires which require different amounts of electric energy to render them red hot, depending upon the surface of heated metal which they expose to the air. The broad flat blades requiring more energy then the narrower blades. The broadest blades require from 25 to 35 amperes at one volt, or from 25 to 35 watts. According to E. L. Smith, M. D., the degree of heat of the platinum point is important. Cherry red heat is generally used. The object is to press the mucous membrane down to the periosteum with the edge of the electrode, with the least amount of cicatrical tissue.

If hypersensitive areas are to be destroyed, then use the electrode flat with white heat and make a superficial burn. When the platinum point comes in contact with the tissues it will be noticed that it lowers the heating point; hence, if a large area is to be treated, it will be necesssary to go in with a higher point of heat than is needed.



FIGS. 8,746 to 8,750.—Various electric cautery knives. The snare cautery consisting of a loop of platinum wire which is placed around the growth or part to be removed, then the loop drawn tight and the current passed through it, so that the flowing wire is pulled through the part, consumes a smaller number of watt, but requires a greater voltage to send a sufficient amount of current through the platinum wires. The current for the operation of electric cautery knives may be either continuous or alternating.

CHAPTER 147

Prone Pressure Method for Resuscitation

Recommended by

National Electric Light Association

Follow These Instructions Even if Victim Appears Dead

I.—Free the Victim from the Circuit Immediately.

1. Quickly release the victim from the current, being very careful to avoid receiving a shock.

Use any dry insulator (rubber gloves, clothing, wood, rope, etc.) to move either the victim or the conductor. Beware of using metal or any moist material. If both of the victim's hands be grasping live conductors endeavor to free them one at a time. If necessary shut off current.

Begin at once to get the subject to breathe (resuscitation), for a moment of delay is serious. Use "Prone Pressure Method" for four (4) hours if necessary, or until a doctor has advised that rigor mortis has set in.

2. Open the nearest switch, if that be the quickest way to break the circuit.

3. If necessary to cut a live wire, use an ax or a hatchet with a dry wooden handle, turning your face away to protect it from electrical flash.

NOTE.—***Observe the Following Precautions:*** *a*. The victim's loose clothing, if dry, may be used to pull him away; do not touch the soles or heels of his shoes while he remains in contact—the nails are dangerous. If this be impossible, use rubber gloves, a dry coat, a dry rope, a dry stick or board, or any other *dry insulator* to move either the victim or the conductor, so as to break the electrical contact. *b*. If the bare skin of the victim must be touched by your hands, be sure to cover them with rubber gloves, mackintosh, rubber sheeting or dry cloth; or stand on a dry board or on some other dry insulating surface. If possible, use only *one* hand. If the man receive a shock while on a pole, first see that his belt is secure around the pole, if possible above cross arm so victim will not fall, then break the current. Pass a hand line under his arms, preferably through his body belt, securely knot it, and pass the end of the line over the first cross arm above the victim. If you be alone, pass the line once around this cross arm. If you be not alone, drop the line to those at the base of the pole. As soon as the rope is taut, free the victim's safety belt and spurs and descend the pole, guiding the victim. When the victim is about three feet from the ground, lower rapidly so that the victim's feet hit the ground hard.

II.—Attend Instantly to Victim's Breathing

1. As soon as the victim is clear of the live conductor, quickly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.).

If the mouth be tight shut, pay no attention to the above-mentioned instructions until later, but immediately begin resuscitation. The patient will breathe through his nose and after resuscitation has been carried on a short time, the jaws will probably relax, and any foreign substance in the mouth can then be removed. Do not stop to loosen the patient's clothing; ***every moment of delay is serious.***

2. Lay the patient on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face resting on hand or forearm so that the nose and mouth are free for breathing, as in fig. 8,751.

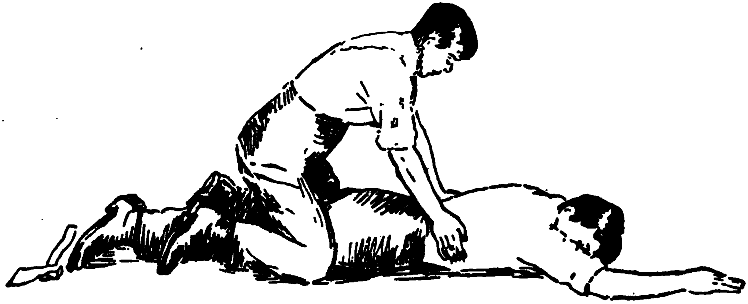


FIG. 8,751.—Resuscitation for electrical shock by Prone pressure method. ***First position.***

3. Kneel, straddling the patient's hips, with the knees just below the patient's hip bones or opening of pants pockets.

Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, the thumb alongside of the fingers, the tips of the fingers just out of sight as in fig. 8,751.

4. With arms held straight, swing foward slowly so that the weight of your body is gradually brought to bear upon the subject, as in fig. 8,752.

This operation, which should take from two to three seconds, ***must not be violent***—internal organs may be injured. The lower part of the chest and also the abdomen are thus compressed, and air is forced out of the lungs, the diaphragm is kept in natural motion, other organs are massaged and the circulation of the blood accelerated.

5. Now *immediately* swing backward so as to completely remove the pressure, thus returning to the position shown in fig. 8,753.

Through their elasticity, the chest walls expand, and the pressure being removed the diaphragm descends, and the lungs are thus supplied with fresh air.

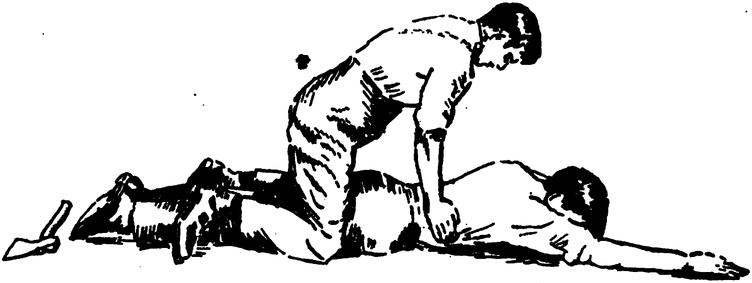


FIG. 8,752.—Resuscitation for electrical shock by Prone pressure method. ***Second position.***

6. After two seconds swing forward again.

Thus repeat deliberately twelve to fifteen times a minute the double movement of compression and release—a complete respiration in four or five seconds. If a watch or a clock be not visible, follow the natural rate of your own deep breathing, the proper rate may be determined by counting—swinging forward with each expiration and backward with each inspiration.

7. As soon as this artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest or waist. (*Keep the patient warm.*)

Place ammonia near the nose, determining safe distance by first trying how near it may be held to your own. Then the assistant should hit the patient's shoe heels about twenty times with a stick, and repeat this operation about every five minutes, until breathing commences. Do not give any liquids whatever by mouth until the patient is fully conscious.

8. Continue artificial respiration without interruption (if necessary for four hours) until natural breathing is restored.

Cases are on record of success after three and one-half hours of effort. The ordinary tests for death are not conclusive in cases of electric shock and doctors must be so advised by *you*, if necessary.

FIG. 8,753.—Resuscitation from electrical shock by Prone pressure method. ***Third position.***

9. When the patient revives, he should be kept prone (lying down)—and not allowed to get up or be raised under any consideration unless on the advice of a doctor.

If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water, or a drink of hot ginger tea or coffee. The patient should then have any other injuries attended to and be kept warm, being placed in the most comfortable position.

10. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries.

He should not be moved from this point until he is breathing normally of his own volition, and then moved only in a lying position. Should it be necessary, due to extreme weather conditions, etc., to move the patient before he is breathing normally, he should be kept in a prone position and placed upon a hard surface (door or shutter) or on the floor of a conveyance, resuscitation being carried on during the time that he is being moved.

11. A brief return of spontaneous respiration is not a certain indication for terminating the treatment.

Not infrequently, the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched, and if normal breathing stops, artificial respiration should be resumed at once.

III.—Send for a Doctor

If other persons be present when an accident occurs, send one of them for a doctor without a moment's delay.

If alone with the patient, do not neglect the immediate and continued resuscitation of the patient for at least one hour before calling a doctor to assist in further resuscitation efforts. A published up-to-date list of doctors posted by the company is recommended.

IV.—First Care of Burns

When natural respiration has been restored, burns, if serious, should be immediately attended to while waiting for the doctor to arrive.

A raw or blistered surface should be protected from the air. If clothing stick, do not peel it off—cut around it. The adherent cloth, or a dressing of cotton or other soft material applied to the burned surface, should be saturated with picric acid (.5 per cent.) If this be not at hand, use a solution of baking soda (one teaspoonful to a pint of water), or the wound may be coated with a paste of flour and water, or it may be protected with vaseline, carron oil, olive oil, castor oil or machine oil, if clean. Cover the dressing with cotton gauze, lint, clean waste, clean handkerchief, or other soft cloth, held tightly in place by a bandage. The same coverings should be lightly bandaged over a dry, charred burn, but without wetting the burned region or applying oil to it. Do not open blisters.

FIG. 8,754.—Nature of high tension electricity.

Of nearly all accidents arising from contact with electric wires and electric machines it may be said it is more the want of care than the want of knowledge.

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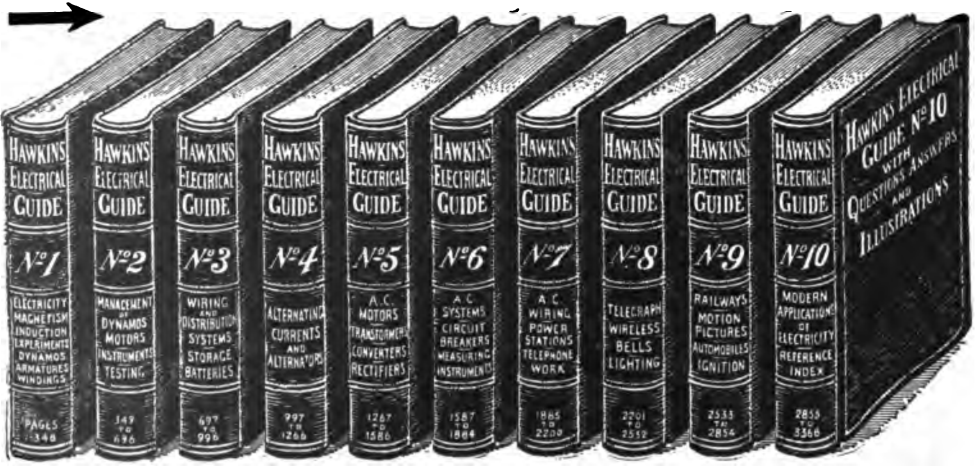

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