HARPER'S EVERYDAY ELECTRICITY

DON·CAMERON·SHAFER

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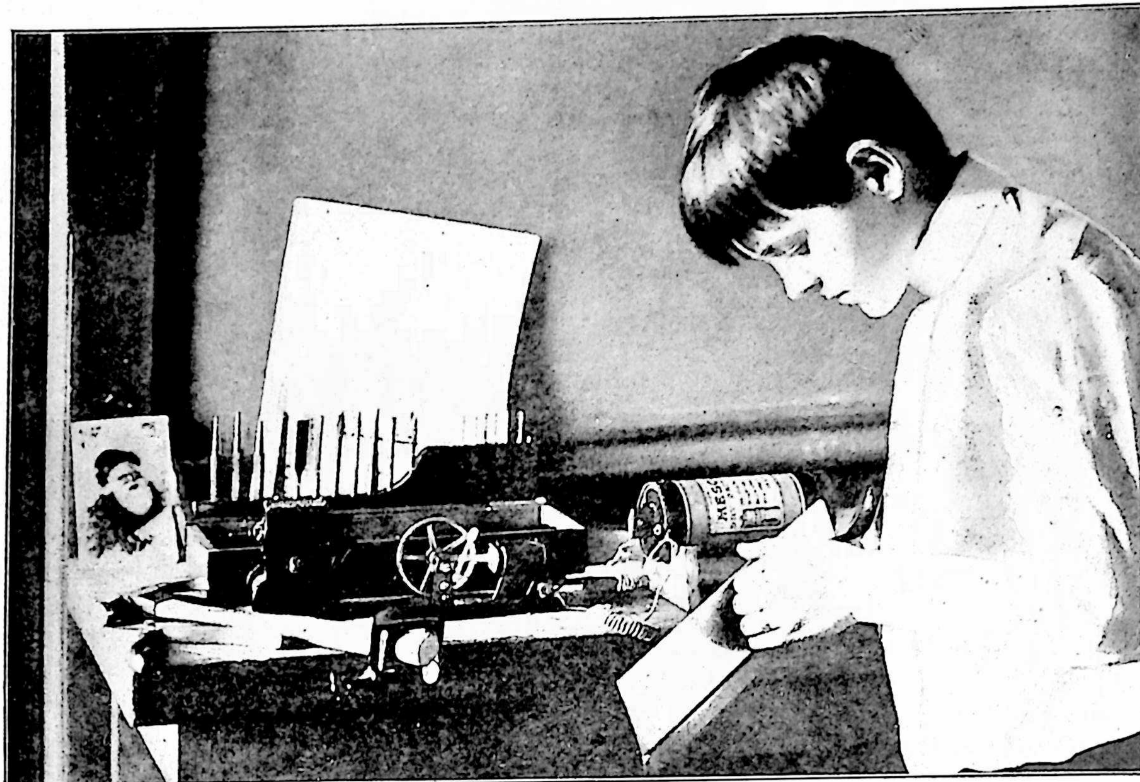
To Paul from
mother

1917



Courtesy of *The American Boy*

A PROBLEM IN ELECTRICITY

HARPER'S EVERY-DAY ELECTRICITY

HOW TO MAKE AND USE FAMILIAR ELECTRICAL APPARATUS

BY
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AUTHOR OF
"HARPER'S BEGINNING ELECTRICITY"

WITH MANY ILLUSTRATIONS

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INTRODUCTION

IT is important that every one should have a common working knowledge of electricity. Only a few of us can hope to become electrical engineers, but there is no reason why we should not all possess a certain understanding of this source of energy. Indeed, some knowledge of the subject would seem absolutely necessary now that electricity is used generally for lighting the home, for power at the factory, for operating the automobile, for cooking purposes, for driving street-cars, ringing door-bells, for telephone and telegraph systems, and a hundred and one other every-day purposes.

Electricity is a form of energy. It is useless to try to explain it. Neither is it necessary to ponder over the various accepted theories pertaining to its origin. We know how it behaves under ordinary conditions. This knowledge, meager enough, is quite sufficient for all practical purposes. We know that electricity flows readily upon good conductors, such as copper wire. We can measure this flow, its pressure or voltage, can tell exactly the resistance in its path, and figure the amount of work it will do. And so it is no matter if we cannot see electricity, if we do not know exactly how and why this form of power, or energy, exists. Those of us who use electricity in so many forms are interested only in results.

Electricity traveling along a copper wire behaves exactly like a stream of water flowing through a pipe so far as actual results are concerned. Electricity *flows* in the form of an invisible *current* over the wire. This current rushes along at the terrific speed of more than 185,000 miles a second. The volume of this current may be increased or decreased at will; its pressure may be raised or lowered; it will produce energy, or horse-power, in exact relation to the volume and its pressure just as a stream of water will produce horse-power. Because electricity is invisible and the flow of current is expressed in *amperes* instead of gallons or cubic feet, the pressure in *volts* instead of pounds to the square inch, the power in *watts* instead of horse-power, it is hard to understand. Once these simple terms are mastered it is easy to understand the flow of electricity over a copper circuit.

Boys are always interested in things electrical. They have an inherent desire to know how things are accomplished, to learn how everything is made. Combined with this is the desire to do things, to build, to construct, to keep hands and mind busy at the same time. It is the purpose of this book to describe and make plain all electrical apparatus in common use. Through these pages the youthful reader will also find detailed descriptions and plans for making a great many interesting and useful experimental electrical devices.

Incorporated herein is a simple explanation of the fundamentals of every-day electricity.[1] The story of electricity is told in few and simple words, from the power-house, where it is manufactured, to the wires which carry it underground and through the air to our homes and offices, factories and mills, mines and railroads, where it is readily changed into light, heat, and mechanical power. Each chapter contains

[1] For a full explanation of elementary electricity and its appliances see *Beginning Electricity*, by Don Cameron Shafer, Harper & Brothers, publishers.

various examples and experiments, amply illustrated with line-drawings and half-tone cuts to demonstrate all important points. A large number of electrical toys, interesting experiments, and practical devices, such as any boy can build, are also fully described and illustrated in detail.

The best way to learn how and why the electric motor produces power is to build a small motor. This is equally true of all electrical apparatus. It is not difficult to construct toy motors. Indeed, any boy with a working knowledge of electricity can easily build a small motor large enough to be operated from the lighting circuit. In order to repair or make any changes or extensions in an ordinary household lighting circuit it is absolutely necessary for the amateur to know exactly what he is doing. He must be perfectly familiar with good wiring practice; must know the value of insulators, the position and location of switches, fuses, cut-outs, and outlets which are the part of every electrical circuit. Without this knowledge it is dangerous to make repairs or changes to household wiring. Properly installed electricity is safer in the house than any other form of energy for heat, power, and light. It cannot explode; it gives off no dangerous fumes and gases. If it is installed as it should be there is no danger of fire.

If we must have electric lights, electric ranges, and cooking-devices in the kitchen and dining-room and electric motors for power it is necessary to know how to care for the various circuits, how to install these devices in the home.

The new metal-filament miniature lamp made electric lighting from batteries a success. A number of serviceable and inexpensive applications of battery-lighting are described in this book. Battery-lighting has also been extended to the automobile, the motor-boat, etc.

It is important that the home lighting system be correctly installed, so that no light is wasted, so the rays are properly reflected, so the eyes are protected. In *Every-day Electricity* this is amply explained and illustrated. Electric heating and cooking devices are new to most of us. Those who desire to use them should fully understand their construction and their limitations. No less a person than Thomas A. Edison has said that the future of electricity means the application of electrical energy to all moving things. This is still the morning of electricity, and the boys of to-day will need to know a great deal about this form of energy in their future lives.

DON CAMERON SHAFER.

HARPER'S EVERY-DAY ELECTRICITY

HARPER'S
EVERY-DAY ELECTRICITY

Chapter I

BATTERIES AS A SOURCE OF ELECTRICITY

ELECTRICITY is secured from two sources. By far the greater portion is produced by magnetic generators, or dynamos. These generators are driven by various sources of mechanical power. Some are driven by steam-turbines, others by gasolene-engines, water-wheels, etc. They produce electricity in large quantities at low cost.

Less than one per cent. of our electrical energy is secured from chemical batteries. This is because batteries are cumbersome and costly where a heavy current is desired.

When only a small amount of electricity is required the battery, or chemical generator, is best and cheapest. In the galvanic cell the energy resulting from certain chemical changes takes the form of electricity. This current may be used for various purposes.

Energy changes its form hundreds of times. Doubtless it exists in many ways of which we have no knowledge. It may lie dormant for centuries, as in the form of coal. It may be stored in the form of certain materials, only to reappear when these substances are consumed by chemical action. When the metal zinc is destroyed by sulphuric acid chemical energy is released and changed into electrical energy. The destruction of the zinc is a form of combustion. It is very similar to the consumption of coal by fire.

There are two classes of batteries used in electrical work. The galvanic, or *primary*, battery actually produces a current of electricity. The storage, or *secondary*, battery merely stores or, more properly, accumulates electric energy in the form of chemical energy. A battery, as the name implies, is composed of two or more galvanic cells. In every-day talk we frequently hear a single cell called a "battery."

Battery Cells Furnish Cheap Electricity

Beyond a doubt battery cells furnish the cheapest, safest, and best means of studying electricity. They lend themselves easily to electrical experiments of all kinds. They can be used over and over again for various purposes until actually worn out. They offer an unlimited opportunity for electrical experiment and for the development of new and novel applications of electricity. Batteries for actual service can be purchased cheaper and better than they can be made. All the pioneers of the greater electrical industry used galvanic cells as a source of current in their experimental work. Indeed, it was not until about forty years ago that the magnetic generator was perfected.

A simple primary battery cell consists of four essential parts. The first is the *container*, usually a glass or porcelain jar. This merely serves to hold the liquid contents of the cell. The second is the liquid itself, which is termed the *electrolyte*. The plates, called *electrodes*, are usually of zinc and copper or zinc and carbon. The zinc plate is slowly consumed by the electrolyte. This chemical action produces a flow of electrical energy. The electricity is taken from the battery plates by *leading*-wires which complete the necessary external circuit. Electricity produced in this way does not differ from that produced by direct-current magnetic generators. It may be used for various purposes, such as lighting small lamps, running small motors, ringing door-bells, operating buzzers, etc.

Just how the chemical action of the electrolyte on the plates produces a flow of electricity is hard to explain. The oxidation of the zinc is really a slow-burning process. The zinc is gradually eaten away until it disappears entirely. The copper or carbon element is not seriously affected by the chemical action. It really is not of serious consequence how this current of electricity is produced. We are more interested in results than theories.

Battery cells have but two serious defects. It is quite impracticable to obtain pure metals for the plates. This results in *local action*, or chemical activity even when the external circuit is broken, so the plates gradually waste away. Amalgamating the zinc plate with a thin coating of mercury remedies this to a certain extent. The negative plate of the cell becomes covered with tiny particles of hydrogen gas which increases the internal resistance of the cell until it ceases to produce a flow of electricity. It is then said to be *polarized.* Means must be provided to eliminate this hydrogen. This is accomplished by adding certain chemicals to the cell which unite with the hydrogen before it collects on the negative electrode. These chemicals are known as depolarizing agents.

When the sulphuric-acid solution in Fig. 1 begins to act upon the zinc it tears the metal apart, changing it into zinc sulphide. It also liberates hydrogen gas which collects on the surface of the copper plate. This action is accompanied by a flow of electricity from the poles and wires of the external circuit back to the zinc.

The electromotive force (abbreviated E. M. F.) of this battery cell is about 1.02 volts. The current produced by the cell is nearly steady and continues to flow as long as both the internal and outer circuits are closed. If either is opened the chemical action ceases, and of course the electricity stops. The chemical action cannot take place unless a path, or circuit, is provided for the flow of what electricity is produced.

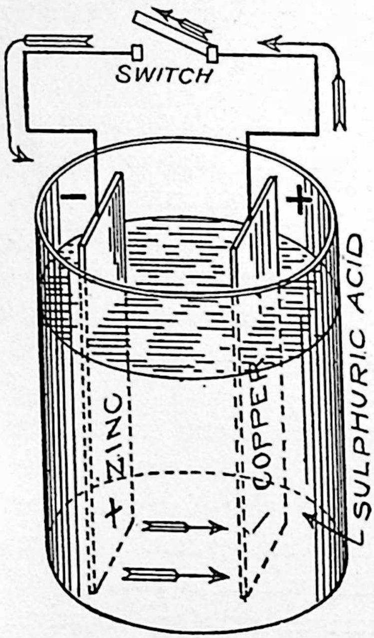


Fig. 1

Elements of the Battery

The E. M. F. of a battery cell is always in direct proportion to the extent of the chemical action on the positive element. By a series of tests it has been found that the following materials are arranged in accordance with their voltage-producing qualities:

1. Aluminum
2. Zinc
3. Tin
4. Cadmium
5. Lead
6. Antimony
7. Bismuth
8. German silver
9. Brass
10. Mercury
11. Iron
12. Steel
13. Copper
14. Silver
15. Gold
16. Carbon
17. Platinum
18. Iron sulphide
19. Manganese dioxide
20. Lead peroxide

Any of these elements in the list may be taken as positive. Those below it in the list will be negative to it. The farther apart they are in the list the greater will be the voltage of the cell. In a practical battery, however, only those elements can be used which are inexpensive and best adapted for the work in hand. For instance, aluminum and gold would make a good battery, but few could afford to use it. Aluminum and lead peroxide would be difficult to handle. Zinc and carbon are cheap, easy to handle, and make the best battery for ordinary purposes.

The Electrolyte

Different solutions are used for different batteries. Among the various compounds used for the electrolyte are the following:

Caustic potash	Silver nitrate
Caustic soda	Bluestone, or copper sulphate
Ammonia	Zinc sulphate
Sulphuric acid	Ferrous sulphate
Nitric acid	Potassium iodide
Hydrochloric acid	Ammonium chloride, sal ammoniac
Iron chloride	Common salt

In the internal circuit of the battery cell the electrical current flows from the positive, zinc, to the negative, carbon, element. In the external circuit, however, this order is reversed, and the electricity flows from the carbon, which is now termed the positive pole, to the zinc, or negative pole. Thus it will be seen, by referring again to Fig. 1, that the current travels over a complete, or circuitous, course.

Primary batteries are roughly divided into two classes, depending upon the service for which they are to be used. For continuous service, where a steady flow of current is required at all times, the closed-circuit battery must be used. This type of battery is peculiarly adapted for such work. Its plates will not easily polarize and destroy its power.

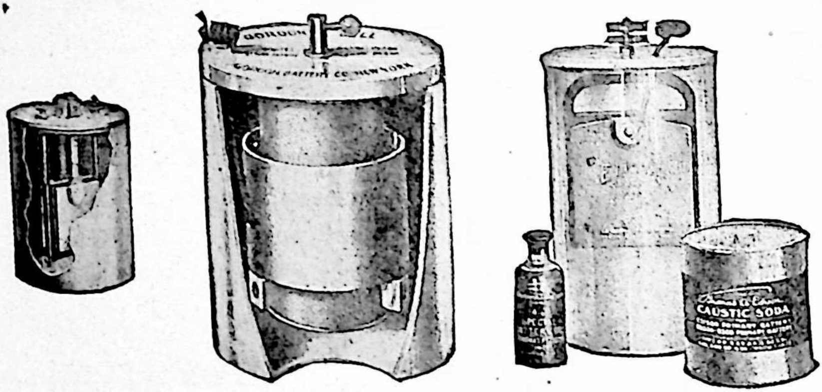


Fig. 2

Neither will it wear out quickly. For intermittent service the open-circuit battery is best. Such batteries produce a good flow of current at a greater pressure. But they soon polarize and wear out. If allowed to rest the depolarizing agent performs its offices, and the cell is ready for more work.

Illustration (Fig. 2) shows types of primary batteries with caustic-soda cells, the sides of the cells being cut away or made transparent to show plates. In Fig. 3, A shows carbon and zinc cells, B two fluid cells, and C zinc and copper gravity cell.

Measuring Electricity

Here it may be well to take a leaf from *Beginning Electricity*, also published by Harper & Brothers, and explain just how electricity is measured. Following are the units used for measuring electricity, with their common equivalents given by way of explanation:

ELECTRICITY	WATER
Volt	Pressure
Potential	Pressure
Electromotive force	Pressure
Ampere	Current, or rate of flow
Watt	Fraction of horse-power
Kilowatt (1,000 watts)	One and one-third horse-power
Resistance	Friction
Ohm	Friction

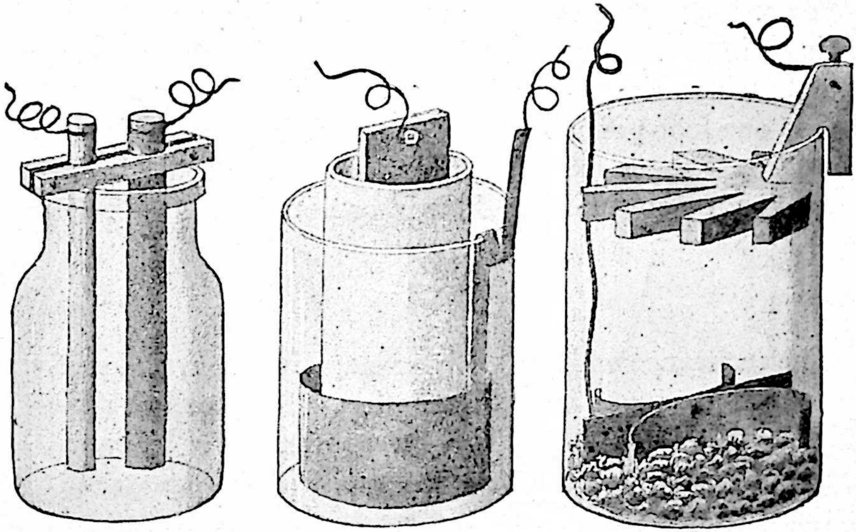


Fig. 3

An *ampere* is the current resulting from *one volt* pushing its way over a *resistance* of *one ohm.*

Amperes × volts = watts
Watts ÷ 746 = horse-power
Volts ÷ amperes = ohms

Force, Energy, and Power

Force is a pressure expressed in a *push* or a *pull.* Energy is the ability to do work. It is divided into potential energy and kinetic energy.

Potential energy is the ability of a body to perform work at any time when it is set free to do so.

Kinetic energy is the ability of a moving body to do work during the time its motion is being arrested.

Work is overcoming resistance through space. In the English system of weights and measures the common unit is the foot-pound.

Power is the rate of doing work. Work is an expression entirely independent of time, but power always takes time into consideration. For instance, to lift one pound one foot is one foot-pound of work, no matter in what time it is done, but it takes sixty times as much power to do it in one second as it would take to do it in one minute.

Friction

The resistance which a body meets with from the surface on which it moves is called friction. It is called sliding-friction when one body slides on another; for instance, a sleigh is pulled along on ice—the friction between the runners of the sleigh and the ice is sliding-friction. It is said to be rolling-friction when one body is rolling on another so that new surfaces continually are coming into contact; for instance, when a wagon is pulled along a road the friction between the wheels and the road is rolling-friction, but the friction between the wheels and their axles is sliding-friction. Sliding-friction varies greatly between different materials, as everybody knows from daily observation. For instance, a sleigh with iron runners can be pulled with less effort on ice than sand, even if the road is ever so smooth. This is because the friction between the iron and ice is a great deal less than the friction between iron and sand.

Closed-Circuit Cells

The closed-circuit cells in common use, named after the men who perfected them, are given in the following table:

NAME	+ PLATE	ELECTROLYTE	DEPOLARIZER	— PLATE	E.M.F.	R.
Daniell	Zinc	Sulphuric acid	Copper sulphate	Copper	1.08	1
Grove	Zinc	Sulphuric acid	Nitric acid	Platinum	1.9	.15
Bunsen	Zinc	Sulphuric acid	Nitric acid	Carbon	1.8	.2
Paggendorff	Zinc	Sulphuric acid	Bichromate of potassium-sulphate acid	Carbon	2	.2
Lande	Zinc	Caustic potash	Copper oxide	Iron	1	.1
Davy	Zinc	Ammonium chloride	Silver chloride	Silver	1.1	4.5

The last column in the above table gives the approximate values of the internal resistance of these cells in ohms. This includes the resistance of the plates as well as that of the liquids.

Open-Circuit Cells

Cells with weak depolarizers recuperate very quickly and are suitable for open circuits. The common types used for this work are as follows:

NAME	+ PLATE	ELECTROLYTE	DEPOLARIZER	— PLATE	E. M. F.	R.
Leclanche	Zinc	Sol. of sal ammoniac	Binoxide of manganese	Carbon	1.48	.5
Law	Zinc	Sol. of sal ammoniac	None	Carbon	1.37	.4
Gassner	Zinc	Oxide of zinc, sal ammoniac, chloride of zinc, plaster	None	Carbon	1.3	.2

Dry-Cell Batteries

Dry-cell batteries are most extensively used for open-circuit service. They are easily transported and handled.

There is no danger of spilling the exciting liquid. The elements cannot be easily disarranged. The dry cell is made up of about the same materials as the wet cell, except the electrolyte and the depolarizer are in paste form, inclosed in a tight metallic cup. Dry cells cannot be readily renewed. They are inexpensive and are generally used in modern battery equipments (Fig. 4).

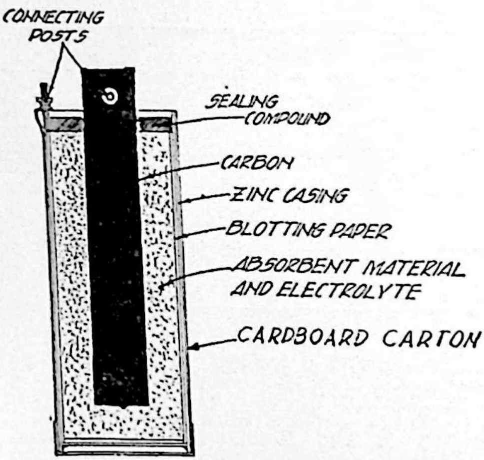


Fig. 4

In the dry cell the zinc tube, or positive element, also serves as the protective container of the cell. The other elements are placed inside the tube and surrounded by a paste-like chemical mixture, made up as follows:

1 part sal ammoniac	1 part granulated carbon
1 part chloride of zinc	3 parts plaster
1 part peroxide of manganese	1 part flour

2 parts water

The top of the tube is sealed with insulating-compound, and the terminals brought out to the binding-posts for connection. The E. M. F. of this cell equals 1.5 volts, and the internal resistance is about .3 ohm.

Dry cells are best for experimental work, as they give out no dangerous gases. There is no acid or corroding liquids to spill out and destroy things. They can be easily and simply connected to various electrical devices. On account of their small cost they can be thrown away when exhausted. They should be kept in a dry place so that the cardboard container will not get damp and corrode the zinc tubes. Care must be taken not to crack or injure the sealing-compound at the top of the cell or it will dry out and become useless. Cells that are more than a year old, even if they have not been extensively used, should be thrown away. Old cells rapidly deteriorate and are practically worthless. Where only a few battery cells are connected up together they can be placed in a bunch. Where many of them are connected in series to produce a higher voltage they must be kept apart in wooden containers.

The Gravity Cell

Closed-circuit batteries, for continuous service, are seldom used except for telegraph-lines, railroad-signals, and burglar-alarms. These cells produce a continuous flow of current. They are not suitable for open-circuit work. A simple closed-circuit cell can be made of a strip of zinc and a strip of copper immersed in a salt solution in a glass jar. Such a cell is useless, except for experimental purposes, as the copper soon polarizes and stops the flow of current.

The *gravity* cell is generally used for closed-circuit work. The plates are copper and zinc. The zinc is in the form of a casting, known as a *crow's-foot* because of its shape. It is made with a protruding lip which fastens to the top of the glass jar and keeps the zinc near the top of the solution. The copper consists of three strips riveted together in a star-shape. This is placed on edge in the bottom of the jar. It is provided with a rubber-insulated copper wire long enough to reach to the top of the jar, where it forms the positive terminal. It is insulated to prevent the wire from coming into contact with the zinc and forming a short circuit and to prevent chemical action on the wire (Fig. 5).

The electrolyte is composed of rain-water and blue vitriol. About three pounds of the crystals are placed about the copper plate and the jar filled with water. The zinc element should be suspended about four inches above the copper element. The water should be sufficient to cover the zinc. If the cell is short-circuited for a few hours the electrolytic action will form zinc sulphate about the zinc element and

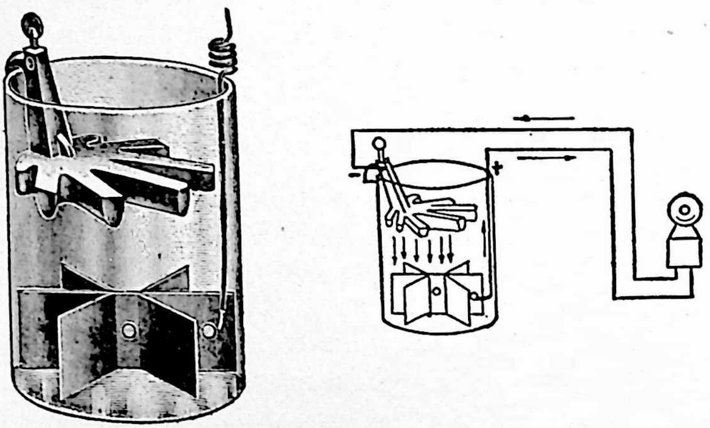


Fig. 5

copper sulphate about the copper. Quick action is secured by adding a small amount of sulphuric acid or common salt.

If there is none of the sulphate solution or sulphuric acid added when the cell is first set up it should be short-circuited. That is, it should be connected between the copper and zinc terminals with a piece of wire for one or two days to form sulphate of zinc and at the same time lower the internal resistance. They should be kept in a room where the temperature is 70° to 85° or 90° Fahrenheit. The internal resistance, which is normally two or three ohms, increases very rapidly with a drop in temperature below this point, 70°. For this reason they should be kept in a warm place, as heat promotes chemical action upon which the cell depends for its operation. The blue line marking the boundary between the blue copper-sulphate solution in the bottom of the cell and the colorless zinc-sulphate solution in the top of the cell should be about half-way between the copper and zinc elements. These solutions remain separate on account of their different specific gravities or densities, the colorless zinc sulphate being lighter in weight for the same volume. It is from this fact that the cell derives its name—*gravity cell*. If the blue line marking the boundary between the two solutions is above this point some of the blue solution, or copper sulphate, can be siphoned off, or the cell may be short-circuited to form more of the zinc sulphate or colorless solution. When the blue line is too low more of the bluestone, or copper-sulphate crystals, and water should be added.

Chapter II

DETAILS OF BATTERY CIRCUITS

THE *electromotive force* of a battery cell is the *moving force.* It causes the flow of current over the wires of the circuit.

This electromotive force, usually abbreviated E. M. F., is really the pressure, or *voltage*, between the terminals of the battery. It is measured and expressed in *volts.*

The electromotive force of a cell is not influenced by the size of the battery plates. The voltage of a small cell is exactly the same as the voltage of a large cell. Only the volume of the current is increased by enlarging the plates. The E. M. F. of a zinc-copper-sulphuric-acid cell is about one volt; that of a zinc-copper-sal-ammoniac cell one and one-half volts. The best batteries give only about two volts.

If batteries are to be used for various purposes it is quite necessary to know just how much electricity each cell will produce. Knowing the capacity of a single cell, it is easy to figure out the proper number of cells for all circuits.

It is not difficult to determine the capacity of a battery cell. They are usually rated in ampere-hours. An ampere-hour really means an ampere of current flowing for one hour. This is best illustrated by a simple example. A cell gives .5 ampere for 30 days continuously. The total number of hours it was in service is 30×24, or 720 hours. Divided by the ampere capacity of the cell, .5, equals 360 ampere-hours, If this same cell was used intermittently for but 10 minutes each hour of the day, then it would last approximately 180 days. Ten minutes each day multiplied by 24 hours equals 240 minutes, or a total of four hours a day. If the ampere-hour capacity of the battery is 360 ampere-hours, then the cell will last in this service for $360 \div (4 \times .5)$, or 180 days.

An ampere-hour is one ampere used for one hour.

A half ampere used for two hours is equal to one ampere-hour. A half ampere used two minutes out of each hour for sixty hours is also equal to an ampere-hour.

The amount of current delivered by a cell depends upon the E. M. F. of the cell and the resistance of the circuit. This current is always equal to the E. M. F., which is expressed in volts, divided by the total resistance of both the external and internal circuits. Example:

$$\frac{\text{Volts}}{\text{Resistance}} = \text{current}$$

A cell of two volts and an internal resistance of one ohm will send .66 ampere of current through a two-ohm wire.

$$2 \text{ volts} \div (1 \text{ ohm} + 2 \text{ ohms}) = .66 \text{ ampere}$$

Remember that the total resistance of the circuit is the resistance of the external circuit added to the resistance of the internal circuit (Fig. 1).

If we have a buzzer line which will not work from a single cell with an E. M. F. of 1.5 volts owing to an excess of external resistance, we can easily add another cell in series and raise the pressure to three volts, or still another, raising it to 4.5 volts, and so on (Fig. 2).

$$1.5 + 1.5 + 1.5 = 4.5 \text{ volts}$$

The positive pole of one cell is connected to the negative pole of the next, and so on. The poles of the end cells are used as the terminals of the battery. A battery connected in series is shown in Fig. 3.

In this case the total E. M. F. of the battery equals the sum of the electromotive forces of each cell, since the external potential of the end cell is made up by adding the potential difference between the poles of the individual cells.

Take, for example, 10 cells, each having a voltage of one volt, with an internal resistance of .025 ohm and an ampere-

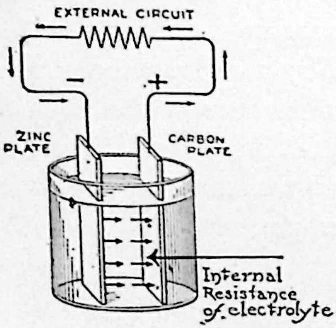


Fig. 1

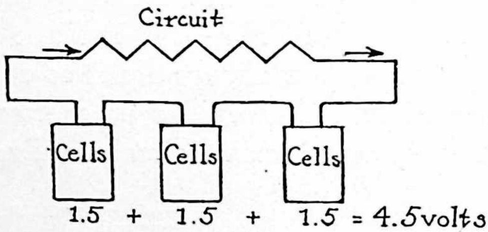


Fig. 2

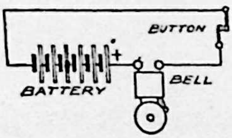


Fig. 3

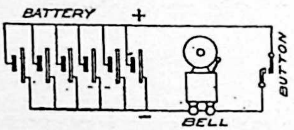


Fig. 4

hour capacity equal to 200. If they are connected in series the total voltage would be 10×1, or 10 volts, an internal resistance of 10×.025, or .25 ohm, but the capacity is only 200 ampere-hours.

When a large current at low voltage is desired the cells are connected in parallel (Fig. 4).

The total ampere-hours available from cells connected in parallel is equal to the sum of the ampere-hour capacities of the cells so connected. The voltage is equal to that of the single cell. The internal resistance is equal to that of a single cell *divided by the number of cells in multiple.*

Connected in this way, the six cells are equal to one cell with plates six times as large as the single cell. The voltage remains the same as in a single cell.

If two cells each of one-volt and 200-ampere-hour capacity are connected in multiple the ampere-hour capacity will be doubled, but the voltage will remain the same.

Series-Parallel Connection

In some instances to obtain the maximum amount of current with a given number of cells it is advisable to use a combination of both methods described above. The cells are connected in separate series groups, and these groups are connected in parallel. Fig. 5 illustrates such a connection.

The total voltage is determined by the number of cells connected in series and the ampere-hour capacity by the number of sets of cells in multiple.

In Fig. 5 these are shown five in series and six in multiple. If we use the same type of cells as described above—one-

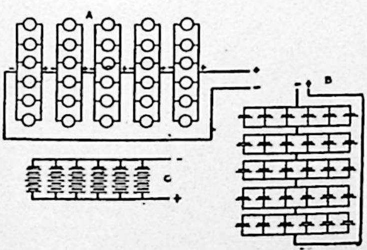


Fig. 5

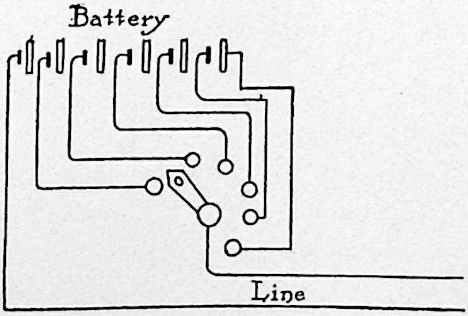


Fig. 6

volt, 200 ampere-hour, and .025-ohm internal resistance—then the voltage available would be five, the ampere-hours 6×200, or 1,200. The internal resistance of an individual cell divided by the number of cells in multiple, or .025 divided by 6, and multiplied by the number of cells in series, which is 5, or $(.025 \div 6) \times 5 = .0208$ ohm.

These conditions above mentioned are determined by the laws of divided circuits.

By inserting in the battery circuit a switch with several points of contact it is possible to get a wide range of variations in the voltage and the current of such a set. The simplest type of such a controlling device is illustrated in Fig. 6.

With this simple switch it is possible to readily connect two, three, four, five, or six batteries in series by merely manipulating the switch-arm to the various positions. This switch is of the greatest value in experimental work. With it a wide range of voltage can be secured.

Chapter III

CONTROLLING BATTERY CIRCUITS

ELECTRICITY likes to choose its own path. It wastes no time in wandering about. It always takes the easiest way home.

But regardless of distance it must always travel over a conductor.

The electric wire is the path over which electricity travels. To keep it on this path the wire, or conductor, must be insulated with non-conductors.

All metals are good conductors of electricity. Water, most liquids, the earth, and various other materials are fairly good conductors.

Air is the best non-conductor. It requires 20,000 volts or more of electricity to jump across one inch of air space. Rubber, glass, and porcelain are also good non-conductors.

The paths, or circuits, over which electricity travels are often as complicated as the city streets over which we travel. But electricity cannot be trusted to find its own way. It must be directed—sent. *It must be under absolute control.*

Electricity is controlled with switches. These are small devices to *make* and *break* the circuit, or to direct it over various paths or lines.

There are hundreds of types of electric switches. New ones are made every day. In fact, every amateur can devise and make his own switches.

The essentials of a good switch are an insulated form, or base, brass or copper contacts, and a suitable insulated handle, key, or button.

There are four kinds of line-switches in common use. They are the *single-pole switch*, the *double-pole switch*, the *triple-pole switch*, and the *four-pole switch*.

A single-pole knife-blade switch is generally used to open and close continuous circuits. It is made of brass or copper strips and provided with an insulated handle. In fact, this handle is not necessary for low voltage, and the brass strip may be bent into handle form (Fig. 1).

The block is three by five inches, and an inch thick. The brass or copper blade is drilled or punched at one end for riveting to the binding-post and an insulating handle fitted to the other end. The binding-post is bent so the side arms are springy enough to make a good connection to the blade when the switch is closed.

All metal contact-points should be clean and well polished, as a coating of rust or dirt acts as an insulator.

The completed switch is merely inserted in the line. Raising or lowering the handle *breaks* and *makes* the circuit.

The Double-Pole Switch

The double-pole switch is used where it is necessary to open and close both the positive and negative *legs* of the circuit. It is merely a double single-pole switch (Fig. 2).

The double-pole switch can be easily made. A glance at the diagram given in Fig. 2 will show the entire construction better than a detailed explanation. The dimensions depend entirely upon where it is to be used.

The triple-pole switch is used only for three-wire circuits. This switch is seldom necessary for amateur work. It is

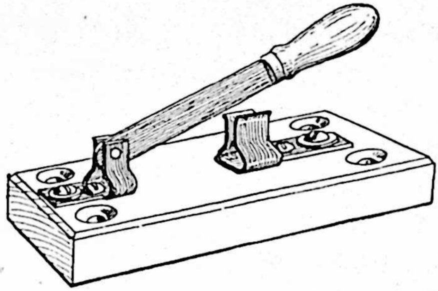


Fig. 1

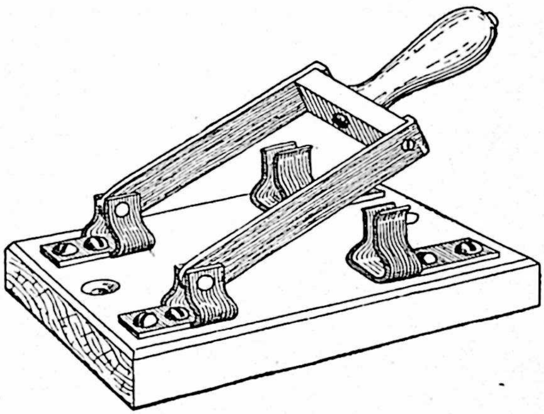


Fig. 2

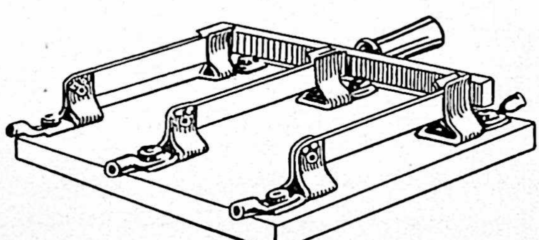


Fig. 3

merely a combination of the single-pole switch and the double-pole switch (Fig. 3).

Battery circuits are generally low-voltage circuits; therefore hard, dry wood is ample insulation for such switchboards, bases, and handles. Care should be taken, however, to keep the wood dry. If exposed to moisture it should be well oiled or varnished. Oil and varnish are good insulating materials and will keep the moisture out.

If the voltage is raised above ten volts dry wood should not be used, and hard rubber or porcelain should be substituted.

The success of all low-voltage electrical circuits depends upon good insulation and perfect connections at all joints, splices, and contact-points. Care should be taken in the manufacture and installation of all controlling devices.

Knobs and handles for low-voltage switches can be turned on a small lathe (Fig. 4).

After the knob is turned a hole is drilled through the center and countersunk for the screw. When the screw is in place the space above the screw-head is filled with melted sealing-wax, flush with the wood, effectively fastening the screw in place and insulating the metal from the hand.

Knobs and handles can also be molded of sealing-wax and hard rubber. Both sealing-wax and hard rubber become soft and plastic under the influence of heat. A plaster-of-Paris mold is suitable where the wax is used. Do not try to work soft rubber.

The mold for hard-rubber insulators is made of wood in two halves. It should be warmed in an oven before the hard rubber, made soft and wax-like by heat, is placed within the halves. It should then be squeezed in a vise.

Directing the Current

To direct the current over various paths a different type of switch is necessary.

Where it is necessary to switch the current from one circuit to another a directing-switch is used. A very good switch of this kind can be easily made of a brass strip and a few empty brass cartridge-shells (Fig. 5).

The baseboard A is six inches square. As many holes are bored as there are circuits. These holes could be arranged in a circular form and the right size to hold the cartridge tightly. The brass strip B is connected to the binding-post by a single screw so it will swing easily. It is

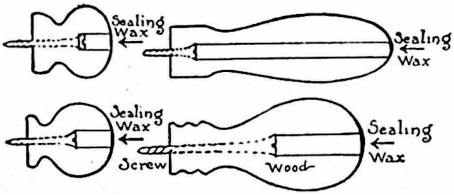


Fig. 4

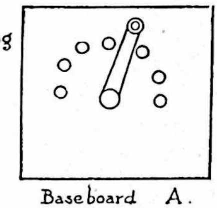


Fig. 5

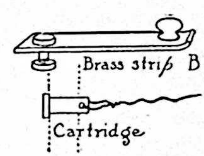


Fig. 6

bent, as shown in the illustration, so as to make a firm contact with the brass heads of the cartridges and provided with a wooden insulating-handle. The leads of the different circuits are connected to the individual cartridge through holes punched through the sides of the brass shell (Fig. 6).

For Open Circuits

For open circuits these switches, as described above, will not do at all. A push-button or a spring switch is necessary for this work. These automatically keep the line open to protect the battery. Otherwise the open-circuit battery would soon run down and cease to produce electricity.

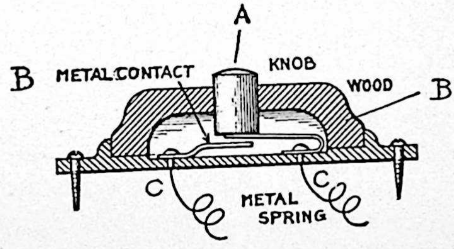


Fig. 7

The best of all these spring devices, for low-voltage circuits, is the ordinary push-button (Fig. 7).

It is evident that pressure on the insulated button A will bring the two metallic parts B, B in contact to which the two lead-wires C, C are connected and thus close the circuit.

This type of push-button is only suitable for battery work where the voltage is not above 15 volts. Its carrying capacity is limited to a fraction of an ampere.

The importance of making good joints and contacts should be remembered. For all permanent work such contact-joints, at switches and otherwise, should be soldered. This insures a perfect connection and an uninterrupted flow of the low-voltage battery current. For temporary work care should be taken to make good clean contacts. Often the failure of an electrical experiment is due to make-shift joints which act as barriers to the current. It requires more than 20,000 volts of electricity to leap across one inch of air space. A little figuring will show just how tiny an air space will stop the flow of a four-volt circuit. A few grains of dirt, a film of oil are quite sufficient.

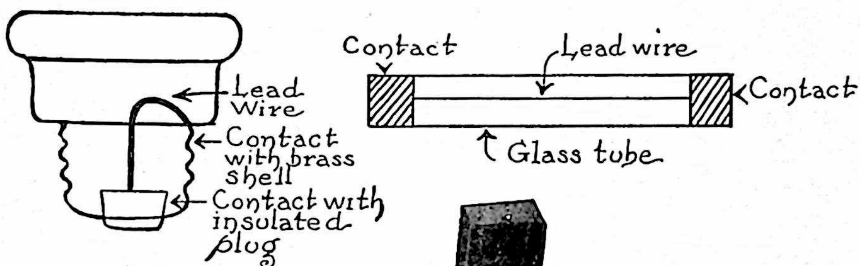
Importance of the Fuse

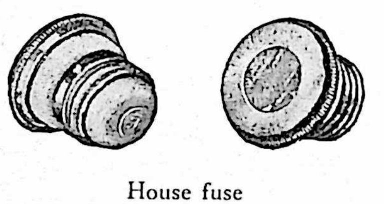
Battery-current wires should be properly fused where they leave or enter a building. This precaution will prevent dangerous stray currents from accidentally entering the building over the telephone, telegraph, wireless, or buzzer circuit wires. *If the electric-light wires or power-transmission wires should blow down and fall across your telephone or telegraph lines, if lightning should strike the poles, a dangerous current might easily enter your home and injure any one near the instrument or set fire to the house.*

This is reason enough why every amateur electric line should be amply protected where it enters the house with a suitable fuse placed in the circuit.

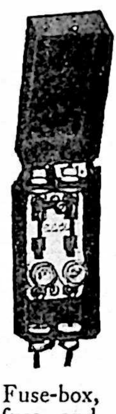
A fuse is merely a device for inserting a bit of lead-composition wire in the circuit. There are various types of fuses (Fig. 8).

It will be noted from Fig. 8 that the fuse designed for telephone lines is merely held in clips on a suitable insulating-block, while the fuse designed for house-lighting circuits is screwed into a socket the same as an incandescent lamp.

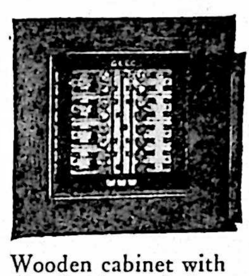




House fuse



Fuse-box, fuse, and switch



Wooden cabinet with distribution switches, fuses, etc.

Fig. 8

These fuses work on the selfsame principle. The bit of lead-composition wire is designed to carry a certain amount of electricity and no more. Any attempt to overload them with current above the stipulated amount will melt the lead wire and thus automatically open the circuit.

Fuses can be bought cheaper than they can be made. They cost but a few cents each. When *burned out* by an excess of current they should be thrown away. Never attempt to repair a fuse.

Fuses also protect the telephone instruments, buzzers, lamps, and other electrical devices from excessive and dangerous currents. Delicate instruments and costly devices might easily be ruined in an instant by stray currents if not properly protected with fuses.

The Electric Buzzer

The simplest of all battery devices is the electric buzzer. Simple as it is, it has a hundred uses. The buzzer is adaptable for signaling, for simple telephone lines, for call-bells, for annunciators and alarms, etc.

The buzzer is merely an electromagnet and a vibrator so combined as to produce a loud buzzing whenever the circuit is closed. Of course the buzz is produced by the rapid vibrating of the armature in front of the electromagnet as it makes and breaks the circuit.

The buzzer is really a little sound-motor. It is a device which turns the electrical energy into mechanical energy, like every other motor. This mechanical energy is used to set up sound-waves in the surrounding air which produces the buzz. The very simplest form of buzzer is shown in Fig. 9.

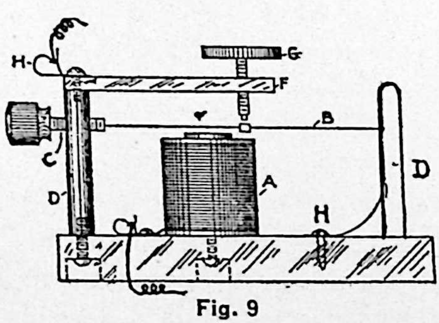


Fig. 9

An electromagnet of four ohms resistance is made by winding cotton-covered No. 36 wire on an ordinary carriage-bolt. This magnet is affixed to the wooden base, which acts as an insulator, as shown in the above picture. Above it is stretched a short piece of steel piano-wire three inches long, between the binding-posts D, D. The tension is regulated by the screw C. At the top of the wooden post D is mounted the brass arm F, which holds the regulating-screw G. On the steel wire opposite the screw G is fastened a bit of platinum, silver, or even iron which is bent in the form of a tube and flattened down tight against the wire so it will stay in place. One battery lead is connected to the binding-post E and the other to the post H, to which are also connected the leads to the magnet.

The operation of the buzzer is very simple. When the current is sent through the electromagnet it attracts the steel wire, pulling it down and away from the screw G. This breaks the circuit, instantly the magnetism ceases, and the wire snaps back against the contact, closing the circuit. This operation is repeated as long as the circuit is closed. The steel wire vibrates at high speed, and this produces the buzzing noise.

Another simple buzzer is made on this same principle by simply bending a piece of steel clock-spring over the electromagnet in place of the piano-wire. The end of the spring is heated to draw the temper and drilled so it can be fastened at one end to the baseboard. It is mounted the same as the wire (Fig. 10).

Buzzers are made for operation on regular lighting-circuits where the voltage is 110 or 120 volts. But those described above are only suitable for operation on low-voltage circuits. Any attempt to place them in lighting-circuits will result in failure and the destruction of the buzzer. A buzzer for a lighting-circuit can be purchased cheaper than it can be made. They are generally used for signaling purposes.

The Electric Bell

The electric bell is but an adaptation of the buzzer principle (Fig. 11).

The clapper A is fixed to the end of the armature B. The vibration of this armature manipulates the clapper against the bell whenever the push-button is pressed, closing the circuit.

The little button on the door-jamb is a spring device which keeps the circuit open between the battery and the

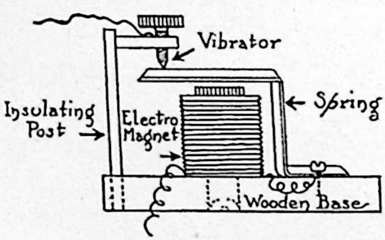


Fig. 10

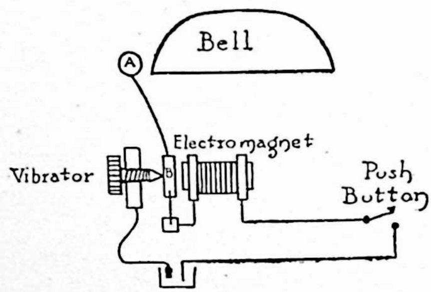


Fig. 11

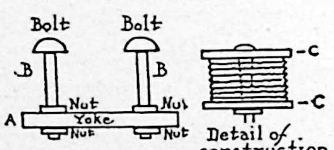


Fig. 12

bell. The pressure of a finger closes the circuit, and the electricity flashes over the line to the bell. The bell itself is somewhat more intricate than it looks. In the little iron box beneath the bell are two small coils of fine insulated wire wrapped tightly about the soft-iron cores. Of course when electricity flows through the insulated wire of these coils the soft-iron cores become electromagnets, differing from a permanent magnet in that when no electricity flows through them, owing to any break in the circuit, they are not magnetic.

When the button is pushed, closing the circuit, these magnets attract a soft-iron plate, or armature, attached to the lower end of the bell clapper and located just in front of the magnetic poles. This iron plate is fastened at one end to a steel spring, but the coils are powerful enough when magnetized to overcome the action of this spring and to pull the plate downward. This action pulls the clapper down against the bell, and at a certain point just before the armature touches the magnet the electric current is broken, destroying the pulling-force of the magnets, and the steel spring throws the clapper back. Of course the circuit is then closed again and the action is repeated as long as the button is pushed.

Electromagnets for buzzer and bell service are best made in three parts (Fig. 12).

The soft-iron yoke A is drilled to admit the two small iron bolts B, B. The bolts are wrapped with two layers of stiff writing-paper, fitted with wooden or cardboard disks (C, C) and wound in the usual manner with fine insulated copper wire. The result is a very powerful electromagnet of compact size.

Details of such battery devices as the telegraph, the telephone, electromagnets, induction-coils, toy motors, etc., are given in full, with illustrations, in *Beginning Electricity*, the first of this series.

Chapter IV

BUZZER SIGNAL SYSTEMS AND BURGLAR-ALARMS

BUZZER SIGNAL systems are very easily installed. They really save many steps. This is especially true of country districts. For instance, suppose the barn is some little distance from the house. It is frequently necessary for some one to go there to call the head of the house or the farm-hand. All these steps and many others could be saved by installing a cheap and handy buzzer call-system.

A buzzer system of this kind requires but a common buzzer, a push-button, a couple of dry-cell batteries (the actual number of cells depending, of course, on the distance), and the necessary wire. The ordinary low-voltage electromagnet buzzer mentioned in the preceding chapter will answer very well indeed. Otherwise, low-voltage buzzers can be purchased for a few cents each. Any ordinary wire can be used, and it need not be insulated for outdoor lines. If iron wire is used it should be of the size commonly known as *telephone wire*. Copper wire may be smaller, as it is a better conductor of the electric current.

One good dry cell will be sufficient to operate lines up to one hundred yards, and an extra cell should be added for every additional fifty yards. This rule will not always hold, owing to the imperfections in the line or poor batteries. Enough cells should be placed in series until the buzzer operates at its best.

Where the line enters the building insulated wire should be spliced to the uncovered outdoor wire. Silk or cotton covered wire will do for indoor work if it is properly reinforced with porcelain or rubber tubes where it passes through the walls. Outdoors the naked wire should be insulated at all points of suspension and where it touches such objects as buildings, trees, walls, etc. Buildings and wood of all kinds will short-circuit the line during damp weather. Common glass insulators will answer for outdoor work. In the absence of these bottle-necks may be used. The bottle-necks can be knocked off and fitted to the end of a wooden holder. Broken glass is sharp—handle it with gloves and care. The holders are nailed to the build-

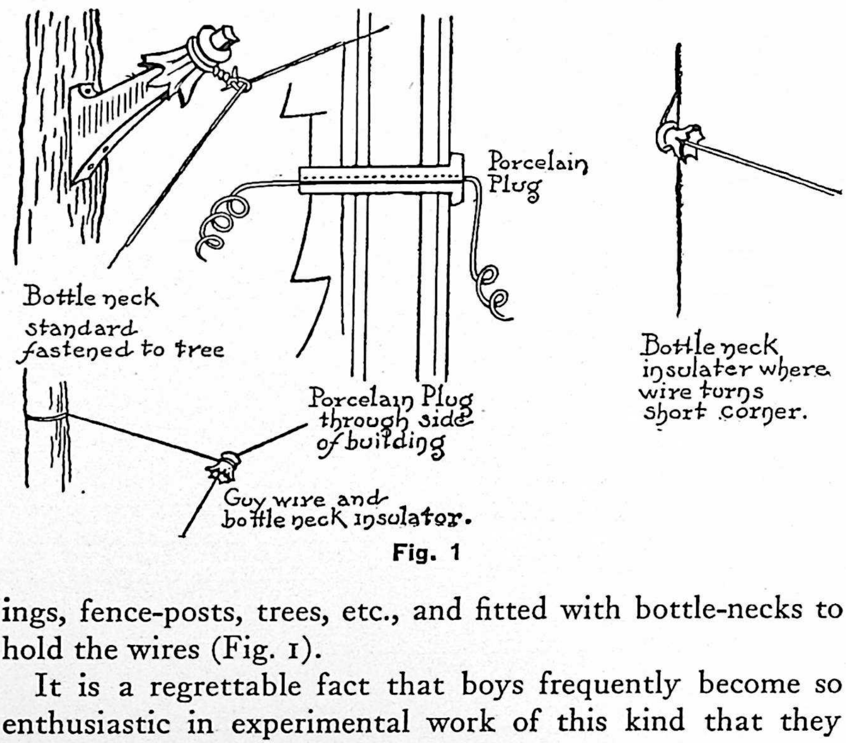
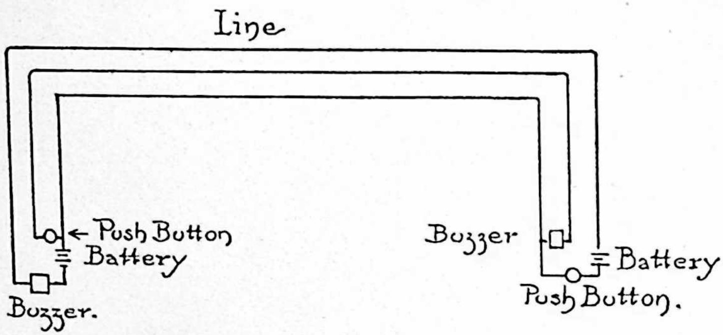


Fig. 1

ings, fence-posts, trees, etc., and fitted with bottle-necks to hold the wires (Fig. 1).

It is a regrettable fact that boys frequently become so enthusiastic in experimental work of this kind that they neglect the most important details. In their haste to get the work done they do not take sufficient pains with little things. *And it is these very little things which mark the difference between success and failure.* Be sure to make all wire connections tight and firm. Be sure to scrape the



BUZZER SIGNAL LINE

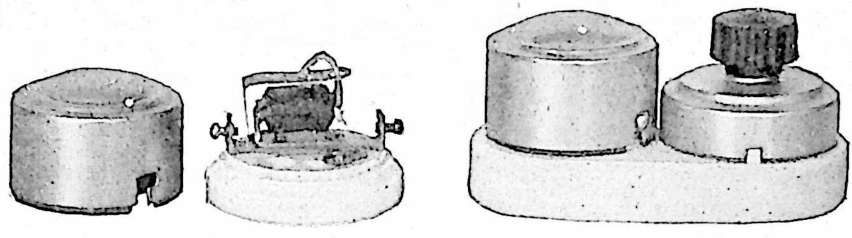
Fig. 2

metal clean and bright when splicing wires. Be sure that binding-posts make a good connection to circuit wires. And be doubly sure that the electric wires are carefully insulated for their entire length against any possible short circuits. Remember to insert a fuse in the line where it enters each building.

A Complete Buzzer Signal System

With these little details firmly in mind it is no trick at all to install a buzzer signal line. It should be used only for short-distance work. For greater distances a telephone or telegraph is better. By following the diagram given above the buzzers and batteries can be easily connected so they will work (Fig. 2).

A simple set of signals can be agreed upon for the buzzer



ALTERNATING-CURRENT BUZZER AND COMBINED SNAP-SWITCH AND BUZZER

line. When such a line is built between the workshops of neighboring boys it is but natural that they should learn to talk over the wires by using a telegraph code (Fig. 3). In this case a short buzz stands for a dot and a long buzz for a dash.

Where the line is built to connect the house with the barn or with the chicken - plant or shop a simple code of signals will answer.

——— One long ring, "Dinner is ready."

– – – Three short rings, "Some one to see you."

——— ———

Two long rings, "You are wanted at the house."

– – – – Four short rings for horse and buggy.

This may be enlarged at will to take in a great

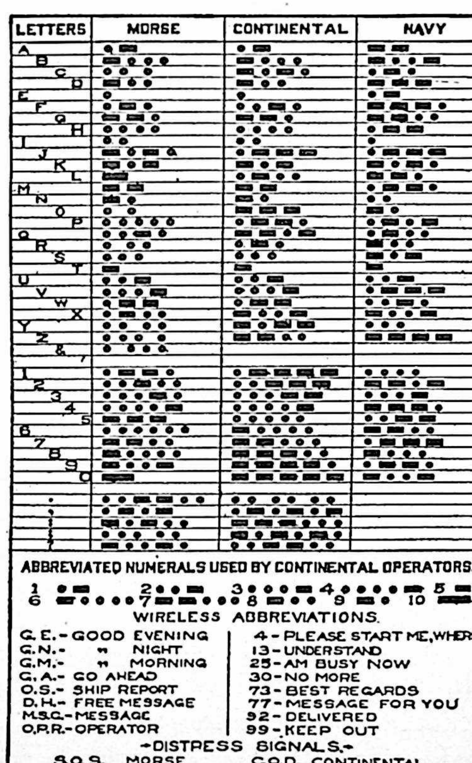


Fig. 3

variety of signals. It is surprising how many steps a system of this kind will save.

It is also easy enough to attach a simple telephone to this buzzer system. In this case the buzzers are used merely for calling the party to the telephone, then the conversation is carried on over the wire. This can be very easily done by attaching a simple telephone - transmission receiver across the line at each station (Fig. 4).

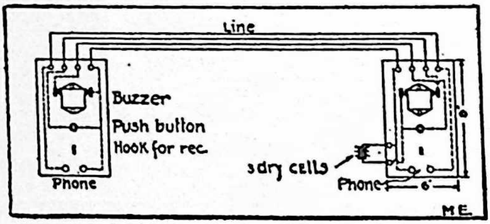


Fig. 4

It is a well-known fact that the telephone transmitter can be used as a receiver for short distances. In this case the instrument is held first to the lips and applied to the ear as soon as your part of the conversation is finished to catch what the other party answers. To operate you merely press the push-button, which operates the buzzer at the other end of the line. When the party answers with a short buzz you talk by means of the receiver. The manner of connecting the receivers to the line is shown in Fig. 5.

In case the distance is so great that a battery and induction coil are necessary for the successful operation of the telephone they should be connected up as shown in Fig. 6.

Installing the Electric Door-Bell

A single dry-battery cell will operate the electric door-bell in any ordinary home. For convenience' sake the bell should be placed in the back of the hall or in the kitchen, where it will be sure to be heard. Any small-size silk or cotton covered wire may be used.

Remember that such a circuit calls for a double length of wire. There must be enough to reach from the front door to the bell and back again to complete the circuit. The push-button is fastened in a conspicuous place beside the front door. A bronze metal-covered button is best for such outdoor service, as it looks better and lasts longer. The wires are concealed as much as possible by running them down along the door-jamb, along the mop-boards, or under the floor. It is the general practice to carry the wires straight down to the cellar, where the battery is connected on. The wires are then fastened to the floor joists and

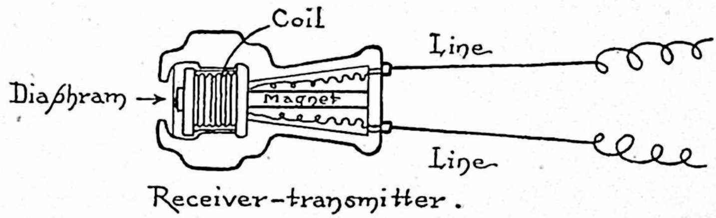


Fig. 5

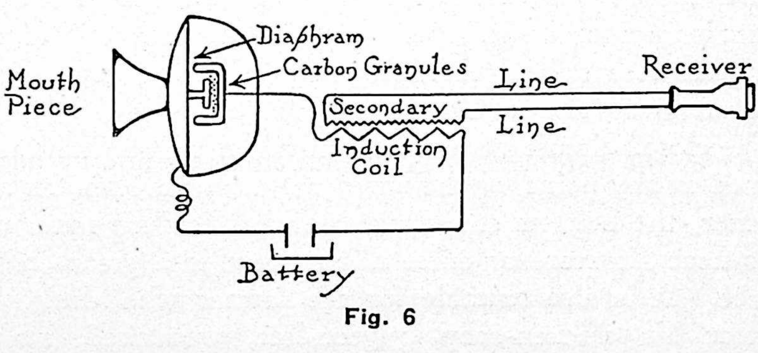


Fig. 6

beams to a point just below the bell, where they are carried up through the floor to the bell (Fig. 7).

It will be seen that the circuit is kept open by the push-button. The pressure of a finger closes the circuit and rings the bell.

Burglar-Alarms

Burglar-alarms are in general use in both city and country. They are very inexpensive and can be easily installed by the amateur. Such alarms can be constructed to guard the doors and windows of the store or shop. They can be easily applied to the chicken-house, the barn, or pigeon-loft. They are also used to protect the home.

A burglar-alarm consists of a battery, the necessary wires and switches, and a suitable gong or bell which rings when the burglar tries to enter.

The only alarm worth considering is the closed-circuit system. In this system the alarm is not sounded by making an electrical connection, but by breaking it. This system absolutely defies the burglar, as any tampering with the wires, either in the buildings or with the internal system including the line itself, instantly sounds the alarm. Of course electric bells can be used in place of buzzers. If the object is to catch the miscreant a good loud buzzer is better. It makes less noise. A loud-toned bell is pretty apt to frighten away the would-be burglar.

The closed-circuit system is so installed that if the line is opened at any point, or the wires are cut or broken in any manner, the buzzers sound the alarm. For the man who lives near his store or office this system is a great convenience. It is also suitable for the farmer who desires to protect his chicken-coop, pigeon-loft, woodshed, stable, barns, etc. The best thing about this system is the fact that the wires do not have to be concealed. They may be exposed to view. If the burglar should cut the wire the bell would ring immediately and announce his unwelcome visit.

The closed-circuit alarm system necessitates a buzzer or bell, a dry battery, an electromagnet, and a gravity battery such as is used for closed-circuit telegraphy work. The apparatus is arranged as in Fig. 8.

In the sketch, A is a pivot on which turns the armature, so fixed that when pushed toward the magnets it will

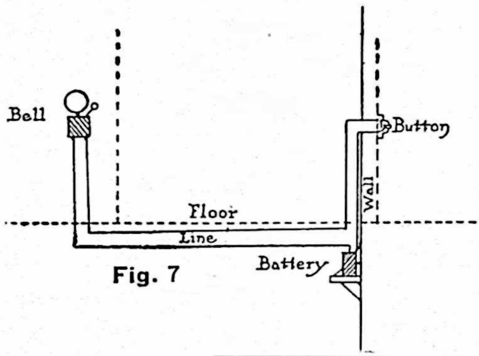


Fig. 7

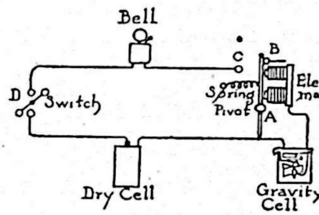


Fig. 8

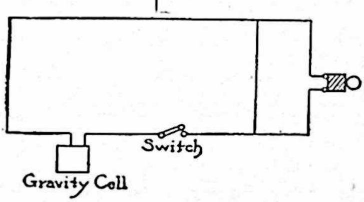


Fig. 9

make connection at B. The electromagnet will hold it there until the closed circuit is broken. Then the spring will pull it against C, making the contact to ring the bell. After the connection has once been broken it cannot be pulled back except by pushing the arm in some mechanical way. D is a switch to turn the bell off during the time the alarm is not wanted. All connections are explained in the sketch.

Connections are made at the various windows by arranging a copper washer on the bottom of the sash and one on the sill so that they make a good contact when the window is closed and break it the instant the window is raised. Door connections are made at the jamb so that the connection is broken when the door is opened.

The dry battery is used on the bell side of the system and the gravity batteries in the relay side.

At best the foregoing is but a suggestion of what may be done in the way of installing burglar-alarms. Working on the same principle as the closed-circuit relay system described above, the device may be installed to suit any condition and for any purpose where such an alarm is necessary. It is even possible and practical to guard fruit-trees with this system. In this case a very fine wire is so arranged that it incloses the trees and must be broken in order to reach the fruit. It may be so concealed that it is accidentally broken by the nocturnal visitor. It is easy enough to protect the chicken-house with such a system or any other barn building. A convenient switch turns off the entire system while the owner does the necessary work about the buildings.

There are places, however, where the closed-circuit burglar-alarm is best. This system is simplest of all, but the circuit wires must be concealed, because if they are cut or broken the alarm is rendered useless. Only the guarding-wires of this system may be exposed to view, as the cutting or breaking of this wire at any point will sound the alarm (Fig. 9).

An intermediate wire keeps the bell short-circuited, and the moment this wire is broken the bell rings and continues until the switch is turned off. This wire should be placed across the doorway so when the door is pushed open it will break the wire; or it may be put at any place where you are sure the intruder will break it.

Other Battery Signal Systems

Battery signal systems are also useful for various other purposes. Where the water for the home is stored in a tank, being raised by a pump whenever the tank is empty, a simple system may be installed to sound a warning when the water in the tank gets low, or to automatically start and stop the electric motor and pump. Both these systems are shown in Fig. 10.

The operation of this signal system is very simple. When the float drops to a certain low level it completes the electrical connection, and the buzzer sounds the alarm or the motor starts the pump. The buzzer may be located in any place desired, but it is usually installed in the kitchen. When it sounds its alarm the hand-pump or gasolene-engine is started up and the tank refilled. Where an electric motor

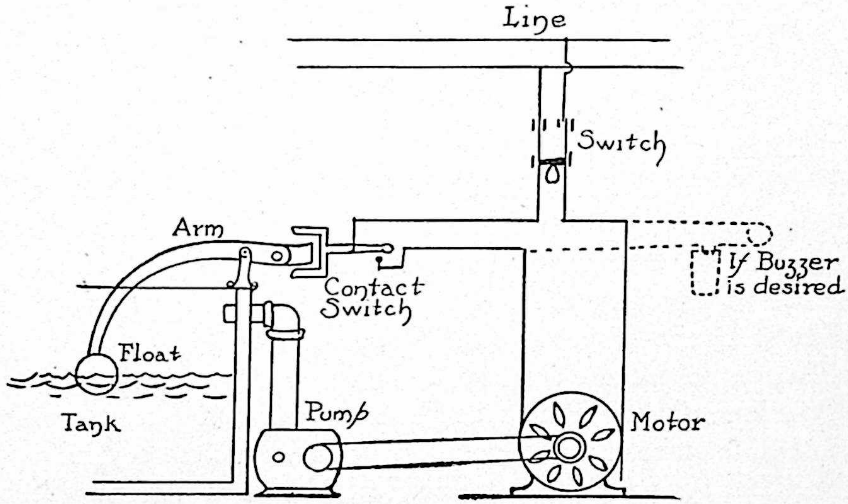


Fig. 10

is used to drive the pump an alarm is not necessary. Of course, dry batteries are always used for open-circuit work of this type.

For the Refrigerator

This same signal system is easily adapted to the water-pan under the refrigerator. These water-pans seem to be always running over on the floor. A buzzer system will give ample warning when the pan is full and should be emptied (Fig. 11).

Perhaps the operation of this device is best shown in the picture. When the float rises to the top of the pan it closes the circuit and sounds the buzzer alarm.

Fire-Alarms

Automatic fire-alarms are also operated by battery currents. The little telltale device which announces the presence of the fire and sounds the alarm is called a thermostat. A thermostat sufficient for this purpose can be made by riveting a strip of hard rubber securely to one side of a strip of clock-spring (Fig. 12).

When heated the steel expands, but the rubber contracts. Consequently the contracting rubber causes the steel spring to *buckle* or bend. Advantage of this is taken so that the buckling spring closes an electrical circuit which rings the alarm (Fig. 13).

These thermostats are usually located where fires are apt to break out. For instance, a farmer-boy arranged one in the incubator and brooder house. When one of the machines became overheated and caught fire the electric bell located in the house sounded the alarm, and the building and contents were saved.

In this case a thermostat was located directly over the incubator and one over each brooder. The wires were extended to the house, where the electric bell was fastened to the wall of the room near the boy's bed.

A metal thermostat is made of a strip of brass brazed to a strip of steel. It acts similar to the steel-rubber combination. There are many modifications of this fire-alarm system. Some of the larger buildings employ fusible plugs which melt with very little extra heat and thus automatically

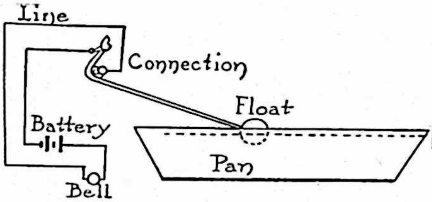


Fig. 11

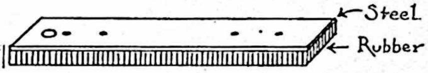


Fig. 12

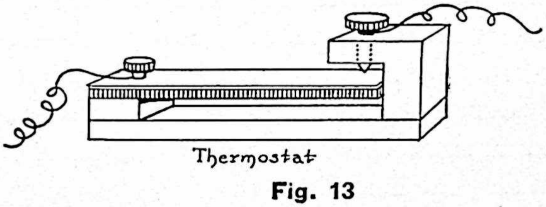


Fig. 13

open the circuit and sound the alarm through a relay and bell. These types are suitable for large buildings only.

There is still another good fire-alarm device which is easily made. It works on the same principle as the fuse. A bit of sealing-wax is used to break the circuit. When this wax melts the circuit is completed and the alarm sounds (Fig. 14).

It requires but a little heat to melt out the intervening

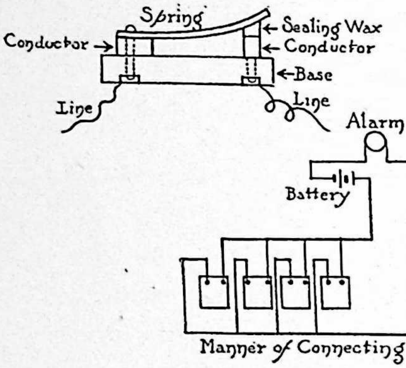


Fig. 14

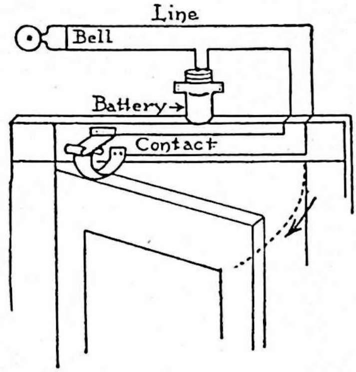


Fig. 15

sealing-wax. Then the steel spring snaps down on the conductor terminal and completes the circuit so the alarm rings.

Door-Alarm

It is often very convenient, especially in workshops and offices, to know just when the door is opened. A simple battery alarm is easily adjusted to any door (Fig. 15).

When the door is opened the lower spring-contact is forced up and against the upper contact, completing the circuit and ringing the bell.

Chapter V

ELECTRIC BATTERIES FOR LIGHTING PURPOSES

BATTERIES are also used for lighting purposes. Either primary or storage batteries may be used for lighting circuits, although their original cost and short life makes this method too expensive for extensive operations.

Many of the electric-light stations throughout the country maintain large storage batteries as an emergency source of power. In case anything happens to the engines, generators, or other machinery the service wires are switched to the battery, which carries the load until repairs can be made.

Household lighting circuits are generally of at least 110 volts. This high voltage is maintained as standard for several important reasons. The cost for copper wire increases in proportion to the drop of voltage. There is a considerable loss of energy where a low-voltage current is carried for any distance. It is at once apparent that to attain this standard voltage with batteries would require nearly a hundred battery cells, connected in series, otherwise the 110-volt lamps would not light. But incandescent lamps are also made in low voltages. With the advent of the new metal-filament lamps a few years ago electric lighting from batteries was made less expensive. For the first time it came into general use, especially on motor-boats and automobiles. These new lamps will give a candle-power of light for every watt of energy consumed, or about a third of the current required for the old miniature lamp. Miniature lamps (Fig. 1) are now made in very low voltages, according to the following table:

MINIATURE LAMPS

CANDLE-POWER	VOLTS	WATTS	AMPERES
Flash-lights	2.7–6.2	......	.35
½	1.5	.6	.40
1	2.8	.84	.3
1½	3.8	1.14	.3
2	6.2	1.86	.3
4	4–6	5	1.25
4–5–6	6–8	7.5–10	.95–1.25
8–10–12	6–8	10–20	2.1–3.35

Knowing the voltage and the amperes required for each miniature lamp, it is easy enough to determine the battery cells necessary for any lighting circuit of this nature. Suppose we desire to install a two-candle-power four-volt lamp to be operated by dry cells. If each cell gives 1.5 volts, then three of these cells connected in series will produce 4.5 volts. Theoretically this is half a volt too much, but in practice it is well to allow at least that much. The ampere-hour capacity of the cells is 50. If the lamp requires ½ of an ampere the cells will keep the lamp burning for 100 hours.

Lighting the Dark-Room

Battery lighting with low-voltage lamps is quite extensively used in the dark-room, where photographic plates and films are developed. Such a lamp is very easily installed. The lamp itself costs but a few cents and can be purchased with a red bulb. A two-candle-power four-volt lamp will answer this purpose very well. This lamp can be operated with three dry cells. Use good insulated wire No. 16 for the circuits, carefully protected with porcelain cleats at all points of contact. Ordinary lamp-cord containing two insulated wires may be safely used and stapled

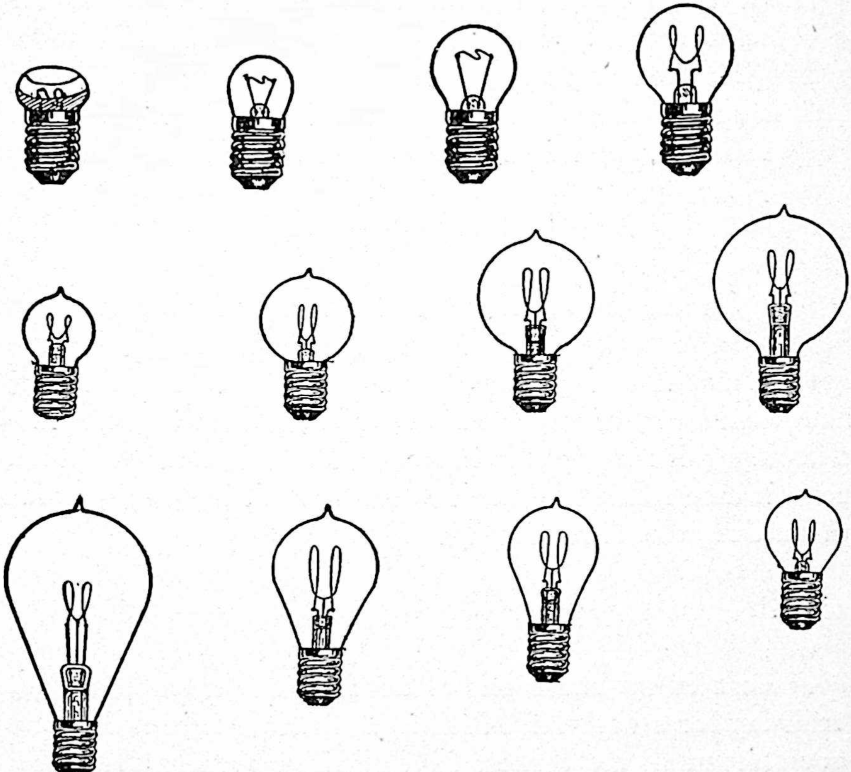


Fig. 1

to the walls, if care is taken not to cut the insulation when the staples are placed. The lamp is usually suspended so the light will fall where needed, and the batteries are placed under the bench or table out of the way. The current is controlled with a common snap-switch or a home-made knife-blade switch (Fig. 2).

In case the lamp is not provided with a red bulb it should be provided with a red shade or screen. The lamp can be mounted in a small wooden box, placed on a handy pedestal, with one side of the box removed and a piece of stiff red paper substituted (Fig. 3).

The wooden pedestal is 12 inches high, the wooden shade is 6 inches square. The lamp is turned on or off with a pull-socket such as used on ordinary electric-lamp sockets. This lamp has the added advantage that the little door is hinged so it can be raised when a white light is wanted.

White and Red Lights

A dark-room is generally all its name implies, and often both a white light and a red light are necessary. While getting materials together, making repairs, or cleaning up, the white light, of larger candle-power, is used. When developing, this lamp is switched out and the red lamp lighted. In this case a suitable six-pole snap-switch is necessary for controlling the lamp (Fig. 4).

Lighting Dark Closets

Almost every house has a dark closet or two, a dark stairway, or a dark store-room. Lights are needed in these rooms even on the lightest day. It is extremely dangerous to enter them with a lighted lamp or a candle, or to strike matches while searching in the darkest corners. These dark closets prevail even in modern houses equipped with electric light, and they are all too frequent in old houses.

The only safe light for a dark closet stored with highly inflammable material, as they always are, is an electric light. Such a closet can be easily and economically lighted with a low-voltage lamp and a common battery circuit. A

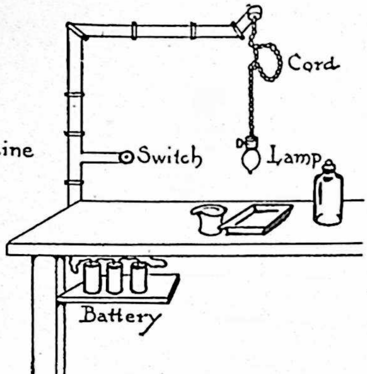


Fig. 2

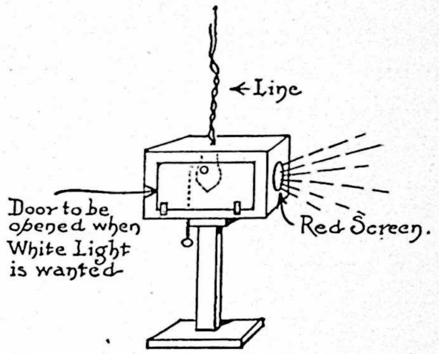


Fig. 3

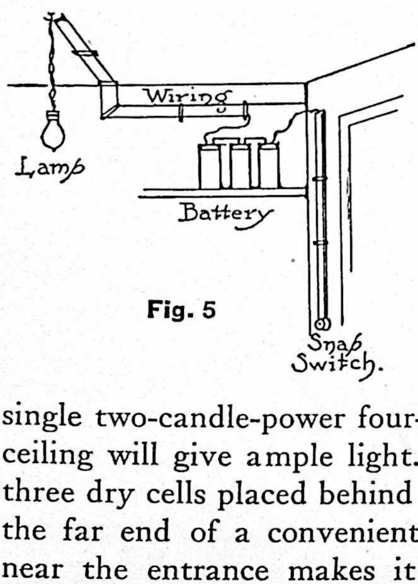


Fig. 5

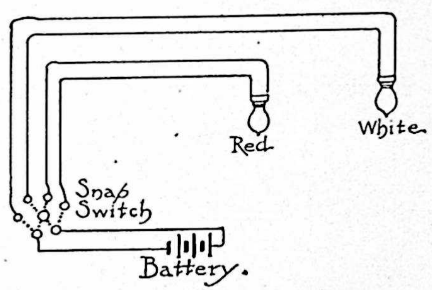


Fig. 4

single two-candle-power four-volt lamp suspended from the ceiling will give ample light. The current is secured from three dry cells placed behind the door, out of the way, or on the far end of a convenient shelf. A snap-switch placed near the entrance makes it convenient to turn the light on and off before entering the room. The manner of wiring depends, of course, on the size and nature of the room, but should be, in general, similar to the system shown in Fig. 5.

Lighting the Attic

In this list should also be included attic lighting. A great many fires start from carelessly held lamps or carelessly dropped matches while folk are searching the attic after dark. By all means the attic should be lighted with electricity. Attic lighting is more extensive than the examples given above and will require more batteries, larger wires, and at least two miniature lamps.

The lights in a dark attic are seldom used, and then only for a short interval, so they can be of larger candle-power, to illuminate a larger area. Two four-candle-power six-volt lamps will give plenty of light. This will require five 1.5-volt cells connected in series, and perhaps six if the wiring is very extensive (Fig. 6).

This system can also be adapted, with such variations as necessary, to instal a lighting system in the cellarway or in

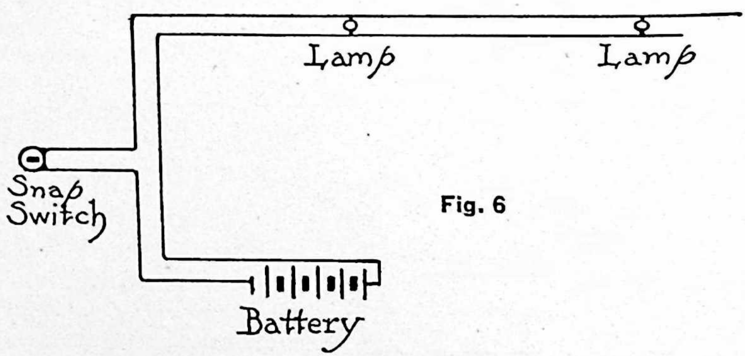


Fig. 6

the portion of the cellar where the daylight is obstructed, as in the vegetable-cellar. In case night work is required about the chicken-house, as frequently happens during the winter months, such a lighting system can be installed in the hen-house. This will eliminate all danger from matches, hand-lamps, or lanterns. The cost of such a system is very insignificant.

Care must be taken in operating all these low-voltage battery lighting circuits to turn the lamps out when not in use. To *leave the lamps burning is a serious drain upon the batteries. When the batteries are worn out they are worthless and must be replaced. Make it a rule to look and be sure the lamps are turned out before you close the door.*

Electric Lights for the Motor-Boat

On all public waterways motor-boats are required by law to carry a certain number of lamps after dark. Gasolene-driven boats of all kinds are easily destroyed by fire. A fire out in the middle of a large lake is as dangerous as it could well be. For this reason matches and oil-lamps are more or less dangerous on motor-boats. Large quantities of oil and gasolene are necessarily spilled about the boat, especially in the engine-room. For this reason electric lamps are safer and best for motor-boat lighting.

Contrary to the general belief, the motor-boat can be lighted from electricity secured from dry batteries. Large boats are usually supplied with an engine-driven dynamo, or generator, or with a large and expensive storage battery for lighting and ignition purposes. These boats are brilliantly lighted each night. But small boats require only the regulation sailing-lights, with, perhaps, a small light or two in the cabin. These boats are seldom used after dark and can be lighted with dry batteries just as well as not.

For small boats, under 30 feet, a six-volt lighting system, similar in many ways to that installed on an automobile, is satisfactory in every way. As a source of current four sets of five cells connected in multiple-series should be installed in a convenient locker where they will be out of the way. It makes no material difference where the battery is located. Rubber-covered wire should be used because the wiring must be proof against dampness, which would cause short circuits and all sorts of trouble. No. 16 rubber-covered copper wire is right. In an ordinary single-cabin boat ten or twelve automobile lamps will be necessary, arranged as follows:

Cabin, two 5-candle-power lamps
Engine-room, one 5-candle-power on flexible cord
Galley, one 2½-candle-power
Steps, one 2½-candle-power
Search-light, one 24-candle-power
Side-lights, two 5-candle-power
Mast-light, one 5-candle-power

The lamps in the galley and for the entrance to the cabin should be fastened to the ceiling. Side-wall brackets are provided for the cabin lamps, and the engine-room lamp is attached to a long flexible cord for trouble-hunting, etc. (Fig. 7).

The search-light is a heavy drain on the battery, but it is seldom used, and then only for short periods. The starboard and port lights (Fig. 8) and the mast-lights must be

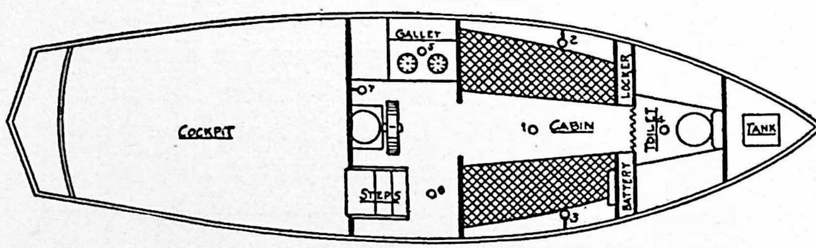


Fig. 7

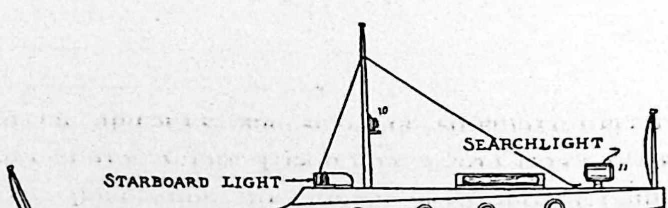
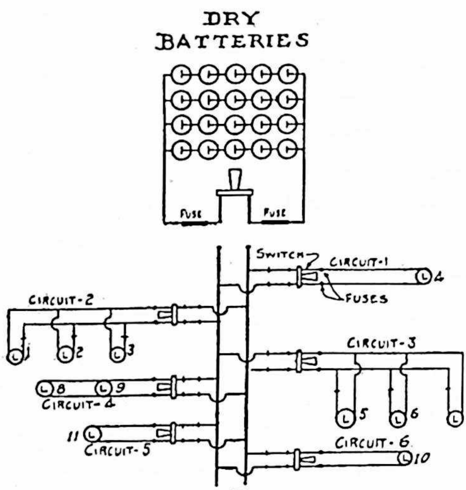


Fig. 8

lighted after sundown on all large rivers, lakes, canals, etc.

The method of connecting the battery and dividing the circuits is best shown in Fig. 9.

The diagram shows a method of connecting batteries and the different circuits to the switchboard. The batteries are connected to a double-pole, double-throw switch. The fuses are of a capacity equal to the sum of the amperages of all the circuits. Six circuits run from the switchboard and should be equipped with switches and fuses of correct capacity. Circuits Nos. 1, 4, 5, and 6 are all controlled directly from the switchboard. Circuits Nos. 2 and 3 are controlled at the switchboard and at the lights.



Wiring Diagram

Fig. 9

The Handy Flash-Light

A flash-light is a very handy little thing to have around the house. They are cheap and inexpensive and will last for a long time. Such a flash-light really consists of a tiny battery, a miniature lamp, with a suitable push-button switch and a short wiring circuit. This apparatus is usually combined in one case, making the lamp handy to carry. The switch keeps the circuit open until the button is pressed, and the lamp remains lighted as long as the button is pressed.

A flash-light can be made of two ordinary dry cells, a miniature lamp, and a simple spring switch. The cells are slipped into a pasteboard tube, one after the other. This tube should be of heavy cardboard fitting snugly about the cells. Or the cells may be placed side by side and wrapped with heavy paper. In the front of the tube (if a tube is used) is fitted a disk of soft wood about an inch thick. This disk is bored to admit the lamp-socket and the two wires from the cells. The cells are connected in series. One of the lead-wires is cut to admit the spring switch for controlling the current. The parts of an ordinary push-button can be used for this switch, or new ones can be devised. The switch is fastened to the inside of the tube, connected to the wires, and arranged so that the button proper operates through a hole in the tube (Fig. 10).

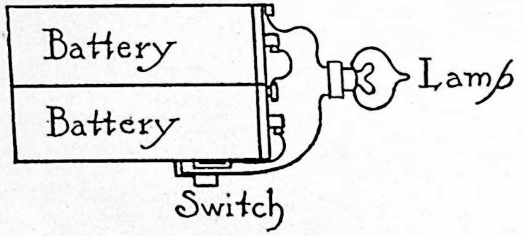


Fig. 10

Series Lighting on the House Circuit

It is a mistake to think that low-voltage lamps cannot be used on ordinary house-lighting circuits. True enough, a six-volt lamp will burn out with a flash if screwed into the lamp-socket on a 112-volt circuit. But nineteen six-volt lamps arranged in series can be used on a 112-volt circuit. The number of low-voltage lamps that can be safely used in series on a high-voltage circuit will be the number of volts of the house circuit divided by the rated voltage of one lamp. If the house voltage is 112 volts and the lamps are marked six volts the number of lamps required will be 112 ÷ 6, or 19 lamps. If you use more lamps than the proper number they will not light brilliantly, and if you use less they will burn too brightly and perhaps be destroyed.

Series lighting with low-voltage lamps on household circuits is seldom employed except for special occasions. Christmas

Fig. 11

trees are generally lighted in this manner. The lamps are arranged in a "string" in series (Fig. 11).

So many fires have occurred from lighting Christmas trees with old-fashioned candles that miniature lamps are now generally used for this purpose. They are perfectly safe and may be used year after year.

Chapter VI

THE STORAGE BATTERY AND ITS USES

THE storage battery is closely related to the primary battery. Its action is about the same. The essential parts are very similar. In fact, a primary gravity cell can be used to a certain extent as a storage battery.

The storage battery is also known as a secondary battery and as an *accumulator*. This latter name is far more correct, as the storage cell does *not* generate electricity. It accumulates, or stores, it.

Now, lest we be misled in the very beginning, it is well to state again that the storage battery does not store electricity, nor even electrical energy. The battery stores up energy, it is true, but it is in the form of chemical energy. The storage battery is a voltaic cell in which a chemical action is first produced by an electric current passed through the cell from some external source. This chemical energy produced in this way may be allowed to lie dormant for a long time, but is ever ready to change back into electricity upon demand.

It should be remembered that the storage battery differs materially from the static accumulator, or Leyden jar. The Leyden jar actually accumulates electrical energy. The storage battery accumulates chemical energy.

There are two kinds of storage batteries—the lead battery and the non-lead battery.

In the lead battery the cathode, or positive plate, is made of lead peroxide, a hard substance of reddish-brown color. The anode, or negative plate, is made of spongy metallic lead. These plates are known as "grids." They are immersed in an electrolyte of dilute sulphuric acid.

The process of storing the electricity, in the form of chemical energy, by sending a current of electricity through the cell, is called "charging." When the cell is producing current it is said to be "discharging."

When the cell is completely discharged both the positive and the negative plates are in the form of lead sulphate, and the electrolyte is practically reduced to water.

When the charging current is again passed through the cell the lead sulphate in the negative plate loses the sulphate part and becomes pure spongy lead. The positive plate also loses its sulphate, which combines with the escaping oxygen gas and forms lead peroxide. In the mean time the water combines with the liberated sulphate, becoming dilute sulphuric acid.

This chemical action takes place in the cell each time it is charged and discharged.

Non-Lead Storage Batteries

The greatest defect of the lead-and-lead storage battery is its weight. Lead, as we all know, is very heavy, and where a large number of cells have to be used to secure the proper voltage and a sufficient amount of electricity, the battery as a whole weighs considerable.

For many years inventors were busy trying to improve the storage battery and reduce its weight. It was found that almost any good primary cell could be charged to a certain extent by passing a current through it. Acting on this principle, Reynier made a secondary, or storage, cell, in which the negative plate was composed of zinc instead of lead. This cell was lighter, but it has several serious defects. Waddell and Entz, two well-known experimenters, constructed cells of copper and zinc, but the electromotive force of the cell was very low. While their cell was light, it required three times as many cells for a given voltage as would be required if the lead cells were used.

Thomas A. Edison reduced the weight of the storage battery considerably when he perfected his nickel-and-iron cell. In this battery the active materials are oxides of nickel and iron. The electrolyte is a solution of caustic potash in distilled water.

Leaving out the chemical details in explaining the action of the Edison cell, it is sufficient to say that when the cell is charged oxygen is transferred from the iron to the nickel electrode. When the cell is discharged it is transferred back again. This cell weighs about half as much as a similar lead cell, but the average voltage of the cell is somewhat less, requiring a greater number of cells in series to produce the same line voltage.

Various Uses of the Storage Battery

We could not very well do without the storage battery. Indeed, it is of such great importance that there is a constant effort on the part of the scientists and electrical engineers to improve the efficiency of the battery, to make it lighter and easier to maintain. The storage battery has many uses. Among the most important are the following:

To supply current for electric automobiles and trucks.

To light gasolene-driven automobiles, to supply current for the ignition of gasolene-automobiles, and for the self-starting motors of such cars.

To drive mining locomotives where it is not expedient to install trolley-wires in the tunnels.

To operate street-cars on short lines where an overhead or underground trolley system would be too costly.

To supply current for electrically driven launches.

For ignition and lighting systems of gasolene motor-boats.

For wireless telegraph systems.

For home lighting service in connection with a private electric plant.

As a source of reserve power for central stations in case of any accident or breakdown of the power-driven generators.

For operation of remote control switches, etc.

For fire and burglar systems.

For long-distance telephone systems.

For miners and watchmen's lanterns.

For the emergency lighting of large public buildings in case the central supply station should suddenly cease to produce current.

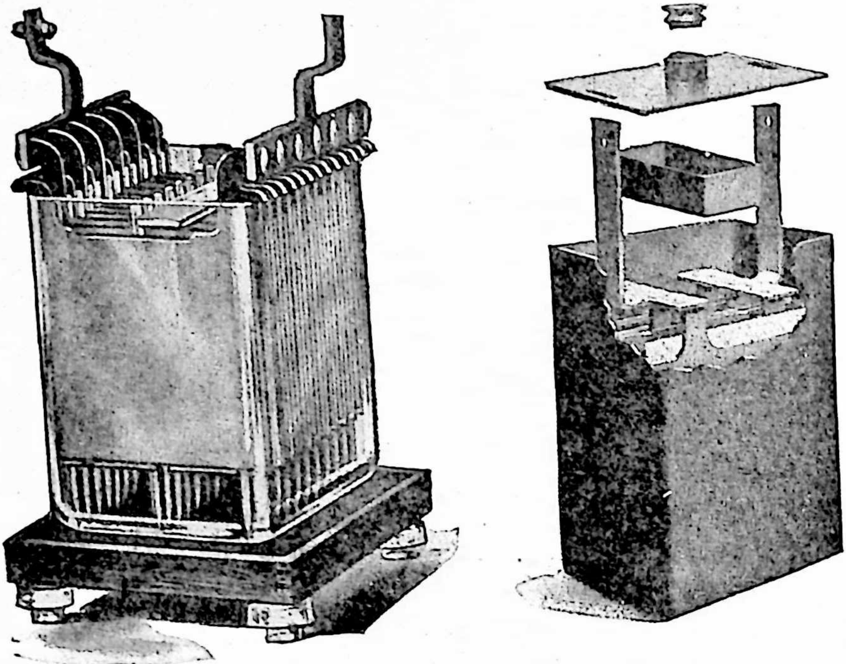
For the lighting of passenger-trains.

The Action of the Battery

A simple storage-battery cell consists of plates of lead, insulated from each other and placed in a glass jar containing dilute sulphuric acid. The upper ends of the metal plates project above the liquid and are each provided with a suitable terminal for connecting purposes (Fig. 1).

This cell cannot be charged with alternating current. Direct current must be used. It is easily seen that the application of an alternating current would have a neutralizing effect on the cell. Instead of flowing steadily into one terminal of the cell and out the other the alternating current would flow first in one terminal and then in the other, and the cell could not be charged.

When alternating current only is available for battery-charging ways and means must be provided to change it into direct current. In large installation this is effected by the use of a machine called a rotary converter, inasmuch as it converts alternating current into direct current.



In glass jar **Fig. 1** In rubber jar

STORAGE CELLS

This is really a combination of an alternating-current motor and a direct-current generator (Fig. 2).

Indeed, a motor-generator set is frequently used for this very purpose. An alternating-current motor is connected on the same shaft with a direct-current generator. Thus, the alternating current which flows into the motor is made over into direct current by the generator at a trifling loss, due to friction, etc. (Fig. 3).

But for smaller current the most efficient device to change alternating current into direct current for battery-charging service is the mercury-arc rectifier (Fig. 4).

The mercury-arc rectifier has no moving parts. It is a small stationary device in which the rectification is brought about in a glass bulb containing mercury and provided with three electrodes. The two upper electrodes are graphite, and the lower one is the mercury in the bottom of the bulb. The air is exhausted from the bulb. Suitable terminals are provided on the outside for connecting the inside electrodes to the circuit. Owing to a natural law the current can pass from either of the graphite electrodes to the mercury, but not in the opposite direction. By considering the electrodes as doors we can imagine that alternating current

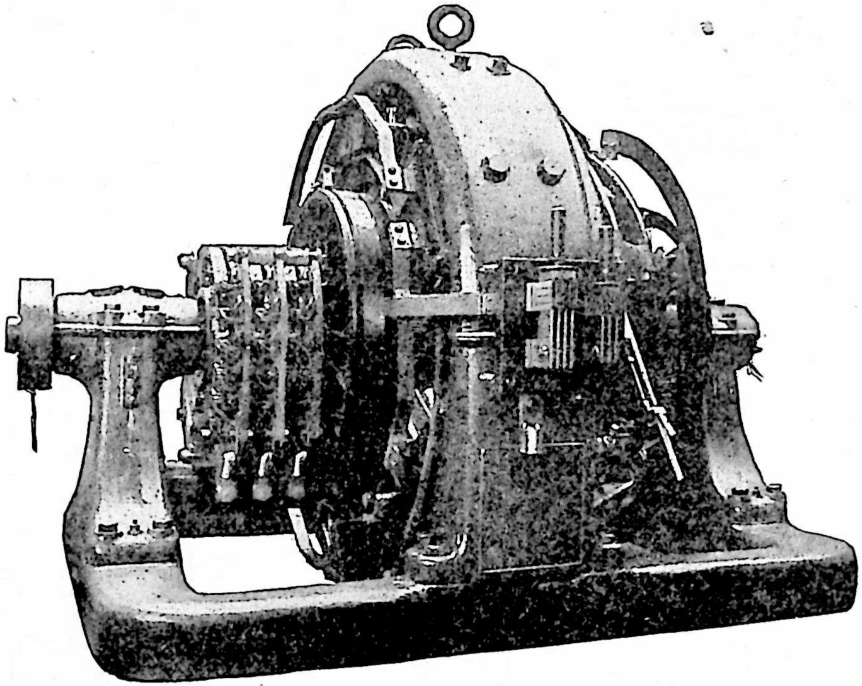


Fig. 2

ROTARY CONVERTER

enters the bulb from two electrodes or doors, using one door when approaching from one direction and the other when in the reversed direction. These doors only open in. There is just one lower door opening out, so it can enter either door but must all flow one way in leaving the bulb. Surging back and forth over the line as often as sixty times a second, the electricity comes to the rectifier as alternating current

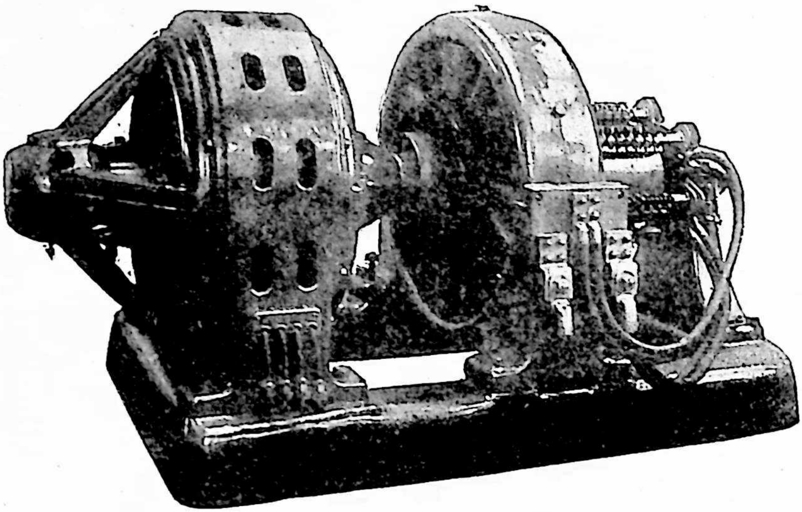


Fig. 3

MOTOR-GENERATOR SET

and leaves it as direct current, with only a trifling loss in the transmission.

The capacity of the rectifier is not very great. So far the device is only used extensively for small work, such as charging storage batteries for automobiles, telephone exchanges, and telegraph offices. It is also used to furnish direct current for arc-lamps used in moving-picture lanterns and for running small direct-current motors from alternating-current circuits.

Resistance of Storage Batteries

The battery cell offers considerable internal resistance to the passage of the charging current. The plates are also

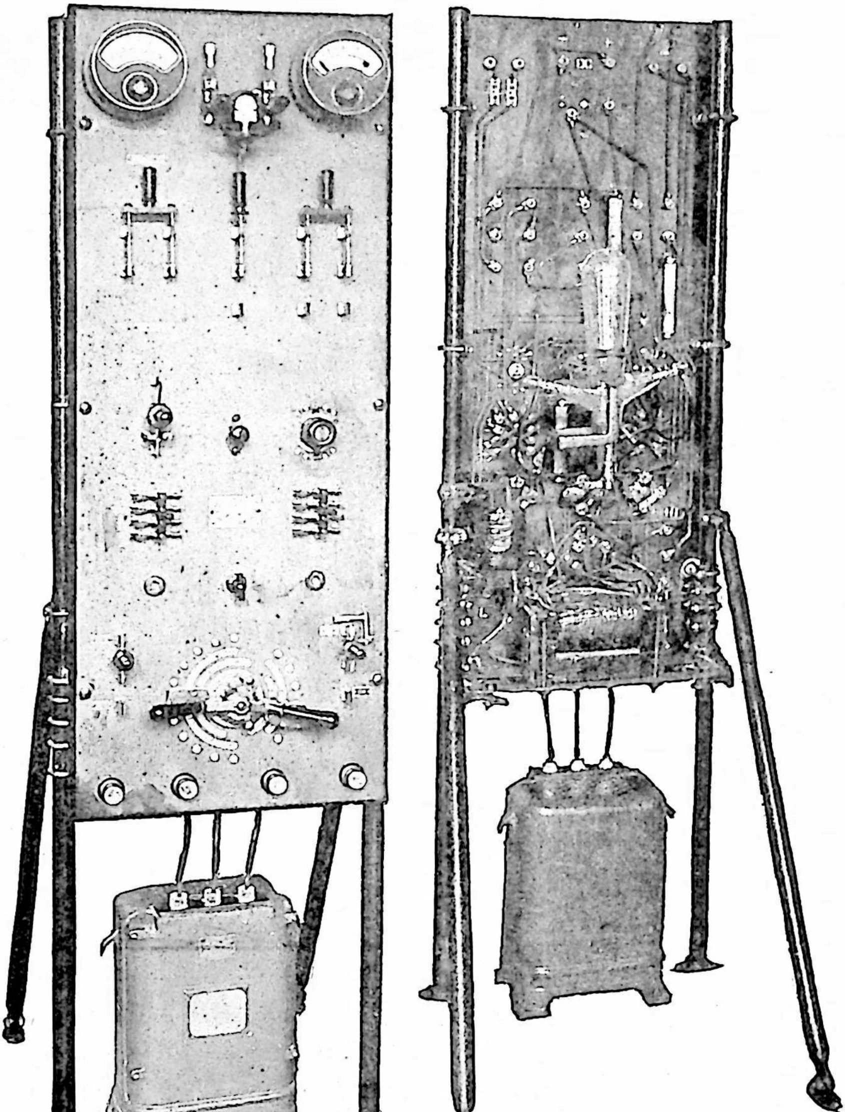


Fig. 4

Front View Back View

SINGLE-PHASE MERCURY-ARC RECTIFIER FOR CHARGING SIGNAL BATTERIES subject to an action similar to polarization in a primary cell. For these reasons in charging a storage battery a larger voltage is required than the cell is capable of producing on discharge.

The storage battery will not give back as much electrical energy as was put in it. It is not 100 per cent. efficient, owing to a heat loss, loss through internal resistance, etc.

Making an Experimental Storage Battery

To understand the operation of a storage battery and to provide another very interesting experiment it is well to make a small cell. The size of the cell decides the quantity of current it will deliver. The number of cells, in series, determines the strength, or voltage. A rough estimate of one ampere of current for each 20 square inches of positive plate surface, counting both sides, will approximate the amount of current a cell will produce. Each cell will give a pressure, or potential, of about two volts. No matter what the size of the cell, it will deliver but two volts' pressure. In order to procure a higher voltage a sufficient number of cells must be connected in series.

A good experimental cell can be made in a common drinking-glass, using two lead plates. From a piece of sheet lead one-eighth of an inch thick cut two rectangular plates. These plates should be just large enough to slip in the glass at a distance of about an inch apart. They should not touch the bottom of the glass. A strip of hard wood, dry and of fine grain, one inch square and long enough to reach well across the top of the glass, should be well soaked in hot wax. Either beeswax or paraffin may be used (Fig. 5).

The lead plates must now be fastened to either side of the wooden cross-piece. Punch or bore small holes through the top of each lead strip and screw firmly in place. Use small screws, and be sure they do not meet through the wood and

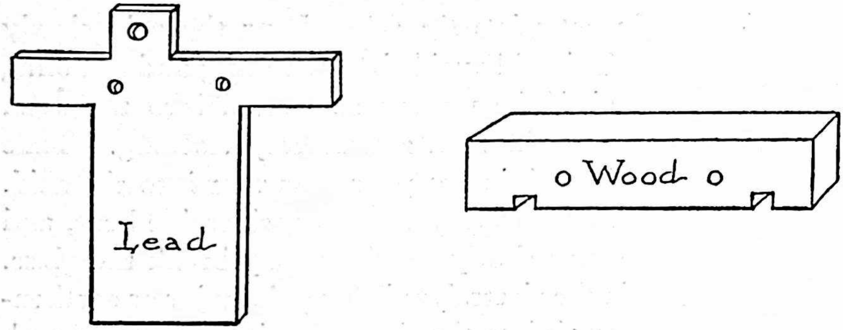


Fig. 5

thus short-circuit the cell. It is best to punch the holes in different parts of the plates so as to be sure the screws will not touch when assembled.

For terminals a small lug can be left on top of each plate when they are cut, or a copper wire can be wound around one of the screws, between the lead and the wood, just before the screw is fastened in place (Fig. 6).

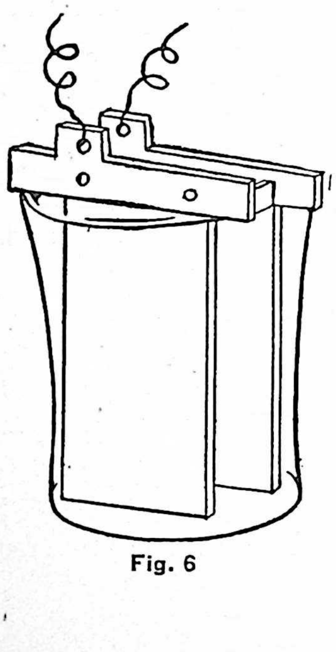


Fig. 6

Care should be taken to scrape both the copper wire and the lead plate to form a good connection. The wire terminals should be short, so as to reduce external resistance.

The electrolyte for this battery is a mixture of acid and water. Use one part of pure sulphuric acid to four parts of water. It is best to do this by measure. Find out how many table-spoonfuls of water the tumbler will hold. If it holds ten, then the mixture should contain two of acid to eight of water.

Never pour the water into the acid. Pour the acid slowly into the water. This will avoid the sputtering and bubbling which would result if the water was poured into the acid. Flying acid will burn the flesh and destroy clothing. Take no chances with it, and do not pour the water into the acid.

But pouring acid into water causes considerable heat, and unless it is done very slowly this heat may break the glass. It is better to mix the electrolyte in a crockery jar or earthen-ware basin and pour it into the glass when it has become cool.

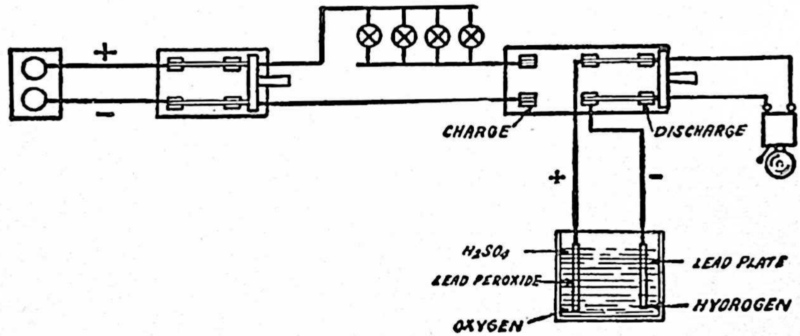
This miniature storage battery may be charged with four dry-battery cells connected in series-multiple so as to give a good flow of current at about three volts. The cell should be given a long charge the first time. It will work better when it has been charged and discharged several times.

It is very interesting to watch the action of this cell while it is being charged and discharged. Owing to the glass container every change of the battery plates can be noted.

When a current of electricity is run into this cell the water is decomposed into its two component gases—hydrogen and oxygen. The oxygen is liberated at the positive plate (the one at which the current enters), and hydrogen forms at the negative plate (the one by which the current leaves the cell). The oxygen acts on the positive plate and converts its surface into peroxide of lead. The negative plate suffers no chemical change, but merely has its surface rendered soft and porous. This alteration of the plates continues so long as the charging current is applied, within certain limits, of course, for each cell has its limit of capacity.

The positive plate soon becomes dark chocolate-brown in color, caused by the change of its surface into peroxide of lead, which is nearly black. The negative plate assumes a velvety-gray appearance—its surface merely having changed into spongy lead. If the charging current be now disconnected and the plates in the cell connected by a wire a reversal of the process of charging will occur. The peroxide of lead will now gradually return to ordinary metallic lead, and while this change is taking place a current of electricity will flow through the wire from the brown positive to the gray negative.

A lead storage battery of this kind, made in a two-quart glass jar, using larger plates, can be charged directly from the lighting circuit *if it is direct current.* Any attempt to



APPARATUS USED

1 Reversible Switch; 4 110-Volt Lamps; 1 Bell; 2 Lead Plates; 1 Jar with Dilute Acid; Wire for Connections.

Fig. 7

charge a battery with alternating current will fail. Connect the battery to the direct-current line as shown in Fig. 7.

Open the switch to the bell and cut in on the direct-current line. The lamp, used as resistance, will burn brightly. The acid solution will boil; soon the positive plate will turn brown. Now cut out the current, and open switch to bell, and it will ring, showing that the battery is charged.

Chapter VII

PRODUCING AND DISTRIBUTING ELECTRICAL ENERGY

ELECTRICITY such as lights our homes and drives our street-cars and factories is produced in large power-houses.

The generators, or dynamos, in such power-houses are driven by engines or water-wheels. Where water-power is available the energy of the falling water can be changed into electricity very cheaply. Where water-power cannot be used steam-engines are employed to drive the generators.

The interior of a modern steam-driven electrical plant is a wonderful place. The old reciprocating engine has been relegated to the past, and the powerful steam-turbine engine has taken its place. You will see no huge, throbbing pistons sliding in their oiled sockets; no whirring, flapping belts, no purring dynamos. True enough, you will see all of these things in power-stations built years ago, but in those being installed to-day these things are conspicuous by their absence. Instead, the powerful turbine steam-engine and the rotating part of the electric generator are mounted on the same shaft and placed in the same frame. When this mighty turbo-generator, as it is called, is working at full capacity, pouring out a steady stream of electrical energy, no moving parts are visible to the casual observer, and there is a total absence of noise and clatter. Only a faint hum, bespeaking a mighty hidden force, is heard. The steel frame of the engine is so steady that a silver dollar can be balanced upon its edge on top of the frame while the turbine is whirling at full speed (Fig. 1).

The current produced by the turbo-generator is carried on heavy insulated cables to the switchboards and instruments. After being measured it is sent out over the various distribution lines to all parts of the circuits.

The water-wheel-driven plant differs but little from the steam-plant, except no coal has to be burned as a source of energy. There is really very little difference between a

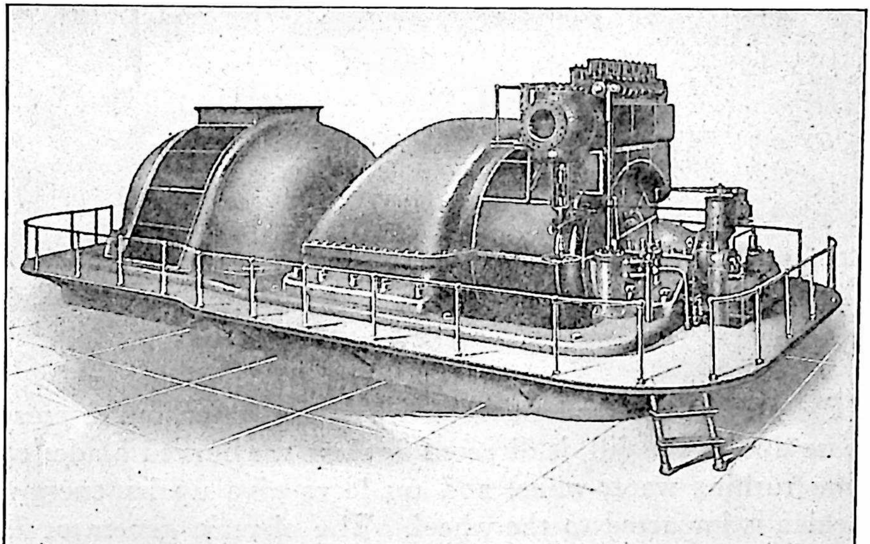


Fig. 1

HORIZONTAL CURTIS STEAM TURBO-GENERATOR

modern high-pressure water-wheel and a turbine steam-engine. Both work on the same principle. In the steam-turbine the streams of high-pressure steam are directed against the revolving blades of the turbine. Impinging against these curved blades, the steam gradually gives up its energy as it passes from stage to stage through the engine

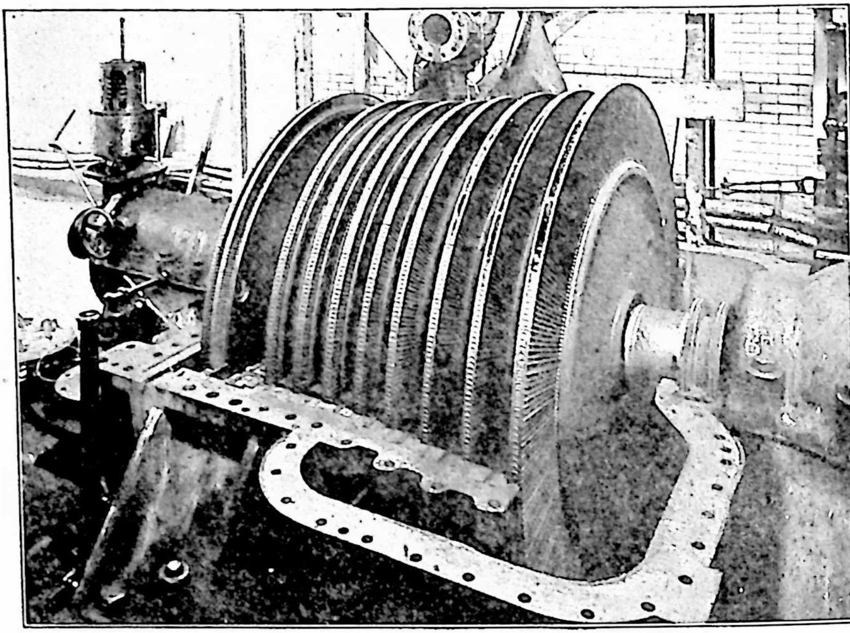


Fig. 2

HORIZONTAL STEAM-TURBINE SHOWING BLADES

(Fig. 2). In the modern water-wheel the water, under pressure due to the fall, is directed against the curved blades of the turbine water-wheel and made to give up its energy, which is imparted to the wheel. The electric generator is usually direct connected on the same shaft and mounted either over or by the side of the water-wheel. Thus the revolving part of the generator turns with the water-wheel.

The current generated in the water-wheel plant is distributed much the same as that produced in the steam-power plant.

Loss in Producing Electricity from Steam

There is a tremendous loss in producing electricity from steam. Coal is the energy of the sun, stored up for our use, In order to convert this energy into electricity it has to pass through various stages, and not without serious loss.

Assuming that the energy stored in coal is 100 per cent., then 29.68 per cent. of this is wasted in the furnace in converting the energy of the coal into steam energy. Of this steam, representing 70.32 per cent. of the coal-energy, 89.9 per cent. is lost in heat waste and 1.5 per cent. in friction. So that actually only 5.3 per cent. of the heat-energy of the coal is transmitted by the engine to the generator. The total losses en route to the generator equal 94.7 per cent. of the coal-energy.

The electric generator is very efficient. Of the energy supplied it by the steam-engine only about 10 per cent. is lost in resistance and eddy currents. The efficiency of an average generator is 92.5 per cent. The energy of the coal coming out of the generator in the form of electricity will be, therefore, 5.3 per cent. ×.925 only, or 4.9 per cent. of the original coal-energy. And, remember, some of this is lost in transmission, and at the electric lamp we receive only 4 per cent. of the potential energy of the coal.

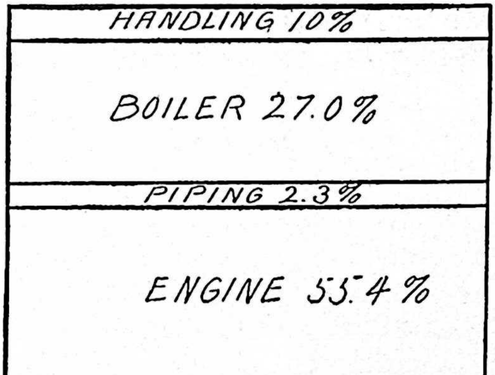


Fig. 3

And the electric lamp wastes 95 per cent. of this in useless heat and gives but 5 per cent. in light.

If these figures are hard to understand the above example can be easily comprehended by referring to the diagrammatic drawing which shows the various losses (Fig. 3).

The following summary shows the proportion of losses from the original supply of coal en route from the mines to the electric lamp:

WHERE THE ENERGY OF THE COAL IS LOST

	PER CENT.
Losses due to handling coal	10
Losses in boiler	27
Losses in piping	2.3
Losses in steam-engine	55.4
Losses in generator	.4
Losses in transformers	.3
Losses in transmission line	.2
Losses in switches, etc.	.4
Losses in heating the lamp	3.8
Total losses	99.8
Used for lighting	.2

Distributing Electricity About the City

After the electricity is generated in the power-house it has to be distributed to the customers.

In nearly every city there are four important electrical circuits for the distribution of electricity. Each of these circuits requires a separate set of wires or return circuits running to and from the power-house: the trolley or street-car circuit, the incandescent-lighting circuit, the arc or street-lighting circuit, the power circuit.

Telephones, telegraphs, burglar-alarms, fire-alarms, etc., require individual wires and are in no way related to the light and power service. Sometimes they are customers of the lighting company, to a certain extent, buying current for their storage batteries.

Electricity is sent out from the power-house, or central station, over one set of wires to supply current for the lighting of homes, offices, factories, etc. This current usually enters the building at a voltage, or pressure, of 110 volts (Fig. 4). In case this lighting service extends for miles beyond the power-house a higher voltage is used on the transmission lines which is "stepped down" to the proper amount for the home by use of a small transformer located on the electric-light pole in front of the house. For shorter distances the current is sent out at about 220 volts, and by the use of a third, or neutral, wire in the house-wiring 110 voltage is available.

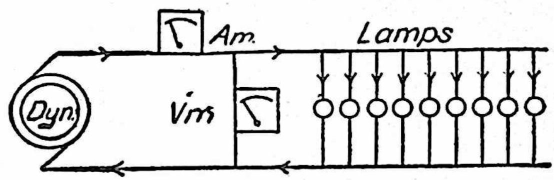


Fig. 4

But the house-lighting circuit in this day and age is also used for small motors, heating-devices, etc. In fact, any such electrical device of the proper voltage can be used on the house-lighting circuit, providing it does not consume more than 600 watts of electrical energy. *If it consumes more than this it will surely blow the fuses, and this is a sign it is dangerous to use such a device, providing, of course, the fuses are in good condition and not weakened by long service. As a rule any device that will blow a six-ampere fuse is too heavy for household service.*

If larger motors or more extensive heating and cooking service is desired the electric-light company will cheerfully install an additional circuit in the house. And this is also better for the customer, as he can secure a better rate per kilowatt for heating and power than for ordinary lighting. Like any other commodity, electricity can be purchased cheaper in large quantities.

Lighting the Streets

It requires another set of wires for the street-lighting service. Inasmuch as the street-lamps are not in use in the daytime the household-lighting wires are not used for this purpose, except in very small installations in villages where all-day electric service is not available. In the cities where series, high-voltage arc-lamps are used a special circuit for the street-lamps is always installed. With this arrangement the street-lamps can be switched on and off independent of all other circuits (Fig. 5).

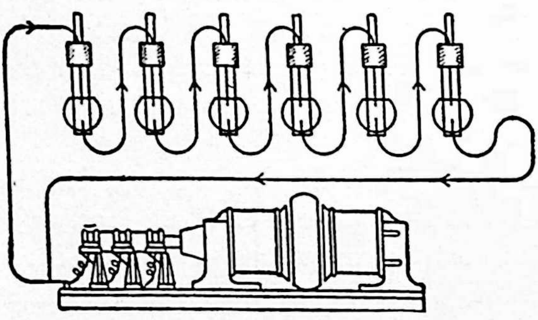


Fig. 5

Another circuit must be provided for the trolley-cars. The lighting circuit is usually alternating current, but direct current must be supplied to the trolley-cars. All are familiar with the trolley-wire. The current, usually at a pressure of about 500 volts, is sent out over this trolley-wire, and after it passes through the trolley-car motors, *via* the trolley-wheel, the trolley-pole, etc., it returns to the power-house by way of the steel rails, or short-cuts, through the earth over a ground return (Fig. 6).

Another circuit is provided for the power-load in cities where electricity is extensively used in factories and shops for power purposes. This circuit is designed to carry a heavy current of electricity and supplies all the electric motors in service with electrical power.

It is not necessary to go into the engineering details of a modern power-house in order to understand the distribution of electrical energy. It is easy enough to comprehend how the energy of the coal or the falling water is changed into electricity through the medium of the turbine and the

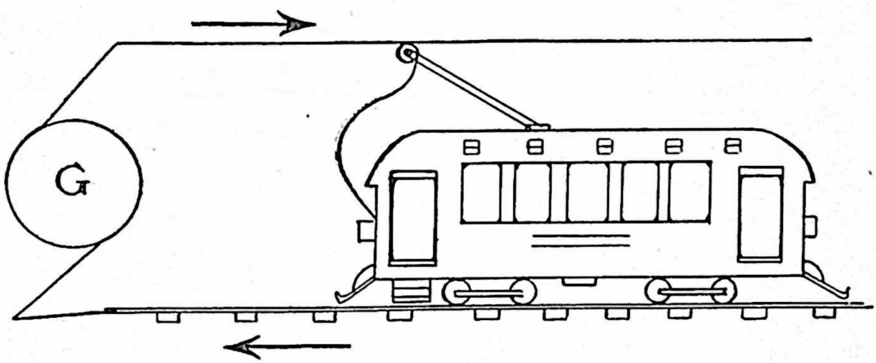


Fig. 6

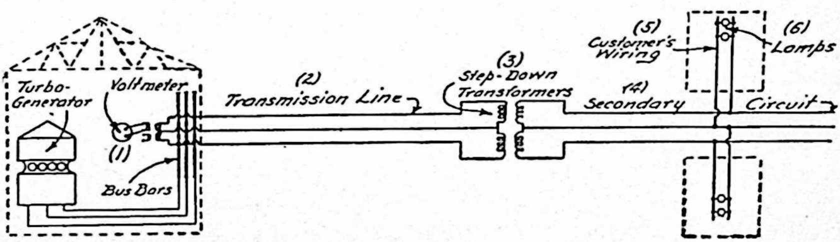


Fig. 7

generator. This energy is sent out over the city through the various conductors, much the same as the city water is distributed through various pipe systems (Fig. 7).

In the modern city or large village we can easily draw water from the faucet whenever we want to. And in this day and age we can do the same with electricity. It is always "on tap" in the home or office or factory, and we can use just as much of it or just as little as we desire.

Measuring the Current

When we draw water at the kitchen sink it first passes through a water-meter. This measures the exact amount of water we use, and we pay for it accordingly at so much a gallon or cubic foot.

When we use electricity for light, heat, or power the current flows first through the electric meter, which measures the exact amount of energy we consume and pay for at so much a kilowatt-hour.

Chapter VIII

ELECTRIC CIRCUITS AND HOW THEY ARE INSTALLED

THERE are several different methods of installing household electric circuits. These several systems may differ somewhat in their constructional details, but the idea of a return circuit must always be incorporated. It is not the electricity which is used, but the energy of the flowing current.

Referring again to the comparison of electricity to water in a pipe, it is apparent that if current flows into the house ways and means must be provided for it to flow out again, or it will cease to flow entirely.

If a small water-motor is placed on the kitchen faucet to run the washing-machine a way must be provided for the exit of the water which passes through the motor, or the wheel would not run. It is not the water which turns the wheel, but the energy of the water. The water-wheel could be immersed in a pan of water, but it would not run, because the water possesses no apparent energy. If the water is carried into the house through a half-inch pipe under a pressure of 100 pounds to the square inch of pipe it will not flow unless another pipe is arranged so as to carry away the used water. If these two pipes are arranged side by side and connected by a number of tiny water-wheels which can be turned on and off like an electric lamp the current will begin to flow the instant any one of the wheels is turned on (Fig. 1).

There is no flow, no motion in the pipe A until an outlet is provided at the water-wheel B, although the pressure in the pipe A is constant. As soon as the valve is turned to the wheel B the flow begins, and some of the energy of the water is turned into mechanical energy by the wheel. The water flows on out of the pipe C to its original source. Of course, some of its pressure, or energy, is gone, having been turned into mechanical energy.

In this way it is easy to understand that the pressure, or voltage, is constant in the electric-light wires even though

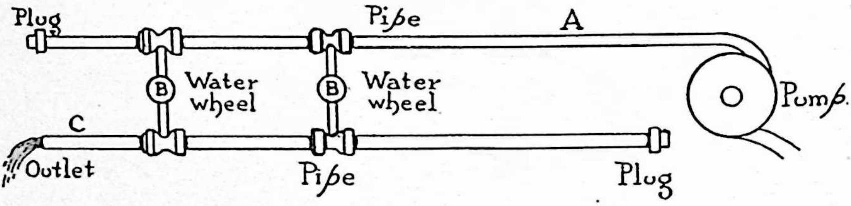


Fig. 1

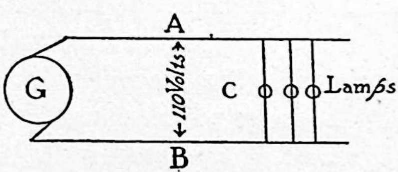


Fig. 2

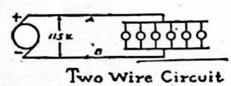


Fig. 3

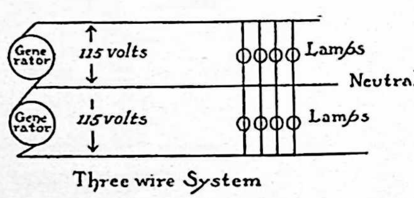


Fig. 4

there is no flow of current. The instant a lamp is switched on the current begins to move, and it is this *force* which is changed into *light-energy* (Fig. 2).

The voltage, or electrical pressure, is constant at A and B, but the current cannot flow until the lamp switch is turned at C. This permits current to flow from A to B through the lamp C and thence back to its source in the power-house. In passing through the lamp C some of the electrical energy is turned into light-energy, *but the volume of the current remains the same.* This is true because the electricity is *not* burned in the lamp. Only its energy is consumed or changed into light.

The Two-Wire Circuit

The two-wire circuit is commonly used in wiring houses and buildings for electric light where the current is not carried over any considerable distance. The two-wire circuit, as its name implies, consists of a single circuitous path through two parallel wires. The lamps, or other electrical devices, are merely connected in parallel between the two wires, thus completing the circuit (Fig. 3).

The two-wire system is the simplest, but it is the most expensive, and expense is an item to be seriously considered in large installations. For ordinary household use and for small installations this item of expense is too small to be seriously considered. The two-wire system is so simple it can be easily understood by the layman, and this simplicity counterbalances the cost.

The Three-Wire Circuit

By doubling the voltage of any circuit the line loss is only one-quarter as great. By transmitting the current at 220 volts wiring can be used having only one-quarter the area that would be necessary at 110 volts. *In other words, a smaller wire could be used for the higher voltage, which would mean a great saving in the cost of copper.* This saving, by nearly doubling the voltage of the line, has led to the establishment of the 220-volt three-wire circuit, especially in the cities. Lamps of 110 volts are standard, and if they are to be used on 220-volt circuits they must be arranged two in series. Ordinarily this would compel one to burn two lamps at once. If three lamps were wanted four would have to be burned, and so on. To avoid this a third wire is employed, called a neutral, which composes the three-wire system (Fig. 4).

The neutral wire is usually the same size as the others. In a three-wire system of this kind there is only three-eighths as much copper as in a two-wire system. This is a considerable saving where a whole city is wired.

The Conducting-Wires

Pure copper wire is generally used for house-wiring because it is the best and cheapest conductor of electricity available. Its resistance is very low compared with aluminum or iron wire. A copper wire one-tenth of an inch in diameter has a resistance of one ohm in a thousand feet. An iron wire of the same size has six times the resistance.

Never substitute an iron wire for a copper wire of the same size in a lighting circuit.

In installing electrical circuits it is important to know the line resistance. All this data is now collected in tabulated form and is easily available. If we know the resistance of a hundred feet of a certain size wire we can find the resistance of a thousand feet by multiplying by ten, and so on. The resistance of any copper wire depends upon the length and diameter of the wire.

Example. The resistance of a copper wire one-tenth of an inch in diameter is one ohm per 1,000 feet. What is the resistance of 6,000 feet?

1,000 feet = 1-ohm resistance
6,000 feet = 1 × 6, or 6 ohms

In this case the resistance of 500 feet of the same wire would be one-half ohm.

The resistance also depends upon the diameter of the wire as well as upon its length. The area of the end of the wire is known as the *cross-section.* If a square wire is used, measuring one inch on each side, its cross-section would be

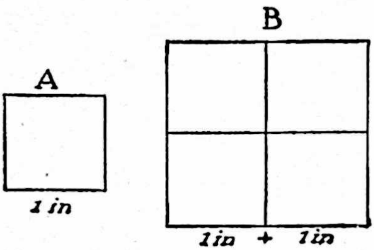


Fig. 5

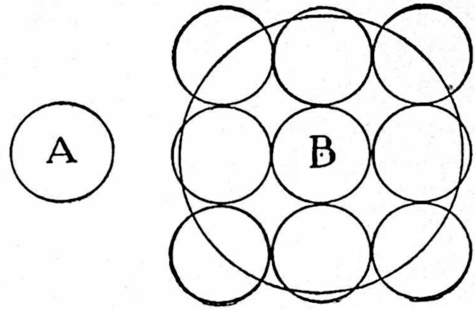


Fig. 6

one square inch. If the diameter of this wire was doubled, making it two inches on each side, its area would be four times as large, or four square inches (Fig. 5).

The cross-section of A is one square inch. In B the dimensions are doubled, it being two inches along each side, but the area, or cross-section, is quadrupled. In plainer words, A contains enough copper to make four wires the size of B. *Therefore, it will carry four times the current at the same resistance as A, or the same current at one-quarter the resistance.*

A wire four inches square will make 16 wires one inch square; a wire six inches square will make 36 wires one inch square. In simple arithmetic the cross-section of a square wire is always equal to *the square of its diameter.*

If the resistance of a certain wire is one ohm to every hundred feet the resistance of four similar wires connected in parallel will be but one-fourth of an ohm, because the current can flow through the four wires four times as easy as it could through the single wire.

If the resistance of 100 feet of inch square copper wire is one ohm, the resistance of 100 feet of two-inch wire will be 1÷4, or .25 ohm. The resistance of 100 feet of three-inch wire will be 1÷9, or .0111 ohm.

Inasmuch as wire is always drawn in circular form we cannot figure the area in square inches. The rules for figuring square wire apply also to round wire (Fig. 6).

The cross-section of B is nine times the area of A, or contains the same area as nine wires one inch in diameter, if the parts projecting beyond the large circle are used to fill the chinks left inside.

The area of a round wire is determined in *circular mils.* A mil means one thousand. An imaginary wire 1–1,000 of an inch in diameter has been adopted as the unit for round wire. It is called a *circular mil.* A wire 10–1,000 of an inch in diameter contains 10×10, or 100 circular mils. This method of determining the cross-section of a wire in mils is easiest and best because to find the area in square inches would involve large fractions and hard examples.

Any circle will contain the equivalent of as many unit circles as the square of the diameter in mils.

The unit wire is the mil-foot, or a copper wire one foot long and 1–1,000 of an inch in diameter. A mil-foot of copper has a resistance of 10.4 ohms. With this as a unit we can easily compute the resistance of any length or size of copper wire.

Example. If the resistance of one foot of wire one mil in diameter is 10.4 ohms, what would be the resistance of a wire one foot long and 10 mils in diameter?

A wire with a diameter of 10 mils is equivalent to 10×10, or 100 wires one mil in diameter, since it contains an area of 100 circular mils. If the resistance of a wire one mil in diameter is 10.4 ohms the resistance of a 10-mil wire is equal to 10.4÷100, or .104 ohm.

After we have determined the resistance of a foot of wire we have only to multiply this by the length, and we have the total resistance of any number of feet as desired.

In the above example the resistance of 1,000 feet of 10-mil wire would be .104×1,000, or 104 ohms.

To find the resistance of any length of any size wire multiply the resistance of a mil-foot, 10.4 ohms, by the length in feet, and divide by the circular-mil area.

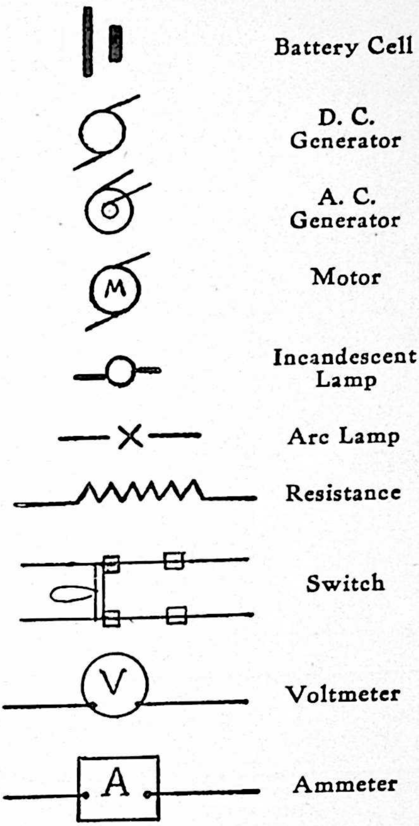


Fig. 7

SYMBOLS

$$\text{Resistance of wire} = \frac{\text{resistance per mil-foot} \times \text{length in feet}}{\text{circular-mil area}}$$

Knowing the length and the size of a wire and the current it is to carry, it is easy to compute the voltage drop, or loss of voltage due to resistance, in the wire.

The voltage drop in a copper wire 2,000 feet long and .204 inch in diameter with a current of 40 amperes is 20 volts.

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

$$\text{Resistance} = \frac{\text{mil-foot resistance} \times \text{length of wire}}{\text{circular mils}}$$

$$\text{Resistance} = \frac{10.4 \times 2{,}000}{204 \times 204} = .5 \text{ ohm}$$

$$.5 \text{ ohm} \times 40 \text{ amperes} = 20 \text{ volts}$$

While it is best for the amateur to figure out several examples of this nature so he will understand the process, this data is given below in tabulated form.

Every conductor offers some resistance to the flow of electricity. This resistance changes some of the electrical energy to heat-energy. Therefore every copper wire has a certain capacity, and any current in excess of this amount will heat the wire to the danger-point. Engineers have adopted the following tables showing the carrying-capacity of different size wires:

ALLOWABLE CARRYING-CAPACITIES OF COPPER WIRES, AND OTHER DATA

B. & S. GAGE	DIAMETER, INCHES	CIRCULAR MILS	AMPERES, RUBBER INSULATION		AMPERES, OTHER INSULATION		RESISTANCE PER 1,000 FT. AT 75° FAHR.	WEIGHT PER 1,000 FT. IN LBS.
			Old Rating	New Rating	Old Rating	New Rating		
18	.04	1,625	3	3	5	5	6.21	4.5
16	.05	2,583	6	6	8	10	3.97	7.8
14	.064	4,106	12	15	16	20	2.53	12.5
12	.08	6,530	17	20	23	25	1.589	19.8
10	.101	10,381	24	25	32	30	1.	31.5
8	.128	16,510	33	35	46	50	.63	50
6	.162	26,250	46	50	65	70	.392	79
5	.181	33,100	54	55	77	80	.31	100
4	.204	41,740	65	70	92	90	.248	126
3	.229	52,630	76	80	110	100	.197	159
2	.257	66,370	90	90	131	125	.157	200.5
1	.289	83,690	107	100	156	.150	.123	253
0	.324	105,500	127	125	185	200	.099	319
00	.364	133,100	150	150	220	225	.077	402
000	.409	167,800	177	175	262	275	.063	506
0000	.460	211,600	210	225	312	325	.05	640
....	.633	400,000	330	325	500	500	.025	1,211
....	.708	500,000	390	400	590	600	.02	1,514
....	.774	600,000	450	450	680	680	.0168	1,817
....	.836	700,000	500	500	760	760	.0143	2,120
....	.895	800,000	550	550	840	840	.0125	2,422

RESISTANCES PER MIL-FOOT

MATERIAL	OHMS PER MIL-FOOT
Aluminum	18.7
Copper, annealed	10.4
Copper, hard-drawn	10.65
Iron, annealed	90
Iron, soft	64
German silver	114–275
Special alloys	283–300
Nichrome	600

The symbols used in the electrical industry should be learned by every amateur electrician (Fig. 7).

Chapter IX

INDOOR WIRING SYSTEMS

A COMPLETE metallic circuit must be installed for conducting the electrical energy to and from the points where it is to be used.

The proper placing of such conductors is termed *electric wiring.*

Electric wiring for buildings of all kinds must be installed in accordance with the rules and regulations set down by the National Board of Fire Underwriters. These rules are published in the *National Electric Code.* They should be followed closely, with such other local requirements as are necessary in order to secure fire protection through insurance. These rules cover everything, from the proper size of wire to insulators, switches, outlets, fuses, etc., and the manner of installing same.

There are four methods of interior wiring, each approved by the underwriters, as follows: open, or exposed, work; molding work; concealed knob and tube work; interior conduit and armored cable work.

Open, or exposed, wiring is the cheapest and at the same time it is one of the safest and best methods, as the wires are constantly in sight (Fig. 1). This style of wiring is generally used in barns, sheds, mills, and factories where the appearance of the wires on ceilings and walls is of no great importance. It is also extensively used in the home.

It is really a good way of wiring an old house, because floors and walls do not have to be ripped up to install this system of wiring. The wires can be painted the same color as the walls and ceilings and thus made hardly noticeable.

The wires used for open work must be well insulated. In damp places, as in the basement or cellar, rubber-covered wire should always be used.

For house circuits of 120 volts or less No. 14 heavily insulated copper wire is suitable. These wires are supported on porcelain insulators, made especially for this purpose, which separate the wires two and one-half inches from each other and keep them at least a half-inch from the walls. This half-inch of air space is one of the best insulators. It requires nearly 20,000 volts of electrical pressure to break down one inch of air space. As it would take 10,000 volts to leap across a half-inch of dry air, the 110-volt circuit is entirely safe for this distance.

The wires should always be protected with porcelain tubes where they pass through partitions, walls, or ceilings, and where they pass over pipes and other wires, iron girders, etc. (Fig. 2).

The tubes should always be long enough to reach entirely through a partition or floor and project at least half an inch on each side. In making short corners and bends with open work the wires should receive additional support (Fig. 3).

In making taps, or branch lines, the wires should be reinforced with a bit of porcelain tubing wherever they cross (Fig. 4).

Molding Work

Molding work is still used to a certain extent, although it is rapidly giving way before armored cable work, as the latter is much easier to install. In this style of wiring the wires are run along the walls and ceiling, but they are concealed from view by wooden molding. This molding is made in two pieces. The wires are placed close together in grooves provided for that purpose and covered with a wooden cap, which is fastened in place with small screws. The size of the molding varies with local requirements and regulations. It is grooved for either two or three wires, depending on whether it is to be used for two or three wire circuits. The capping is made to conform with the woodwork in the room, and is, therefore, less conspicuous than open wiring. *It cannot be used for concealed wall and floor work and should never be installed in damp places. Approved rubber-covered wires should always be used with this molding.* The same precautions should be taken in passing through floors and ceilings to add the porcelain tubes as with open wiring (Fig. 5).

Metal molding is also extensively used in wiring old houses. This has the advantage of being vastly smaller in size and is more easily concealed from view. Special fittings are made for this system of wiring, and the metal cover should always be thoroughly grounded (Fig. 6).

Knob and Tube Work

Concealed knob and tube work is the cheapest way of wiring new houses, but it is hardly to be recommended. The wires are all concealed within the walls and beneath the floors. Only approved rubber-covered wire is used. This wire is supported by knobs and tubes on the joints and studding. Otherwise it is insulated by at least an inch of air space. Each wire should be covered with a piece of insulating tubing at all outlets, switches, distribution centers, etc. Where the wires pass through beams, joists, etc., they must be protected with porcelain tubes. They

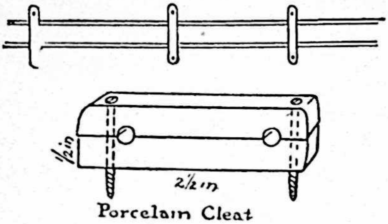


Fig. 1

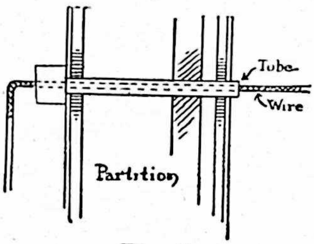


Fig. 2

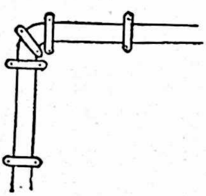


Fig. 3

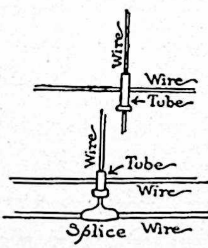


Fig. 4

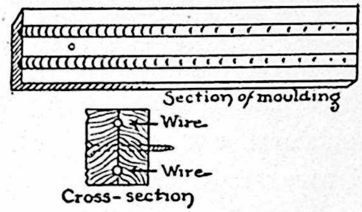


Fig. 5

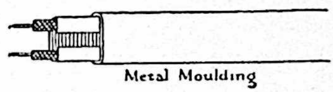


Fig. 6

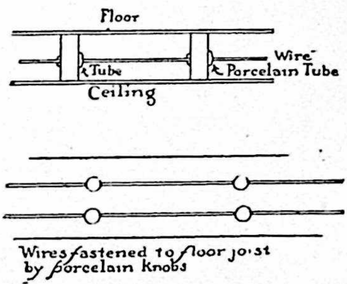


Fig. 7

Fig. 8

should also be protected in this way at all contact-points and where they pass over beams, pipes, etc. (Fig. 7).

Protecting the Wires with Pipe

For new buildings the insulated wires are pulled into iron pipes. These pipes are built in the walls and ceilings, completely out of sight. This is the safest and best way to wire a building, although costly. It can hardly be installed after the house is built. For old houses the flexible armored cable is employed. In this case the insulated wires are protected from injury by flexible steel armor (Fig. 8).

Armored Cable Wiring

Where the wires are exposed to dampness lead-covered cable is used. To install the cable holes are bored in the joists and studding, and the cable is merely pulled into place and fastened with metal straps. *This cable does not require extra insulation.* Being flexible and of small size, it can be "fished" between the ceilings and along the floors of old buildings, making it possible to install a system of concealed wiring without tearing up floors, taking off plaster, etc. To fish a wire between the walls a steel tape or a light steel chain is dropped down inside the partitions. The end of the flexible cable is attached to the fish-wire and drawn into place. This is the quickest and safest way to wire an old building

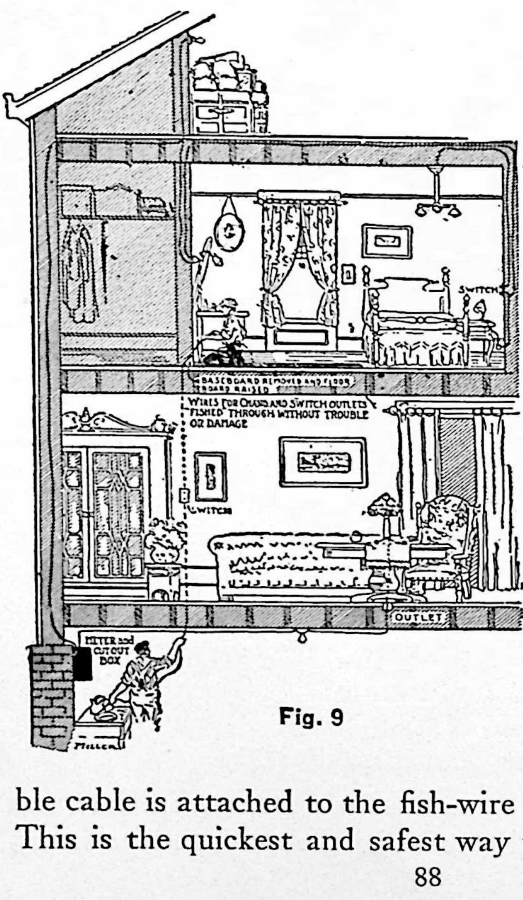


Fig. 9

for electric lights where it is important that the work be concealed (Fig. 9).

Service Wires

Usually the supply of electricity is brought to the house from some outside service, such as the distribution-wires of the electric-light company. Care must be taken in bringing these wires into the house. If the wires are overhead and taken in the upper rooms or attic they must be fastened to the house with glass or porcelain insulators and be provided with *drip-loops*. Where the wires pass through the siding they must also be further protected with heavy porcelain tubes (Fig. 10).

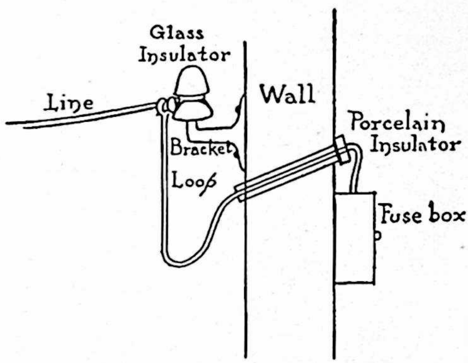


Fig. 10

By slanting the porcelain tubes and arranging the drip-loops the rain cannot follow the wires into the house, causing dampness and leaks and thus destroying the insulation on the wires.

The distribution-board, from which the current is controlled, should be located as near the center of the load as possible. In this way the various branch circuits will be nearly the same length. The distribution-board, consisting of a double-pole switch and fuses for each circuit, should be incased in a fireproof box. Such a box is usually made of wood and lined with asbestos paper.

In wiring barns, sheds, and small buildings the open wiring may be installed, but it is best and safest to use the armored cable, which costs but a little more and is cheapest in the end.

Where the circuit passes outdoors from building to building wires covered with weatherproof insulation should be used. They should be suspended from heavy glass or porcelain insulators, being tied in place with a bit of insulated wire (Fig. 11).

The same care must be taken when entering a barn building, as noted above under the subhead of "Service Wires." A small distribution-box should be installed. Usually a single knife-blade switch and a set of fuses will be

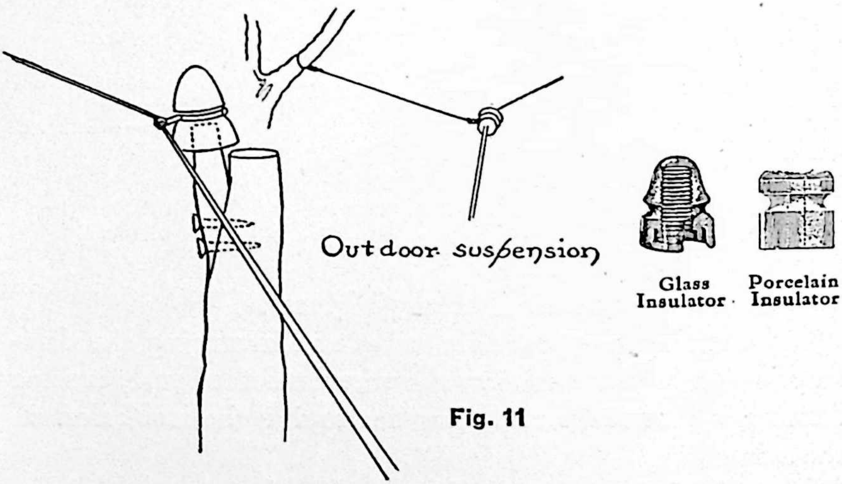


Fig. 11

sufficient. Every circuit and every branch circuit should be properly fused.

Installing the Fuse

The fuse is the weakest place in the entire circuit. It is made so purposely. It is a safety-valve for the household wiring. The method of fusing a house circuit is best shown in Fig. 12.

To the right of the meter the two sets of plugs protect their separate circuits. Here it should be said that the National Board of Fire Underwriters has placed a limit on the number of lights, fans, and other appliances that may be used on a circuit protected by one pair of fuse-plugs. And the quantity of electricity which that circuit could be made to carry in comparative safety is far in excess of what that circuit is ever permitted to receive. For example, if 50 amperes of electricity is known to raise above normal the temperature of a certain size wire the safe carrying-capacity of that wire, as ruled by the underwriters, is far below 50 amperes. And switches, lamp-sockets, and all other fittings are marked along the same safe lines.

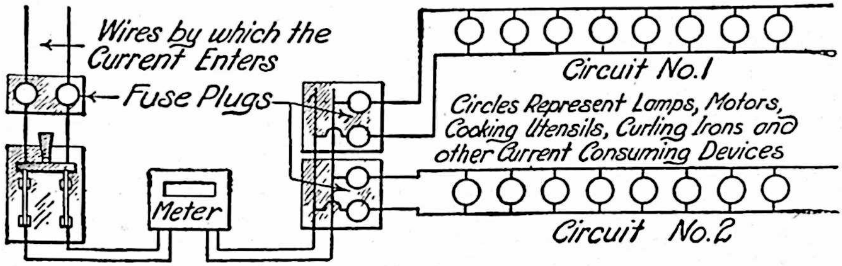


Fig. 12

To return to the drawing, circuits No. 1 and No. 2 would be protected with nothing less than six-ampere plugs. The main fuse-block would be supplied with plugs of twice that carrying-capacity, so that, whereas the main fuse-plugs would take care of any short circuits or excess current that might occur in the main switch or in the meter, the other and smaller fuses would afford individual protection to their respective circuits. And, though the flash occasioned by the blowing of these fuses could hardly escape the fireproof casement of the plugs, still, as a matter of extra precaution, the fire underwriters' rules require in most cases all fuse-plugs and circuit switches to be inclosed in metal or other non-inflammable cabinets. If a wooden box is used it should be lined with asbestos paper.

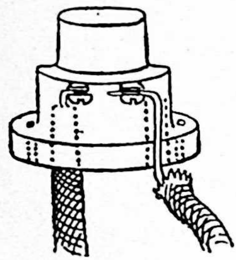


Fig. 13

Great care should also be taken in installing lamp-sockets and outlets. Only enough insulation should be scraped from the wire to make the necessary connections. The insulated wire should be pulled far enough into the porcelain base of the socket so as to form a complete protection. *Never leave an exposed wire. If it so happens that a naked wire appears it should be carefully wrapped with insulating-tape* (Fig. 13).

Branch Circuits

The load for the average branch circuit should never exceed 550 watts. It is far better to keep on the safe side of this. Ten 55-watt lamps is a big load for a No. 14 wire circuit. It would be better to divide this into two circuits. It is always better to figure out the load for the various circuits in accordance with examples given in Chapter VIII so as to be on the safe side. This is especially true where heating and cooking devices or small motors are to be used on house-wiring circuits.

Under no circumstances must any one replace a blown fuse with a *bridge* or a fuse made to carry more than the line will safely hold. Time and time again it has been found that fires were caused by some one, totally ignorant of the uses and abuses of electric wiring, repairing a broken fuse with a bit of copper wire, thus eliminating this important safety

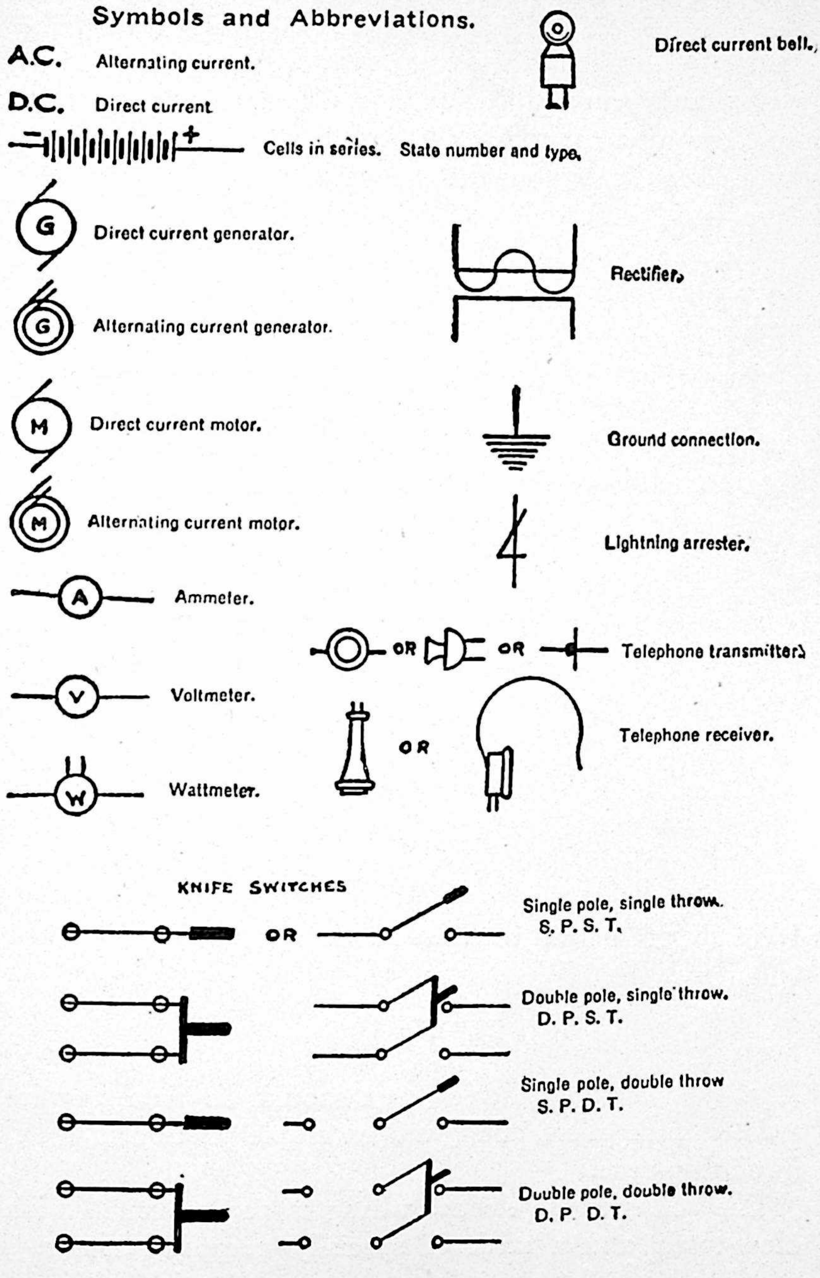

Symbols and Abbreviations.
A.C. Alternating current.
D.C. Direct current
Direct current bell.
Cells in series. State number and type.
Direct current generator.
Rectifier.
Alternating current generator.
Direct current motor.
Ground connection.
Alternating current motor.
Lightning arrester.
Ammeter.
OR
OR
Telephone transmitter.
Voltmeter.
OR
Telephone receiver.
Wattmeter.
KNIFE SWITCHES
OR
Single pole, single throw.
S. P. S. T.
Double pole, single throw.
D. P. S. T.
Single pole, double throw
S. P. D. T.
Double pole, double throw.
D. P. D. T.

Fig. 14

device. When the excess of current came there was no fuse to blow and protect the line, and a fire resulted. *When a fuse blows repair it with a new fuse and nothing else.*

If a circuit is supposed to carry not more than 10 amperes never install a fuse of any greater capacity than this. *Be sure the line is safe, and keep it so.*

Never make any repairs to the electric wiring, or any extensions to wiring already installed, without remembering and enforcing every rule and precaution noted in this chapter.

In many cases the rules and regulations require that the electric-light wires should be soldered at all joints. This is a rule well worth following, whether arbitrary or not.

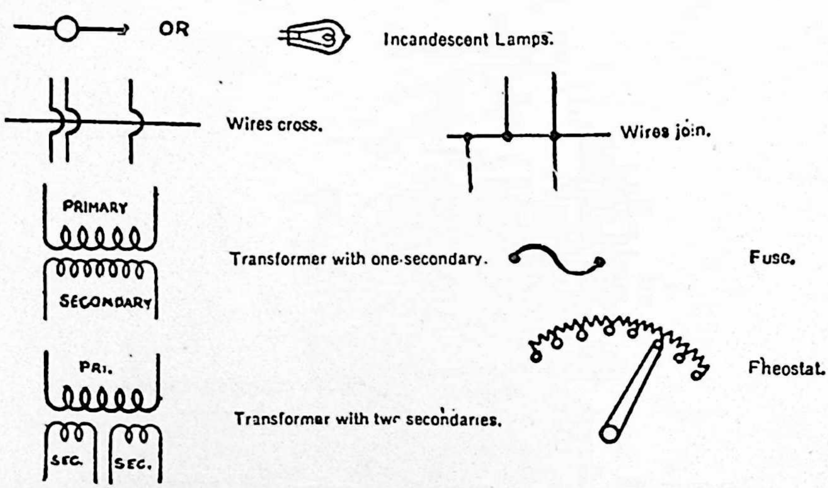


Fig. 15

If they are not soldered they should be firmly spliced, twisted with pliers, and given an ample protecting coat of insulating-tape.

The soldering of electric wiring is accomplished with a blow-torch and a stick of specially prepared solder. It requires but a few seconds to coat a splice with solder.

Symbols, Tables, Etc., Pertaining to House Wiring

A symbol, or mark, has been adopted by the electrical fraternity to signify the location of all electrical apparatus in drawings, plans, and blue-prints. To be able to read and

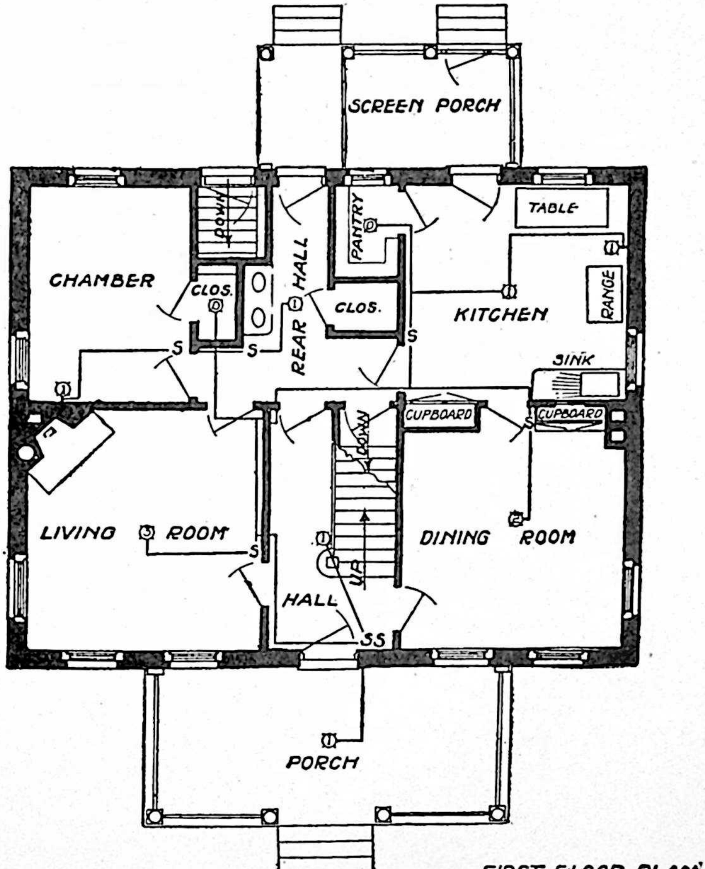


Fig. 16

understand an architect's drawing or an engineer's blue-print it is necessary to learn these various symbols (Figs. 14–15).

In the above reproduction of a blue-print such as architects prepare for a modern house the various symbols are used to mark the exact location of the wall and ceiling lamps, the various outlets and switches, as well as the electric cooking and heating devices which the owner desires to use (Fig. 16).

Chapter X

CONTROLLING THE ELECTRIC CURRENT

ELECTRICITY is brought to our homes over the service wires.

It is distributed to each room over the wiring system.

Here switches must be installed for controlling the current, for turning it off and on. Suitable lamp-sockets, outlets, boxes, receptacles, etc., must be installed for the lamps, heating and cooking devices, and all other electrical apparatus to be used.

The ordinary lamp-socket is a very simple device. It is made of brass and porcelain. The two lead-wires are brought up into the porcelain base and fastened to the terminal screws of the socket. The brass lining to this socket is threaded so the lamp-bulb can be screwed in place. The mere screwing in of the lamp completes the circuit (Fig. 1).

The threaded brass base of the lamp is one terminal. The brass seat is the second terminal. These correspond to the terminals in the socket. When the lamp is screwed in place the connection is made and the current is turned on and off by the switch-key.

This is only one of the many varieties of sockets on the market. However much they may vary in design, the principle is the same as that described here.

There is but one rule for adjusting wall and ceiling sockets. The insulation should be kept perfect. Remove only enough of the insulating-material from the wires to make a good connection at the socket terminals. *Be sure the insulated wires are brought well up into the base of the porcelain socket.*

For desk-lamps, heating-devices, small motors, etc., screw-sockets are a nuisance. It is better to install plug receptacles. These are usually located in the baseboard near the

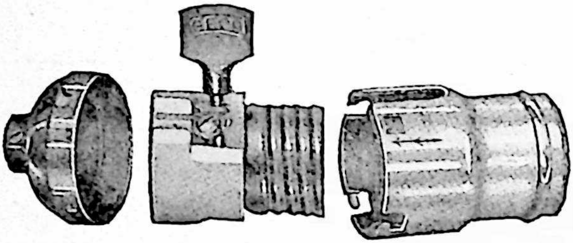


Fig. 1

INTERIOR OF KEY-SOCKET

Fig. 3

PULL-SOCKET

floor. To make the connection the forked plug at one end of the flexible cord is merely pushed into the receptacle.

The great variety of plugs, receptacles, sockets, etc., is best illustrated by the photographs of such devices (Figs. 2 A, 2 B, and 2 C).

The pull-socket is another familiar type of socket. A short chain provided with a small ball is pulled to turn on and off the light (Fig. 3).

This type of socket is very convenient for ceiling fixtures which are often installed too high for a short person to reach the keys to turn on the lights. The pull-chain can be extended to any length.

Adding to the Comfort of Electric Light

Just wiring the house for electric lights is not all there is to a good job of wiring. There are many little things which

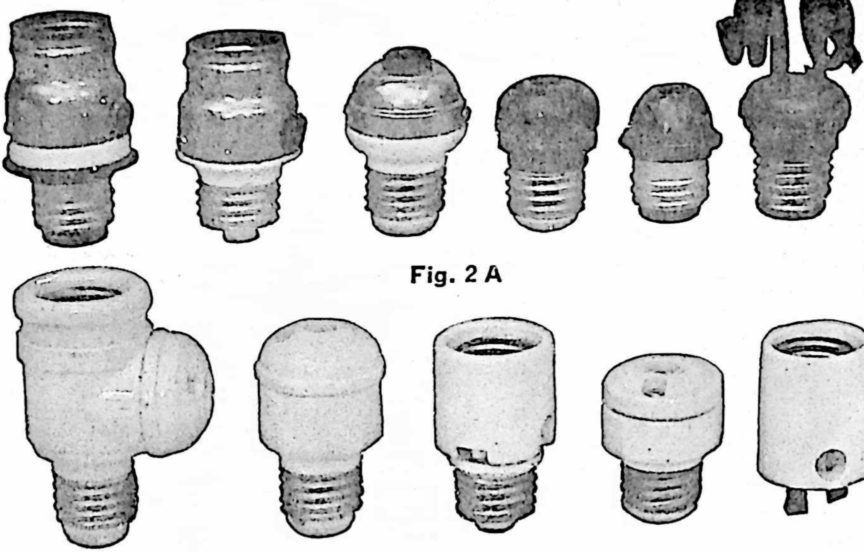


Fig. 2 A

STANDARD ATTACHING-PLUGS

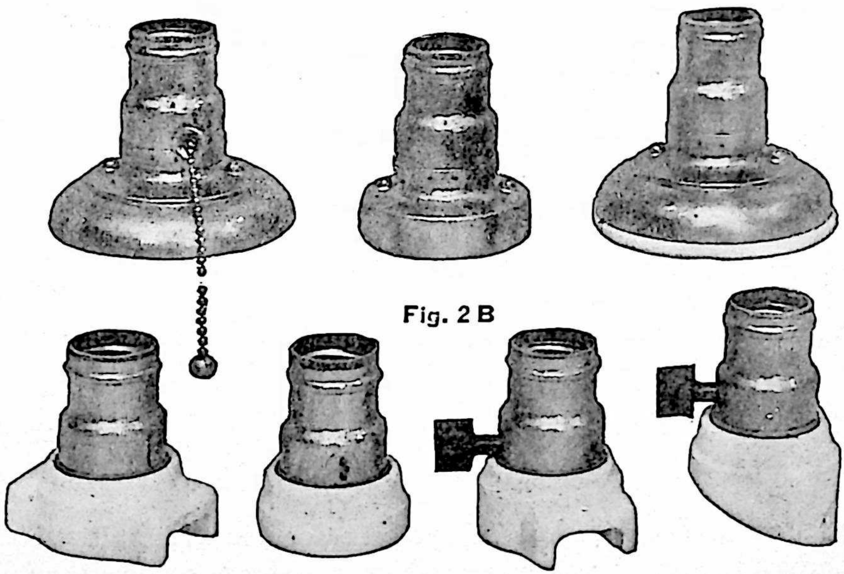
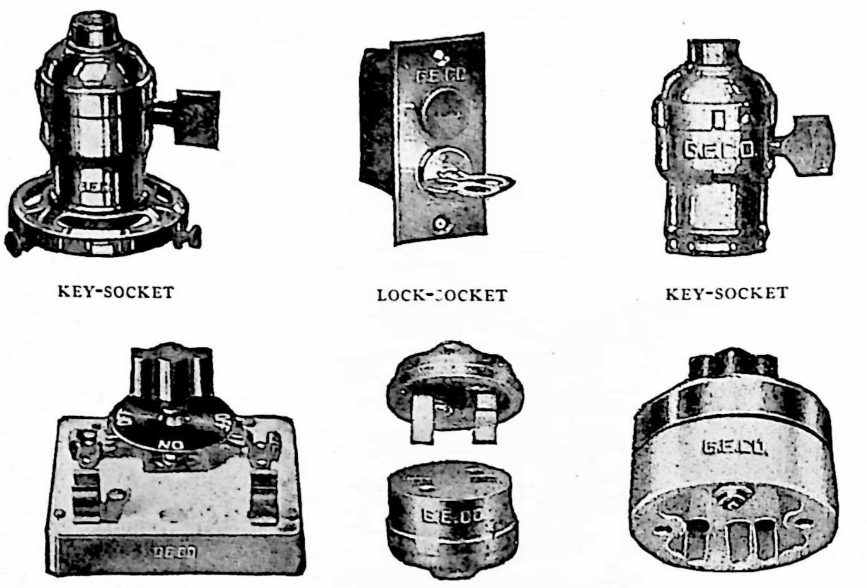


Fig. 2 B

METAL SHELL RECEPTACLES

DIFFERENT TYPES OF SOCKETS, SWITCHES, AND PLUG RECEPTACLES FOR ELECTRIC WIRING are practically inexpensive but which add materially to the comfort and convenience of the home. The following conveniences may perhaps be considered in the nature of luxuries, but none of them entails costly equipment, and they add that touch of ease and refinement which gives thorough charm to the home.

Side-wall Switches. Locate the side-wall switches so that they are beside the door which is most used in entering



KEY-SOCKET — LOCK-SOCKET — KEY-SOCKET

INTERIOR OF INDICATING-SWITCH — PLUG AND RECEPTACLE — SNAP-SWITCH

Fig. 2 C

DIFFERENT TYPES OF SOCKETS, SWITCHES, AND PLUG RECEPTACLES FOR ELECTRIC WIRING

the room, and on the knob side of the door, so that it may be handy on entering and will not be covered when the door is swung open.

Three-way Switches. That is the name for the side-wall switches that control the upper and lower hall lights from either position. It is an unending comfort and protection.

The Master Switch. A further protection against burglars is the "master switch" in the master's bedroom, which throws on the lights of the entire lower floor. This is a great convenience when it is necessary to look over the house in the dead of night.

The Closet-door Switch. In most clothes-closets there are dark corners. A small lamp can be installed inside the closet and out of the way, controlled by an automatic door-switch, so that as the door is opened the light goes on.

Current-taps and Lead-cords. When there are no base-board receptacles available current-taps or double-outlet sockets can be placed in the fixtures to connect up any appliances desired without sacrificing the light.

Wall-Switches

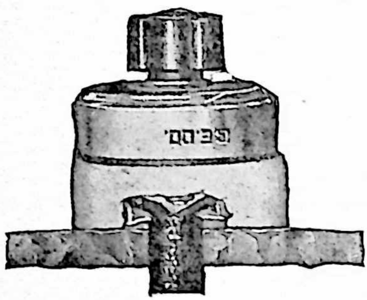
When electric lights were first installed some twenty-odd years ago the light was turned on and off by a simple key adjusted in the lamp-socket. This idea still prevails in many sockets, although the mechanism has been improved. Key-sockets are all right in every way, but they are far from being the most convenient.

Where key-sockets are installed it is necessary to grope around in the dark for the lamp before the light can be turned on. To obviate this nuisance the wall-switch was brought out.

By the aid of small switches the lights can be turned on before entering the room. The switch is located beside the door, and the lamp can be placed either on the ceiling or the side-wall or in any desired spot, irrespective of the switch which controls it.

The wall-switch is a very simple device designed to make and break the circuit. It consists of a loop of wire running up to the lamp circuit, wherever that may be, and it is operated by a small key (Fig. 4).

It will be noted that the current must flow through the switch before it can reach the lamp. The connection at the



SWITCH SHOWING MANNER OF INSTALLING

INTERIOR OF SNAP-SWITCH

Fig. 4

lamp-socket is turned on continuously so that when the key is turned at the switch the connection is made and the lamp lights. Another half-turn of the key breaks the circuit and turns out the lamp.

These wall-switches can be located where most convenient to the occupants of the house. Electric lights in the home would not be nearly so convenient without them. With suitable switches the entire house can be lighted from the front hall or any floor at a time, and the rooms can be illuminated before one enters them. There is no need of groping in the dark, of stumbling over the furniture, of striking matches or carrying a dangerous light.

Placing the Switch

Beginning with the porch light, it is generally wise to have the switch either in the vestibule or on the wall of the hall at the right of the front door. This permits the light to be turned off and on quickly if the porch light is not allowed to burn all the evening. The hall or reception-room light should also be controlled by a switch on the side-wall, but removed from the switch belonging to the vestibule light, for if the two switches are together there is danger of using the wrong one. Another switch for the down-stairs hall or reception-room should be at the head of the stairs. It admits of entering a lighted hall on descending the stairs.

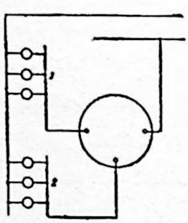
Most living-rooms connect with the hall and with the dining-room. For this reason two switches are desirable—one on the wall near the door to the hall and the other on the wall near the door entering into the dining-room. This allows of instant illumination of the room on entering from either direction. In this room it is preferable to have central fixtures, with one or more side-lights to read under. Dining-room lighting is provided by a central fixture holding several lights. So many artistic and beautiful electric fixtures now come for use over the dining-room table that the light is an ornamental feature of the room. The switch for this room should be on the wall at the right of the kitchen door. This is convenient for the servants, and as a rule one switch suffices for this room (Fig. 5).

Wall-switches are very easy to install. The same rules and regulations for installing indoor wiring circuit apply to this work. The wires should be carefully insulated just the same as the lamp circuits, as the same current flows over the switch wires. If the open system of wiring is used throughout the house the same kind should be employed for the wall-switches, using the same size wire, with the same insulation, the same porcelain blocks, tubes, etc.

Where the wooden molding is used for the wiring this should also be used for the switches. The same holds true for the knob and tube work and for the armored cable.

Two and Three Way Switches

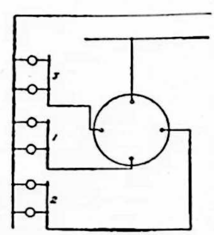
A way has been devised of installing wall-switches so it is entirely possible to light the lamps in the upper hall from the lower floor and turn them off again without coming back down-stairs. This is called a three-way switch (Fig. 6).



TWO-CIRCUIT ELECTROLIER SWITCHES

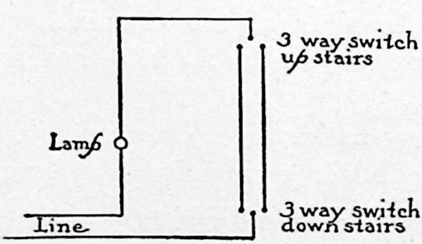
1st Position—Circuit—1
2nd Position—Circuit—2
3rd Position—Circuit—1 and 2
4th Position—Circuit—off

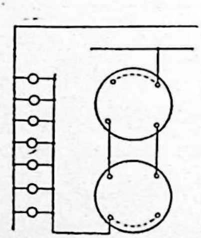
Fig. 5



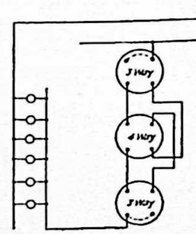
THREE-CIRCUIT ELECTROLIER SWITCHES

1st Position—Circuit—1
2nd Position—Circuit—1 and 2
3rd Position—Circuit—1, 2, and 3
4th Position—Circuit—off





THREE-WAY SWITCHES



THREE AND FOUR WAY SWITCHES

Fig. 6

When the switch is turned at the foot of the stairs the lamps in the upper hall are lighted. When the switch located in the upper hall is turned the lamps are extinguished, but, note closely, *it is entirely possible to turn them on again from either switch.*

The Master Switch

There is a way of connecting up the lights so that every one can be turned on at once from one switch. This is called the "burglar-alarm switch." Upon hearing any unusual noise in the house every light can be snapped on from the upper hall or the bedroom. The manner of installing this switch is best shown in Fig. 7.

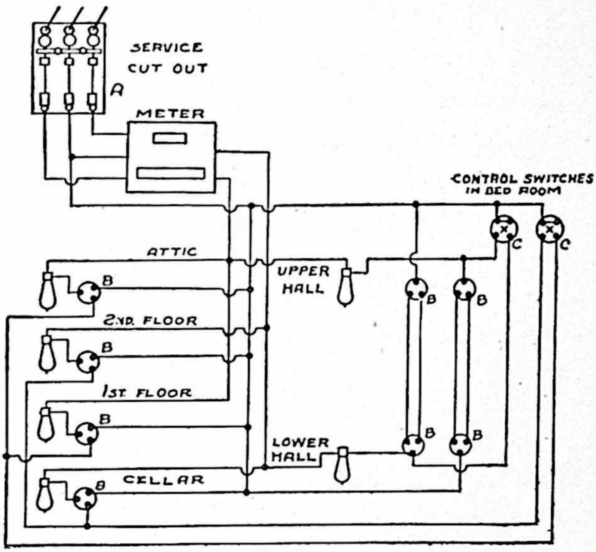


Fig. 7

Insulators

Those materials which resist the flow of electricity are called non-conductors, insulators, dielectrics.

Once dry air was thought to be the only perfect insulator. Now we know that wireless waves are easily transmitted through it. There are no perfect insulators, or at least none have yet been found.

There are two ways of applying insulating-material to a circuit. One is to insulate the wires at all contact-points, depending upon the resistance of the air for the rest. The other is to inclose the entire wire with an insulating covering.

Rubber, or its compounds, are generally used for covering wire. This is usually reinforced with an outer covering of cotton or hemp braiding to prevent any deterioration of the rubber.

There are a great many insulating-compounds used in electrical work, but they are more for the engineer and the manufacturer than the layman.

Many common materials are good insulators for ordinary work. Among them are the following: mica, or isinglass; gutta-percha; shellac; ebonite, or hard rubber; paraffin; glass; porcelain.

Dry paper and cloth are good insulators for low-voltage circuits.

Glass has a high dielectric strength, about 12,000 volts per millimeter, and for continuous voltage of about 83,000 volts per millimeter. Water readily condenses on the surface, and rain-water dissolves enough of the glass to slightly roughen the surface so that dirt, soot, smoke, etc., accumulate. When this becomes moist the line leakage is very appreciable. Experiment has shown that glass in which potash is used in the manufacture has higher resistance than the glass in which soda is used. It is suitable for line insulators on low or medium voltage circuits. On account of the varying composition it is easily broken by slight blows or stresses. In many places it is being replaced by porcelain on the low-voltage telephone and telegraph circuits.

Gutta-percha is very valuable as an insulation if it can be protected from air and light, both of which act to oxidize it.

If submerged in water or protected by lead sheath this oxidation is hardly perceptible. At 46° Centigrade it softens, is plastic at 50°, and melts at 100°. The dielectric strength of untreated gutta-percha varies from 10,000 to 25,000 volts per millimeter.

Lava is a mineral, and is becoming a very important insulating-substance. It can be machined, and does not shrink nor expand from the effects of moisture, and but slightly from heat. After having been machined it is baked to 1,100° Centigrade, making it extremely hard.

Mica, which is used very extensively, is one of the most valuable insulating-materials. In nature, it is of a rock formation, and is a silicate of aluminum and potassium or sodium. This is used largely in the construction of very delicate electrical apparatus as well as the heavier and more rugged construction. This may be split down as fine as .006 millimeter. The dielectric strength varies from 17,500 to 28,500 volts per millimeter, depending upon the composition of the specimen.

Paraffin is used largely to impregnate insulating cloths, papers, etc., and in lead-covered cable work to exclude moisture from splices and taps. It melts at about 64° Centigrade and has a dielectric strength of about 8,000 volts per millimeter.

Porcelain is largely used for line insulators, knobs, fittings, switch-bases, etc.; tensile strength per square inch, 1,800 pounds; compression strength per square inch, 15,000 pounds; dielectric strength, 16,000 volts per millimeter. At very high temperatures it loses its properties, becoming a fair conductor.

The various compounds of rubber are very extensively used for insulated wires and cables. Several different gums are used, but the one giving most satisfactory results is known as para. It is vulcanized by heating to 120° Centigrade and mixing the proper amount of sulphur. Higher temperatures produce hard-rubber compounds known as ebonite and vulcanite.

Chapter XI

THE USE AND MISUSE OF LIGHT

TO understand artificial illumination it is quite necessary to know the details of the process of seeing. The eye is certainly a wonderful piece of mechanism. There are really six parts to the eye—the iris, the cornea, the pupil, the lens, the retina, and the optic nerve (Fig. 1).

The action of the eye is very similar to that of a camera. Light passes through the cornea, pupil, and lens of the eye to the retina, and is registered on the optic nerve just as

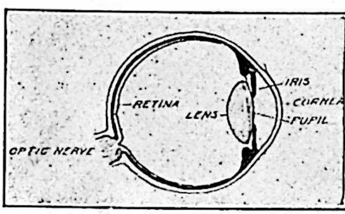


Fig. 1

NATURAL EYE

EYE STRAINED BY LIGHT-GLARE

Fig. 2

light passes through the lens of a camera and is registered on the sensitive plate. The retina is far more sensitive than the photograph plate. It is a curtain of nerve fibers which end in the optic nerve and go directly to the brain. The lens of a camera is fixed, but that of the eye automatically changes its thickness to focus the light-rays on the retina. This action of the lens is called the "accommodation" of the eye. When the light is bad the focusing-muscles soon tire out trying to keep objects in focus. The muscles which move the eye also get tired, and the result is eye-strain. The iris of the eye regulates the amount of light admitted to the lens. It is an automatic curtain which opens wide when the light is dim and shuts to a pin-point when the light is intense. In this way it protects the delicate eye nerves from a dangerous flood of brilliant light (Fig. 2).

The proper amount of artificial light depends on how much it helps one to see. Glaring and brilliant lamps are undesirable. Too much light in the wrong place is extravagance. The light should be steady. Flickering lights produce the same effect upon the eye as when we leave a darkened room and step out into the glare of intense sunlight. The eye always endeavors to automatically adjust itself to the light It cannot keep pace with a flickering light without tiring in a few minutes.

Care should be taken when installing household lamps to avoid unshaded and brilliant points of light. Reflected light from polished metal or glass, bright varnishes, and white paper is also bad for the eyes.

Lamps can be so placed that they are a hindrance rather than a help to vision. Place an unshaded lamp before a picture and note how much of the picture is visible. The pupil tries to shut out the bright light and in so doing it renders less bright things all but invisible. By holding the hand so as to cover the bright rays the entire picture in all its detail is visible.

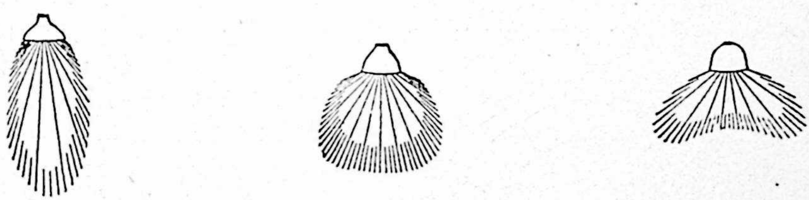
Mankind has grown accustomed to light falling from above. Light coming from any other direction hurts the eyes. Light reflected upward from snow explains why men go snow-blind in the arctics. Glossy white paper often produces the same effect upon the eyes as snow-blindness, only in a milder degree.

When installing new lamps in the home or changing the old lamps see that the flame-points of light are well screened and shaded with opal glass or white shades.

Light-Streams

The best way to understand light is to compare it with water. A stream of light can be directed anywhere at will. It can be focused to a concentrated stream. It can be diffused in a gentle spray to cover a large area. It would be folly to try to sprinkle a flower-bed with a concentrated stream of water under high pressure. It would tear up the bed, destroy the flowers, and otherwise ruin it. It would also be folly to try to wash high windows with a lawn-sprinkler throwing a fine spray of water.

This is usually true of light. Don't use a concentrated stream of light where a fine diffused spray should be used. Shades and reflectors should be installed to diffuse and direct the light where it is wanted and to suit various conditions (Fig. 3).



FOCUSING-DISTRIBUTION — INTENSIVE DISTRIBUTION — EXTENSIVE DISTRIBUTION

Fig. 3

Measuring Light

Light can be measured. Its intensity is expressed in candle-powers. A candle-power is the amount of light given by a standard candle. Thus, a 16-candle-power electric lamp gives as much light as 16 candles. A 20-candle-power lamp gives as much light as 20 standard candles.

All calculations of light are based on the law of inverse squares. The intensity of the light varies inversely as the square of the distance (Fig. 4).

Thus, in Fig. 4, the surface C, being twice the distance

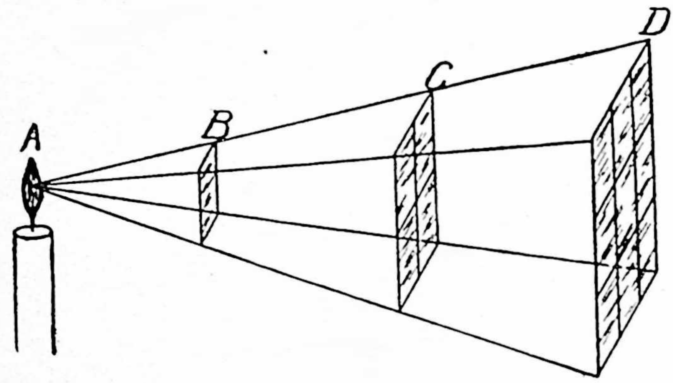


Fig. 4

from A that B is, will be lighted by the same number of light-rays, but, as the area is four times as large, the intensity will only be one-fourth. Likewise D, which is three times the distance and nine times the area of A, will have only one-ninth the intensity.

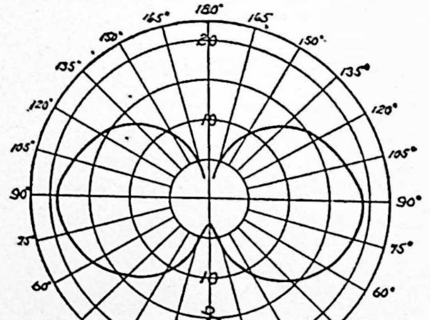


Fig. 5

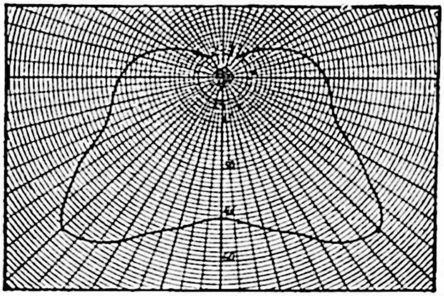
LIGHT DISTRIBUTION OF A 25-WATT "MAZDA." CLEAR, WITHOUT REFLECTOR

The intensity of light is measured with a *photometer*. This merely compares the light with a standard light source located in the instrument, the candle-power of which is known. The result of a test where a 25-watt lamp was tried out to find its light distribution is shown in the photometric curve (Fig. 5).

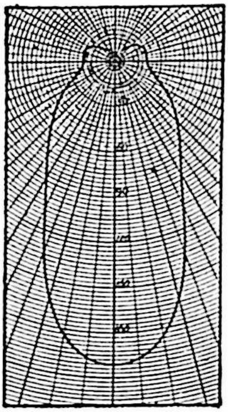
The effect of placing a concentrating-shade above this lamp is shown in Fig. 6.

Light is Easily Absorbed

Nearly all globes or reflectors absorb some light. Of course the light absorbed is light lost. The percentage of light



THE SAME LAMP EQUIPPED WITH A CONCENTRATING REFLECTOR GIVES THIS TYPE OF DISTRIBUTION



SAME LAMP WITH "FOCUSING" REFLECTOR

Fig. 6

absorbed by various reflectors is given in the following table.

	PER CENT.
Clear-glass globes	5 to 12
Light sand-blasted globes	10 " 20
Alabaster globes	10 " 20
Canary-colored globes	15 " 20
Light-blue globes	15 " 25
Heavy-blue globes	15 " 30
Ribbed-glass globes	15 " 30
Opaline-glass globes	15 " 40
Ground-glass globes	20 " 30
Medium opalescent globes	35 " 40
Heavy opalescent globes	30 " 60
Flame-glass globes	30 " 60
Signal-green glass globes	80 " 90
Ruby-red globes	85 " 90
Cobalt-blue globes	90 " 95

From this table it can be seen that if a table-lamp is provided with a heavy green shade only from 10 to 20 per cent. of the light-rays are able to find their way through the green glass. The rest is absorbed by the glass itself. If this globe were replaced with a globe of alabaster white conditions would be exactly reversed, and 80 to 90 per cent. of the light would be diffused about the room and only from 10 to 20 per cent. would be absorbed by the shade.

Where the shade of a table-lamp acts as a light-sponge and absorbs most of the light it is a very expensive ornament. In order to obtain enough light to read by large-candle-power lamps have to be used to allow for the light that is thus absorbed and wasted. With a globe which does not absorb the light smaller candle-power lamps may be used, with a consequent saving of current and lowering of the monthly light bill.

The Spectrum

To understand this absorption of light we must study the light itself with the aid of a prism. Ordinary sunlight is a mixture of red, orange, yellow, green, blue, and violet. When these colors are all combined they produce a white light (Fig. 7).

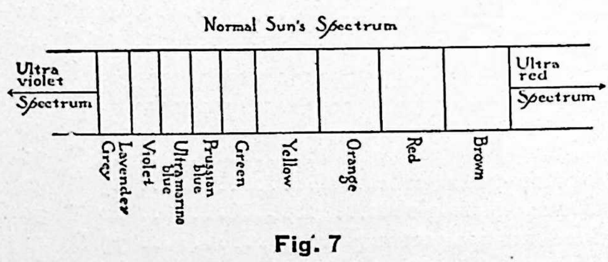


Fig. 7

Light is supposed to be a wave-motion. The length of these waves varies in accordance with the color of the light. These light-rays are longest at the red end of the spectrum and shortest at the blue end. When a material reflects all of the rays it appears white. When it absorbs all the light-rays it appears black. A red cloth is red only because it absorbs all the other colors of the spectrum and reflects back to our eyes the red rays. This is easily proven by standing under the light from a mercury-arc tube. This light has no red rays. A person standing in it is as pale as death. There is no color to the skin, and the lips appear blue-black and mottled.

Color Values

Because various colors and shades depend upon the absorption and reflection of light-rays which compose the spectrum they are factors to be seriously considered in lighting a room. Objects appear light when reflecting those rays which make up white light and dark when they absorb them. Light walls will always give more useful reflected illumination than dark walls.

The following table gives the reflecting qualities of various colored walls.

INCREASE OF ILLUMINATION FOR VARIOUS COLORED WALL-COVERINGS

COLOR OF WALL	REFLECTION
White paper	.70
Chrome-yellow painted	.62
Orange paper	.50
Plain deal (clean)	.45
Yellow paper	.40
Yellow painted (clean)	.40
Light-pink paper	.36
Plain deal (dirty)	.20
Yellow painted (dirty)	.20
Emerald-green paper	.18
Dark-brown paper	.13
Vermilion paper	.12
Blue-green paper	.12
Cobalt-blue paper	.12
Deep-chocolate paper	.04

The effective illumination in a room with orange-colored paper would be about twice that in a room with deep-chocolate paper if the lamps were the same. In other words, the effective illumination in a room papered with a deep-chocolate-colored paper would be doubled by repapering the room with an orange-colored paper. In very few instances will the increase of illumination in actual practice be as great as that shown by this table, due to the fact that the bulbs of lamps become dirty, thus lowering the candle-power, while the walls become dirty and dingy, thus decreasing the amount of light reflected. Moreover, in many cases the lamps are not replaced when their candle-power falls below 80 per cent. of their initial value, at which time they should be considered useless.

From this data it would appear that the most efficient lighting-installation would be one in which clear lamps are used in clear glass globes or reflectors and in a room finished in pure-white paper. Such an installation, however, would defeat its own purpose because it would seriously fatigue the eyes in a very short time and would ultimately injure them permanently.

Placing the Lamps

Lamps hanging at an angle throw too much light high up on the walls and not enough in the center of the room, where it is necessary (Fig. 8).

Where the lamps hang straight down they should be provided with reflectors which give the most useful distribution of the light (Fig. 9).

Indirect lighting is not as efficient as direct lighting. It cannot be used unless the ceilings and walls are finished very light to reflect as much light as possible (Fig. 10).

No reflector can increase the amount of light which issues from the lamp. Reflectors can merely guide the light to where it

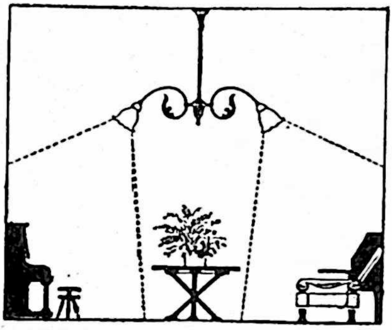


Fig. 8

THE LAMPS HANGING AT AN ANGLE THROW TOO MUCH LIGHT HIGH UP ON THE WALL

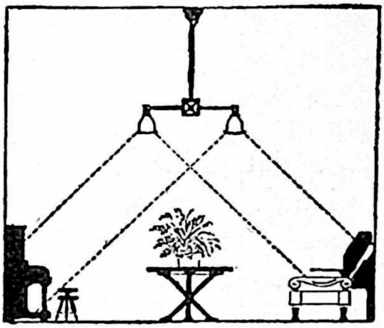


Fig. 9

FIXTURES WITH REFLECTORS PENDENT GIVE THE MAXIMUM ECONOMY OF LIGHT

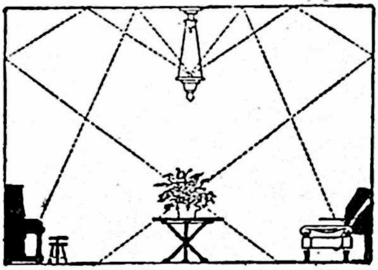


Fig. 10

SHOWING HOW IN "INDIRECT LIGHTING" THE LIGHT IS THROWN AGAINST THE CEILING AND REFLECTED

is needed. It is a mistake to think that electric lamps and fixtures do not need cleaning. Dirt and dust accumulate on both lamp-globes and reflectors. They absorb and waste much light.

How to Figure Cost of Light

The amount of electricity taken by an electric lamp is expressed in watts. Most electric lamps now manufactured have the number of watts which they are rated to consume printed on the label on the bulb. The old-fashioned carbon-filament incandescent lamp of 16 candle-power takes from 50 to 60 watts.

To determine the cost of operating an electric lamp divide the number of watts it consumes by 1,000, to reduce it to kilowatts, and multiply the number of hours the lamp is to be operated by the kilowatts to obtain the kilowatt-hours of electrical energy. The kilowatt-hours multiplied by the rate per kilowatt-hour which is charged gives the cost of operation for the stated time.

Watts ÷ 1,000 = kilowatts
Kilowatts × hours = kilowatt-hours
Kilowatt-hours × rate = cost

The consumption of gas-lamps is expressed in cubic feet of gas per hour. The number of cubic feet of gas per hour taken by a burner, divided by 1,000, and multiplied by the cost per thousand cubic feet of gas and by the hours of burning, gives its cost of operation for the stated time.

It is really a surprise to most users of electricity to learn that they are buying the current in known quantities and that economy in its use will make it go twice as far at half the cost. Suppose you had to perform a certain amount of work and hired a man with an engine of five horse-power to do it. It will be assumed that the engine takes four hours to do the work. Now if we call the amount of work that an engine of one horse-power will do in one hour a "horse-power-hour"—this is merely an arbitrary term—it is obvious that the engine of five horse-power will do five horse-power-hours of work in one hour, or 20 horse-power-hours in four hours. Another man with an engine of 10 horse-power would do the same amount of work in two hours, for he would do 10×2, or 20 horse-power-hours of work. Now, what do we pay for—for the horse-power or the horse-power-hours? Obviously the latter.

In the case of electric service we use another unit similar to the horse-power in kind but not in quantity. This unit is called, just for want of a better name, a watt. Thus, on an electric toaster, for instance, there may be seen a little plate on which is marked "500 watts," which means that the toaster takes 500 watts of electricity to heat it properly. (There are 746 watts in a horse-power.) But we do not pay for watts any more than we did for horse-power in the above example. It is work, or energy, that costs money. Thus we establish another unit similar to the horse-power-hour and call it a "watt-hour," which means the quantity of energy developed by a watt in one hour. Thus the 500-watt toaster would consume 500 watt-hours of electricity in one hour, or 1,000 watt-hours in two hours, 1,500 in three hours, and so on.

When we consider large quantities of electric current it is convenient to use a larger unit than the watt. The one chosen is called the "kilowatt," which is simply 1,000 watts. Similarly, the kilowatt-hour is equal to 1,000 watt-hours. The electric-light companies charge for their electrical energy by the kilowatt-hour, so this unit is very important. As all small lamps and apparatus are rated in watts, we must calculate their energy consumption first in watt-hours, and then divide by 1,000 to bring this to kilowatt-hours, and finally multiply the number of kilowatt-hours by the price in cents charged per kilowatt-hour, the answer being the amount of the bill.

The number of hours a day that these lamps are in use varies, of course, with the season of the year and with the family requirements. As an average case, suppose that the kitchen lamp is used three hours a day for 30 days a month. A 16-candle-power carbon lamp takes 50 watts. In one hour it consumes 50 watt-hours of electrical energy. In three hours (that is, one day) it uses up 50 × 3, or 150 watt-hours. In 30 days, or one month, the amount consumed is 150 × 30, or 4,500 watt-hours. Dividing the watt-hours by 1,000 to obtain the number of kilowatt-hours, it is apparent that in one month the kitchen lamp uses 4–½ kilowatt-hours of electricity, which, at the rate of 10 cents a kilowatt-hour, would cost 45 cents.

If the new metal-filament lamps were used the total cost of lighting would be very much smaller, although the initial cost of the lamps would be increased. Assuming that the same amount of light were used—that is, the same total candle-power for the same number of hours—the cost for current would be about one-third. A 40-watt metal-filament lamp will give a light of 32 candle-power, and one of these lamps can easily be identified by the "40w" which appears on a little printed tag pasted on the globe near the screw-plug—and so for lamps of other wattages. As a rule, when these lamps are employed more illumination is obtained than when carbon lamps are used. The light is also much brighter and more pleasing, its intensity being softened in many cases by the use of frosted lamps or light-diffusing globes. The following table shows a worked-out example, using metal-filament lamps. The cost of illumination is obvious.

LAMPS USED	LAMPS	HOURS A DAY	WATT-HOURS A DAY	KILOWATT-HOURS A MONTH	TOTAL COST PER MONTH AT $.10 KW.
Kitchen.....	1 20-c-p., 25-w.	3	75	2.25	$ .22½
Dining-room	1 48-c-p., 60-w.	1	60	1.8	.18
Living-room	2 32-c-p., 40-w.	2	160	4.8	.48
Bath-room ..	1 20-c-p., 25-w.	1	25	.750	.07½
Bedroom....	1 32-c-p., 40-w.	1	40	1.2	.12
Bedroom....	1 32-c-p., 40-w.	1	40	1.2	.12
Store-room...	1 20-c-p., 25-w.	...	.....	.....	....
Basement ...	3 20-c-p., 25-w.	...	.....	.....	....
Corridor.....	1 20-c-p., 25-w.	½	12.5	.375	.03¾
Stairs.......	1 20-c-p., 25-w.	½	12.5	.375	.03¾
Hall........	1 20-c-p., 25-w.	2	50	1.5	.15
Porch.......	1 32-c-p., 40-w.	...	.....	.....	....
Total.....	15 lamps	...	475	14.25	$1.42½

Calculating Illumination

Whenever a person is figuring on installing electric light, for either the home, the office, or the shop, the first question to be considered is the amount of light which will be necessary for the rooms or the work in hand.

It is not necessary to send for an illuminating engineer to locate and find out how many and what candle-power lamps are necessary to light any given room.

But in order to go about this work intelligently it is necessary to know the meaning of candle-power and foot-candle.

In England and America the sperm candle is the standard for measuring candle-power, and the light which this will give at any point one foot away is called a foot-candle. If a standard 16-candle-power incandescent lamp be suspended vertically the light which it will give at a point one foot away from the lamp and in a horizontal plane passing through the filament will be 16 foot-candles. Since the intensity of the light varies inversely as the square of the distance, at a point two feet away four foot-candles will be given and at a distance of four feet from the lamp one foot-candle of light would be the intensity, thus the unit foot-candle is derived.

The following table, showing the desired illumination for various uses, is practical for all ordinary purposes.

	FOOT-CANDLES REQUIRED		
Bookkeeping	3	to	5
Corridor, halls	.5	"	1
Depots, assembly-halls, and churches	.75	"	1.5
Drafting-rooms	5	"	10
Desk-lighting	2	"	5
Factory, general, where individual drops are used	2	"	3
Factory	4	"	5
Hotel halls	1	"	1.5
Hotel rooms	2	"	3
Offices (waiting-rooms)	1.25	"	2.5
Office (private)	2	"	3
Offices (general)	3	"	4
Offices (where desk-lights are used)	1.5	"	2.5
Reading	1	"	3
Residence	1	"	3
Stores (light goods)	2	"	3.5
Stores (dry-goods)	4	"	6
Stores (clothing)	4	"	7
Store windows	5	"	20
School-rooms	2	"	3

It must be remembered that it makes a big difference whether the room is finished in light or dark. Where the finish and paper are dark you have to provide an excess of illumination to make up for that which is absorbed by the dark finishings. Light finish and light paper reflect a great deal of light and make it possible to illuminate a room with less candle-power than one finished in dark oak and dark-brown paper.

It is always well to remember that a number of small lights give a better distribution of light than a few lamps of high candle-power.

Correcting the Light in the Kitchen

It is at once apparent that the kitchen should be the best-lighted room in the house. Unfortunately, this is seldom the case, although the most of the household work is done right in this room.

Go in almost any kitchen and you will find it lighted either by a single lamp fastened up against the wall in the worst possible place or by a small electric drop-light hanging down from the ceiling. Arranged without thought or plan, these kitchen lights are generally far too small to be effective. They are usually so situated that the worker is always standing in her own light. The best way to light a kitchen is to install a large incandescent lamp in the ceiling, equipping it with a proper reflector to diffuse the light evenly over the entire room. For an ordinary kitchen a 50-candle-power metal-filament lamp should be used. This lamp should be provided with a pull-socket and a long chain so that it can easily turn on and off. By suspending the chain about six feet from the floor it can be easily reached when the light is needed or when it is to be turned off.

Side-lamps cannot be made to do the work of a ceiling-lamp even if high-candle-power lamps and reflectors are used, but they can usually be made more effective by this means.

Lighting the China-Closet

An automatic switch which turns on an electric light when the china-closet door is opened will save many a pretty and valuable dish from being broken. The china-closet is usually situated in the darkest corner of the house. The interior is very dark, indeed, and it is quite impossible to take out the dishes and to replace them without accident. The dishes collide with one another, chipping the edges, knocking off the handles, and often enough cracking or breaking expensive china.

With a little ingenuity a spring can be so arranged that the opening of the door will automatically light a small electric lamp within the closet. The closing of the door turns off the light. The spring-switch is concealed between the edge of the door and the jamb or is fastened to the door-hinge.

Lighting the Cellar

Why will people living in houses lighted by electricity continue to stumble up and down dark cellar stairs when a small switch costing but a few cents can be installed so as to turn on the light in the cellarway before venturing down the stairs?

Every cellar should be equipped with electric light, and a small eight-candle-power lamp should be placed in the cellar-way in such a position that it will effectively light the entire stairway from top to bottom. This lamp can easily be connected with a wall-switch located in the kitchen so it can be snapped on before going down-stairs. An eight-candle-power metal-filament lamp will burn for a hundred hours for a total cost of but ten cents, and, as it burns but a few minutes each time, it can be used a year for a dime. The lamp itself costs but a few cents, and it can be installed very easily and quickly.

Nearly every one has trouble to remember to turn off the cellar lamps. It is quite a common thing for the best and most thoughtful of us to forget to turn them off.

Often they burn for days without being noticed. This can be easily remedied by installing a buzzer on the circuit. A "pilot lamp," usually of red, placed near the switch will help. But this, too, is easily overlooked and forgotten. A buzzer is by all means better. It continues to buzz as long as the cellar lamps are lighted and only ceases its clamor when you turn out the lights. There is no danger that even the most absent-minded will forget the little wall-buzzer. They cost but a few cents and are easily attached to the electric wires.

Electricity for the Bedroom

Very little care and attention is given to the placing of electricity in the bedroom. Apparently the contractor just sticks a wall-fixture in wherever it is most convenient, and the occupant of the room has to make the best of a bad job. Just as often as not the electric light is located up against the wall where it ought not to be.

Not only is it important that the electric light for the bedroom be located where it is most convenient and where the entire efficiency of the lamp is available, but other outlets should be provided in case an extra lamp is desirable during sickness or for reading purposes. Now and then auxiliary electric devices, such as the small electric flatiron, the electric fan, the electric shaving-mug, the electric luminous radiator, are desired, and where only one outlet is provided the lamp has to be taken out whenever anything else is used. Of course, this is a great inconvenience during the hours of darkness.

An electric shaving-mug is very serviceable in homes where hot water is not always on tap, and in connection with the shaving-mirror it is quite handy to have an electric light that may be adjusted to render its best service. The electric curling-iron and the electric hair-drier appeal very strongly to the ladies of the house, the former having distinct advantages over the curling-iron which has to be heated by gas, with the accompanying soot and danger of excessively high temperatures. The electric vibrator is another apparatus which may be used in the bedroom. Fans, radiators, and other common devices may also be wanted in this part of the house. A reading-lamp which can be placed in a convenient position at the bedside is also a comfort and convenience. A number of outlets are just as desirable in the bedroom as in any other portion of a residence. If the greatest use is to be made of electric current the owner should bear all these points in mind when laying out the wiring scheme.

Illuminating the Rest of the New Home

Home-builders are very apt to leave the question of artificial illumination entirely to the architect in charge. This in itself is well enough, but to-day illuminating engineering is an established profession, and it is very easy to secure reliable information on this important subject of proper illumination.

The architect is too prone to lean toward the artistic in lamp-fixtures and placement. Artistic effect is all right enough, but it should always be secondary to good, healthful illumination. The eyes should be considered first and the decorative scheme last.

With electricity it is possible always to have the lamps just where you want them. After the house is occupied it is frequently found that the lamps need changing or that additional lamps are necessary. If a few such minor changes are necessary for the comfort of the eyes they should not be neglected. The work will really cost but little. Another important item which most folk overlook is the fact that electric lamps can be had in a great variety of sizes, from the little fellow of but eight candle-power all the way up to units of two hundred or even 500 candle-power. It is folly to burn a 20 candle-power lamp where an eight-candle-power will answer all purposes. And it is equally wrong to try to read by an eight or ten candle-power lamp where a thirty is required. In the end the eyes will suffer. It is always cheaper and easier to buy suitable lamps than it is to purchase glasses.

When building a new home or when planning a new system of illumination for the old home the following important rules should be most carefully considered.

1. Always use a shade or reflector with a lamp. A bare lamp, which produces a glare, especially when near the level of the eye, should never be employed without a protecting device.

2. When possible mount the lamps high so as to be out of the ordinary line of the eye.

3. If the ceiling of your room is low use two or three small lamps rather than one large lamp. If the ceiling is high larger lamps may be used. Metal-filament lamps are made in a large variety of sizes, suiting them to practically all conditions in the home.

4. Reflectors are designed for given sizes of lamps. If you use a 40-watt lamp secure a 40-watt reflector. Always use the reflector-holder which is designed for the particular lamp in question.

5. Do not forget that too much light may be as harmful as too little. If your eyes become tired and hurt toward the end of the evening they may be either blinded by too much light or strained by an insufficiency of light.

6. Keep the lamps and reflectors clean. Much larger losses of light due to dust and dirt occur than you would imagine.

Chapter XII

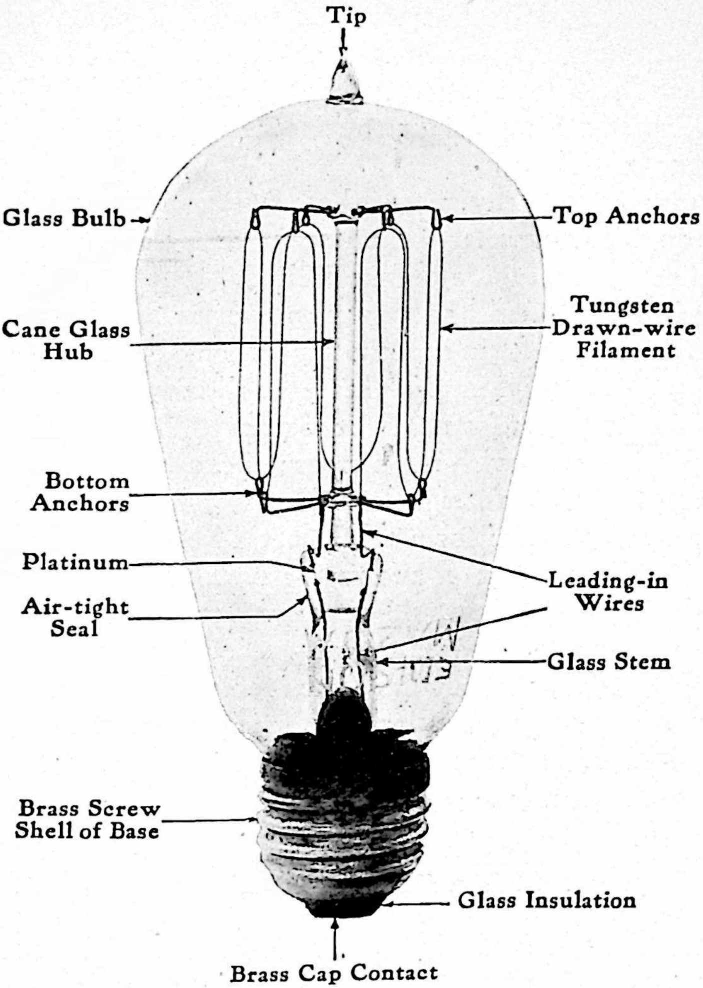
THE INCANDESCENT LAMP AND ITS ADAPTATIONS

THERE are several kinds of electric lamps. The incandescent lamp used for ordinary indoor-lighting purposes is most common.

Incandescent means literally to *glow with heat.* In fact, such a lamp is made luminous by heat.

To the ordinary user of electricity for home lighting the electric lamp is but a lamp. They do not know how it is constructed or why one lamp is better than another. The life of an electric lamp, its economy and durability, depend almost entirely upon the little hair-like filament, or wire, located within the glass bulb, which glows with light when the electricity is turned on. No matter how nicely the globe and base are made, no matter what care is taken in the assembly of the various parts, the life of the lamp and its usefulness depend upon the filament.

The incandescent-lamp filament is confined in a small glass globe from which the air has been exhausted to keep the wire from burning up. This glass globe also acts as a very effective shield for the lamp, making it possible to use the lamps very near inflammable materials without danger. This is especially valuable in homes where there are children, for they cannot possibly set fire to the house or burn themselves with electric lamps. The electric lamp produces so little heat that nothing can catch fire from being blown against the globe.



INCANDESCENT LAMP

If an old-fashioned carbon filament is used the light will be of a poor yellowish quality and the cost for current will be high. This is because the filament is made of carbonized cellulose, which is a vegetable paste. Carbon lamps are now out of date, being replaced by the metal-filament tungsten lamps which give a better light for less cost. The tungsten metal is drawn into fine wire, from which the filaments are made. This wire is really very strong for its size, being of less diameter than a hair, but it has the tensile strength of piano-steel.

Strange as it may seem, there are thousands of people who do not know that incandescent lamps can be obtained in almost any candle-power desired. They accept whatever is given them and pay whatever is asked without a question. More than half the time a complaint for excessive cost of electric-lighting is traceable direct to lamps of too high candle-power for the light required. That cost mounts up in direct ratio with the increase of candle-power is shown by the fact that an eight-candle-power tungsten lamp will burn for 100 hours for a total cost of but 10 cents, where the rate is 10 cents a kilowatt. A 20-candle-power lamp on the same circuit would only burn 40 hours for 10 cents, and a 32-candle-power lamp but 25 hours.

With proper glass shades and reflectors to direct the light where it is most needed lamps of small candle-power can be used with better light effect than those of high candle-power where the light is misdirected, absorbed, and wasted.

Light Caused by Resistance

The light emitted by an incandescent lamp is caused by resistance. The metal filament inside the glass globe resists the flow of current to a considerable degree. In forcing its way over this obstacle in its path the electricity heats the filament white-hot. As soon as any object is heated to incandescence, by whatever source, it emits light-rays.

When you turn on the electric light the current flows over one conducting-wire to the lamp, then inside the glass globe, through the tiny lead wires concealed within the glass stem. Here it encounters the resisting filament. But the current is so strong, so full of power, that it forces its way through the filament wire in spite of this resistance and back over the return wire of the circuit. Of course, it requires energy to force its way over this obstruction in its path. This energy is changed into heat-energy and from heat to light energy. It is this energy we pay for when the monthly light bill comes in.

Experimenting with the Incandescent Lamp

The air is exhausted from every incandescent-lamp globe. If air were allowed in contact with the delicate filament the tiny wire would be burned up in a flash. You can easily prove this. Take an old incandescent lamp and place it in the lamp-socket. It will burn steadily, evidencing that the vacuum is still good. Now take a pair of pliers and carefully break off the tip of the glass globe. This tip marks the place where the bulb was sealed after the air was exhausted. Break a tiny hole in this tip and let in the air. Now screw the lamp into the socket and turn on the current. In a flash the filament will be fused and destroyed. The oxygen of the air has burned it up. Without air there can be no combustion, hence the need of the vacuum.

And so, to experiment with incandescent lamps we must have a suitable vacuum. A good vacuum is impossible without an air-pump. But for minor experiments a partial vacuum will do.

It is possible to carry on quite an extensive experiment in this line by inverting a common glass in a shallow dish filled with water (Fig. 1).

By using rubber-insulated wires to carry the current through the water to the filament beneath the glass the filament may be lighted. The oxygen within the inverted glass will soon burn up, so it cannot destroy the filament.

But this apparatus is very unsatisfactory. A better vacuum is more suitable to the task in hand.

Secure an ordinary glass jelly-jar with a good smooth top. Next prepare a piece of dry hard wood four inches square

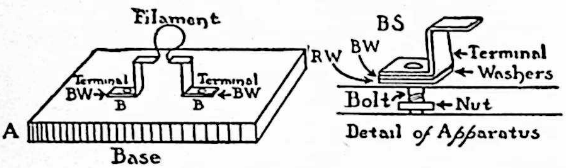


Fig. 2

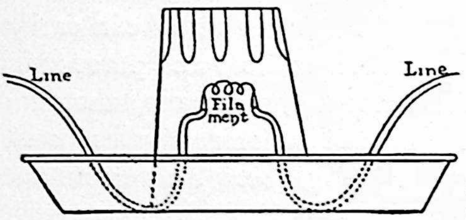


Fig. 1

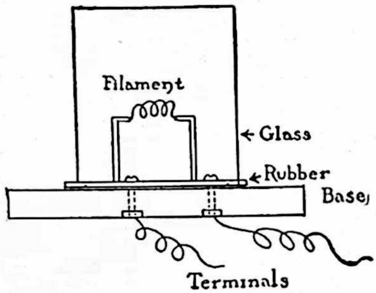


Fig. 3

and one inch thick by varnishing it on one side and along the edges, leaving one side unvarnished. Heavy shellac varnish should be used. This will fill the pores of the wood and make it reasonably air-tight. Drill two small holes through this wooden base an inch and a half apart (unless the mouth of the glass jar is smaller). These are for the wire terminals. As these terminals must be air-tight, small bolts with nuts and rubber washers must be used (Fig. 2).

A is the wooden base, B, B are the bolts, RW is the rubber washer, and BW, BW are the brass washers. BS are the brass strips for the terminal connections. The terminals are split, or doubled, to hold the filament in place.

With this for the base of our experimental lamp and the jelly-jar for the globe we are ready for the experiments. But first a way must be found to exhaust the oxygen from the globe, else the experiment will certainly fail. It is this oxygen of the air which fuses the hair-like filament. If the oxygen can be destroyed the result will be the same as though the air was pumped out.

To destroy the oxygen within our globe we will burn it up. Wet a can-rubber, such as are used to seal fruit-cans, and place it on the baseboards so the glass jar can be inverted over the terminals. Place a few drops of alcohol inside the rubber ring and set it afire. Now quickly invert the jelly-jar over the rubber, pressing it firmly in place. In a second or two the alcohol blaze will die out for want of oxygen. Without oxygen fire cannot burn. When the available supply is consumed the fire goes out. The pressure of the outside air will hold the glass jar firmly to the base.

A vacuum made in this way will last for a considerable time if the baseboard is well varnished, the terminals made air-tight, and the rubber new and springy. It will last long enough for our experiments.

This apparatus can be connected directly to the lighting-circuit, providing an indicating-switch is used. An indicating-switch, as its name suggests, tells when the current is on and off. One can be purchased for a few cents. When the current is turned on the word "on" appears in white letters on a black background to indicate that the current is flowing. When turned off, the word "off" appears. It would be dangerous to use the lighting-current without this switch because sooner or later the operator would forget whether or not the current was on and would try to adjust one of the terminals and thus get a shock. Current from the lighting-circuit is not dangerous, but it is best handled with extreme care.

With an indicating-switch adjusted to the baseboard of our apparatus tiny metal wires, bits of carbon, etc., can be heated to incandescence in the glass jar. Of course this is only elementary and merely provides a way to study the action of the incandescent lamp. Clamp bits of fine wire an inch or two long between the terminals and turn on the current after the oxygen in the air is destroyed by the burning alcohol. Experiment with various kinds of wire—brass, copper, iron, German silver, and even with bits of platinum and tungsten wire if you can get any, from old lamps or otherwise. Also try the pieces of filament from old carbon incandescent lamps or bits of carbon made from charred paper, thread, etc. (Fig. 3).

A few experiments with this apparatus, crude as it is, will give any one a thorough working knowledge of the incandescent lamp.

But, after all, incandescent lamps can be purchased vastly cheaper than any amateur can make them. It was the general custom among electric-lighting stations to give away old carbon incandescent lamps. The new metal-filament lamps are a bit more expensive.

Adaptations of the Incandescent Lamp

There are hundreds of interesting adaptations of the electric lamp for use about the home. In the very beginning it should be repeated that incandescent lamps can be purchased in all sizes, from eight candle-power to several hundred candle-power, which can be used in ordinary household sockets. Miniature lamps are also made to fit small candelabrum sockets, or socket-adapters, which are more in accord with the size of the lamp.

As miniature lamps are all of low voltage, they should be always connected in series for service on ordinary household circuits. For instance, 11 lamps of 10 volts each should be used in series for a 110-volt circuit.

Illuminated House Number

In the city it is quite important that the house number be illuminated at night. It is entirely possible to so arrange the porch light that it illuminates the house number at the same time. This can be done in a number of ways. Perhaps the easiest is to paint, in black letters, the house number on the white lamp-shade itself. Still another way is to build a little wooden box, with a glass front, and place the number on the glass (Fig. 4).

The box houses the small porch lamp, which is controlled

Fig. 4

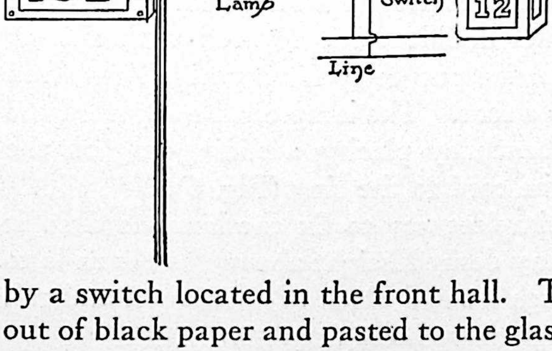
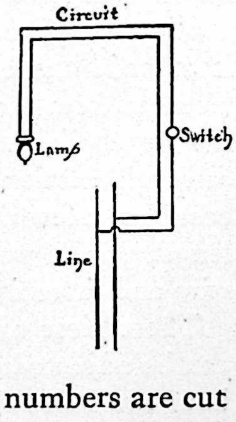


Fig. 5



by a switch located in the front hall. The numbers are cut out of black paper and pasted to the glass.

A good way to accomplish the same purpose is to inclose the porch light in a hanging-lantern, with the number lettered on the glass door of the lantern (Fig. 5).

Such a lantern can be easily made of wood, with the dimensions about six by ten inches. The design of the lantern can be left to the originality of the builder, but the old-fashioned Gothic effect shown above is best. This porch lantern should be suspended from the ceiling, and placed low enough so the number is easily visible from the sidewalk.

Drop-Light for the Work-Bench

A drop-light is essential for the work-bench where night work is necessary. A fixed light is not at all suitable for all kinds of work. It will be in the way for some tasks, and not near enough for others. The light for the work-bench should be provided with a suitable green reflector, which will throw a strong light in a downward direction. The light should be made so it can be moved to any part of the bench and arranged so it can be easily and quickly raised or lowered as the work requires.

Stretch a piece of picture-wire between two screw-eyes so it extends the entire length of the work-bench a little distance from the ceiling. Arrange a long flexible cord for the bench light. This double cord, covered with silk or cotton insulation, is made purposely for portable lights and costs but a few cents a foot. The lamp can be adjusted the length of the work-bench by placing a sliding-ring on the wire and fastening the cord to the ring (Fig. 6).

The easiest and simplest way to fix the lamp-cord so it can be adjusted to any desired height above the bench is to bore two holes through a small block of hard wood and run the lamp-cord through these holes (Fig. 7).

A great many other ingenious ways can be devised to hold the lamp at any desired height.

There is still another combination of the drop-light-picture-wire system for lighting the work-bench. In this

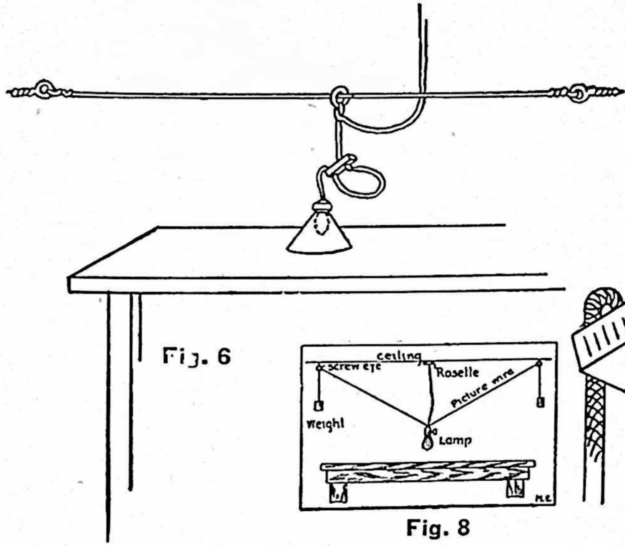


Fig. 6

Fig. 8

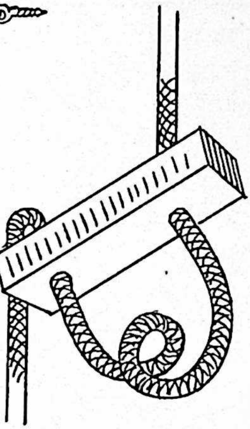


Fig. 7

case the picture-wire is not fastened to the screw-eyes, but passed through them and affixed to counter-weights (Fig. 8).

Suitable Lamp-Shades

A good shade for a hanging-lamp can be made of heavy paper. From the local printing-office get two sheets of heavy paper about 30 inches by 40 inches, one sheet white and one of a suitable color to harmonize with the hangings of the room in which the shade is used. A circle 30 inches in diameter should be circumscribed on both sheets. These circles should then be cut out. Out of each a sector about eight inches wide should be cut away. The two pieces should then be placed one on top of the other with the white underneath, and the edges should be folded as in Fig. 9.

When the base is about 20 inches in diameter the two thicknesses of paper may be fastened by round-headed brass paper-fasteners. These cost but ten cents a box of one hundred. A small hole is now cut in the top, through which the cord is drawn. The lamp-sockets support the paper shade. Be sure the paper shade does not touch the lamp-globe.

Lamps for the Shaving-Mirror

A novel and effective way to light a mirror is to adjust miniature lamps along the edge of the mirror (Fig. 10).

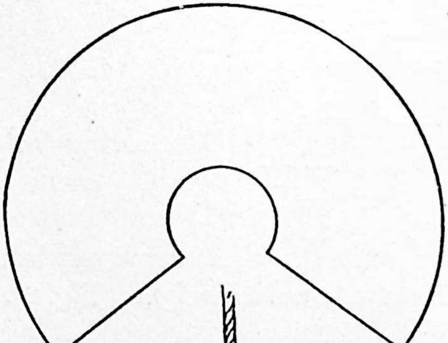


Fig. 9

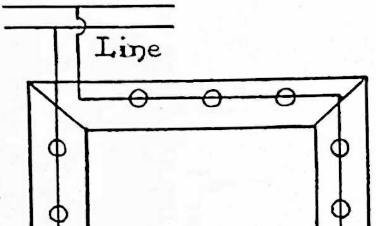


Fig. 10

Take an ordinary mirror and mount on it a number of porcelain receptacles in which are to be inserted miniature incandescent lamps such as are used for Christmas-tree or automobile lighting. These lamps can be bought at electrical-supply stores and are made for various voltages.

The lamps should be wired in series. The wire from one side of the supply circuit goes to the first lamp terminal, from the second terminal of that lamp to the first terminal of the next, and so on around, connecting finally to the other side of the supply circuit. The number of lamps required will be the number of volts in the main circuit divided by the rated voltage of one lamp. Suppose, for instance, the circuit voltage is 110 to 112 volts (the usual house-lighting circuit) and your lamps are marked seven volts; the number required would be sixteen. If you use more lamps they will not glow, or if you use less they will burn too brightly and perhaps burn out.

Lighting the Pantry Shelves

The sliding-wire system mentioned for the work-bench can be very easily adapted for lighting the pantry shelves. Needless to say this system can be used with a small battery system of lighting and miniature low-voltage lamps, or with the ordinary pantry light securing electricity from the house wire (Fig. 11).

You will note by the diagram that the lamp-cord is provided with a small coil-spring or a heavy rubber band, taped to the cord, so the lamp can be raised or lowered for any of the shelves. The cord can be adjusted by means of the small wooden block mentioned in connection with the work-bench lamp.

The "Trouble" Lamp

Every automobile should be provided with a "trouble" lamp, and this little device is also very useful about the home or the barns. The trouble lamp is so called, because it is generally used in looking for trouble, breakdowns, accidents, etc. Its field of usefulness is not confined to lighting odd corners, nooks, and crannies, as it is really of great service in any home and for a hundred uses.

The trouble lamp consists of a long, flexible, well-insulated lamp-cord fitted at one end with a screw-socket for attaching

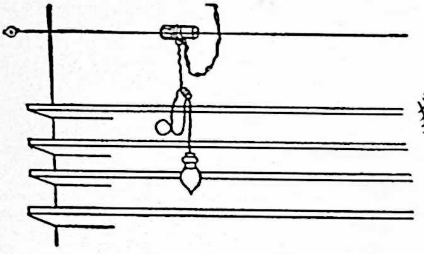


Fig. 11

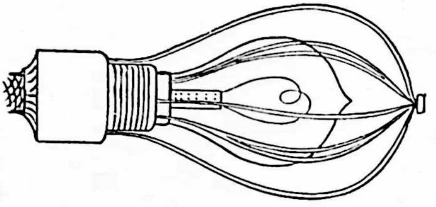


Fig. 12

to the ordinary lamp-socket and at the other end with a lamp and guard. In the case of the automobile the plug should fit the ordinary automobile lamp-socket, and a miniature lamp, of the same voltage as the lamps on the car, should be used.

The cord contains, beneath the heavy insulation, two insulated cables which are made of many fine strands of wire. Being made of many small wires, it can be bent and turned without kinking and breaking and will last for a long time. At least fifteen feet of this wire should be used. The lamp should be guarded against breakage. This is done by surrounding it with a guard of stiff iron wire arranged like a coarse basket. Protected in this way the lamp can be thrust into odd corners, dangled into the midst of wheels and cams, ironwork, and other places without danger of breaking, or it can be laid on the floor for a long time, while you are working, without scorching the woodwork (Fig. 12).

A Dual-Purpose Lamp

Lamps are now made with double filaments, giving two degrees of light, which are a great convenience. By merely pulling the lamp-cord a two-candle-power light is available, pulling it again will give 16 candle-power. This lamp is very convenient for the bath-room or the hall, as the low-candle-power light can be kept burning all night without serious cost, and the mere pulling of the cord will throw on the high light. It saves all danger of stumbling or falling when one is walking about the house in a sleepy condition, as often happens.

Desk-Lamps

Every desk should have an adjustable lamp. A great variety of these lamps are offered for sale at very reasonable prices. But a good one can be easily built on the boy's work bench. The lamp should be of the Mission type, made of hard wood—mahogany, black cherry, or sumac—if it is to be finished with the natural grain and color, and of cherry or oak if it is to be stained. The lamp consists of four parts—the base, the pedestal, the arm, the shade (Fig. 13).

The base is six inches square, an inch and a half thick, with beveled corners and edges. It is mortised for the square pedestal, which is firmly glued in place. The pedestal is ten inches high, two inches square, and slotted for the arm. The arm is eight inches long, two inches square, tongued for the slot in the tip of the pedestal, and fitted for the lamp-socket and shade at the other end. There are two ways of adjusting the lamp-cord. Silk cord may be used, which is merely fastened to base, pedestal, and arm by ornamental brass ring-screws. Or a small hole can be bored through the entire length of the pedestal and arm to admit the cord.

The arm is fixed in the pedestal slot with a thumb-screw. It is raised or lowered by adjusting this screw. There are no hard and fast rules about building this desk-lamp. The woodwork may be as fancy as desired, with scrollwork, carving, and high polish. This is a mere detail to be left to the discretion and energy of the builder. This lamp is not efficient without a suitable shade. A shade of brass is best. Metal shades can be purchased cheaper than they can be made, costing but a few cents each. But a suitable shade can be easily made of a sheet of tin, brass, or hammered copper. The latter is very ornamental. The sheet metal should be cut roughly, as shown in Fig. 14.

The pattern should be about eight inches long and seven inches wide at the widest part. These figures are not definite. They should not be followed except in a general way. It is best to make a paper pattern, and be sure it fits before cutting the metal. When cut, the metal is bent and fastened, as shown in Fig. 15.

After the desk-lamp is done it is easy to make a table-lamp of practically the same design. The Mission table-lamp is made of the same material and the same general construction as the desk-lamp. The only material difference is in the shade. For the table-lamp the shade can be made of wood (Fig. 16).

Lighting the Piano

An adaptation of the above lamp is very easily made for lighting the piano. The details are essentially the same as given above. The lamp consists of a base, a short pedestal, and an arm, with a large fixed shade (Fig. 17).

The base is six inches by six inches and an inch and a half thick. It is mortised for the short pedestal, which, in turn, is mortised for the arm. The lamp-socket is adjusted to the side of the arm, or two sockets are provided for two small lamps. The shade is made of a sheet of brass and two wooden end-pieces. The details are best shown in the diagram.

Decorative Use of Miniature Lamps

There is no limit to the decorative effects made possible by the use of miniature lamps in the home. These lamps

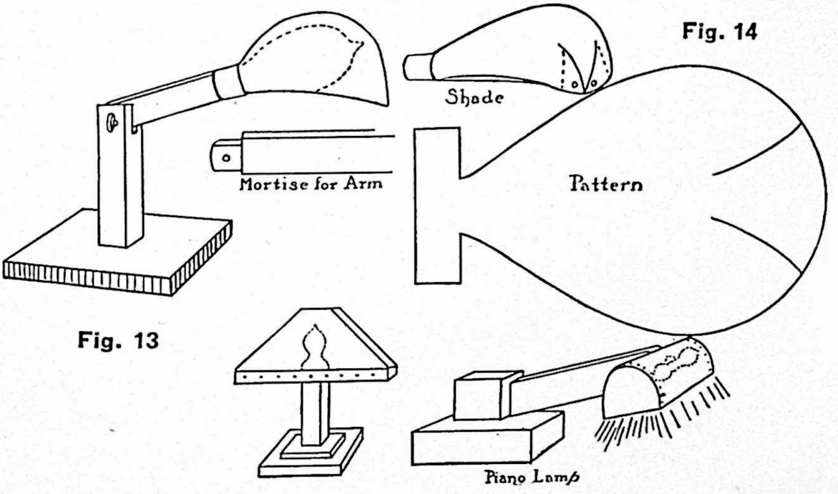


Fig. 15 Fig. 14 Fig. 13 Fig. 16 Fig. 17

come in a great variety of shapes and colors, in all small candle-powers. Some of them are shaped like apples, plums, various other fruits, flowers, manikins, animals, fowls, etc., etc. For balls and parties, holidays and special occasions these lamps can be used with wonderful effect for decorative lighting.

These miniature lamps come in all voltages. When used on the household-service wires, from an ordinary lamp-socket, several of them must be used in series. Thus, ten 12-volt lamps should be connected in series for use on a 120-volt circuit. It would ruin a low-voltage lamp in a second or two to attach it directly to the ordinary high-voltage circuit. If too many lamps are used in series they will not burn bright.

These tiny decorative lamps have been used extensively for table-decorating. A centerpiece of flowers or fruit may be very effectively lighted with these small lamps, using such bulbs as are shaped to resemble the fruit or the flowers.

Miniature lamps lend themselves readily to the decoration of rooms. They may be festooned from the ceiling, with flowers or evergreens, they may be arched over doorways or windows, and used in a dozen other ways which add greatly to the decorative effect.

Chapter XIII

RESISTANCE, AND HOW IT CHANGES ELECTRICITY TO HEAT

ALL known conductors offer some opposition to the flow of the electric current. This opposition is well named *resistance*. In some manner, akin to friction, it retards, or impedes, the flow of electricity.

To understand electric heat you must be perfectly familiar with this strange quality of resistance, which cannot be seen and is, therefore, hard to comprehend. Electrical resistance is very similar to friction which opposes and retards the flow of water in a pipe.

Friction is opposition to *mechanical* motion.

Resistance is opposition to *electrical* motion.

For the sake of convenience we speak of this "electrical friction" as *resistance*.

There seems to be no perfect conductor for the electric current. Even the best copper wire resists the flow of electricity to a certain extent. It is a significant fact that this resistance changes in degree when the wire is heated. This would indicate that the resistance is caused by some peculiarity of the molecules composing the metal.

Electricity flows along a conductor in the form of a *current*, very similar to the flow of a current of water, only much faster. A velocity of 300 *feet* a second is high for a stream of water. Electricity flows at the rate of 186,000 *miles* a second.

To fully understand resistance you must remember that the flow of the electric current depends upon three things—its pressure, or *potential;* the quantity of its flow, or *amperage;* and the amount of *resistance* in its path.

Let us see if we can comprehend this better by comparing it with the flow of water in a pipe.

Now, water in a pail is measured by gallons. But water in a pipe is always measured by *gallons per second.* The time element is always considered. We do not say there are 100 gallons of water in a pipe. We say the water flows through the pipe at a rate of *15 gallons a second.*

In this same way we never try to tell how much electricity there is on a wire. We always say that so much current is flowing over the wire each second. The quantity of water is measured in gallons. The quantity of electricity is measured in *coulombs.* But "coulombs per second" is a clumsy phrase, and it has been happily shortened to *amperes,* which literally means *coulombs per second.*

Thus the amount of current flowing over a wire is expressed in amperes. For example, it requires a continuous flow of ¼ ampere through the filament of a tungsten incandescent lamp to keep it glowing on a 110-volt line. The pressure of the current, which causes it to flow, being expressed in volts, and the resistance, which opposes this flow, in *ohms,* the number of amperes flowing can always be found by dividing the volts by the ohms.

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

It requires pressure to force water through a pipe. In hydraulics this pressure is expressed in *pounds per square inch.* It also requires pressure to force electricity along a wire. This electrical pressure is always expressed in *volts.* Thus your village water-supply may operate at a pressure of 80 *pounds* per square inch and your lighting circuit at a pressure of 110 *volts*. You can find the voltage of any circuit by multiplying the ohms by the amperes.

Ohms × amperes = volts

The amount of work a certain number of amperes will do at a certain voltage is expressed in watts. In other words, the product of volts and amperes is known as watts. The watt is the unit of electric power. The electromotive force, or pressure, of one volt forcing one ampere over one ohm resistance will do one watt of work. The term kilowatt means 1,000 watts, and is practically 1-$\frac{1}{3}$ horse-power, or, to be exact, 746 watts equals one horse-power. The power transmitted by a circuit and the rating of power apparatus are usually expressed in watts.

Volts × amperes = watts

The value of the unit horse-power is understood to mean 33,000 foot-pounds per minute. That is, a power capable of raising 33,000 pounds one foot in one minute against the force of gravitation. This unit was originally established by James Watt, the inventor of the steam-engine, to give a rating to his engine. It was found by him to be about equivalent to the power of a strong London draught-horse.

If the current was measured in a lighting circuit of 110 volts, supplying eight lamps of 40 watts each, it should be found to be approximately 2.9 amperes. Each of the lamps consumes 40 watts, then the total power is 8 × 40, or 320 watts. These are on the 110-volt circuit, and, as stated above, watts equals volts times amperes, then the number of amperes would be 320 ÷ 110, or 2.9.

The pressure of ordinary house-lighting circuits is about 110 volts. Voltages of 110 or less are considered safe.

The trolley circuit is usually about 500 volts, and is dangerous. There are several other terms used in place of volts. It is often spoken of as *potential*, *electromotive force*, *E. M. F.*, *potential difference*, *tension*, *etc.*

The ohm was named in honor of Dr. George S. Ohm, a famous German physicist who formulated the laws of electrical resistance. It has been determined that one ohm is the resistance of a uniform column of mercury 106.3 centimeters long, weighing 14.4521 grams at the melting-point of ice. It requires a pressure of one volt to force one ampere of current through one ohm of resistance. If one volt can force but one-tenth of an ampere over a wire we know that the resistance of the wire is 10 ohms. Turn this about and you will see that this will require 10 volts to force one ampere through 10 ohms resistance.

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

Perhaps these units would be more easily understood if arranged in table form.

TERM	UNIT	MEASURING-INSTRUMENT
Electromotive force / Potential	Volt	Voltmeter
Current	Coulomb / Ampere	Ammeter
Resistance	Ohm	Wheatstone Bridge / Ohmmeter
Work	Watt / Kilowatt	Wattmeter

Now that we fully understand the flow of current over a wire and just how its progress is opposed by resistance, let us see what this has to do with electric heating.

Resistance is really an opposing force which has to be overcome before the electric current will flow. In over-

ELECTRIC RADIATOR

coming this resistance some of the electrical energy is changed into heat-energy. This is the secret of all electric heating-devices.

Naturally, the first question is how does this wonderful transformation take place? Rub a coin on the carpet. It will soon become too hot to hold. This is because some of the mechanical energy, represented by the motion of your arm, is changed to heat-energy in overcoming the friction between the coin and the carpet. This demonstrates that in overcoming friction mechanical energy is changed to heat-energy.

This process is almost exactly duplicated in the electric wire. In overcoming the resistance of the conductor some of the electrical energy is changed to heat-energy. Perhaps the molecules composing the metal are rudely pushed aside by the electric current, which travels at terrific speed. This increases the vibration of the molecules. Heat being nothing more or less than the increased vibration of molecules composing matter, the wire soon gets hot.

The greater the length of a conductor the greater the resistance. The greater the cross-section of a conductor the less the resistance, because in the latter case the electrical path is larger, offering more room for the passage of the current. If it has to crowd over a fine wire the resistance is increased.

It is easy enough to measure the resistance of any conductor. Instruments are made for this very purpose; they will be described in succeeding chapters. A 16-candle-power incandescent lamp has a resistance of 500 ohms when cold and 250 ohms when hot. The resistance of 1,000 feet of No. 10 B. & S. gage copper wire is one ohm. A stick of graphite 10 inches long and ¼ inch in diameter has a resistance of about 7,000,000 ohms. The resistance of the human body is anywhere from 1,000 to 10,000 ohms, depending upon the person.

The resistance of various metals is best shown in the following table.

SPECIFIC RESISTANCE OF METALLIC WIRES

MATERIAL	RESISTANCE IN OHMS AT 0° C. OF WIRE 1 FOOT LONG, .001 INCH IN DIAMETER
Silver, annealed	8.781
Silver, hard-drawn	9.538
Copper, annealed	9.529
Copper, hard-drawn	9.741
Gold, annealed	12.56
Gold, hard-drawn	12.78
Aluminum, annealed	17.48
Zinc, pressed	33.76
Platinum, annealed	54.35
Iron, annealed	58.31
Nickel, annealed	74.78
Tin, pressed	79.29
Lead, pressed	115.1
Antimony, pressed	213.1
Bismuth, pressed	787.5
Mercury, pressed	565.9
German silver	125.7
Gold-silver (2 parts gold, 1 part silver by weight)	65.21

Although it was known for a long time that electricity could be changed into heat, it was not until recently that electrical heating-devices were manufactured. For years and years electric heat was but a laboratory experiment. The trend of electrical invention was to eliminate it as much as possible. Over a hundred years ago Davy demonstrated the tremendous heat of the electric arc. Since then the electric furnace has been developed, which will produce a temperature of 3,500° Centigrade, twice that of any fuel-furnace. The electric furnace is now in common use in the smelting of refractory ores and for other purposes.

James Prescott Joule, of England, was the first to experiment with electric heat. He determined that 778 foot-

ELECTRIC COFFEE-POT DISSEMBLED

pounds of work would raise the temperature of one pound of water 1° Fahrenheit. This is the British thermal unit now officially used for measuring heat and abbreviated B. T. U.

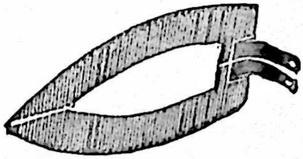
By using the proper size of resistance-wire and the proper amount of electricity any degree of heat may be produced at will. You can graduate the temperature from just enough to warm a heating-pad to the carbon melting-temperatures of the electric furnace. The rate at which this heat is produced is directly proportional to the product of the resistance in ohms of the resister and the square of the current in amperes.

For moderate temperatures the resister consists of a long thin wire or a flat ribbon through which the electricity is made to pass. For high temperatures large resisters are necessary. As this makes the resistance low, only low voltages (5 to 10 volts) are used, and therefore the amperage is high.

For electric heating and cooking the resister usually consists of a long coil, or wire, or its equivalent, in the shape of a flat metal stamping, concealed and carefully insulated within the device itself.

These heating-elements are designed to give a uniform temperature and to conduct the heat rapidly and evenly to the points to be heated. Every precaution is taken to prevent the loss of heat by radiation. While the heating-element forms a part of the device to be heated this unit is made so it can be readily detached and replaced if necessary.

CARTRIDGE HEATING-UNIT



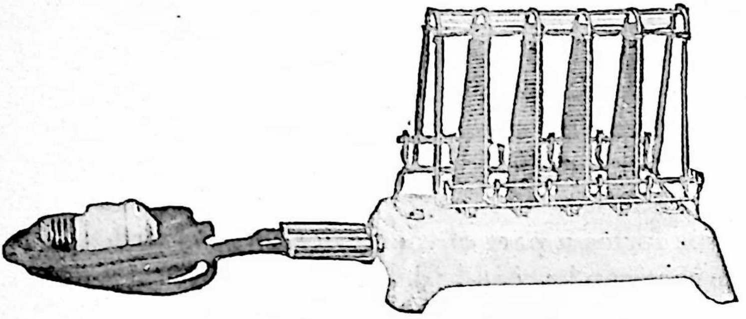
STAMPED-LEAF HEATING-UNIT

SPIRAL-COIL HEATING-UNIT

INCLOSED-DISK HEATING-UNIT

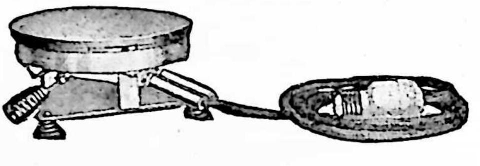
Where the heating-device takes 500 watts or less the ordinary lamp-socket may be used as a source of current. *Where a greater amount of current is required a special heating-circuit must be installed.* Any attempt to draw more than 500 to 600 watts over the electric-light wires will blow the protective fuse. When the fuse blows it is a sure sign that an excess of current has tried to flow over the wire. *The* *blowing of a fuse is always a danger-signal and should not go unheeded.*

The table on the following page gives the watt-consumption of various household electric heating-devices and their ap-



TOASTER

FLATIRON



DISK STOVE

proximate cost per hour where electricity can be had for five cents a kilowatt-hour, the usual heating and cooking rate.

Experience has shown that 300 watt-hours per meal per person is a liberal allowance for electric cooking; or in a family of five four kilowatt-hours per day is an average.

Electric heating is also extensively used in industrial work of all kinds. It is used to heat the tools in book-binderies and hat-factories, it is used in candy-manufacturing, electrotyping, for glue-pots, soldering-irons, shoe-stamping machinery, branding-irons, for welding, tempering, annealing, and in other ways too numerous to mention.

RESISTANCE

APPARATUS	WATTS	CENTS PER HOUR
Broilers, 3 heats	300 to 1,200	1.5 to 6
Chafing-dishes, 3 heats	200 " 500	1 " 2.5
Cigar-lighters	75	.375
Coffee-percolators for 6-in. stove	100 " 440	.5 " 2.2
Coil-heaters	110 " 440	.5 " 2.2
Corn-poppers	300	1.5
Curling-iron heaters	60	.3
Double boilers for 6-in., 3-heat stove	100 " 440	.5 " 2.2
Flatiron (domestic size), 3 lbs	275	1.37
Flatiron (domestic size), 4 lbs	350	1.75
Flatiron (domestic size), 5 lbs	400	2
Flatiron (domestic size), 6 lbs	475	2.4
Flatiron (domestic size), 7.5 lbs	540	2.7
Flatiron (domestic size), 9 lbs	610	3.05
Foot-warmers	50 " 400	.25 " 2
Frying-kettles, 8-in. diameter	825	4.125
Griddle-cake cookers, 9 ins. by 12 ins., 3 heats	330 " 880	1.7 " 4.4
Griddle-cake cookers, 12 ins. by 18 ins., 3 heats	500 " 1,500	2.5 " 7.5
Heating-pads	50	.25
Instantaneous-flow water-heaters	2,000	10
Kitchenettes (complete), average	1,500	7.5
Nursery milk-warmers	450	2.25
Ornamental stoves	250 " 500	1.25 " 2.5
Ovens	1,200 " 1,500	6 " 7.5
Plate-warmers	300	1.5
Radiators	700 " 6,000	3.5 " 30
Ranges, 3 heats, 4 to 6 people	1,000 " 4,515	5 " 22
Ranges, 3 heats, 6 to 12 people	1,100 " 5,250	5.5 " 26
Ranges, 3 heats, 12 to 20 people	2,000 " 7,200	10 " 36
Shaving-mugs	150	.75
Stoves (plain), 4.5 ins., 3 heats	50 " 220	.25 " 1.1
Stoves (plain), 6 ins., 3 heats	100 " 440	.5 " 2.2
Stoves (plain), 7 ins., 3 heats	120 " 600	.6 " 3
Stoves (plain), 8 ins., 3 heats	165 " 825	.82 " 4.125
Stoves (plain), 10 ins., 3 heats	275 " 1,100	1.3 " 5.5
Stoves (plain), 12 ins., 3 heats	325 " 1,300	1.6 " 6.5
Stove, traveler's	200	1
Toasters, 9 ins. by 12 ins., 3 heats	330 " 880	1.6 " 4.4
Toasters, 12 ins. by 18 ins., 3 heats	500 " 1,500	2.5 " 7.5
Urns, 1 gal., 3 heats	110 " 440	.5 " 2.2
Urns, 2 gals., 3 heats	220 " 660	1.1 " 3.3
Urns, 3 gals., 3 heats	330 " 1,320	1.3 " 6.6
Urns, 5 gals., 3 heats	400 " 1,700	2 " 8.5
Waffle-irons, 2 waffles	770	3.75
Waffle-irons, 3 waffles	1,150	5.75

Chapter XIV

ELECTRIC HEATING-DEVICES AND HOW THEY ARE MADE

GERMAN-SILVER wire with a very high resistance is generally used by amateurs for the resistance in heating-devices. A few special alloys have been perfected and patented which have a greater resistance than German silver. They are also available for the amateur.

A suitable device for testing the heating-properties of various materials can be made easily. The inexperienced amateur should use battery currents until he has become thoroughly familiar with handling higher voltages. Electric-light voltages, 110 to 120 volts, are safe, but they are not to be trifled with. Twenty-four dry cells will be quite enough for experimental purposes, as they will give about 30 volts if connected up in series. Half this number will do in a pinch. A simple testing-standard consists of an insulated base, two insulated standards, and two sliding-conductors for holding the wire to be tested (Fig. 1).

For the low-battery currents the base can be made of hard wood, well seasoned, and soaked with varnish. Soak it well in shellac-varnish and dry thoroughly before using. The base should be about ten inches long, five inches wide, and an inch thick. The uprights should be two inches square, six inches high, and mortised to fit the base so they are placed eight inches apart in the middle of the same. The copper conductors should be eight inches long, sawn or split at one end for the admission of the wire to be tested, and ringed at the other for proper connection with the battery terminals. Bore a hole through the top of each wooden standard to admit a piece of porcelain tube such as is used to insulate house wiring where it passes through floors and ceilings. This will effectively insulate the conductors. The copper rods should be large enough to fit snugly in this tube and at the same time admit of being shoved back and forth. This device should also be pro-

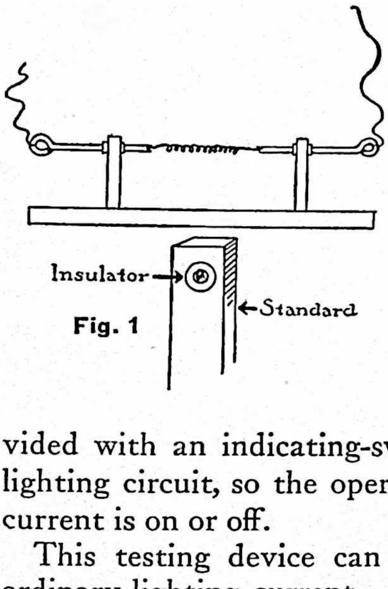


Fig. 1

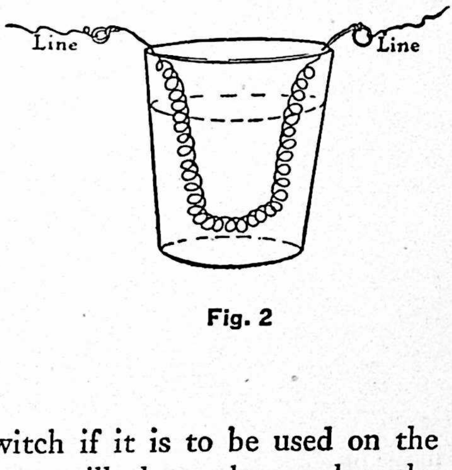


Fig. 2

vided with an indicating-switch if it is to be used on the lighting circuit, so the operator will always know when the current is on or off.

This testing device can be used for either battery or ordinary lighting current. If the house-lighting current is to be used at about 110 volts the terminals are connected to an ordinary desk-lamp cord. This cord consists of two insulated wires covered with silk and has a suitable plug connection to screw into the lamp-socket.

With this device a number of different metals can be tested. Place a strip of thin sheet lead six inches long and a quarter of an inch wide between the "jaws" of the copper terminals and turn on the current. In a few minutes it will become quite hot and melt.

Bits of iron wire will become red-hot. Brass and German-silver wire will also become hot. It will be noted that the finer the wire the quicker and easier it is heated. The resistance of German silver is 18 times that of pure copper. No. 24 copper wire has a resistance of 20.9 ohms per pound. The same size wire of German silver has a resistance of 376.2 ohms. Soft steel has 10 times the resistance of copper; platinum, 5.7 times; nickel, 7.9; iron, 6.1; and aluminum, 1.8.

Wrap some German-silver wire around a lead-pencil to form a spiral six inches long, each turn one-eighth inch apart. Hold it in place awhile until the wire "sets," so it will not unwind when the pencil is removed. Loop this coil in a glass tumbler and arrange between the terminals of the heat-testing machine, and we have the first simple heating-device (Fig. 2).

The electrical energy flowing through the wire coil is changed by resistance to heat-energy and it will soon raise the temperature of the water to the boiling-point. *This is the principle upon which all heating-devices are constructed.* With the knowledge of these fundamentals, and knowing the value of proper insulation, any common heating and cooking device can be made.

Toy Electric Incubator

One of the best applications of electric heat is the toy electric incubator. This simple device is easily made and entirely automatic in operation. A heating-unit, consisting of a coil of German-silver wire, is concealed beneath the egg-tray of the machine. With the aid of an electromagnet and a column of mercury the temperature is automatically maintained at 104° Fahrenheit, which is the correct hatching-temperature. Of course, the eggs have to be turned and sprinkled occasionally, as in any other incubator. This device is suitable only for experiment and amusement, as but a few eggs can be hatched.

Build a double box fifteen inches high, eight inches wide, and eight inches deep. Fit it with a small glass door so the eggs can be watched. Arrange a rack, or a shelf of perforated wood, six inches from the bottom (Fig. 3).

In this lower compartment is to be concealed the heating-unit, a coil of German-silver wire wound on a porcelain base

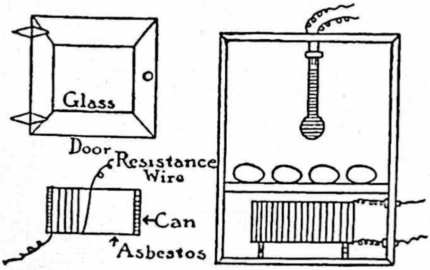


Fig. 3

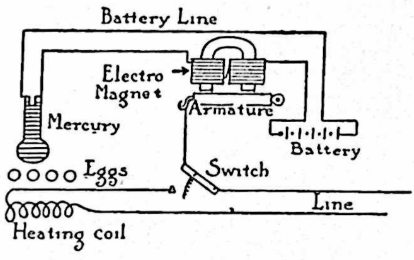


Fig. 4

and carefully insulated. This coil can be made by wrapping a baking-powder tin can with asbestos paper and winding the wire on that. The coils should be one-eighth inch apart.

This resistance-unit will furnish the necessary heat for the experiment. It is best to line this lower compartment with asbestos paper. The whole device should be operated where there is no danger in case it gets afire, like any other incubator.

The eggs are placed on the hatching-tray, as shown in the illustration, and the device connected to the lighting circuit, or to a suitable battery circuit.

This incubator is kept at a constant temperature by a novel switching-device. A glass tube containing mercury is arranged in the top of the hatching-chamber. Through the cork or cover of this tube protrude two platinum wires which are connected to a battery circuit and operate an electromagnet. The manner of installing this device is best shown in Fig. 4.

Whenever the temperature of the hatching-chamber exceeds 104° the mercury rises and makes a connection between the platinum points. This energizes the electromagnet, which raises the armature and "breaks" the circuit to the heating-unit. When the chamber cools sufficiently the mercury drops down in the tube, breaking the circuit to the electromagnet, and closing the circuit to the heating-unit. The size of the heating-unit and the amount of mercury in the tube can be determined only by actual experiment.

Electric Soldering-Iron

Any ordinary soldering-iron can be made into an electrically heated iron. Wrap the face of the iron with one layer of mica. Over this place a layer of one-sixteenth-inch sheet asbestos. Now wind twenty-five turns of No. 20 high-resistance wire over the asbestos covering. Cover with a layer of mica and wrap another twenty-five turns over this. Now arrange the terminals for connection with the leading-in wires and cover with a layer of mica and another layer of asbestos paper, and the iron is ready to finish (Fig. 5).

A protective jacket of sheet brass, or a winding of copper wire, must be laid over this heating-unit to protect it from injury while the tool is being used. The leads are connected to insulated wires and brought out through a suitable hole bored in the wooden handle and connected to the regulation cord and plug for attaching to the electric-light socket.

The Electric Cigar-Lighter

The electric cigar-lighter consists of a small coil of very fine resistance-wire and a suitable base or container. Very fine resistance-wire, No. 39, should be used. Wrap this over a darning-needle to form a very small coil three inches in length. Withdraw the needle and insert a piece of asbestos string in its place. Be sure that all the turns of the coil are separate from one another one sixteenth of an inch, so it won't short-circuit. This coil should be mounted in a circular piece of asbestos board one-half inch thick. Cut out a disk of this board one inch in diameter. Groove it with a small gouge to form a spiral recess for the resistance-coil. Bore a hole at each end of this groove so the terminals of the coil can be brought to the back of the disk (Fig. 6).

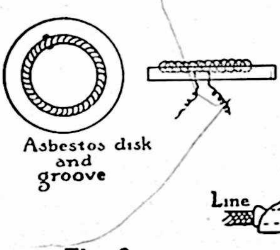


Fig. 6

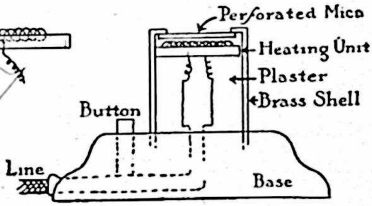


Fig. 7

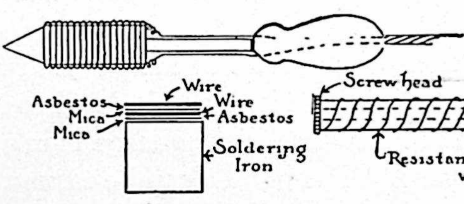


Fig. 5

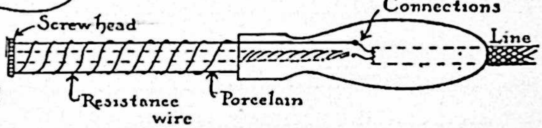


Fig. 8

This, when covered with a perforated disk of mica, forms the heating-element of the cigar-lighter. To be effective it must be mounted in a metal and plaster-of-Paris receptacle.

The disk is fitted to a circular brass holder, which in turn is fastened to a wooden base or handle (Fig. 7).

The insulated wires are brought through the base to the coil terminals and fastened thereto. The brass container is filled with plaster-of-Paris and fastened to the base. A suitable push-button switch is arranged in the base to turn on and off the current when the lighter is to be used. This lighter is suitable for either direct or alternating current at 110 volts. When the button is pushed the coil should heat sufficiently to turn a bright cherry red. It should char wood through the mica covering.

Heating the Shaving-Mug

Hot water is not always convenient for shaving purposes, especially in the early morning. In this case a suitable electric shaving-mug-heater is very handy. A heater of the immersion type—meaning that it is to be immersed in the water in the mug—can be made by any boy handy with tools. It consists of a suitable insulating-handle, a porcelain base, and the necessary resistance-wire.

Select a piece of porcelain tube, such as is used in house wiring, four inches long and free from bad spots, cracks, etc. At the hardware store you can get a good heavy screw five inches long which will pass through the hole in the porcelain tube. The head of this screw should form a suitable base for the porcelain tube. If the screw-head is too large it can be filed down even with the tube. The handle can be turned of hard wood, maple preferred. A small hole is bored to admit the threaded end of the screw and to form one terminal of the device. Another hole is bored parallel with this for the other terminal (Fig. 8).

About ten feet of No. 24 resistance-wire will be necessary.

Solder one end of this to the head of the screw. Wind the remainder of the wire on the porcelain tube, taking care that the turns are evenly spaced and one-eighth of an inch between turns. The winding should be very firm and tight to avoid slipping. This end of the resistance-wire is fastened to the other screw terminal in the wooden handle. The lead wire of the lamp-cord is brought into the end of the base and connected to the terminals, as shown in the preceding illustration. The handle for this device can be turned on a lathe or taken from an old screw-driver or file.

The lamp-cord used for connecting the device with the lighting-socket should be about five feet in length, or longer if necessary. The other end of the cord is provided with a common screw-plug which fits in the lamp-socket in place of the lamp. This device takes about 200 watts, and is entirely safe for the lighting circuit.

In using this type of immersion heater care must be taken to place it in the shaving-mug before turning in the water, or the porcelain will crack. It should never be used with a metal mug. Use it only with china or porcelain mugs of good insulating qualities. Place the heater in the mug, turn in the water, and turn on the "juice." In one minute the water will be hot enough for shaving purposes. Do not operate this heater for any length of time unless it is immersed in water. If you do it will get too hot and crack the porcelain.

An Electric Toaster

An electric toaster is somewhat harder to make than the simple electric heating-devices described in preceding pages. Nevertheless, the amateur can make one with very little trouble and expense. Perhaps in this case it will be better to show a detailed drawing of the toaster first. In that way it will be easy to take up its component parts and describe them in detail (Fig. 9).

The base of this toaster is made of slate, marble, or heavy white asbestos board. It can be of hard wood covered with asbestos paper, but this is hardly to be recommended. The base should be about eight inches long and five inches wide. At each corner is fastened, with rivet or bolt, a small cylindrical porcelain insulator at least one inch high for the legs. The frame is a sheet of copper or brass or even tin, although this latter is not so handsome. It is bent into a rectangular shape, as shown in the diagram, and fastened to the base with small screws or bolts. The heating-element of this toaster consists of three flat coils of resistance-wire, about No. 25, wound on uprights of heavy mica. The mica strips are supported in the frame by double cross-pieces of metal, and they are notched so as to hold the wire coils without slipping. A suitable rack is built up around these coils to protect them from the bread while it is being toasted. Another wire rack holds the bread in place. When the toast is done it can be conveniently stacked on the top of the metal frame.

About fifteen feet of the resistance-wire will be necessary for this type of toaster. If it gets too hot it can be readily shortened. The terminals of the resistance-wire are brought out through the insulating-base to suitable plugs for attaching to the heating-device cord. These cords, as sold in the open market, consist of about five feet of heavily insulated double wire, to one end of which is attached a screw-plug for the lamp-socket and to the other a suitable plug-contact for the heating-device terminals. The terminals to the toaster should be made to fit the cord you have on hand or the one you intend to use.

A Serviceable Immersion Heater

The immersion heater has a hundred uses about the house. It is especially useful when hot water is wanted in a hurry at night or in case of illness in the family. But an immersion heater is harder to make, as it must be water-tight. Select a piece of brass pipe four inches long and with an inside diameter of about one inch. Cut threads on the inside of each end for a distance of a quarter of an inch. For one end

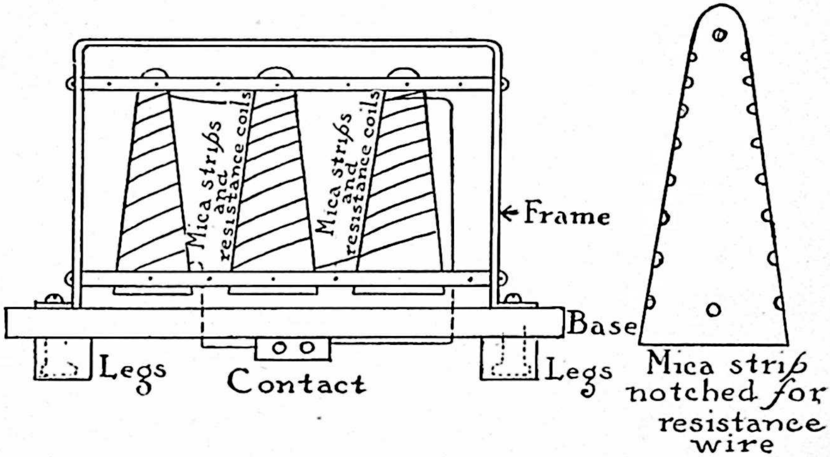


Fig. 9

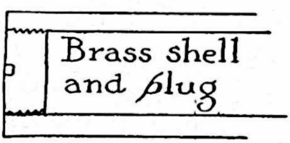


Fig. 10

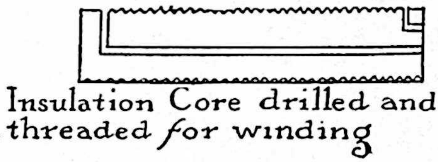


Fig. 11

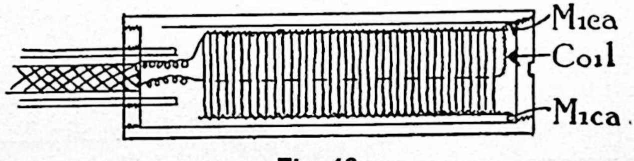


Fig. 12

of this tube provide a brass plug threaded to fit and slotted with a hack-saw so it can be screwed in place, flush with the edge of the tube. Now solder it firmly in place. The other end of the tube is also provided with a brass plug, but this plug is drilled and threaded for a one-eighth-inch brass pipe (Fig. 10).

On the lathe turn a cylinder of any suitable insulating and heat-resisting material, such as lava board or any of the various compounds manufactured for this purpose. The cylinder should be seven-eighths of an inch in diameter, or small enough so it will drop inside the brass tube. Drill it lengthwise for one terminal wire and slot it for the other as shown in the diagram (Fig. 11). Place the tube in the lathe and thread it twenty-four turns to the inch. In this thread wind No. 24 resistance-wire. It will take about twenty feet of wire. Lead one end of the wire through the hole in the tube and the other through the slot. Splice the ends of the resistance-wire to asbestos-covered heat-resisting wire. Bring this wire up through the brass tube and screw the same in place (Fig. 12).

Finish off with solder and polish: Now fasten on the handle, through which a hole has been bored for the lead-wires. An attachment-plug on the end of the cord for connecting with the lamp-socket completes the immersion heater.

The Electric Radiator

An electric radiator can be made of ordinary carbon incandescent lamps. These lamps give off fully 95 per cent. heat and less than 5 per cent. light. By fitting a hard-wood base with receptacles for ten of these lamps, connected in multiple, and arranging a metal hood for the radiation of the heat produced, a very good emergency air-heater can be made. The porcelain bases are mounted on a wooden block and connected in multiple. When mounting the receptacles remember to allow room for the lamp-bulbs which are larger than the bases. Otherwise mount as closely as possible. Connect the bases so that all the outside connections are on one wire and all the inside connections on the other (Fig. 13).

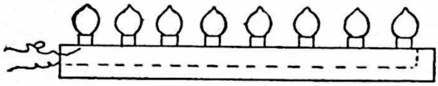


Fig. 13

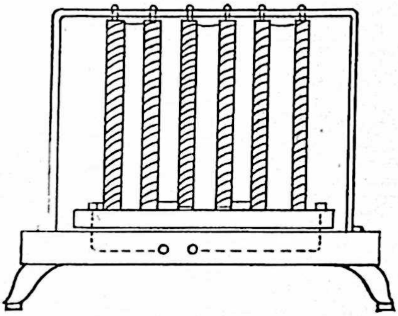


Fig. 14

The last socket is left without a lamp. In this the plug is screwed for connecting the lamp with the lighting-socket. A metal hood, with suitable holes for the circulation of the heated air, is arranged for the heater. The amount of heat produced by the electric "stove" can be varied by lessening or adding to the number of lamps.

Of course this device takes plenty of current and is really quite expensive. By dipping the lamps in metallic paint the heat will radiate from the glass bulbs much faster.

A more serviceable electric heater can be made by following the suggestion in Fig. 14.

The porcelain tubes are about 18 inches long and wound with No. 26 resistance-wire, using about 25 feet to each tube. Six of these tubes are arranged side by side in a suitable metal receptacle, mounted on an insulated base. This heater is suitable for 110-volt circuits and consumes about 500 watts.

Only a few of the many applications and possibilities of electric heat are enumerated above. The imagination of every amateur will conjure up a dozen and one other things equally as interesting and instructive. Boys skilled in the use of tools have made good serviceable electric flatirons, electric cookers, disk stoves, electric radiators, electric coffee-pots, and many other applications.

It is freely predicted by men who ought to know that when our coal-supply is exhausted electric heat produced by water-power will keep us warm and cook our food, unless some other and cheaper form of heat is discovered in the mean time.

Chapter XV

GENERATING ELECTRICITY BY MECHANICAL POWER

THE electricity used to light buildings and streets, to drive trolley-cars and motors, for the electrification of railroads, etc., is produced by large mechanical generators, or dynamos, driven by steam-engines or water-wheels.

A generator is a machine to produce electrical energy. At first thought, after a careful study of the chemical battery, this would seem quite impossible. Indeed, it was so considered up to the very day in 1831 when Michael Faraday demonstrated to the contrary. The dynamo, a device of iron and copper, actually generates an electric current. For this reason it is better known to-day as a *generator*. The word *dynamo*, once in good usage, is now all but obsolete in the great electrical industry.

Electromagnetic Induction

In all mechanical generators electricity is produced by a process called *induction*. Induction is hard to grasp. It means "the production of magnetization, or electrification, in a body by the mere proximity of magnetized or electrified bodies." In other words, if a piece of soft iron is held near a powerful magnet, although not touching it in any way, it will become magnetized by the influence of the *rays* issuing from the magnet (Fig. 1).

To fully understand induction it will be necessary to conduct a few simple experiments with this new force.

Hold a compass near a magnet and the needle will be violently agitated. It will persist in pointing toward the magnet, regardless of the earth's magnetic poles. Even though the compass be held some distance away from the magnet it will be visibly affected. This proves that the

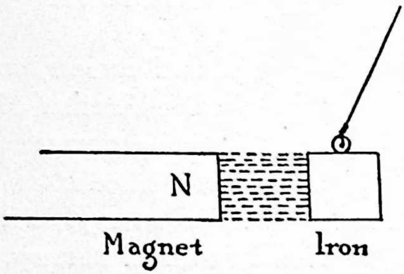


Fig. 1

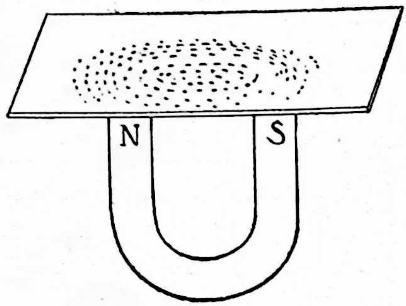


Fig. 3

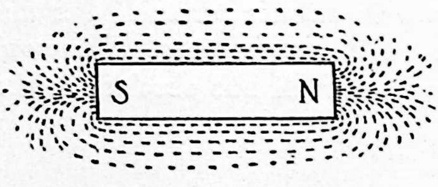


Fig. 2

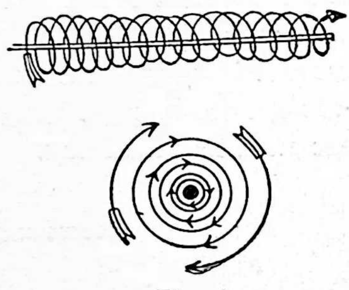


Fig. 4

magnetic influence extends out into the air for a considerable distance around every magnet. A magnet is supposed to be quite surrounded with these invisible rays called *lines of force*, or *magnetic rays*.

A bit of soft iron brought within the influence of these rays, yet not touching the magnet, will become magnetized.

You can easily prove this. The soft iron by itself will not attract iron filings. Suspend it before the poles of a good horseshoe-magnet, and it will attract the iron filings. When the magnet is taken away from the immediate neighborhood of the soft iron this magnetism ceases. This is because soft iron, while easily magnetized, loses its magnetism just as easily. When suspended before the poles of the magnet the soft iron becomes magnetic by *induction.*

It will pay to stop and investigate these mysterious rays just a little. The lines of force in the magnetic field are quite invisible. They surround every magnet, being of greater density at the poles. They flow out of the north pole and into the south pole (Fig. 2).

These lines of force can be easily demonstrated with a common magnet, a thin piece of cardboard, and some fine iron filings. Place the cardboard over the poles of the magnet and dust with the iron filings. Tap the paper lightly with the finger. This will assist the filings to arrange themselves (Fig. 3).

It will be seen that the iron filings have arranged themselves in distinct curved lines. These lines represent the invisible lines of force ever flowing through the air between the poles of the magnet.

Magnetic rays, or lines of force, extend around every conductor of electricity, every wire carrying a current, as well as every magnet (Fig. 4).

Inducing an Electric Current

Many years ago Faraday demonstrated that if a bit of copper wire is passed across the lines of force, between the poles of a magnet, so as to cut the rays at right angles, a current of electricity will be generated in the wire (Fig. 5).

To try this experiment a little device called a *detector* (because it is used to "detect" weak electrical currents) is quite necessary. An ordinary compass can be utilized for this work. Place the loop of copper wire so a portion of it lays across the face of the compass immediately above and

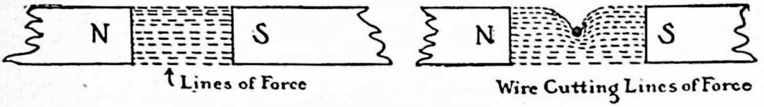


Fig. 5

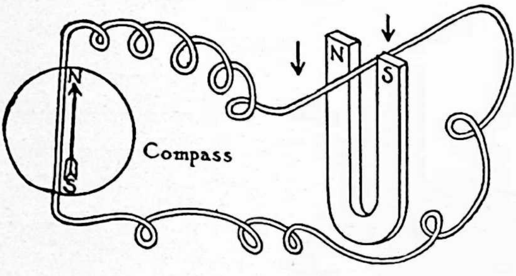


Fig. 6

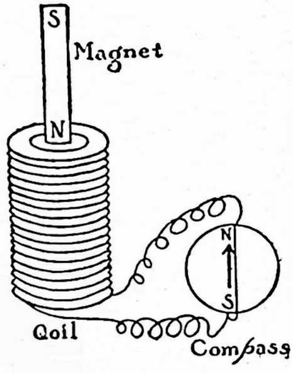


Fig. 7

parallel to the compass-needle. Now if a weak current of electricity passes over this wire the compass-needle will swing out at right angles to the wire, pointing east and west instead of north and south. This is owing to one of the natural laws of magnetism that similar magnetic poles *repel* each other, and dissimilar poles *attract* each other (Fig. 6).

Pass the wire down between the poles of a good horseshoe-magnet, watching the compass the while. It will be seen that the needle swings at right angles to the wire, as stated above, evidencing that a current of electricity has been generated in the wire.

This experiment can be made plainer with a suitable coil, or spool, of insulated copper wire. Connect the coil terminals to a galvanometer, or to a compass detector, as described above. Now thrust the north pole of a good bar-magnet into the center of the coil. Instantly the compass-needle will be deflected, proving that a current of electricity has been *induced* in the wire loops of the coil. You will notice that this current flows *only when the magnet is in motion*. When the magnet is at rest in the coil there is no flow of electricity. When it is extracted from the coil another current is generated, but the needle shows that *it flows in the opposite direction*. The current flows one way through the coil when the magnet is inserted and the opposite way when it is withdrawn. If the magnet is moved very slowly no current will result. The faster it is moved the greater the current induced (Fig. 7).

It makes no difference whether the coil is moved over the magnet or the magnet thrust into the coil, the result is exactly the same.

Perhaps the best example of an induced current is to be found in the operation of an *induction-coil*. This coil is really a small transformer. It consists of a *primary coil*, through which flows a current of electricity from a battery. Wrapped around this primary coil, but effectively insulated from it, is the *secondary coil*, consisting of many turns of very fine insulated wire. We know that no current can flow from the primary coil to the secondary coil owing to the heavy insulation. And yet when a pulsating current of low voltage and high amperage is sent through this primary coil it induces a current to flow in the windings of the secondary coil. This secondary current is of high voltage and low amperage. The device cannot increase the amount of power, although it does increase its pressure, or voltage.

Just how this secondary current is induced we will not attempt to explain. It might satisfy an idle curiosity, but would be of no particular value to the work in hand. Let us accept as a fact, amply proven by experiment, that whenever a conductor is moved within the lines of force in a magnetic field a current of electricity is produced. The strength of this current depends upon the speed of the conductor and the density of the magnetic field.

This is the whole story of the electric generator.

When you pass a wire down between the poles of a magnet electricity is produced. In reality some of the mechanical energy of your body has been changed to electrical energy. If we use a steam-engine or a water-wheel to whirl a number of these loops in a magnetic field we can change any amount of mechanical energy into electrical energy. The electricity produced in this way does not differ from that produced by chemical batteries. It can be used for light, power, heat, etc. To force these loops across the lines of magnetic force requires considerable power, however, as the attraction of the powerful magnets has to be overcome. There is also some loss of energy in friction, eddy currents, etc. For every 746 watts, or one horse-power, of electrical energy produced we have to use somewhat over one horse-power of mechanical energy.

To follow the path of the electric current produced by the mechanical generator we must take up a single loop of the conductive wire from the armature, or rotating part (Fig. 8).

When this loop of copper wire is stationary no current flows. When it first begins to move its motion is parallel with the lines of magnetic force flowing between the magnetic poles, as shown by the illustration. This also results in no flow of current. But when the top of the loop begins to cut down and across the lines of force and the bottom of the loop begins to cut up and across the lines a current begins to flow in the wire conductor. This current continues to flow as long as the loop is cutting the lines of force at right angles. When the conductor again parallels these lines the current stops. *This completes a half-revolution of the loop.* Now the top of the loop, being at the bottom of the field, begins to cut the lines of force in an upward direction. The bottom of the loop, now at the top, cuts them on the other side in a downward motion. The result is another current in the loop, but it *flows in the opposite direction.*

Thus, with every complete rotation of the wire loop *two* currents of electricity are produced, one flowing to the right and the other to the left. The electricity, surging first one way and then the other, is known as *alternating current.* The electromotive force generated in the armature-windings of any generator is alternating in character. If *direct*

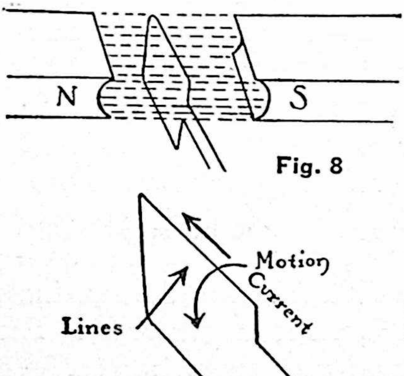


Fig. 8

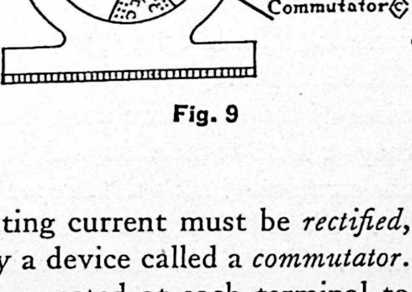


Fig. 9

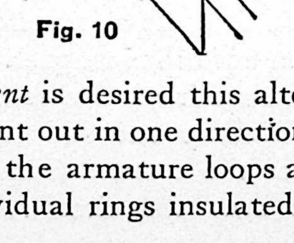


Fig. 10

current is desired this alternating current must be *rectified,* or sent out in one direction, by a device called a *commutator.*

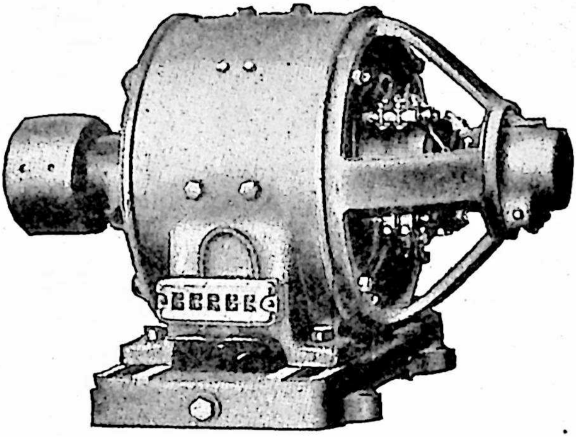
If the armature loops are connected at each terminal to individual rings insulated from each other and the current is taken from these rings by sliding-contacts an alternating current will flow over the line. If a split ring is used and the loop terminals are connected to alternate sections of the ring a direct current will result. This direct current will be pulsating in character. It will not flow even and steady like a stream of water.

Now that we understand how the generator creates an electric current, we will take one of the machines apart and see how it is made. Let us first consider the side and end elevation of a simple direct-current generator (Fig. 9).

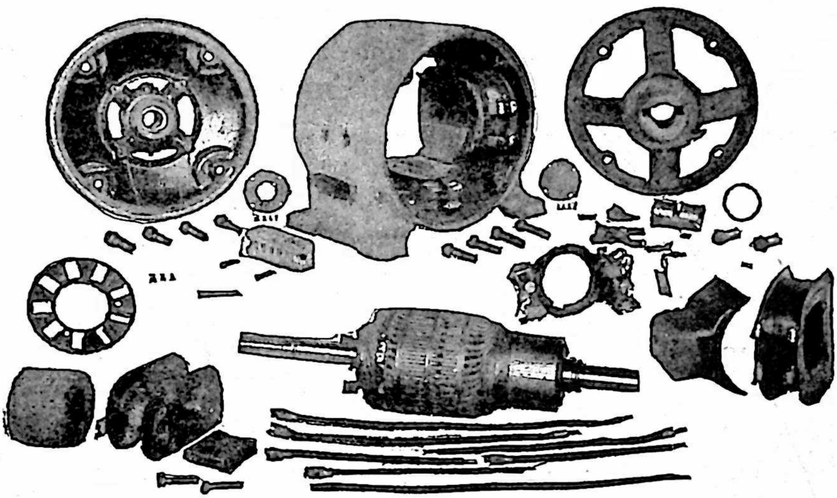
This dynamo can be divided into three essential parts. The first of these is the magnetic poles (MP) upon which the exciting-coils (EC) of insulated wire are wound to produce the electromagnets. It is the function of these coils to supply the field with its magnetism. The iron frame of the machine acts as the yoke to connect the pole-pieces of the magnets. The design of the soft-iron pole-pieces is such as to cause the magnetic lines of force to pass straight across from pole to pole with considerable density.

The second essential part of the machine is the armature (*a*). This consists of a number of copper loops systematically arranged over a soft-iron core. When this armature is rotated in the magnetic field these loops of copper wire cut the lines of force at right angles and produce the flow of current. These copper wires are connected to the terminals of the armature, which is known as the commutator (*c*). The wires of the armature are mounted on a heavy iron shaft so they can be rotated in the field. This shaft also performs the same service as a "keeper" to a horseshoe-magnet.

The third important part of the machine is the commutator. This is a small device affixed to one end of the armature shaft designed to collect the current from the armature coils and send it out over the circuit. The



DIRECT-CURRENT GENERATOR



DISSEMBLED VIEW OF DIRECT-CURRENT GENERATOR

commutator (*c*) is made of copper strips which are insulated from each other by sheets of mica or other insulating-material. Each end of each wire in the armature is connected to one of these copper bars in the commutator. The current is picked off of these commutator-bars by the *brushes*, or sliding-contacts, and carried away to the external circuit.

There is a simple rule which, if remembered, will enable any one to understand the action of a generator. If the index finger of the right hand is extended along the armature coil, with the thumb and second fingers at right angles to it, it will show the direction of the current generated, the direction of the magnetic lines, and the direction of motion (Fig. 10).

It is quite necessary to have a number of such loops in the armature in order to have enough potential difference for practical work. By simply increasing or decreasing the speed of the armature the electromotive force, or potential difference, or voltage, is increased or decreased. The electromotive force of the generator depends upon the number of conductors cutting across the lines of force, the speed of the armature, and the density of the field. All generators are built to give a certain amount of current when run at a certain speed.

The capacity of a generator is usually given in kilowatts, inscribed on the name-plate, along with its voltage. To find the horse-power you must multiply the kilowatts by 1,000, to reduce it to watts, and divide by 746, the number of watts equaling one horse-power. A generator rated at 3 kilowatts is equal to $3 \times 1{,}000$, or 3,000 watts $\div$ 746, or about 4 horse-power.

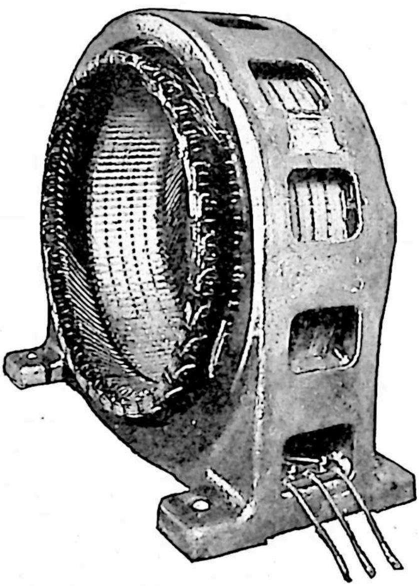
Different Kinds of Generators

Electric generators are roughly divided into two kinds—the *alternating-current* generator and the *direct-current* generator. Of these the alternating-current machine is best known and generally used.

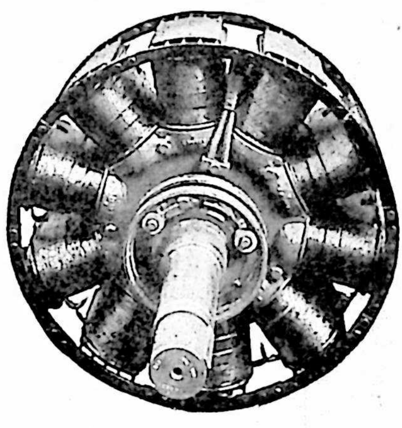
There are a number of different designs of both alternating and direct current generators.

The well-known direct-current machines may be two-pole, four-pole, six-pole, and even more. The field-coils may be excited from an independent source, by *shunt* connection with the circuit, or by series or compound connection. The design of direct-current machines varies with the work it is expected to do.

Although the current in the armature of a *direct-current* machine is alternating in character, the design of a modern alternating-current machine differs materially from the



STATOR FOR ALTERNATING-CURRENT GENERATOR



ROTOR FOR ALTERNATING-CURRENT GENERATOR

direct-current type. The alternating-current generator is usually called an *alternator*. The part that revolves is known as the *rotor*. The frame and part that is stationary is the *stator*. It is the general practice to reverse the order in these machines and revolve the "field," while the "armature" stands still. This is so the armature may be better insulated and not subjected to the centrifugal force of being whirled at high speed.

All generators require power to whirl the armature in the magnetic field. The power required is directly proportional to the current-flow and the voltage. The power required depends upon the amount of work, represented in kilowatts, the generator has to do, plus a small loss in friction and heat. This loss is small, as the efficiency of a good generator is often over 95 per cent. If 100 horse-power is used to drive the machine, 95 horse-power of electrical energy is available for use.

Chapter XVI

CONSTRUCTION DETAILS OF A SMALL GENERATOR

THE smallest generator which can be made on the workbench is but a loop of copper wire whirled between the poles of a good horseshoe-magnet. This device is but a toy. The galvanometer or compass detector will show that it actually produces a pulsating current of electricity (Fig. 1).

The loop of copper wire is mounted on a small wooden shaft, which effectively insulates it. The ends of the loop are brought out to a split brass ring insulated from the shaft. The wooden shaft is supported by a suitable frame and whirled by the small crank. A small pulley affixed to the shaft and belted to a large pulley, which is driven by a crank, will give greater speed.

Making a Magnet

Perhaps you will have to make this magnet. If so select a piece of tool-steel an inch and a quarter wide and an eighth of an inch thick. This steel should be nine inches long so that when it is bent in U-shape it will form a horseshoe four inches high. To bend this piece of steel it will have to be heated. To retemper, heat it a dull cherry-red and plunge quickly into cold water. Test it with a file and when it is quite hard it is ready to be magnetized.

To magnetize this bit of steel lay it face down, with the ends touching the poles of a good horseshoe-magnet. Stroke it gently with the soft iron "keeper" of the magnet. Rub both with the keeper, beginning at the curved end of the magnet and rubbing toward the curved end of the steel. Be careful to rub the steel always in one direction. After twenty strokes turn magnet and steel and rub an equal number of times on the other side in the same way. Be careful in turning to keep the same poles facing (Fig. 2).

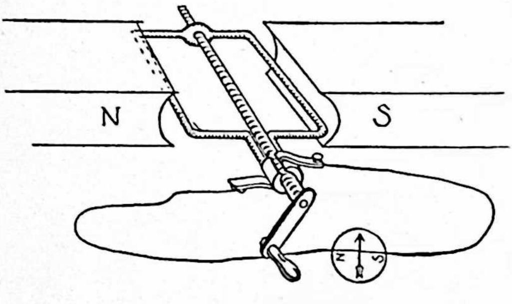


Fig. 1

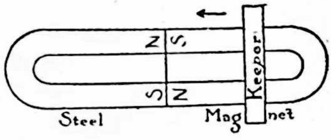


Fig. 2

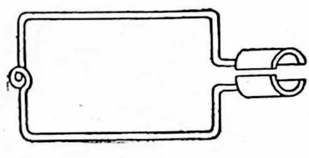


Fig. 3

It is a simple matter to mount this magnet in a wooden frame and arrange the armature shaft and loop. The loop should not touch the sides of the magnet. It should pass very near it, however. The greatest difficulty will be found to connect the ends of the loop with the commutator-rings. This is best shown in a diagram (Fig. 3).

When the armature shaft is whirled rapidly in the magnetic field so the copper loop cuts the lines of force flowing from pole to pole a current of electricity will be generated. The compass detector will show the extent and direction of this current.

This device is but a toy. It is possible to clamp together a number of similar horseshoe-magnets and arrange a drumarmature so it can be whirled rapidly between the poles. In this way a considerable flow of current can be produced. This is really a *magneto* similar to those used for ignition and lighting purposes on automobiles (Fig. 4).

Building a Generator

In constructing a small generator the amateur will always have more or less trouble with the frame and

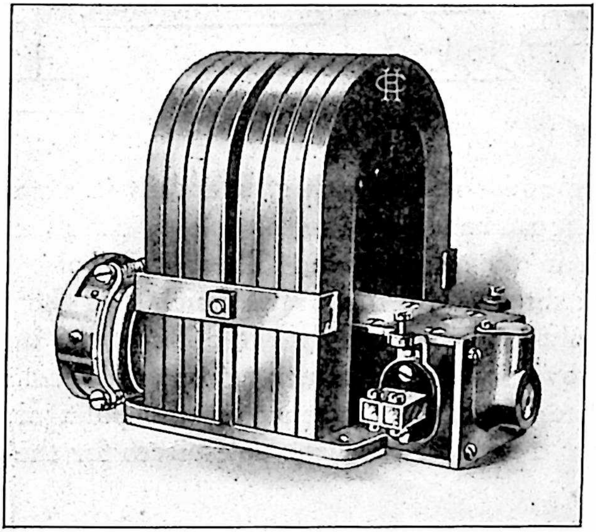


Fig. 4

MAGNETO SUCH AS IS USED FOR IGNITION PURPOSES ON AN AUTOMOBILE

pole-pieces. The frame must be of soft iron. For large-size machines this frame must be cast. For smaller machines it can be made in sections, bolted together. The frame of a small generator of this latter type consists of the electromagnets, the yoke, and the pole-pieces (Fig. 5).

The electromagnets E–E, consisting of spools of insulated copper wire, are slipped on the iron cores C–C and are held together by the yoke Y. The pole-pieces P–P, which direct the lines of force between the poles, can be easily and quickly sawed from a piece of iron pipe. Select a piece of pipe two inches in diameter and as wide as desired, usually

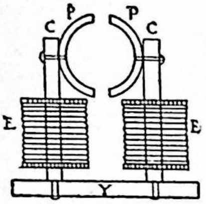


Fig. 5

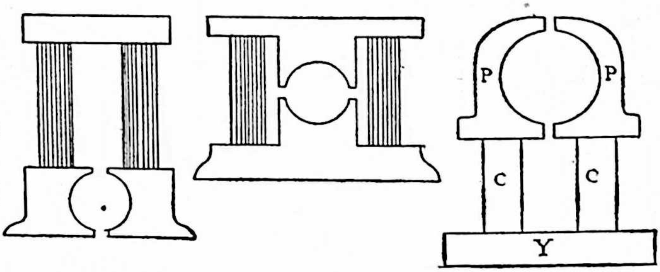


Fig. 6

about one and one-half inches, and drill it exactly in the middle so it can be fastened to the poles of the electromagnet, as shown in the illustration. These drill-holes should be tapped or threaded for the screws which hold them in place. Now with a hack-saw cut out a section of the iron pipe as shown above. Remove an inch at top and bottom. When these plates are firmly fastened to the poles of the electromagnet they form excellent pole-pieces for the revolving armature.

Adjusting the Electromagnet

There is but one possible error in adjusting the electromagnet coils. The wire turns of the coils must be always in the same direction, otherwise the spools will neutralize each other and no magnetism will result. Be sure the spools are wound in the *same direction.* In winding the spools use fine, well-insulated copper wire. Bring the ends of the wire out to suitable terminals for connection with a battery for energizing the magnet.

Frames of Cast Iron

For all practical generators of 25 watts and larger the frame should be of cast iron. A number of different styles of generator frames suitable for the amateur to make are shown in Fig. 6.

There is quite a trick in making patterns for the foundryman. Bear in mind that a "flask," or the frame in which the casting is made, consists of two parts. One-half of the impression is made in the molding-sand in each half of this frame. Patterns should be made of soft wood. White pine is right. For the reason given above all patterns should taper slightly from the "parting line" where the flask opens. This is so the pattern can be easily removed from the sand without spoiling the impression. On all large patterns a little surplus has to be allowed for shrinkage. But for small castings, such as the amateur will require, this is not necessary. However, one-sixteenth of an inch should be allowed if the casting is to be machined or finished. All sharp corners should be slightly rounded, as the sand will not take a sharp edge. A small generator of from 25 to 50 watts will require a casting five inches wide, three inches thick, and ten inches high.

Making the Armature

Making the frame is simplicity itself compared with making the armature. Whether the frame is made of separate pieces bolted together, cast in a whole block, or built up out of pieces of sheet iron cut in the proper shape, makes little difference. The effect will be much the same. But special attention must be paid to the armature, or no current will result.

The armature must consist of a suitable shaft, so it can be rotated, and carefully made slots for the conductor wires. The size of the armature will depend, naturally, on the size of the generator frame and the distance between the pole-pieces. So no attempt will be made to give dimensions in describing the armature. Whether big or little, they are made the same way (Fig. 7).

The armature shaft is made of soft iron. It can be easily worked in a lathe. Being so small, metal cutting-tools are not necessary. The rough shaft can be whirled in the foot-lathe and cut with a file. This is easier and better than filing and assures an accurate, well-centered shaft. It is not so easy to slot the armature. This can be done best with a coarse hack-saw. It can be done with a narrow file, but it is hard work. By all means use a saw if you can.

Winding the Armature

The armature as depicted above is wound with four loops of insulated copper wire. These loops of wire are just long enough to extend entirely around the armature for connection with the commutator segments as shown in Fig. 8.

The coils of wire must fit tightly in the grooves in the armature. Heavy shellac varnish will help to hold them in place. If they are loose they will certainly fly out when the armature is whirled at high speed. Be careful in assembling the coils not to cut the insulation where the wire bends sharply over the edges of the slots. Each end of the copper loop should be soldered to its particular section of the commutator. These sections should be opposite each other on the shaft.

The Commutator

The commutator is nothing more or less than a split ring fastened to the armature shaft. But it must be insulated from the shaft, and each section must be insulated from every other section (Fig. 9).

This commutator consists of eight sections. The problem of insulating them one from the other is easy enough for large machines. Then the sections are large enough to be handled. For small machines this is not so easy.

The best way to make a small commutator is to cut a ring of heavy brass a little larger than the armature shaft upon which it is to be mounted. Mount this on a wooden

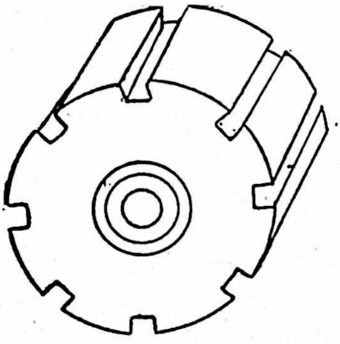


Fig. 7

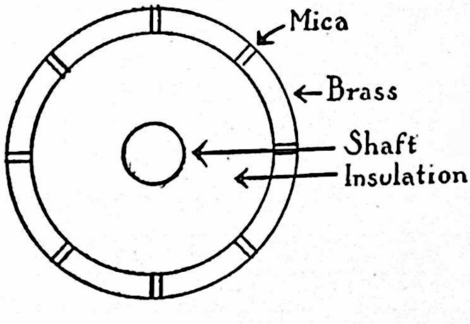


Fig. 9

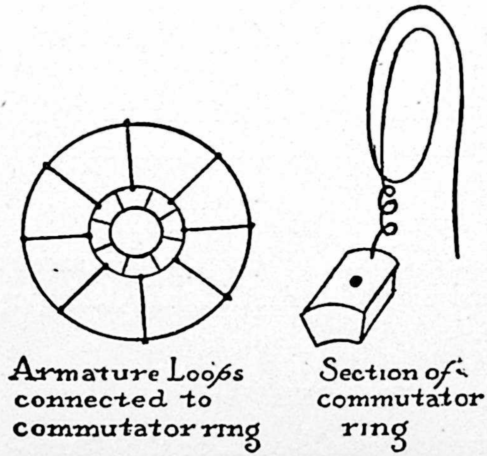


Fig. 8

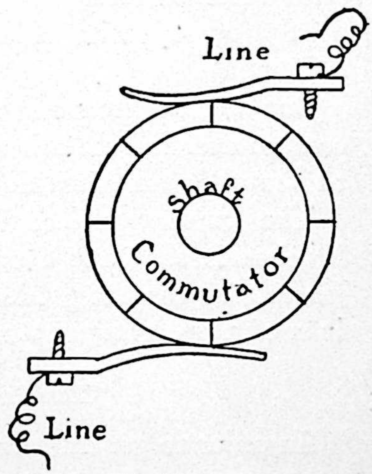


Fig. 10

shaft so it can be handled and worked. Mark this brass ring into its respective sections, using a compass and awl. Saw into each mark, but be careful not to saw way through. Gradually work entirely around the ring until every section is sawed nearly through. Then it will be an easy matter to cut them out. If the ring is split first the sections will become harder and harder to work.

These sections are soldered to the armature loops as described above. The shaft is covered with shellac where the commutator is supposed to fit. While the varnish is still wet slip on a thin sleeve of mica. This will insulate the brass commutator from the shaft. The commutator sections are held in place by hard-rubber rings, or rings of any good insulating-material, or even with rubber bands. Each section must now be insulated from its neighbor with a tiny strip of mica or with sealing-wax.

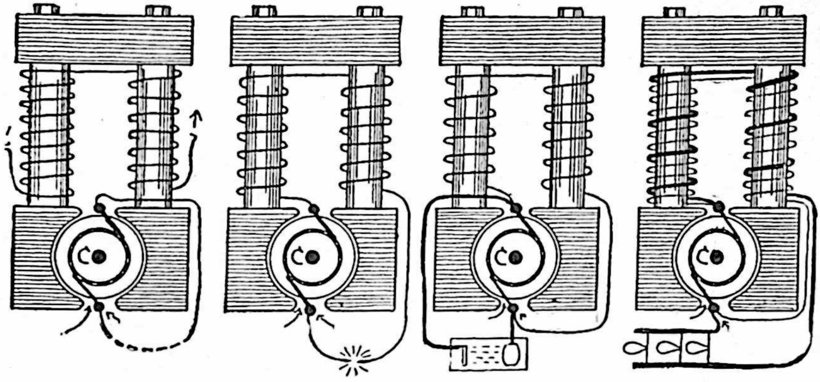
The commutator-brushes, which pick the current from the sections and send it out over the line, always in one direction, are very easily made. They are merely strips of spring-brass fastened to an insulating-base and arranged to press lightly on opposite sides of the revolving commutator (Fig. 10).

One brush collects current from the topmost section of the commutator and the other presses against the bottom section as shown in the illustration.

The current collected from the commutator by the brushes is sent out over the circuit in exactly the same manner as current produced by a chemical battery, except it is of a pulsating nature.

Exciting the Field-Coils

In order to generate current the field-coils, or the electro-magnet, must be excited. A current of electricity must be sent through the insulated wire of the coils or it will not become magnetic. For all small generators a separate supply of current from an ordinary dry-battery cell is best.



A. Field excited by separate circuit.
B. Series-wound armature and field.
C. Shunt-wound armature and field.
D. Compound-wound armature and field.

Fig. 11

For larger generators the "field" may be placed in *series* with the external circuit, or a portion of the current produced may be *shunted* through the field-coils (Fig. 11).

Power for the Small Generator

Hand-power is all right for toy generators. As these must be revolved at high speed, a belt and pulley are necessary. Larger machines must be operated by some form of mechanical power. A small water-motor which can be operated on the kitchen faucet makes an ideal source of cheap power. A small home-made windmill can also be used, or even the gasolene-engine, if the generator is quite large.

To drive a generator with an engine it is necessary to be able to figure the speed of pulleys, shafts, etc. Generators must be driven at high speed, from 1,500 to 2,500 revolutions per minute. In order to determine the speed of a pulley multiply the speed of the "driver" by its diameter in inches and divide by the diameter of the "driven." Thus a pulley two inches in diameter, revolving 1,800 times a minute, will drive a 10-inch pulley at 360 revolutions per minute.

$$1{,}800 \times 2 = 3{,}600 \div 10 = 360 \text{ R. P. M.}$$

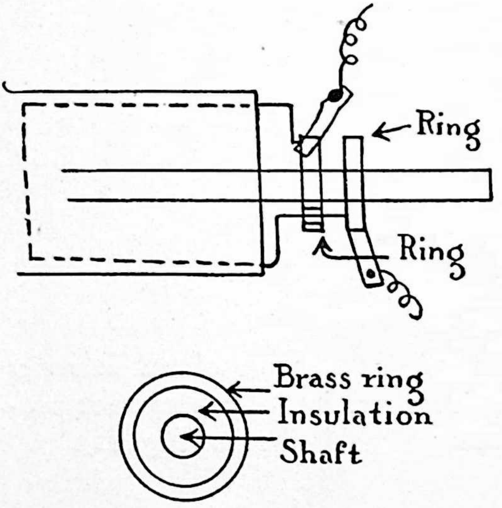


Fig. 12

Small generators can be used to light miniature lamps, to operate small motors, or to experiment with storage batteries, electroplating, etc.

Alternating - Current Generators

By simply placing contact - rings on the armature shaft the generators mentioned above will produce alternating current. These contact-rings must be insulated from the shaft and from each other. They can be made of brass and insulated with strips of mica, or even with hard rubber (Fig. 12).

Chapter XVII

THE DIFFERENCE BETWEEN DIRECT AND ALTERNATING CURRENT

DIRECT current flows always in one direction.

Alternating current pulsates back and forth over the line, first one way and then the other.

At first only direct current was desired. Then all generators were made with split-ring commutators so the alternating current of the armature was always sent out to the external circuit in one direction or in a continuous stream.

As the use of electricity extended it was soon discovered that alternating current had many inherent advantages over direct current. It was easier to generate alternating current in higher voltages. It could be more easily and cheaply transmitted, because the voltage could be raised or lowered at will. For these reasons and others alternating current is now almost entirely used for light and power except in special instances. For the most part, our trolley-lines still use direct current. A number of steam-railroads have been electrified to use direct current. In a few of the larger cities direct-current light and power systems are still in use. And, of course, direct current has to be used in charging storage batteries.

Inasmuch as alternating current is the kind we all use, speaking generally, it is well to stop and give this our serious consideration.

An alternating current, according to the definition, is one that changes its value, and reverses in direction at certain regular intervals.

Now let us see if we cannot understand this better by comparing it with water in a pipe (Fig. 1).

Here we have a cylinder provided with a piston and filled with water. Connected to each end of the cylinder is an endless pipe system. When the piston P is moved toward the other end of the cylinder it forces a certain quantity of water through the pipe circuit. This water flows back into the cylinder behind the piston. When the motion of the piston is reversed and it is moved back an equal amount of water is forced through the pipe system *in the other direction.*

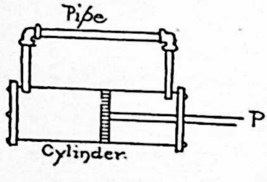


Fig. 1

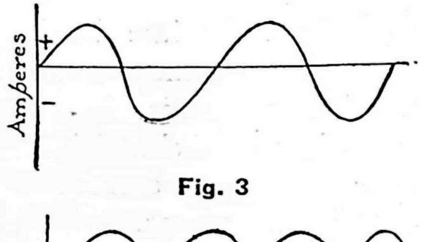


Fig. 3

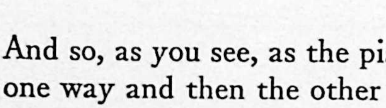


Fig. 2

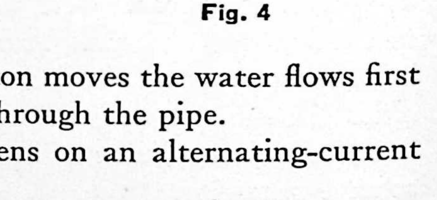


Fig. 4

And so, as you see, as the piston moves the water flows first one way and then the other through the pipe.

This is exactly what happens on an alternating-current electric circuit (Fig. 2).

The current leaves the generator in the direction of the arrows and flows over the wire circuit and back to the generator. As the armature of the generator turns, corresponding to the movement of the piston in the water-cylinder, the current leaves the generator from the other side and flows over the circuit *in the opposite direction.*

Referring again to the single armature loop cutting the invisible lines of force between two magnetic poles, it will be remembered that at the first half-revolution of the loop a current is gradually built up to maximum, flowing from the right to the left, and then gradually drops back to minimum as the loop begins to *parallel* the lines of force. At the second half of the revolution a similar current is produced, but it flows from left to right. This is best illustrated by the current curve shown in Fig. 3.

The flow of current during one half-revolution is called an *alternation.*

Two alternations, or a complete revolution of the loop, is called a *cycle.*

The number of cycles passed through in a second is called the *frequency.*

Of course, there are a number of armature "loops" in a modern alternator. When two or more alternating currents have the same frequency and pass through their values at the same time they are said to be in *synchronism* or in *phase.*

For household use alternating current is generated at sixty cycles. This is too fast for the human eye to see, even if electricity could be seen. An ordinary incandescent lamp will not flicker at sixty cycles because the filament does not get a chance to cool off between the alternations. For power use, for long-distance transmission, and for railway service a frequency of twenty-five cycles a second is used.

A two-phase alternator has two separate windings. These are arranged so that the voltage in one is at zero at the instant the voltage in the other is at maximum (Fig. 4).

By referring again to the armature loops we can readily see how this happens (Fig. 5).

When the coil A is cutting no lines of force the coil B is cutting them at the maximum rate, therefore produces maximum voltage when A produces no voltage.

In the three-phase alternator still another series of windings, or "loop," is applied to the armature (Fig. 6).

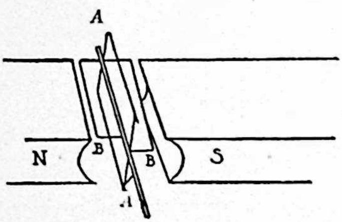


Fig. 5

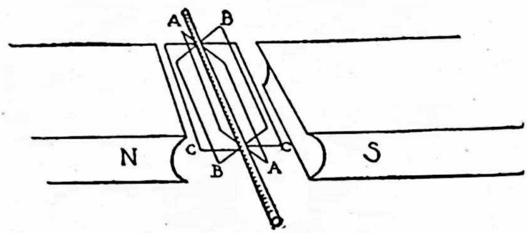


Fig. 6

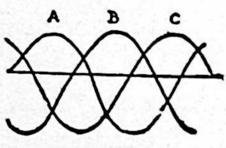


Fig. 7

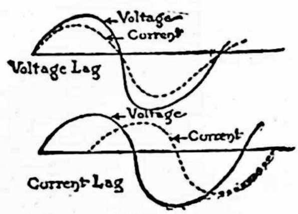


Fig. 8

The action of the three-phase machine is shown in Fig. 7.

Let's see if we have this straight.

An alternator arranged to give to a two-wire circuit a single voltage is called a single-phase machine. An alternator arranged to give two separate and distinct voltages, one of which is a maximum when the other is zero, and *vice versa*, as indicated by Fig. 4, is called a two-phase machine. An alternator arranged to supply to three wires three voltages separated in phase from each other by an angle of 120° (Fig. 6) is called a three-phase machine.

In the alternating circuit not always does the current, or amperage, keep pace with the electromotive force, or voltage. When they travel along together they are said to be in phase. When the current drops behind the voltage it is said to lag. This is shown in Fig. 8.

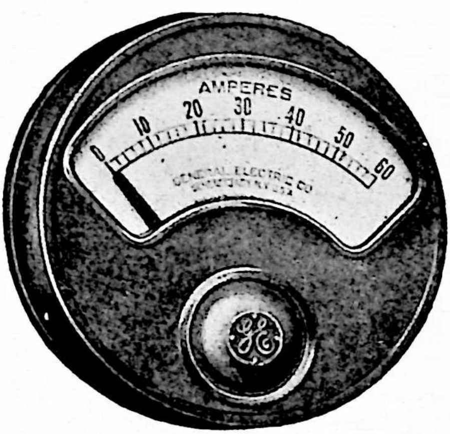
These diagrams used to illustrate the salient points of this chapter are elementary at best. Perhaps the reader will better understand the nature of an alternating generator, or alternator, by referring to the illustration of a modern machine shown in detail in Chapter XV.

Chapter XVIII

MEASURING ELECTRICITY

WHEN they first began to sell electrical energy they were puzzled to know just how to measure it. Inasmuch as electricity is an invisible force, traveling at terrific speed, with many strange ways peculiar to itself, it was not until very recent times that electrical measuring-instruments were perfected.

To find out how much electricity there is we must measure the *voltage*, or pressure, the current-flow, or *amperage*, and the amount of work it will do, or the *watts*. In addition to this a modern power-house equipment calls for instruments to measure power factor, frequency, to detect grounds, etc.



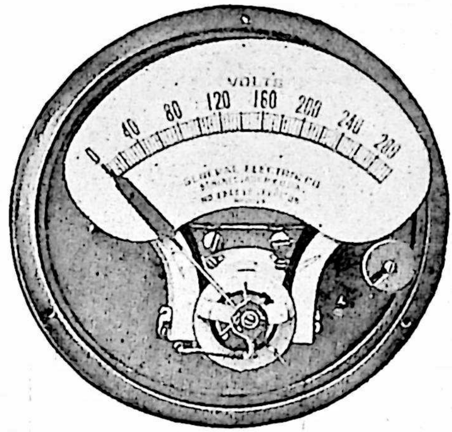
AMMETER

Instruments for measuring current are called *ammeters*. They measure the current-flow, or the number of *amperes*.

Instruments for measuring the electrical pressure, or *voltage*, are called *voltmeters*.

For measuring the energy of electricity, or the amount of work it will do, the *watt-hour meter*, or the *wattmeter*, is used.

Some meters depend upon the action of a magnet or a solenoid for the movement of the pointer over the dial. Others are but small motors, chemical cells, static devices, etc.



VOLTMETER

The simplest of all electrical measuring-instruments is the *galvanometer*. It is only used to register the amount of very small currents. The galvanometer consists of a small upright coil of insulated copper wire provided with suitable terminals for connecting it in the circuit. Inside this coil is mounted a magnetic needle delicately balanced on a very fine strand of silk. Immediately beneath this needle is a circular piece of cardboard upon which is printed the calibrated scale for reading the instrument (Fig. 1).

These instruments are intended for experimental and laboratory use. They are employed in measuring very small currents, and are of especial value in making experiments. The instrument is "set up" so the needle is balanced in the center of the coil, as shown in the illustration. When a very small current is sent through the coil the needle will be deflected, and its strength can be read on the calibrated scale. This instrument also shows the direction of the current through the coil.

Many of the first instruments for measuring electricity were of the electrolyte and hot-wire type. The first Edison measuring-apparatus was nothing more or less than a chemical cell. The weight of metal deposited or of water decomposed by a given quantity of electricity is known. So the electrolyte cell may be used as a quantity-measuring instrument. By taking out the cathode plate and weighing it to see how much metal has been deposited upon it by the passage of the current the amount of current can be determined.

The hot-wire meters depend upon a resistance-wire which is heated by the passage of the electric current. The common type of hot-wire instrument is shown in Fig. 2.

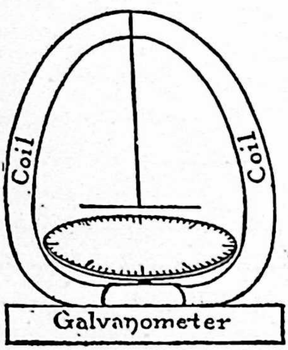


Fig. 1

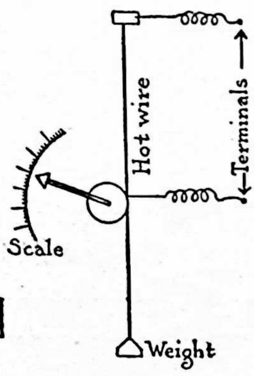


Fig. 2

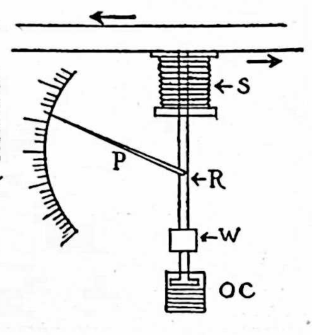


Fig. 3

The first ammeters and voltmeters were of the Kelvin type, with gravity or spring control. This instrument was perfected by Lord Kelvin. Its action is depicted in Fig. 3.

The soft-iron rod R is drawn into the coil, or solenoid, S, in proportion to the current flowing through the line. The movement of the rod up and down causes the pointer P to play over the scale. The rod R is pulled from the coil by the force of gravity acting on the weight W working in the oil-cup OC.

This instrument can be used for either alternating or direct current. The calibration of the dial is determined by the number of turns in the solenoid coil.

The Ammeter

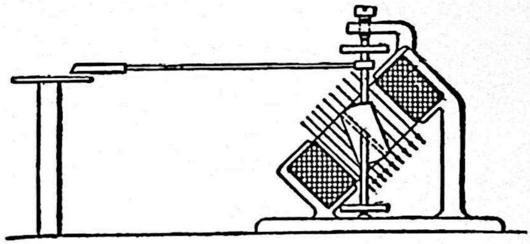


Fig. 4

The *ammeter* is constructed along the same lines as the galvanometer. There are a number of different types of these instruments. In the Thomson inclined-coil ammeter the coil which carries the current is mounted at an angle to the shaft which supports the pointer, or indicator. Mounted on the shaft is a bundle of iron strips, held in position by a spring, so that when there is no current in the coil its position is parallel with the plane of the coil (Fig. 4).

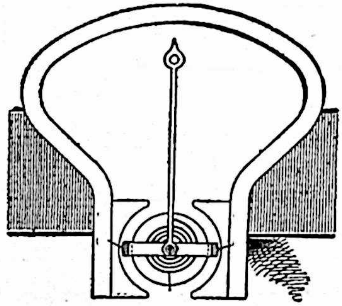


Fig. 6

When a current is sent through the coil the iron strips then take up a position parallel with the magnetic field. This rotates the shaft and moves the pointer.

The plunger type of ammeter works on the principle of a solenoid, or hollow magnetic coil (Fig. 5).

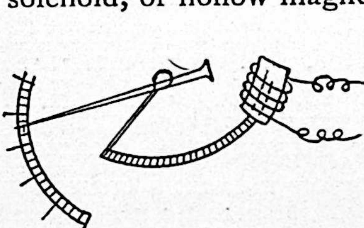


Fig. 5

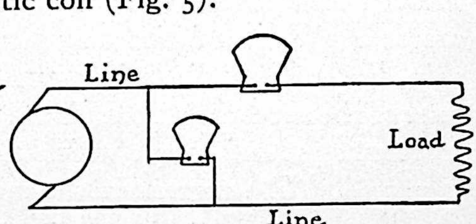


Fig. 7

The current is sent through the coil C, which exerts a magnetic pull on the soft-iron plunger P. This draws the iron rod into the magnetic coil, or solenoid, and causes the pointer to move over the magnetic scale.

The Voltmeter

The voltmeter is built on the same general principle as the ammeter. The principle of the moving-coil voltmeter is best shown in Fig. 6.

To the horseshoe-magnet is fastened two pole-pieces similar to a toy motor. To the pointer is affixed a narrow rectangular coil of wire which swings on a pivot between the pole-pieces of the magnet. Its motion is controlled by a bronze hair-spring. The action of the instrument is due to the fact that the moving coil when carrying a current endeavors to turn into such a position that the lines of force it produces will coincide in direction with those flowing from the permanent magnet.

The voltmeter and ammeter are connected to the line as shown in Fig. 7.

The Watt-Hour Meter

Electricity is sold by the kilowatt-hour. For this reason watt-hour meters are necessary. These show the total kilowatt-hours consumed in the circuit for a given period of time. The wattmeter installed in the home to register the amount of electrical energy consumed is really a tiny electric motor of the most delicate structure and the best workmanship, housed in a little iron-and-glass box. The revolving part of the motor is an aluminum disk mounted between two electromagnets through which the current to be measured is passed. The current in the magnets induces a current in the disk, and this current flowing in the field of the electric magnets causes the disk to revolve with a speed directly proportional to the amount of current that is passing through the magnets. With each complete revolution of the disk a black band is seen to pass the glass-covered aperture in the face of the meter-box, and a definite number of revolutions of the disk indicate that one kilowatt-hour of electricity has passed through the meter.

There are four dials on the face of the meter-box, and the disk is geared to them in such a way that when one kilowatt-hour passes through the meter the disk revolves a sufficient number of times to cause the indicator of the right-hand dial to move one-tenth of the distance around its circle. That is, if the meter is set at zero the indicator on the right-hand dial will move from zero to one in measuring one kilowatt-hour of electricity.

In reading the dial of a meter it is necessary to read the number last passed by the pointer. This is important for accurate reading. The dial farthest to the right is read and the number set down. Then the next dial to the left is read and the number is written just to the left of the first number, and so on until the four readings have been taken and recorded. The numbers are not added together, but are read as one whole number just as they stand (Fig. 8).

As an example, suppose the pointer of the left-hand dial has just passed four, the hand of the second dial is between the one and two, the third is between three and four, and the pointer of the fourth or right-hand dial is between two and three, then the meter reads four, one, three, two. Four thousand one hundred and thirty-two kilowatt-hours have passed through it since it started from zero. The right-hand dial registers kilowatt-hours singly, the next dial registers them by tens, the third by hundreds, and the fourth or left-hand dial by thousands. In every case the number printed above the dial is the number of units registered by one complete revolution of the dial hand. The reading of the previous month is subtracted from the new reading and the resulting number of kilowatt-hours. If the resident's rate is twelve cents per kilowatt-hour a simple multiplication gives the amount of the month's bill.

The house meter is usually read every month. The meter-reader has a record of what the last reading was. By

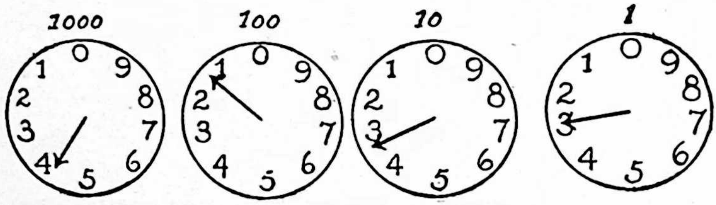


Fig. 8

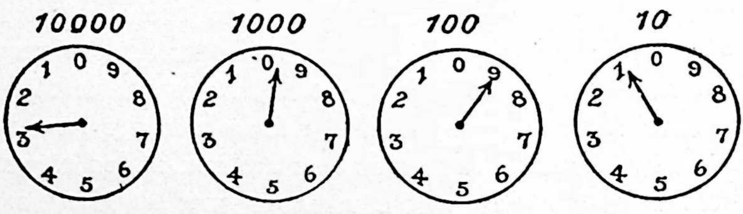


Fig. 9

setting down the present reading and subtracting the former reading from it he can determine the kilowatt-hours consumed in the month—*viz.:*

9,568 = Present reading
9,542 = Former reading

———

.26 = Kilowatts
.12 = Rate

———

3.12 = Amount of bill

In reading the meter be sure to watch two dials at the same time. Take the meter as shown in Fig. 9.

In the dial marked 10,000 we see the pointer between 2 and 3, which means that it did not reach the 3 yet, but to

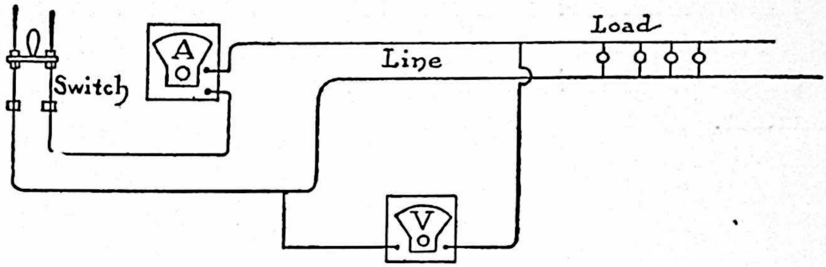


Fig. 10

make sure we look at the next dial and find the pointer between 9 and 10 but not quite reaching the zero mark; we therefore read the first figure as 2 and the second one as 9. The third dial marked 100 shows the pointer just at the figure 9, but we do not know whether it has already reached 9 or it is still 8; we look at the last dial to the right and see the pointer at 1, showing that the third figure has already gone beyond 9, and the last two figures are 9 and 1, the number of kilowatt-hours being 2,991, provided there is no multiplier to be used with this meter. In this manner by watching the dial next to the right of the one which is

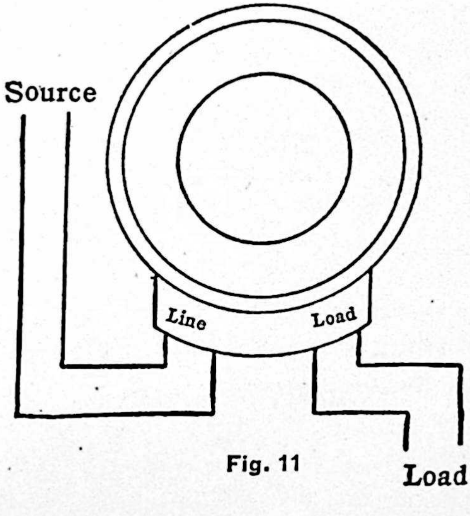


Fig. 11

being read it is easy to make sure of each figure in succession from left to right.

The voltmeter and ammeter are connected to the line as shown in Fig. 10.

The wattmeter is connected to the circuit as shown in Fig. 11.

Other electrical instruments are of no interest to the amateur.

Chapter XIX

TRANSFORMING ELECTRICAL ENERGY INTO MECHANICAL ENERGY

ELECTRICAL energy can be changed to mechanical energy. This transformation is brought about through the medium of an electric motor.

The mechanical energy of a steam-engine is changed into electrical energy by the generator, or dynamo. This energy is sent out over the wire circuit. It may be changed back again into mechanical energy at any point and with trifling loss by the use of an electric motor.

There is no mystery about the electric motor. It is merely a reversal of the process by which a generator produces current. *In fact, a generator may be used as a motor by simply connecting it to an electric circuit.* The power of the electric motor is the product of the *force* exerted between a magnetic field and a conductor carrying an electric current.

Look at an ordinary electric motor. You will observe that there are no sliding-pistons, no buckets, no belts, no gears, nothing to indicate where the mysterious power comes from. The motor consists of two essential parts—the frame and coils which combine to form the magnetic field and the rotating part, or armature, carrying the copper conductors. There is nothing to indicate whence comes this energy which turns the armature between the poles of the field-magnets.

The armature does not touch the pole-pieces of the field-coils, and yet it spins at high speed. Apparently no moving force is acting on the armature, and still it will produce enormous power. The motion of a small armature in a one-kilowatt (1-⅓ horse-power) motor is so easy, so smooth, so noiseless that any one not familiar with its power would think it could be stopped with the pressure of a finger. Don't try it! Invisible this force may be, and hard to comprehend, but it is not to be denied.

Let us try a few experiments and see if we cannot discover this source of power.

We know from previous experiment that every magnet is quite surrounded with invisible rays called *lines of force*. These rays seem to pour out of the north pole and flow through the surrounding air to enter the south pole (Fig. 1).

This is equally true of every wire carrying an electric current. A magnetic field is set up about the wire. Inasmuch as there are no north and south poles to such a wire the lines of force are distributed about the wire in circles, moving from left to right (Fig. 2).

Remember that lines of force are constantly flowing between the magnetic poles in the field of the motor and another set of lines of force is flowing around the wires of the conductor in the armature of the motor (Fig. 3).

The action of these opposing forces tends to push the armature wire down between the poles of the magnet when held in one position and up when held in another.

Take a copper wire which is connected to a good battery and move it between the poles of a powerful horseshoe-magnet (Fig. 4).

When the copper wire A, which is carrying a flow of current from the battery, is moved between the poles of the magnet without touching them an invisible force will seize upon the wire and tend to move it from the magnetic field. *The force which moves this wire depends upon the strength of the magnet and the amount of current flowing through the wire.* If a very powerful electromagnet is used and a heavy current sent through the wire you will be surprised at the force exerted.

The energy of an electric motor is secured by placing many such armature wires, carrying heavy currents, between the opposing poles of strong electromagnets.

The force which moves the wire in the experiment described above is utilized in the motor to rotate the armature.

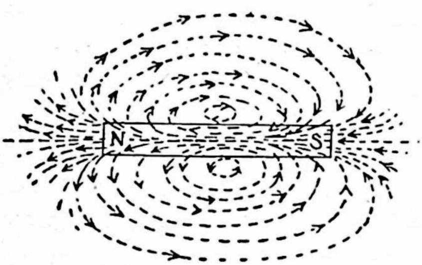


Fig. 1

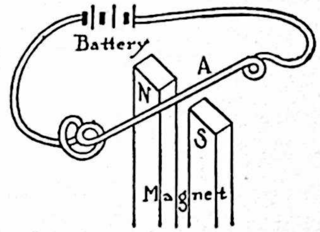


Fig. 4

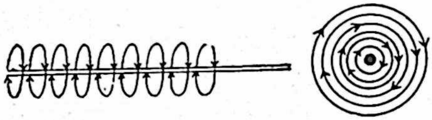


Fig. 2

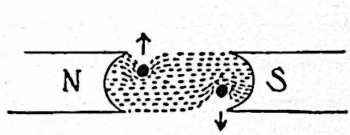


Fig. 5

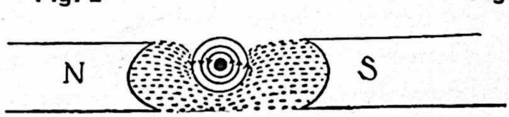


Fig. 3

The wires of the armature are arranged in the form of loops. With this arrangement the current flows in opposite directions when the wires are near opposing poles. So, as you see, the magnetic force which is *pulling* one side of the loop down is *pushing* the other side up (Fig. 5).

When the lines of force are pushing up the left side of the loop before the north pole the same force is pushing down on the right side of the loop before the south pole. When the armature loop is pushed out of the way another immediately takes its place. In this way, and by using several poles, the motion of the armature is made continuous.

Direct-Current Motors

There are two kinds of electric motors—direct-current and alternating-current. Only direct-current motors can be used on direct lines. By this same rule only alternating-current motors can be used on alternating-current lines.

Direct-current motors are subdivided into three classes—*viz.*, *series*, *shunt*, and *compound* motors. Their class is determined by the manner of connecting the field and armature windings. Each class has its peculiar field where it is best suited for the work in hand.

The series motor has the armature and field windings connected in series (Fig. 6).

The series motor is best adapted for intermittent service where heavy loads must be brought to full speed without an excessive demand for energy. They are generally used for elevators, hoists, street-cars, electric railroads, etc.

When unloaded, a series motor will race and continue to increase in speed until the armature is destroyed by the great centrifugal force set up. When a heavy load is thrown on the series motor the speed of the motor decreases, resulting in large currents through both armature and field, resulting in stronger pull to take care of the increased load; on the other hand, when a heavy load is thrown on the shunt motor the speed remains about as before, and the motor has to get its increased pulling-powers from increased current in the armature only. The shunt motor cannot slow down like the series motor and take the increased load at a slower rate, but must tackle the job at about the same speed it maintains on a light load. In order to take care of the same loadings, therefore, the shunt motor would have to be much larger than the series motor. In short, when a fairly constant speed is desired a shunt motor can be used, but

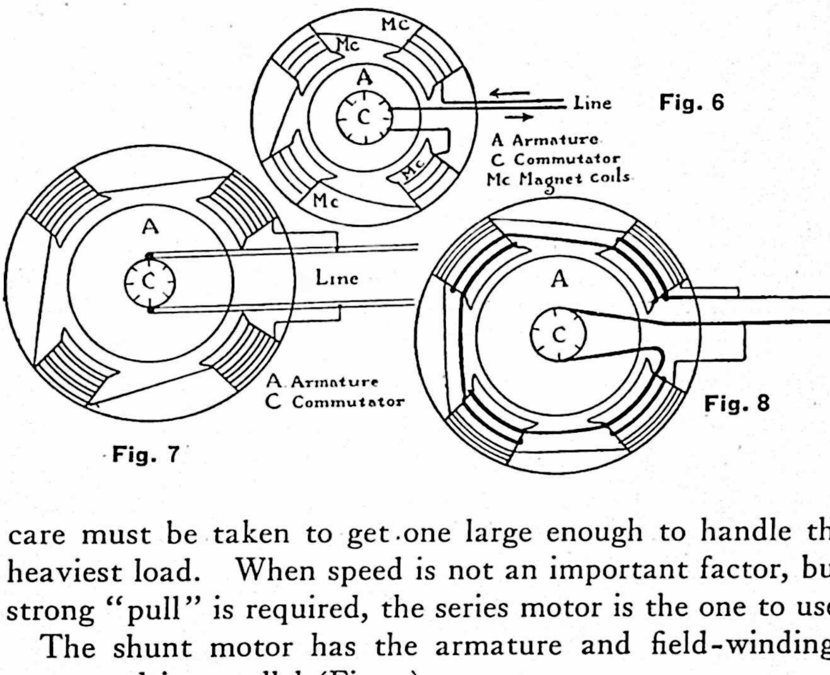


Fig. 6

Fig. 7

Fig. 8

care must be taken to get one large enough to handle the heaviest load. When speed is not an important factor, but strong "pull" is required, the series motor is the one to use.

The shunt motor has the armature and field-windings connected in parallel (Fig. 7).

This is a constant-speed machine, regardless of the load. The only way to regulate the speed of a shunt motor is to insert resistance in series with the armature, which decreases the speed, or to insert resistance in the field, which increases the speed. But placing resistance in the armature circuit is a waste of energy. Only a certain amount of resistance can be placed in series with the field without excessive sparking.

The compound motor, as the name suggests, is a combination of the series and shunt type (Fig. 8).

This machine has two distinct field-windings, one in series with the armature and one in parallel with it. The speed of this motor depends upon the relative value of the shunt and series windings.

Alternating-Current Motors

The alternating-current motors are divided into three general classes—the *induction-motor*, the *synchronous motor*, and the *commutator-motor*. The induction-motor is practically a constant-speed machine. The rotor may be either short-circuited or wound. In motors of the wound type the speed may be increased by inserting resistance in the rotor circuit. The squirrel-cage type of induction-motor is very simple. It is compact and reliable wherever a constant speed is wanted. It will start under full load. If started with a light load an automatic starter, or *compensator*, is used to keep the current within the safety limit. In the wound type of induction-motor slip-rings are provided so resistance may be inserted in the rotor circuit to vary the speed.

The synchronous motor will not start under load. It must run at one speed. The field is excited by an independent source using direct current. They are seldom used except where constant speed is necessary and a large amount of power required.

In the synchronous motor the electrical energy is impressed upon the armature, fed directly to it from the line, and the fields excited from a separate direct-current source. In the induction-motor the electrical energy from the line is impressed on the field, the current in the armature being induced by transformer action. The induction-motor is essentially a constant-speed machine. Its speed can be varied by varying the number of poles in the field.

The synchronous type of motor is not in common use. It is seldom employed where the induction-motor can be used, but it has marked advantages over the induction-motor in some cases. It could be used advantageously in place of an induction-motor where the latter would seriously interfere with the voltage regulation of the line. It requires more care than an induction-motor, is not self-exciting, and is not easily started. Single-phase synchronous motors cannot start themselves at all; they must have an auxiliary starting-device. Two and three phase synchronous motors will start themselves if they are free of load. After they attain normal speed they can be loaded to capacity.

The commutator-motor is a later invention. It has the advantage of permitting a wide range of speed by varying the voltage.

There are three different classes of the above-mentioned alternating-current motors—*single-phase*, *two-phase*, and *three-phase*. Each class has its own peculiar characteristics and uses.

Devices are made so a single-phase motor can be used on a two or three phase line, or *vice versa*.

The dissembled view of a five-horse-power induction-motor will enable any one to understand its construction (Fig. 9).

Power Applications in the Home

The burden of housework has been materially lightened by electricity. Small motors are now made purposely to drive the washing-machine and the wringer, to operate the

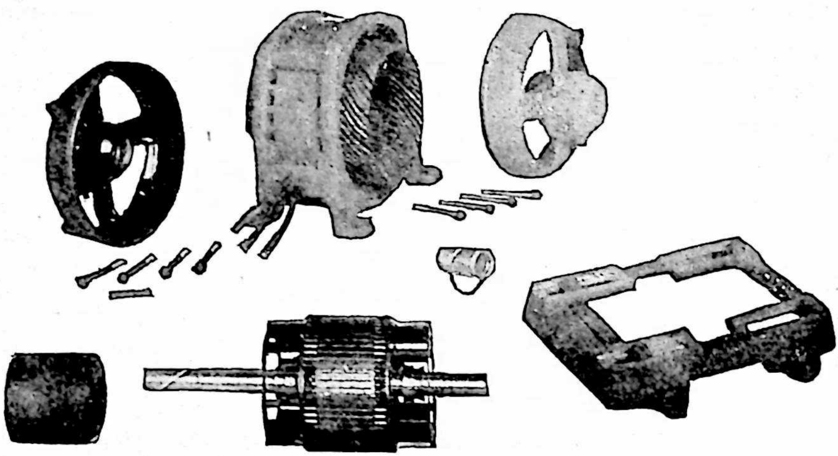


Fig. 9

DISSEMBLED VIEW OF A FIVE-HORSE-POWER INDUCTION-MOTOR

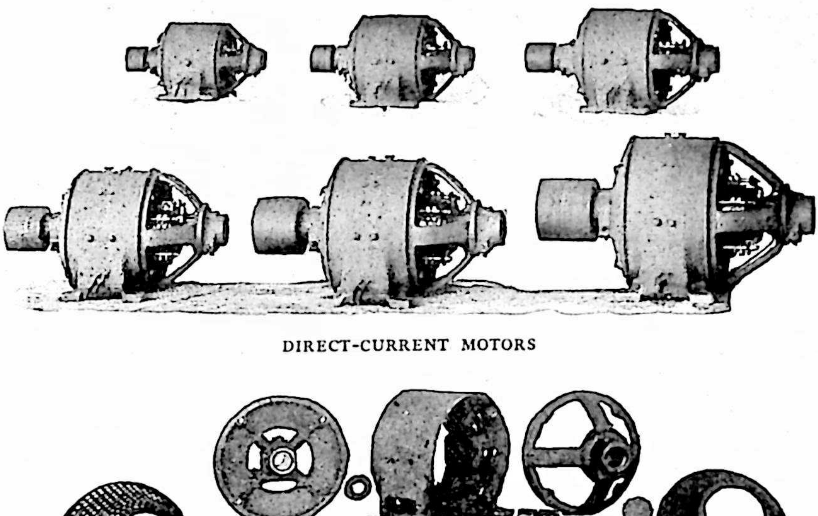
vacuum cleaner, to sharpen knives, grind the foodstuffs, freeze the ice-cream, and to do all the other hard work about the house. These motors are very easily installed. Nearly all of them can be connected to the lighting circuit with an ordinary screw-plug and flexible cord which is readily attached to the electric-light socket in place of the lamp.

Electric Fans

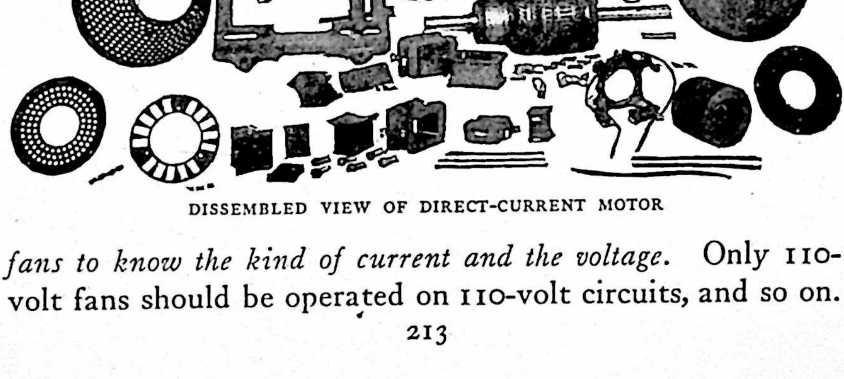
Electric fans are made in many sizes and styles, including desk-fans, ceiling-fans, oscillating-fans, wall-fans, etc. The ordinary portable eight, ten, and twelve inch fans are best suitable for the home. They cost but a few dollars each. The eight-inch fan (its size determined by the diameter of the fan) is light and easily carried from room to room. It consumes even less current than a small electric lamp and may be operated all day long for four or five cents. The ten and twelve inch fans take but little more current.

The electric fan is nothing more or less than an ordinary metal propeller fan of four or six curved blades, affixed directly to the armature, or rotor, of the tiny motor. The whole is mounted on a suitable base and standard. The revolving blades are protected by a wire guard or screen. The whirling blades catch the air and propel it out in a strong current. These fans are also made to oscillate, to swing back and forth, if desired.

Fans are made for both direct and alternating current and for any standard voltage. *Care should be taken when buying*



DIRECT-CURRENT MOTORS



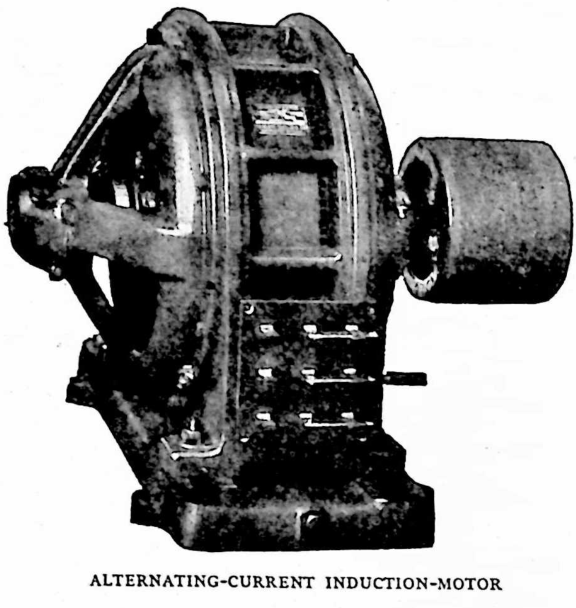
DISSEMBLED VIEW OF DIRECT-CURRENT MOTOR

fans to know the kind of current and the voltage. Only 110-volt fans should be operated on 110-volt circuits, and so on.

Direct-current fans will not run on alternating-current lines, and *vice versa*.

The Kitchen Motor

A small motor can be arranged in the kitchen to do much of the hard work in connection with the preparation of food. This motor is easily connected to the ice-cream freezer, the coffee-grinder, butter-churn, dough-mixer, fruit-press, potato-peeler, meat and food chopper, washing-machine, wringer, and ventilator, and for any other applications where power is required.

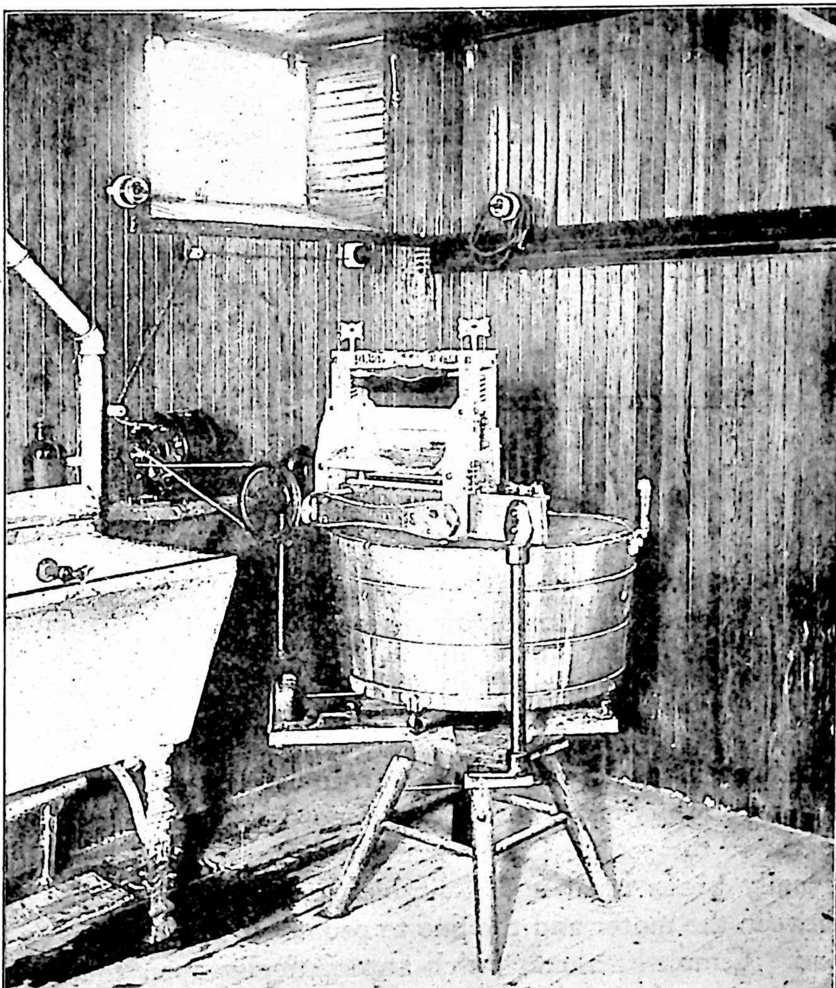


ALTERNATING-CURRENT INDUCTION-MOTOR

A small one-sixth to one-quarter horse-power motor is amply large enough for the kitchen. These motors can be operated from the lamp-socket. They consume about 300 watts of electricity. Each motor is provided with a slotted base so it can be bolted to the floor, walls, or ceilings. The kitchen devices can be operated by a system of shafting and suitable pulleys (Fig. 10).

The proper speed for each device is determined by the size of the pulleys used. The method of figuring pulley-speeds is described in a previous chapter.

A small motor is excellent for driving the small tools of



MOTOR-DRIVEN WASHING-MACHINE AND WRINGER the boy's work-shop, such as the lathe, saw, and boring-mill. It can also be connected to the grindstone, ash-sifter, cream-separator, and any other small power device.

A small electric motor is almost a necessity on the country place or farm where electric current is available. Every day the electric wires are reaching farther and farther into the country. More and more country people are installing electricity for light and power.

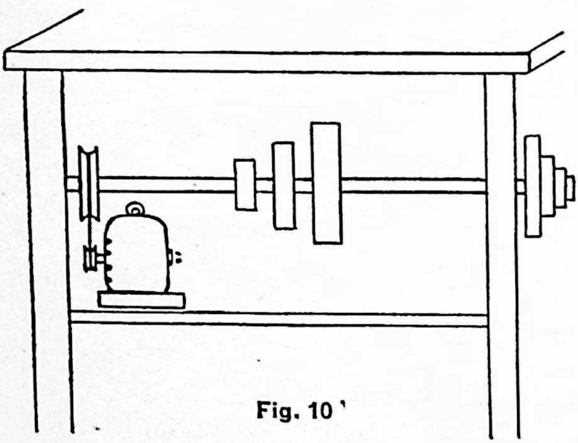


Fig. 10

The first cost of a one-horse-power motor is about fifty dollars; the average operating cost of the motor will be about six cents per horse-power-hour.

Installing Electric Power

In installing electric motors care must be taken to see that they are properly fused. Any motor will work itself to death, so to speak. It will struggle with any load until it actually burns itself up. Suitable fuses should be placed between the motor and the line to protect it in case of overload. Circuit-breakers, which automatically open the line when too much current tries to pass, are used for this purpose with large motors. The circuit-breaker is a spring-switch operated by an electromagnet. An excessive current operates a trigger, and the spring throws the switch open.

Electric motors are the most convenient form of power. They can be had in all sizes, from a mere fraction of a horse-power to single units of 6,000 horse-power. They are free from noise, dirt, and danger, and are adaptable to all forms of work. Electric power is gradually superseding all other forms in mills, factories, machine-shops, etc. As the electric motor can be connected to the machine itself, it eliminates all power loss through long shafts, pulleys, and flapping belts.

When buying a motor you must know whether it is to be used on direct or alternating current and the electrical pressure of the line, or voltage.

If your place is supplied with alternating current, buy an alternating-current motor only, and be sure to specify whether it is *single* or *polyphase* current and the number of cycles.

Alternating-current *induction-motors* can be safely used in the house or barn without fear of fire, as they will not spark. Direct-current motors for farm service should be installed in a separate fireproof building or inclosed with a protective cover.

Chapter XX

HELPS FOR THE SMALL MOTOR-BUILDER

THE first electric motor should be but a toy. Never attempt to construct a motor of any size until you have fully mastered the construction details of a little one.

Toy motors are not hard to make. If one has a fully equipped work-room with a small lathe the task is very simple. Lathes and work-shops are not absolutely necessary. A very good motor can be built with very few tools on a corner of the kitchen table.

Not every boy has a good metal lathe, with the proper tools for turning and finishing iron. Excellent work can be done with a wood-turning lathe for small work by using soft-iron parts and turning them down with a file. Center the work in the lathe, turn rapidly, and hold the file against the part to be cut away. In the absence of a lathe the iron parts of the motor can be built up out of sheet-iron strips.

By following the instruction given below, illustrated in detail with drawings, a toy motor can be easily constructed.

For the sake of simplicity let us combine the motor frame and the electromagnet into one piece. It would be a very difficult job to make this frame of a single piece of iron unless a pattern was made first and a casting poured. But we can make even a better frame by building it up out of sections, or laminations, cut from sheet iron. Sheet iron is soft and can be readily cut with a pair of tinsmith's shears or a fine metal saw. If it bends it can be readily straightened with a block and mallet. The rough edges left by the shears or saw can be easily worked down smooth with a file. First make a good pattern out of heavy cardboard to the dimensions given in Fig. 1.

Lay this pattern on a piece of sheet iron and cut out a duplicate. Work carefully and cut true to the pattern. When the section is cut in the rough finish it down smooth and nice with a file. Use a round file on the pole-pieces and see that they are circular and true.

When the first section is done cut out enough more strips to build up a frame for the motor one inch thick. If the sections are straightened out with a mallet and block it is not necessary to bolt them together. One of the sections, the middle one, should be left with a notched spur on either side so the frame can be fastened to the base when completed (Fig. 2).

The sections of sheet iron are stacked together and bound firmly in place by wrapping with insulation tape or cloth dipped in shellac varnish. Wind this firmly about the "necks"; cut away for the electromagnet-coils. The electromagnet is wound with five layers of well-insulated fine copper wire. Lay on five layers to each coil. Be sure to have an equal number of layers, and see that the wire is wound the *same way* in both instances. Fig. 3 shows the frame with one coil wound and the other side with the insulation ready to receive the second coil. The ends of the copper wire are brought out behind the frame and fastened to terminals for connection with the battery cells.

Making the Armature

Nearly every one has difficulty making the first armature. This is usually the result of too much haste. In the hurry to get the motor done—for youth is often as impatient as enthusiastic—the important little details of the armature are slighted, and consequently the motor will not run.

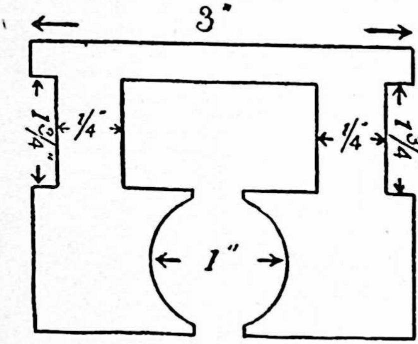


Fig. 1

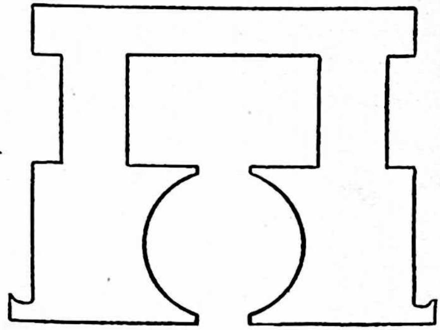


Fig. 2

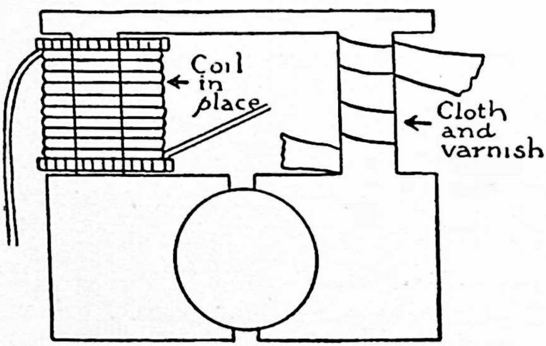


Fig. 3

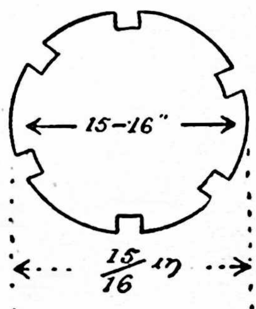


Fig. 4

Build up the armature out of sheet-iron disks much the same way as the frame was constructed. The diameter of the frame inside the pole-pieces is one inch. Therefore the armature must be a trifle less so it can revolve between the poles without quite touching. Cut out a disk of cardboard as shown in Fig. 4.

The disk should be fifteen-sixteenths of an inch in diameter. This will leave the thickness of a sheet of paper between the finished armature and the pole-pieces. Mark the disk into six equal sections, as shown above, where it is to be cut for the insertion of the armature coils. When the cardboard disk is done, cut out as many sheet-iron disks as there are sections in the frame, or so the armature will be equally as thick as the frame. Drill a hole for the armature shaft exactly in the center of each section. With a small file cut the slots for the coils. Be exact about this cutting. They must be true to the pattern.

Mounting the Armature

The armature is mounted on a rod or spindle. Thread the spindle at each end so the armature sections can be fastened in place with lock-nuts as shown in Fig. 5.

It is easy enough to mount this armature in a wooden frame so it can be whirled between the poles of the electro-magnet without touching. If it should touch any little

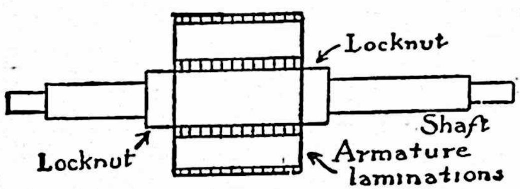


Fig. 5

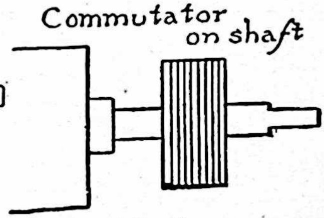


Fig. 6

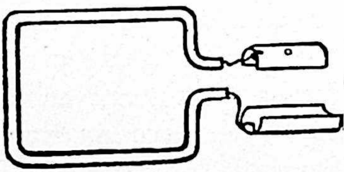


Fig. 8

Fig. 7

irregularity can be corrected with the use of a sharp file. Do not forget that files get dull from service the same as any other tool. It is not practical to sharpen files. Old ones are thrown away.

Making and mounting the commutator for this motor requires more skill than making any other part. The best and easiest way is to make a small wooden ring which can be slipped over the armature shaft. This ring may also be turned from hard rubber, lava-board, or any other good insulating-material which can be readily worked. Over this ring mount a thin brass sleeve. Tack the brass to the wood in six places as shown in Fig. 6.

If small tacks are hard to get make them out of pins with a file. When the tacks are all in place cut the brass ring into six sections as shown in Fig. 7 and fill the cuts with sealing-wax.

The armature is wound with six loops of insulated copper wire. One end of the wire is fastened to a section of the commutator, either through a small hole or by soldering. The wire is wound once around the armature and fastened to the opposite section of the commutator (Fig. 8).

When all six of these coils have been laid in place the armature is ready to be mounted in the frame so it can be whirled between the pole-pieces of the electromagnet. The armature shaft can be set up in a small wooden frame. First the screw-threads should be filled with solder and smoothed off with a file. Sealing-wax can be used for this purpose, but it will not last so long as solder. The commutator brushes are merely two strips of brass arranged to press lightly against opposite sides of the commutator (Fig. 9).

This type of motor is connected so the armature and the field are in series. Two or three ordinary dry-battery cells ought to make it run very nicely.

A Larger Motor

The design for larger motors varies considerably.

In order to assist those who are interested in motor-building the following plans and specifications have been prepared for a motor large enough to operate a small fan

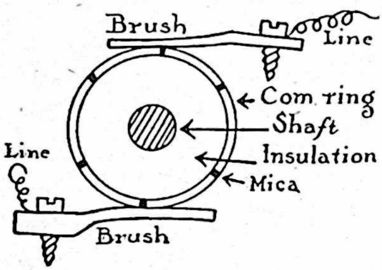


Fig. 9

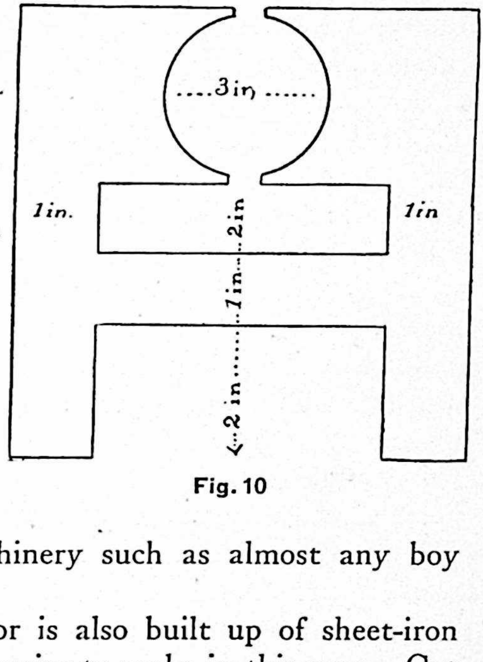


Fig. 10

or to drive the toy machinery such as almost any boy possesses.

The frame of this motor is also built up of sheet-iron sections because they are easier to make in this way. Cut out, as before, a cardboard pattern to the dimensions given in Fig. 10.

The pattern cannot be made perfectly true without using a square and compass. Work carefully and be sure that the pattern is laid out exact before cutting the cardboard with a sharp knife. When the pattern is done, lay it on the sheet iron and cut out a duplicate. The sheet iron can be cut best with a hack-saw. This is a fine ribbon saw fastened in a suitable handle and made purposely for cutting iron. It will saw soft iron, such as sheet iron, almost as fast as a common saw will cut hard wood. By using a fine saw even the pole-pieces can be cut out, but they must be finished with a round file. It is best to lay the cardboard on the iron and mark the pattern out carefully with a scratch-awl, running the awl around the edge of the pattern. The following sections can be cut very easily by fastening the first finished section and the next strip in a good vise and sawing out the iron with the hack-saw.

Saw out and finish enough sections to build up a pile one inch thick. The two sections which form the outside of this frame should be cut with "lugs," which can be turned up with a pair of pliers. They are drilled for the bolts which fasten the finished frame to the wooden base of the motor.

Mark each section of the frame for the binding-bolts, and drill four holes in each piece. Unless you can be exact with this work it is better to stack the sections, fasten them firmly together so they will not "creep," and drill the four holes through the entire pile. Otherwise the holes may not jibe when finished. Insert bolts and fasten sections in place.

Wind the electromagnet (the center connecting "neck" of the frame) with No. 18 gage cotton-covered copper wire, first covering that portion of the frame with cloth soaked in shellac varnish. When the first layer is on, cover with cardboard and varnish before starting the next layer. The finished coil should be about half an inch deep. This will require eight or ten layers. Be sure to leave long ends for making proper connections with the circuit.

When a battery current is sent through this coil the frame will be strongly magnetic. Test it to see if it is all right in this respect before continuing.

Another Type of Armature

A motor armature is a wonderful bit of mechanism. It assumes a hundred different shapes and forms as one progresses in motor construction, from a single loop of copper wire to an intricate winding difficult to understand.

For a motor of the size given above, standing nearly eight inches high, calling for an armature nearly three inches in diameter and an inch thick, a different type must be used.

The armature for this motor is built of strips of sheet iron, or *laminations*, laid one upon another into a pile an inch thick. These armature laminations must be made with care, by the same process and tools as used in making the laminations for the frame. Make a good cardboard pattern as shown in Fig. 11.

It is easy enough to make this armature and to mount it upon a metal shaft, but winding it is quite another thing. Before any attempt is made to wind it a three-section commutator must be made and affixed to the shaft. A ring, or sleeve, of insulating-material is affixed to the armature shaft as in all motors of this kind. Cut three pieces of thin brass with an "ear," or lug, as shown in Fig. 12.

Tack these sections on the insulated part of the commutator so the lugs are toward the armature laminations. *Be sure* that the spacing between the three sections of this commutator occupies exactly the position in relation to the armature laminations as shown in Fig. 13.

The armature is now ready to wind. Secure a small quantity of No. 22 cotton-covered copper wire. Cover the armature legs with a coating of paper and shellac and dry thoroughly. Now wind on four layers of the wire on each leg, or pole. Insulate each layer from the next with paper and varnish. Begin to wind from the bottom of the leg

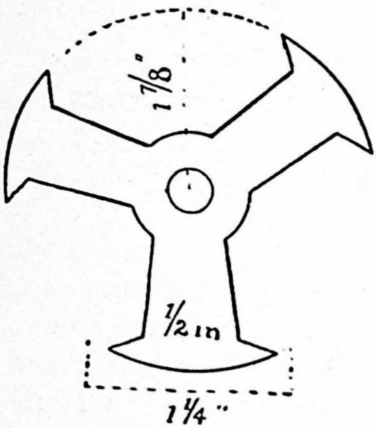


Fig. 11

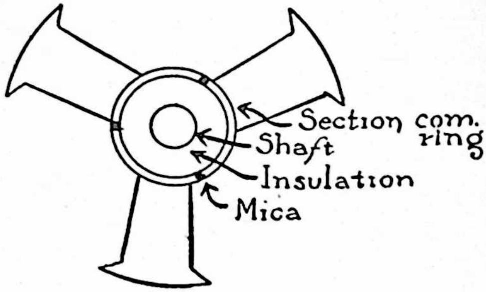


Fig. 13

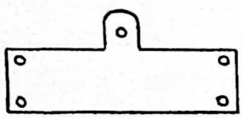


Fig. 12

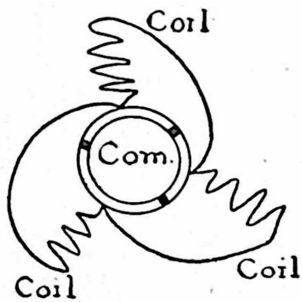


Fig. 14

nearest the shaft, leaving three inches of end so the wires can be connected to the commutator later. Wind all three coils in the same manner and *in the same direction.* The *outside* end of the first coil is now connected to the *inside* end of the next coil. All three coils are connected together in this way and fastened to the ears of the commutator as shown in Fig. 14.

Study the drawings carefully. Be sure the armature-windings are put on and connected as shown. Be doubly certain that the commutator sections are arranged per diagram.

Assembling the Motor

Set the frame up on a polished hard-wood base an inch and a half thick and somewhat larger than the entire motor to give it stability. Screw the frame firmly to this base at the four corners. The screws pass through the lugs on the end laminations of the frame heretofore described and left for this very purpose.

A frame is necessary to support the armature between the pole-pieces. This frame can be built up of wood on either side of the motor or can be made of ordinary strips of one-eighth-inch brass bolted to the motor frame. The brushes, which send the current through the armature coils, are merely strips of spring-brass mounted on an insulated base and provided with binding-posts for convenience in connecting up the motor.

When the motor is assembled connect the armature and field-winding in *series* with three or four ordinary dry cells. The motor can be reversed at will by installing a small reversing-switch on the base. The speed can be varied by placing a little resistance in the armature circuit. By mounting a pulley on the armature shaft this motor will develop considerable power for its size.

Generators Can be Used as Motors

As noted elsewhere, generators can be used as motors by sending a current of electricity through them. Therefore the small generators described in the chapter devoted to that subject can be used as small motors.

It may well be that some who read these pages will aspire to make a small one-eighth to one-quarter horse-power motor for operation on the regular household circuit. Inasmuch as these circuits vary so widely, being all the way from low-voltage direct current to single, two, and three phase alternating current of 110 to 250 volts, no attempt will be made to describe such a motor. Those who have the time and the tools, and who have progressed in the subject far enough to be capable of the work, must first determine exactly the kind of current available before they attempt such a motor. For instance, a one-quarter-horse-power motor suitable for low-voltage (20-volt) direct current cannot be used on 110-volt polyphase alternating current. For the latter a specially designed machine is necessary. Neither can a 110-volt alternating-current motor be operated on a 250-volt circuit.

Chapter XXI

THE INDUCTION-COIL AND THE OPERATION OF THE TRANSFORMER

THE study of induced currents leads afar into the wonderland of electricity.

A piece of iron held near a magnet becomes magnetic. This is due to *induction.* The qualities of the magnet are transferred through the air to the iron.

A piece of iron wrapped with an insulated wire through which a current of electricity is flowing also becomes a powerful magnet. This magnetism is also induced in the iron by the process known as induction.

Induction means *to lead* in from one to the other. The current of the insulated wire, so to speak, is *led in* to the iron core and it becomes magnetic.

Move a copper wire between the poles of a magnet, and a current will be induced or *led into* the wire.

Induced currents are always the result of the cutting of *lines of force.* The amount of electromotive force *induced* depends upon the following factors:

The speed of the conductor moving across the lines of force. The more rapid this movement the greater the E. M. F. induced.

The strength of the magnetic field, or the number of lines of force. The stronger the field the greater the E. M. F. induced.

The number of conductors cutting the lines of force. The more conductors the more E. M. F. induced.

The induced electromotive force depends upon the number of lines of force *cut per second.*

Suppose a moving conductor cuts 100,000,000 lines of force each second and this induces, or creates, an E. M. F. of one volt. Then if it cuts 200,000,000 lines a second it will create a pressure equal to two volts. And so, to induce an E. M. F. of 110 volts the conductor would have to cut 11,000,000,000 lines each second.

By multiplying the number of poles in the magnetic field and thus increasing the number of lines of force; by multiplying the number of conductors cutting these lines and increasing their speed per second the induced E. M. F. may be increased.

It matters little whether we move conductors across lines of force or lines of force across conductors, the result is much the same. Out of this natural law of electricity grew the dynamo, or generator, as we know it to-day. And as a result of further research and investigation we have the induction-coil and the modern transformer.

Let us follow humbly in the footsteps of the great Faraday himself in order that we may fully understand this process called induction.

Faraday wound two insulated wires on a stick, being careful that they did not touch each other at any point. One of these wires was connected to a battery. The other was connected to a current-detector, or galvanometer (Fig. 1).

Faraday noticed that whenever the current in the wire (No. 1) was made or broken a current was induced, or caused to flow, through the wire (No. 2), although this second wire was not touching the first wire. This was a wonderful discovery for that day and age. But Faraday pursued the investigation still further. He noted that when the current was flowing steadily through the first wire no current was induced in the second wire. *The current appeared only when the battery current was made or broken in the first wire.* This induced current in the second wire flowed one way through the wire when the current was "made" and the other way when it was "broken."

Faraday next took an iron ring and wound half of it with coils, or turns, of insulated wire and connected this wire to a battery. The second half of the ring he wound with a second insulated wire and connected this to a galvanometer, or detector (Fig. 2).

Now, the coils were not even close to each other, although wound upon the same soft-iron ring, or core. Strangely

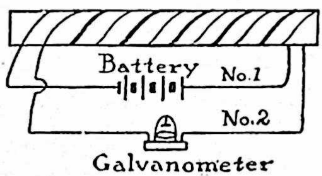


Fig. 1

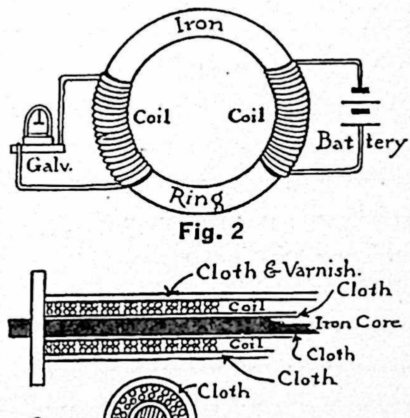


Fig. 2

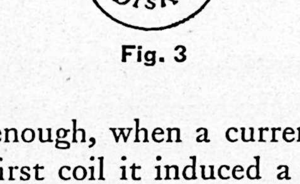


Fig. 3

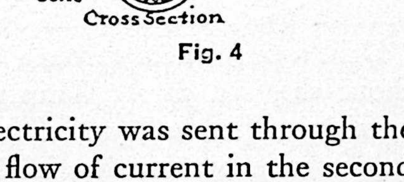


Fig. 4

enough, when a current of electricity was sent through the first coil it induced a similar flow of current in the second wire. This current, like that of the first experiment, was induced only on the "make" and "break" of the battery current.

The wire connected to the battery, or source of current, became known as the primary wire. The wire in which the current is induced was named the *secondary* wire, and so they are called to this very day.

The first practical development of this induced current was the induction-coil. Now, the induction-coil is nothing more or less than a transformer. Its action is exactly the same as described in the Faraday experiments above. The induction-coil does not produce a current of electricity. It only *transforms* it from a *high* to a *low* voltage or from a *low* to a *high* voltage.

The induction-coil of whatever size consists of a soft-iron *core*, and a *primary* winding connected to a source of current, such as a battery. Over this is wound the secondary coil of very fine wire, which is connected to the external circuit. In order to insure a steady flow of induced current through the secondary coil (because the induction takes place only when the current is made or broken) a little spring device called a *vibrator* is used to make and break the primary current very rapidly.

It is no trick at all to make an induction-coil. Take a rod of iron five inches long and three-eighths of an inch in diameter. A bundle of small soft-iron wires, such as stove-pipe wire, of the same length and thickness will be even better. At each end fit a wooden disk to make of the whole a spool, as shown in Fig. 3.

Drill a small hole through the right-hand end-piece just above the iron core. Wrap the core with cardboard and varnish. Wind a layer of rather coarse cotton-insulated copper wire by drawing it through the hole in the disk. When the first layer is done cover with cardboard and varnish. Put on another layer, winding the coils close together. This should bring the wire back to the same end where it started. Drill another hole through the wooden end and bring this wire out. Leave long ends for connecting with the circuit. Cover with cardboard and varnish. This completes the winding of the *primary* coil (Fig. 4).

The secondary coil is laid over this in much the same way. First cover the primary coil with cloth and varnish. Very fine silk-covered copper wire is used for the secondary winding. As before, a hole is drilled through the wooden disk, or end-piece, and a length of the wire left for connecting purposes. Wind the fine wire close and carefully. Take good care not to break it, as it is very delicate. Over each layer place a protective covering of writing-paper. Lay on eight or ten layers. Take the end of the wire out through the wooden disk on the opposite side from where it was started. Cover the hole with cardboard and varnish for protection (Fig. 5).

Take the vibrator from an electric bell and arrange it so it will make and break the circuit as shown in Fig. 6.

The vibrator is adjusted so it plays with a steady hum. This sends a pulsating current through the coils. If the terminals of the secondary coil are brought close together a brilliant spark will jump across the intervening air gap.

The induction-coil is a plaything. It can be used for many interesting experiments with Geissler tubes, etc. It is used in telephone work and to raise the voltage of battery currents for ignition purposes in automobiles and gasolene-engines.

The Transformer

The induction-coil is used to raise the voltage of direct current.

As the vibrator is clumsy, inefficient, and has many other serious defects, it cannot be used for heavy currents. For this reason alternating current has come into general use, as its voltage can be readily raised or lowered with a transformer.

As alternating current is continually surging back and forth through the line, no vibrating device to make and break its flow is necessary to create induced currents.

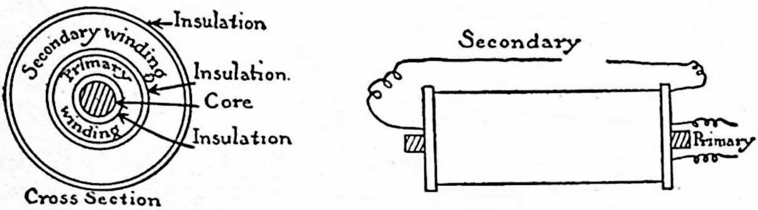


Fig. 5

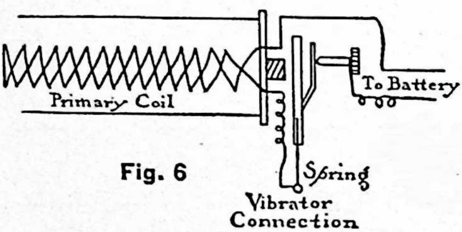


Fig. 6

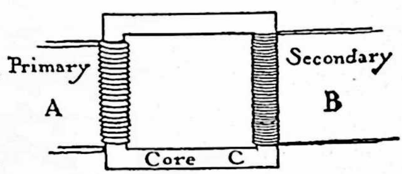


Fig. 7

Therefore, the transformer has no moving parts. It consists of but two coils of insulated wire wrapped around an iron core.

The action of the transformer is still a matter of theory. Take, for example, the elementary transformer shown in Fig. 7.

An alternating current is sent through the primary coil A. This induces a second current, alternating in character, in the secondary coil B. Obviously this current must travel through, or be transmitted by, the iron core C.

Theory has it that the magnetism of the iron core, produced by the turns of the primary coil A, varies according to the ever-changing values of the alternating current traveling through the turns of the primary coil. Every turn of the primary coil is encircled with lines of force when the current surges through them. When the current swings from right to left of these lines encircle the wire in one direction. As the current changes from left to right these lines of force circle the wire in the opposite direction. Therefore the magnetism, or lines of force, in the iron core are constantly changing as they pass through a regular cycle of values.

The lines of force created in the iron core are cut by the many turns of the windings of the secondary coil. This induces an electromotive force in the secondary windings.

The value of the E. M. F. induced in this secondary winding depends absolutely on the number of lines of force cut per second. If a hundred lines cutting ten turns produces the same E. M. F. as ten lines cutting one hundred turns any pressure can be obtained by varying the number of times the secondary is wound around the iron core. This is best explained by the following case.

A pressure of 110 volts is desired. A certain primary and core give a pressure of one volt with ten turns. To obtain the desired 110 volts the number of turns on the secondary must be increased 110 times, or brought up to a total of 1,110 turns. This will give the desired 110 volts.

In this way the voltage of an ordinary 2,300-volt alternating-current generator is "stepped up" to 60,000 volts for transmission (Fig. 8).

The above diagram shows the complete layout of a modern high-tension alternating-current system. The current is generated at 2,300 volts. After it leaves the generator it is transformed, or stepped up, to 60,000 volts for transmission to the place where it is to be used. Here the voltage is stepped down for service. A rotary converter changes the alternating current into direct current for use on the street-railway lines, etc.

The transformer does not generate electricity. It merely *raises* or *lowers* its voltage, with some loss in heat, etc.

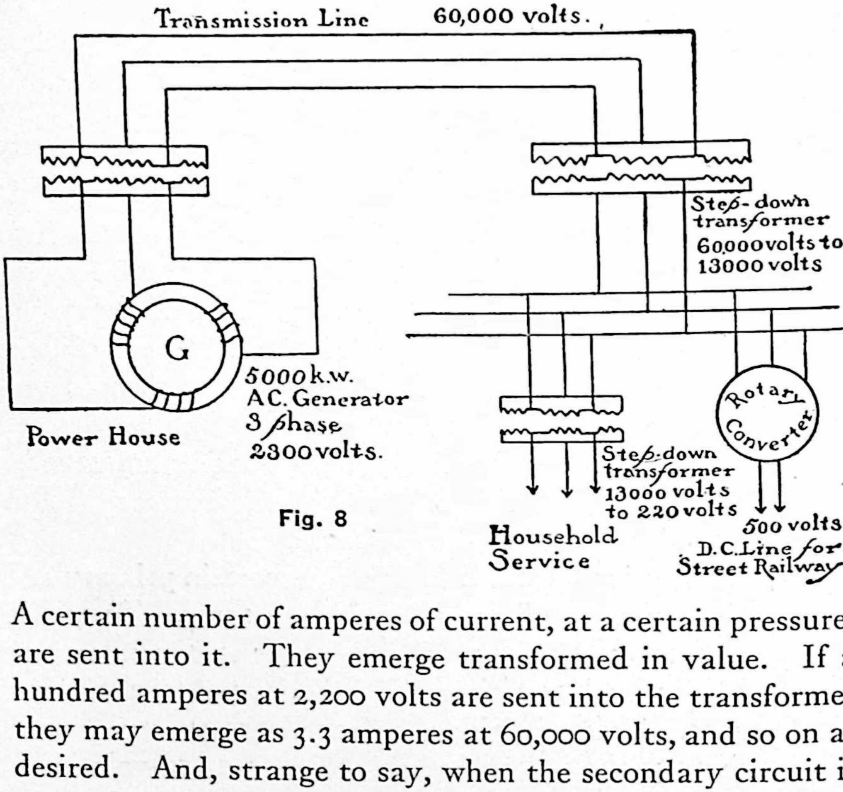


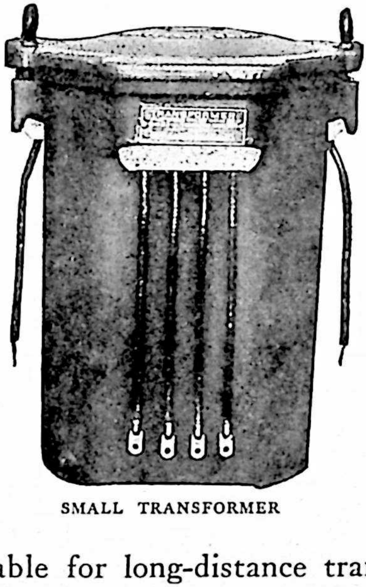
Fig. 8

A certain number of amperes of current, at a certain pressure, are sent into it. They emerge transformed in value. If a hundred amperes at 2,200 volts are sent into the transformer they may emerge as 3.3 amperes at 60,000 volts, and so on as desired. And, strange to say, when the secondary circuit is open there is practically no flow of current through the primary coils. Any one would think, just to look at the diagram of a simple transformer, that the current would short-circuit through the primary coils and blow the fuses on the line. Nothing of the kind happens. When the secondary circuit is open a counter E. M. F. is generated in the transformer which opposes the flow of current through the primary coil. This *back flow* of current effectively balances the primary current so that no more current flows through the transformer when the secondary circuit is open than just enough to magnetize the iron core. This opposition to the flow is properly called *reactance.*

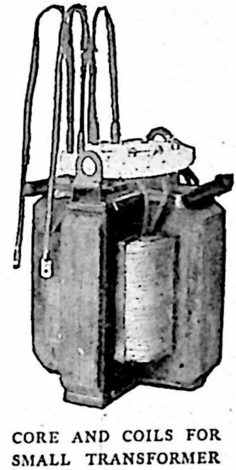
When the secondary current is allowed to flow, by turning on lamp after lamp, this reactance disappears in proportion to the amount of current flowing through the secondary circuit, allowing a proportional increase of current in the primary. In this way the transformer is always nicely balanced.

The Value of the Transformer

The transformer, being a device to raise or lower the voltage, or pressure, of the alternating current, is especially



SMALL TRANSFORMER



CORE AND COILS FOR SMALL TRANSFORMER

valuable for long-distance transmission. For many years the millions of horse-power available from our great water-falls had little commercial value because they could not be utilized in any manufacturing. They were too far removed from manufacturing and shipping points. Even if the energy of the falling water was turned into direct-current electricity, such as was used before the transformer was invented in 1885, nothing was gained. It required enormous quantities of costly copper to transmit low-voltage direct current over even short distances.

A heavy current of electricity at low voltage requires a large copper conductor. The same amount of energy at high voltage can be sent over a small copper wire. This is just as true of water. To produce 100 horse-power from water falling one foot, or with little pressure, would require an enormous amount of water. To produce 100 horse-power from water falling 1,000 feet, or under high pressure, requires but a thin stream and very little water.

By raising the pressure, or voltage, of the electrical energy to 150,000 volts it can be sent for hundreds of miles over a wire no larger than your finger. If this voltage was dropped to 15,000 it would require a wire one hundred times as large. With copper costing about fifteen cents a pound this is a material saving.

In the cities where the service wires extend for miles beyond the power-house it is important to transmit the current at 2,200 volts and then step it down with small transformers to 110 volts for household use. Not only is there a saving in cost of line material, but the voltage drop and line losses are less at the higher voltage.

Chapter XXII

SMALL TRANSFORMERS FOR HOUSEHOLD CIRCUITS

VERY often it would be most convenient if low-voltage current could be taken direct from the house circuit for ringing door-bells, lighting small lamps, or for various experiments.

Low-voltage apparatus can be operated from 110-volt, or ordinary household voltages, by inserting resistance in series with the apparatus. For instance, a 10-volt motor can be operated on a 120-volt line by connecting a 110-volt lamp in series with the motor.

The amateur who desires to utilize the household circuit for experimental purposes will do well to make a good resistance-box, or *rheostat*. This device is very simple and permits of any degree of resistance desired.

The resistance-box is not a transformer. It does not "step down" the high voltage to a lower voltage. It consumes, by resistance, a portion of the electrical pressure, or voltage. This portion may be varied at the will of the operator. Consequently the resistance-box is far from being as economical as a transformer for the same service.

Making a Resistance-Box

Take a long piece of iron wire about the size of the lead in a pencil. Wind it upon a three-eighth-inch round stick to form a coil fifteen inches long. Lay on the turns tight and close together. When this is done remove the stick and stretch the coil to twenty inches. This will leave a small air gap between each turn of the wire.

Mount this on a wooden base ten inches square and an inch thick. Mark a six-inch circle in the center of this board. With a half-inch gouge-chisel work a circular channel in this baseboard half an inch deep. Line this channel and cover the baseboard with asbestos paper and press the wire coils firmly in place (Fig. 1).

One end of the wire is brought out to a binding-post for connection to the circuit. The other terminal is connected

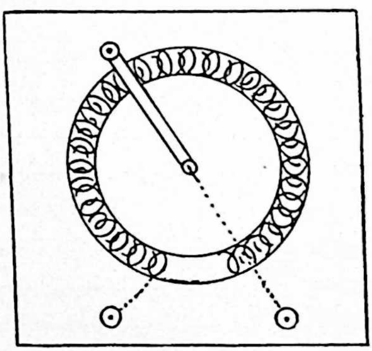


Fig. 1

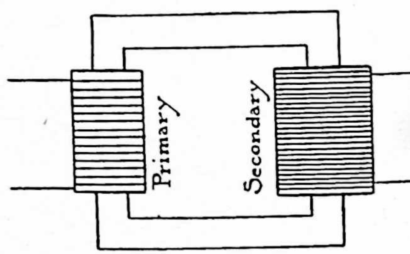


Fig. 2

to the center arm and post as shown in the above illustration. When completed the brass strip can be swung with the aid of the insulated handle, or knob, to any position on the coil. As the brass contact is moved along on the coil the amount of resistance-wire in the path of the circuit is increased. As it is moved back the amount is diminished. With this simple instrument a wide range of resistance can be had in an instant.

Details of Transformer Construction

No transformer gives 100 per cent. efficiency. Some of the best come very near this, only about 2 per cent. of the current being lost. There is an established ratio between the voltages in the primary and secondary coils. This is also true of the amperage (Fig. 2).

If there are 10 turns in the primary coil shown above and 100 turns in the secondary coil the voltage obtainable from the secondary should be 10 times that put into the primary. But the amperage of the secondary, remember, will be but one-tenth of that of the primary. On the other hand, the watts obtainable from the secondary will be the same as from the primary, since the wattage of the line is always the produce of the amperes times the voltage. One ampere at 100 volts will do the same amount of work as 100 amperes at a pressure of one volt.

If a current of 100 volts and 10 amperes is sent through the primary coil a current of 1,000 volts and one ampere can be taken from the secondary. And this secondary current would have the same amount of energy as the primary current, less a trifling loss in the operation of the transformer.

In large transformers solid-iron cores are not used, due to excessive heating and eddy currents. The core is built up of laminations which are partially insulated from each other. This eliminates, or reduces, the eddy currents. The laminations of the core are arranged to run at *right angles* to the current, otherwise the effect would be as bad as though solid iron was used.

Building Small Transformers

A small transformer to step down the house current from 110 volts to 10 volts is not hard to make. In design it is much like an electromagnet. It consists of two coils and an iron yoke as shown in Fig. 3.

The yoke is simply two bolts four inches long connected together with soft-iron strips of equal dimensions, leaving a space of three inches between the bolts, as illustrated. Wooden disks are slipped on the bolts to form spools. The spool A is wound with 500 ohms of No. 36 wire. Referring

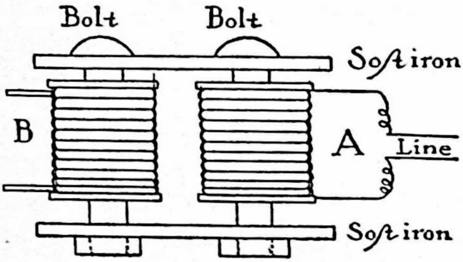


Fig. 3

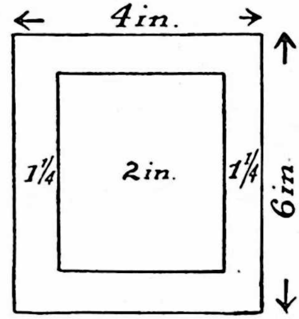


Fig. 4

to the wire table, we find that the resistance for one foot of No. 36 wire is .512 ohm. To obtain 500 ohms resistance we will have to wind on about 1,000 feet of the wire. Cover the iron bolt with varnished cloth or cardboard. Cover every layer of wire with a piece of heavy writing-paper. Be sure the paper comes flush up against the wooden ends of the spool so the layers of wire cannot possibly touch one another.

The spool B is wound with No. 13 wire in the same manner as the first spool, with varnished cloth over the core and writing-paper between each layer of wire. The finished transformer can be mounted on a suitable base. The terminals of the primary coil A are connected to the line and the terminals of the secondary coil B to the apparatus to be operated.

A Core-Type Step-Down Transformer

Transformers are made in two types. In the core transformer the coils are wound upon the soft-iron core. In the shell-type transformer the core surrounds the coils. The core type is easiest to make.

Build up out of sheet-iron laminations a core 1-¼ inches thick, 6 inches high, and 4 inches wide (Fig. 4).

To saw out the center of each lamination holes are drilled to admit the hack-saw blade. The finished core is smoothed and touched up nicely with a sharp file. The corners should not be too sharp.

Where the coils are to be placed cover with pieces of heavy cotton cloth saturated with shellac. Dry and wind on the primary coils. Be sure to wind both legs in the same direction, just the same as you wind an electromagnet. The primary consists of No. 23 insulated wire, 400 turns to each leg, or 800 turns in all (Fig. 5).

Wind the primary wire evenly in snug layers. Over each layer place a covering of heavy paper or cotton cloth. Unless the wire is wound tight the finished coil will be loose and unsatisfactory. Be careful not to break the wire. If it breaks it must be carefully spliced and insulated.

Cover the primary coils with three or four layers of heavy cotton cloth and shellac liberally. Be sure the ends are long enough for proper connection when the coils are done.

The secondary coil is laid immediately over the primary coil. This secondary coil is made up of about 40 turns of No. 13 insulated copper wire to each leg, or about 80 turns in all (Fig. 6).

The finished coils are wound with a good coating of heavy cotton cloth, fixed in place with shellac varnish or with friction-tape.

Connecting the Coils

Care must be taken in connecting up the coils, or the transformer will not work at all. Take the primary coils first. If they are right they are wound both in the same direction. When the two coils are connected the current flowing over the wire should move in opposite directions around the two legs of the core (Fig. 7).

The finished transformer should be mounted on a suitable base and arranged so the terminals of the primary windings

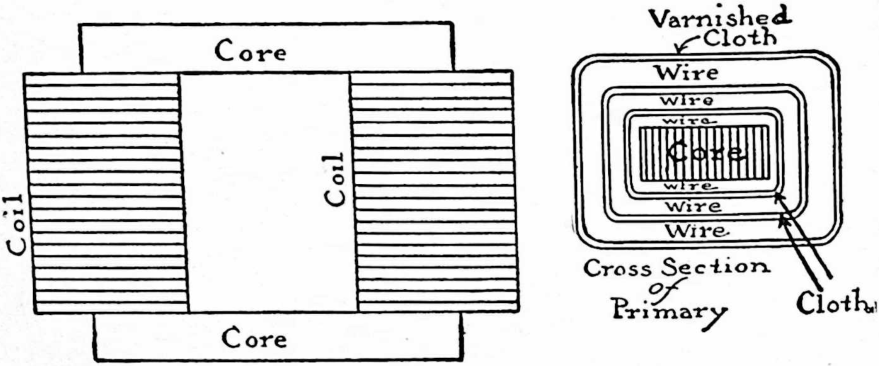


Fig. 5

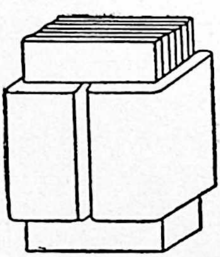


Fig. 6

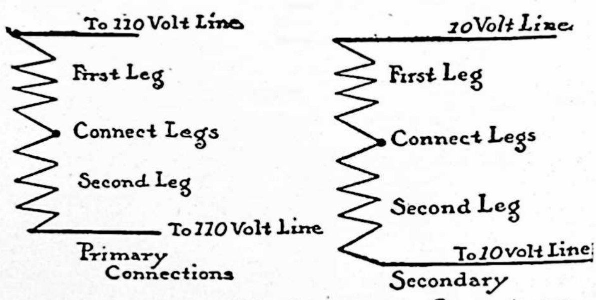


Fig. 7

can be connected to the 110-volt line. The secondary terminals are brought out to binding-posts so they can be connected to the secondary line, consisting of the electric bell, miniature lamp, small motor, or other apparatus requiring a low-voltage alternating current of about 10 volts.

The small transformer offers an unlimited field for the experimenter. From the very elementary device, consisting of but a few turns of the primary wire and several turns for the secondary, there is hardly a limit to the experiments possible. When one has mastered the principles of the transformer it is easy enough to figure out a machine of any desired size and to build it on the work-bench.

Chapter XXIII

A SMALL ELECTRIC PLANT FOR THE COUNTRY HOME

ELECTRIC light, electric motors, electric heating and cooking are for those only who have electricity at their disposal. Electricity is vastly different from coal and gasolene. You can go to the village and buy a ton of coal and haul it home. You can burn this coal under a steam-boiler and utilize its energy to drive the farm machinery, to heat the house, or to cook the food. You can buy a few gallons of gasolene and carry it in a can. This liquid fuel can be used also to drive engines, to run automobiles, even to cook the food if necessary. But you cannot drive to town and purchase a gallon of electricity!

Coal and gasolene were made for us many thousands of years ago when Dame Nature stored up the energy of the sun and locked it securely in her bosom for the benefit of mankind. If she has any electricity stored up for us we have not found it to date.

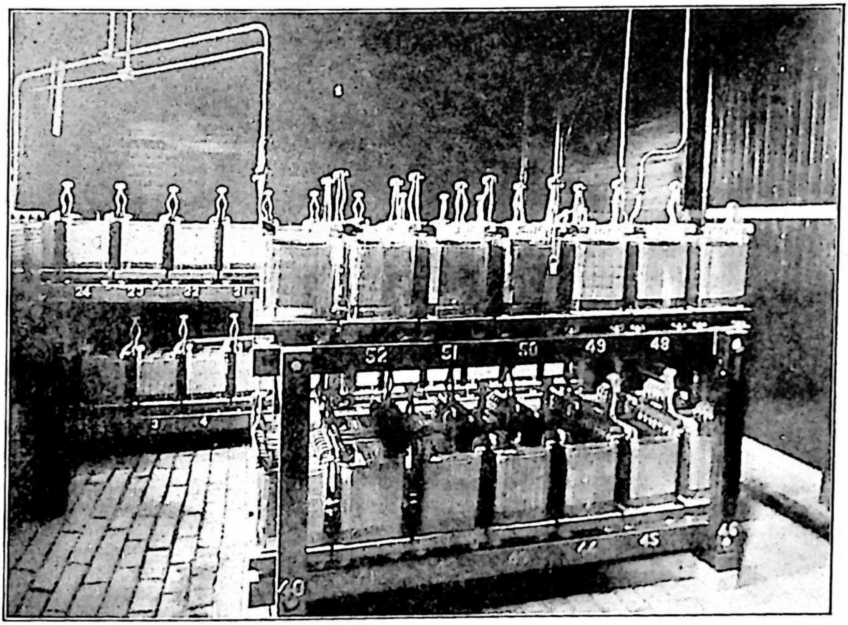
Those who live away from the cities and villages, where electricity is produced by central power-stations and distributed about these centers for the convenience of customers, must make their own electricity on the premises.

Electricity is merely a transformation of energy. Therefore, to make electricity we must first have a source of energy. Energy is available on the farm in several forms. A few farms have suitable streams of water from which a few horse-power of energy can be produced. Others can use large windmills with considerable success. And, very fortunately, those who live in the hilly and mountainous districts, where a steady wind is seldom available, are the very ones who have water-power. On the other hand, the level prairie land where water is absent is a favorite place for the four winds, and there is seldom a day when the windmill is idle for twenty-four hours.

For those farms where neither wind nor water is available, and these are far in the majority, there is the gasolene-engine, which is a very compact and economical source of power.

Essentials of the Private Plant

Whatever the source of power, be it wind or water or engine, the plant must consist of a suitable generator, a storage



AUXILIARY STORAGE-BATTERY FOR USE WHEN PLANT IS NOT RUNNING battery to supply current when the driving-power is not working, a system of wiring for the buildings, and a suitable switchboard for the control of the current.

The generator can be purchased in any size desired. For very small plants they are usually bought to supply a certain number of lamps—ten lamps, twenty-five, fifty lamps, etc. For larger sizes they are rated in kilowatts, a one-kilowatt machine being equal to one and one-third horse-power.

The storage battery is composed of individual cells, and it may be as large or as small as desired. The wiring for the buildings differs in no way from that described in previous chapters.

There is no better form of artificial illumination than electricity. It is the most convenient, the safest, and the cheapest when everything is taken into consideration. With a small electric-light plant the entire country home can be lighted from cellar to garret, including all the dark closets. The lines can also be readily extended to the yards, barns, stables, hen-houses, etc. With suitable switches these lamps can be controlled from the house. In case of trouble or an unusual noise in the night the yards and barns can be instantly illuminated by throwing a master switch.

By installing a private electric plant any one can have all the electrical conveniences of the city.

Uses of Electricity in the Farm Home

Lighting	Frying-pan	Vegetable-peeler
Electric fan	Griddle-iron	Plate-warmer
Sewing-machine	Broiler	Heating-pad
Electric iron	Soup-kettle	Curling-iron
Washing-machine	Cereal-cooker	Shaving-mug
Wringer	Egg-boiler	Cigar-lighter
Mangle	Egg-beater	Sealing-wax heater

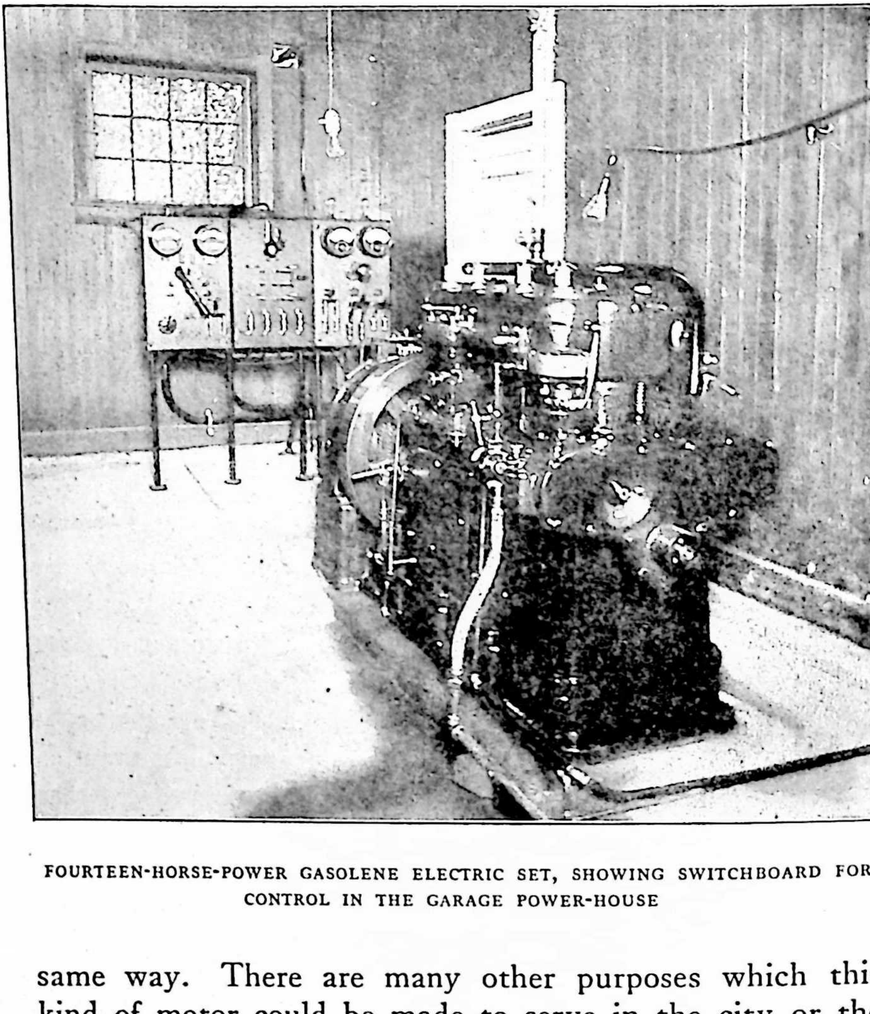
- Refrigeration
- Vacuum cleaner
- Radiant toaster
- Tea-kettle
- Coffee-percolator
- Chafing-dish
- Baby milk-warmer
- Radiant grill
- Waffle-iron
- Hot plate
- Corn-popper
- Water-heater
- Stove
- Oven
- Electric range
- Fireless cooker
- Sausage-stuffer
- Meat-grinder
- Coffee-grinder
- Bread-mixer
- Pumps for water-supply
- Ice-crusher
- Ice-cream freezer
- Buffer and grinder
- Furnace-blower
- Foot-warmer
- Air-heater
- Luminous radiator

Electric Light for the Farm-House

On an average, artificial illumination is required not more than four hours a day in most farm-houses. Only two rooms in the house need to be illuminated for this long every day—the kitchen and the living-room. Bedrooms are lighted for short intervals only, and the cellar and woodshed lights are snapped on for only a few minutes at a time. For the whole house and for the barn an average of three hours per day for each lamp would seem to be ample, and five lamps will afford much more light than now suffices for all the purposes of the farmstead. If the householder can get rid of the idea that if he introduces electric light he must have clusters of flashing bulbs all over his premises, then the electric light would seem to be within reach at a comparatively small expense.

Electric Motors for the Home

Small motors have a great variety of uses. Recently a young man purchased a tiny motor to drive his turning-lathe. He soon had it fitted so that it would run a polishing and grinding wheel, sanding-wheels, and small circular saws. Then he bought a large pulley-wheel and operated the washing-machine with the motor. At the beginning of the warm weather he equipped the ice-cream freezer to be driven in the



FOURTEEN-HORSE-POWER GASOLENE ELECTRIC SET, SHOWING SWITCHBOARD FOR CONTROL IN THE GARAGE POWER-HOUSE

same way. There are many other purposes which this kind of motor could be made to serve in the city or the suburbs.

The General Utility is a small motor designed especially for use in the home. It is provided with several attachments, any of which can be easily added or removed. With these the motor will run the sewing-machine, a polisher for cleaning silverware, a sharpener for tools and knives, fans for ventilating the house or furnishing a draught for the furnace, a lathe, or any other similar device. By means of a flexible shaft it can be employed in polishing brass and other metal trimmings on an automobile, carriage, or fixtures, since a handle makes it easily portable in one hand, while the other is free to apply the polisher.

Electric fans are seldom classified as motors, but they are nothing more or less.

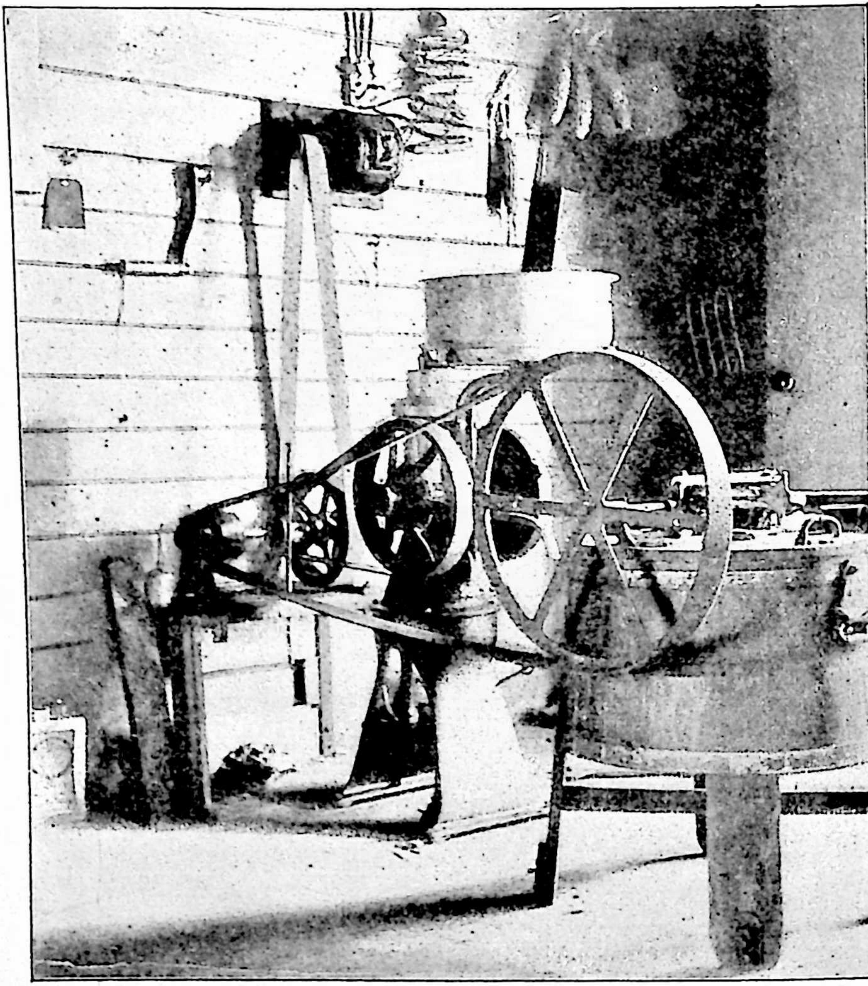
SIZE OF MOTORS TO USE ON DIFFERENT HOUSEHOLD MACHINES

MACHINE	H.-P. OF MOTOR		
	MIN.	MAX.	SIZE MOST COMMONLY USED
Sewing-machine	......	......	1/30
Buffer and grinder	1/30	1/30	1/30
Vacuum cleaner	1/8	5	1/8 to 1/4
Ice-cream freezer	1/8	1/4	1/8
Washing-machine	1/8	2	1/8 to 1/2
Meat-grinder	1/4	3/4	1/4
Water-pump	1/4	1	1/2

Electric Motors for Farm Power

It has been practically demonstrated that electricity is the ideal power for farm use, because it can be readily transmitted with safety and economy to any point where needed and applied in any quantity desired. With electricity the power-plant, whether the energy is generated from water, steam, or gasolene, is always located in one place and the current is transmitted over insulated wires to the milk-room, the dairy, the hay-loft, or to any other part of the farm and farm-buildings to do the work or to dispel the darkness.

The amount of power required to operate most farm machinery is small. The presence of a plant of sufficient capacity to operate one or two particular machines often makes it possible to use the power for many of the other purposes. The amount of work that a small motor will do may be judged from the table on the following page.



CREAM-SEPARATOR AND WASHING-MACHINE OPERATED BY ONE-QUARTER-HORSE-POWER MOTOR

SIZE OF MOTORS TO USE ON THE DIFFERENT FARM MACHINES

MACHINES	H.-P. OF MOTOR		
	MIN.	MAX.	SIZE MOST COMMONLY USED ON AVERAGE FARMS
Feed-grinders (small)	3	10	5
Feed-grinders (large)	10	30	15
Ensilage-cutters	10	25	15 to 20
Shredders and huskers	10	20	15
Threshers, 19-in. cylinder	12	18	15
Threshers, 32-in. cylinder	30	50	40
Corn-shellers, single-hole	3/4	1-1/2	1
Power-shellers	10	15	15
Fanning-mills	......	......	1/4
Grain-graders	......	......	1/4
Grain-elevators	1-1/2	5	3
Concrete-mixers	2	10	5
Groomer, vacuum cleaner	1	3	2
Groomer, revolving-system	1	2	1
Hay-hoists	3	15	5
Root-cutters	1	5	2
Cord-wood saws	3	10	5
Wood-splitters	1	4	2
Hay-balers	3	10	7-1/2
Oat-crushers	2	10	5
Water-pump	1/2	5	3
Cream-separator	1/10	1/4	1/8
Churn	1/8	3	1/4
Milking-machine, vacuum-system	1	3	3
Refrigeration	1/2	10	5

Righting Wrong Impressions

A great many wrong impressions have resulted from the recently awakened interest in small electric plants for the country place. A man in Kansas purchased several electric lamps and was disappointed because they would not light. He was very much surprised when he found out that he could not use them without installing a private electric plant. Another farmer in the Northwest bought an electric motor and, of course, it was useless for him without a source of current to supply the motor with electricity. A motor without electricity is of no more use than a gasolene-engine without gasolene.

It is well to know something about electricity before buying electrical apparatus of any kind.

Remember that a small, low-voltage, private electric plant is suitable for electric lighting only. These small plants, driven by windmill or water-wheel, or even by a small engine, are usually of low voltage and produce only a small current. They are suitable for lighting purposes only. Small motors and heating-devices are not yet standardized in these low voltages and, therefore, are not readily available for such low-voltage lines and service. Perhaps some day in the near future electrical devices will be standardized for low-voltage lines, but that day has hardly arrived as yet.

A low-voltage electric plant for lighting service only is the cheapest and easiest kind of plant to install. But, if small motors are to be used, if the current has to be transmitted for any distance, if standard heating and cooking devices are desired, then a plant of standard capacity, *of 110 volts*, should be installed.

The reason why the higher-voltage plant costs somewhat more is found in the storage battery. Each storage-battery cell will give but 2.5 volts. Obviously it would require but 10 cells to supply a 20-volt line. But it would take 55 cells to supply a 110-volt line. If the cells cost about $5 each it is easy to see that the 55-cell battery will cost $275 against $50 for the 20-volt line.

The Power of Water

A great many farm streams are running to waste without lifting a finger, figuratively speaking, to assist with the farm work or to help keep down expenses. It is surprising what a small amount of falling water will produce one horse-power of energy. Even a small trout-brook can be made to light the premises and to supply power for the small chores about the farm.

Falling water possesses more power than we suppose. Water acts as a moving power either by its weight—which is over sixty-two pounds to the cubic foot—or by its pressure or impact. The power of a fall of water is equal to the weight of its volume times the vertical height of its fall. To compute the power of falling water it is necessary to multiply the *volume* of flowing water in *cubic feet per second* by its *weight*—62-½ pounds—and this product by the *vertical height* of the fall in feet, and *divide by 550*, which is the number of foot-pounds representing one horse-power for one second.

A common level can be used to measure the fall of a stream (Fig. 1).

By setting up the level and sighting over it to a suitable marker, or to an adjustable marker on a pole, the fall of any

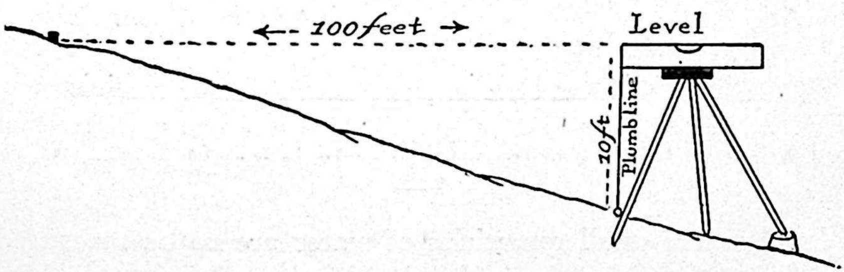


Fig. 1

USING LEVEL TO FIND HEIGHT OF WATERFALL

stream may be figured out with considerable accuracy. If strict accuracy is necessary a surveyor can ascertain the fall in a few hours' work with a surveying-instrument.

To weir a small stream, or to find how many cubic feet of water are flowing per second, a temporary dam has to be built across the stream (Fig. 2).

How to Make a Weir

Place a notched board or plank in the stream at some point where a pond will form above it. The length of the notch in the plank should be from two to four times its

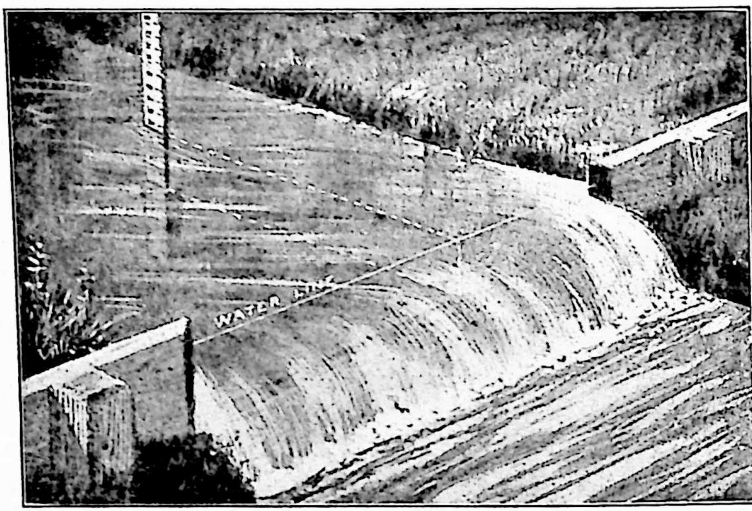


Fig. 2

WEIR

depth where small quantities of water are to be measured and four to eight times the depth where large quantities are to be measured. The edges of the notch should be beveled, as shown in sketch, with the slant down-stream. The distance between the bottom of the notch and the level of the water in the pool below the dam should not be less than twice the depth of the notch. Drive a stake in the pond about six feet above the dam, with its top precisely level with the lower edge of the notch, then complete the dam so that all the water will flow through the notch. The depth of the water flowing through can easily be measured by means of a rule placed on top of the stake as shown in the sketch. It is essential in building a weir that the bottom of the notch should be as nearly level as possible.

One side of the weir is made so it can be pulled back and forth to control the water falling over the face of the weir. This slide is adjusted until the falling water is just a foot deep. Then by simply multiplying this by the linear feet of the "apron," or the width of the stream, will give the volume of water in cubic feet. If the apron is ten feet long and the water falling over it one foot deep, then the total volume is ten cubic feet. If the depth of the water is but six inches, then the total cubic feet will be five.

The volume flowing over the weir per second is found by putting a suitable float in the stream and timing the speed of the stream. Set up two markers ten feet apart (Fig. 3).

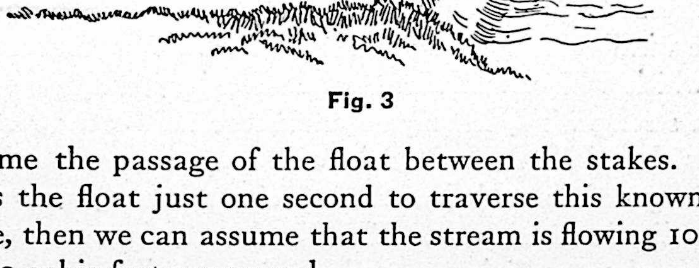


Fig. 3

Time the passage of the float between the stakes. If it takes the float just one second to traverse this known distance, then we can assume that the stream is flowing 10×10, or 100 cubic feet per second.

Multiply the volume of flowing water in cubic feet per minute by its weight, 62-½ pounds, and this product by the vertical height of the fall in feet, and divide by 33,000, the number of foot-pounds representing one horse-power for one minute. A stream of water when flowing over a weir five feet in width by one foot in depth at the rate of one foot a second and having a fall of twenty feet develops 11 horse-power.

The Horse-Power of the Wind

Where there is a strong prevailing wind a good windmill will give quite a little power.

The following table shows the horse-power which can theoretically be realized from a 28-foot wheel exposed to winds of various velocities.

SPEED OF WIND M. P. H.	H.-P.	SPEED OF WIND M. P. H.	H.-P.
2.25	.04	22.5	40
6.7	1.1	33.5	135
11.2	5	45	520
15.7	13	67	1,080

The power available should increase with the cube of wind velocity (since the energy of the air particles increases with the square of their velocity and the number of them striking the wheel-blades per second increases in direct proportion to the wind velocity). It is not practicable to construct a mill which will utilize with equal efficiency a light breeze and a strong wind, hence the curvature and setting of the blades should be such that the mill works most efficiently when exposed to a wind of the velocity generally prevailing in the district concerned. If a wheel be designed to utilize with maximum efficiency a wind of 22.5 miles per hour it will not run in a 7-miles-per-hour breeze, since the power corresponding to this wind is less than the power required to overcome the light-load losses of the wheel and its gearing. Breezes of 8 to 15 miles per hour are much more common than 20-miles-per-hour winds, hence it is generally advisable to employ, for driving electric generators, a very light wheel which will start work in a 3.5-miles-per-hour wind and which can still be used when the wind rises to 10 miles per hour. Such a wheel could not be exposed fully to a 30-miles-per-hour wind, and for safety a device should be mounted on the main wheel so that when the wind pressure exceeds a certain limit the inclination of the blades is changed against the control of a spring in such a manner as to reduce the effective area exposed to the wind. The control-springs may conveniently be set so that they come into operation when the wind velocity exceeds 16 miles per hour and so that the output of the mill is constant in winds above 18 miles per hour.

The Gasolene-Engine

It is estimated that there are at least two million gasolene and oil engines on the farms in this country at the present day, and this number is being added to at the rate of 500,000 annually. The average size of these engines is about seven horse-power.

Any good gasolene-engine may be used to drive an electric generator, provided it gives a fairly constant speed. Of course, it will be necessary to obtain the correct speed ratio between the engine and the generator, but this is easily figured out.

Chapter XXIV

INSTALLING A SMALL ELECTRIC PLANT

THE simplest, cheapest, and smallest lighting-plant which it has ever been my good fortune to hear about consists of but a small battery composed of eight dry cells and two low-voltage battery lamps. With this simple outfit and the necessary wiring and fixtures, costing less than three dollars all together, a barn and stable are lighted with electricity.

This battery lighting outfit is very handy in the wagon-house and stable. It eliminates the striking of dangerous matches and the use of lanterns. As the lamps are used but a few minutes at a time, only long enough to unhitch and put the horse away, the batteries will last for months (Fig. 1).

This diagram shows the wagon-house and adjoining horse-stable lighted with two six-volt eight-candle-power lamps from a battery of eight dry cells. The cells are arranged in series-multiple, as shown in the picture, four cells in series. The battery is placed out of the way on a shelf in the wagon-house. The miniature bases for the lamps will cost ten cents each, and two small snap-switches will cost about the same. The two six-volt battery lamps of eight candle-power each will cost about thirty-five cents each. The amount of No. 18 wire necessary will depend, of course, on the distance the lamps are placed apart and removed from the battery source. The wires are strung on proper insulators, and the switches are arranged on the side-walls near the door where they are most convenient upon entering and leaving the building.

A Small Windmill-Plant

What is perhaps the smallest windmill-driven electric-lighting plant is located in Wisconsin. This tiny plant supplies current for twenty-four lamps (although not all at the same time) and is operated entirely by the farm windmill at a total cost of a few cents a year for lubricating-oil.

The farm consists of about a hundred acres, and is devoted to stock-raising and dairying. The power-windmill is 12 feet in diameter, with a vertical shaft extending down the tower; attached to it are the power-pulleys, etc. In addition to driving the electric-light dynamo this mill is used to operate a drill-press, grindstone, corn-sheller, small

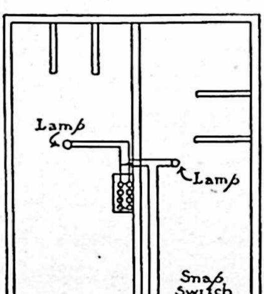


Fig. 1

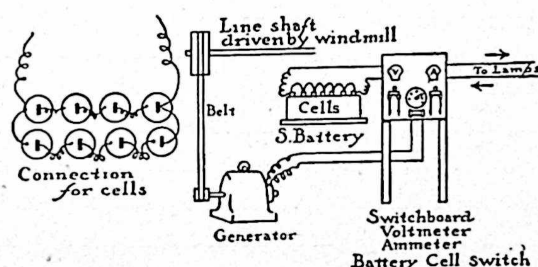


Fig. 2

saw, washing-machine, grain-elevator, and feed-grinder. The dynamo is located in a small building at the base of the windmill tower. This dynamo has a capacity of six amperes at 35 volts, or .21 kilowatt, when driven at full speed of 450 revolutions a minute. The variations in speed, due to irregularities in the wind, are overcome by a small automatic switch placed in the circuit between the generator and the storage batteries which prevents any accidents to the apparatus by breaking the circuit when a certain range of speed has been passed.

This tiny plant illuminates the home, yards, and the barn buildings. All the lamps receive their current from the storage battery, the charging of which is the dynamo's only function. The entire plant, including windmill, generator, battery, wiring, lamps, etc., could be duplicated for not more than $250 (Fig. 2).

Details of a Water-Power Plant

A farmer in eastern New York has harnessed a small trout-stream to an electric generator. There was an ancient sawmill dam on this stream, so he did not have to go to the expense of making an entirely new dam. A few repairs were necessary, however. The volume of water is small, but the fall is 15 feet. He installed a nine-inch upright water-turbine in a wooden case which he built himself. This wheel develops about five horse-power. It is belted to a three-kilowatt, 125-volt, direct-current generator. He next installed a suitable water-wheel governor to insure a steady flow of electricity.

The plant is started and stopped with a 700-foot wire running to the home of a neighbor whose buildings are also lighted from this plant.

This wire controls a valve and counterweight. The entire plant cost about $500, distributed as follows:

Dynamo, 3-kw. (second-hand)	$ 50
Water-wheel, 9-in. (naked)	55
Governor (new)	75
Wire (7,400 ft.)	210
Labor (installing wheel)	40
Fixtures, lamps, etc.	38
Small motor (2 h.-p.)	50
Total	$518

The direct-current generator is of standard voltage and amply large enough to light the farm buildings and the home of a neighbor. It will supply current for electric heating and cooking devices and for motor power up to about four horse-power. This plant is not equipped with a storage battery, although it could be if desired. There is water enough to turn the wheel whenever the lights are necessary.

Electric Lights from the Gasolene-Engine

In figuring out the details of a small electric plant it is necessary to resort to Chinese methods and work backward. It will not do to begin with the generator. First make sure the exact purpose of the proposed plant. If it is to be used for electric lighting only, then we must first figure up the number of lights wanted and the number of hours they will be lighted each day. Make a list as shown in the following table.

ROOM	LAMPS		LAMP-HOURS
Kitchen	1		6
Living-room	2	(lamps for 3hrs. = 1 lamp for	6)
Dining-room	2		3½
Hall	1		2
Woodshed	1		½
Bedrooms (3)	3	(1 lamp each)	4
Barn	2		8
Stable	2		4
Yard	1		1
Total	15	Total	35

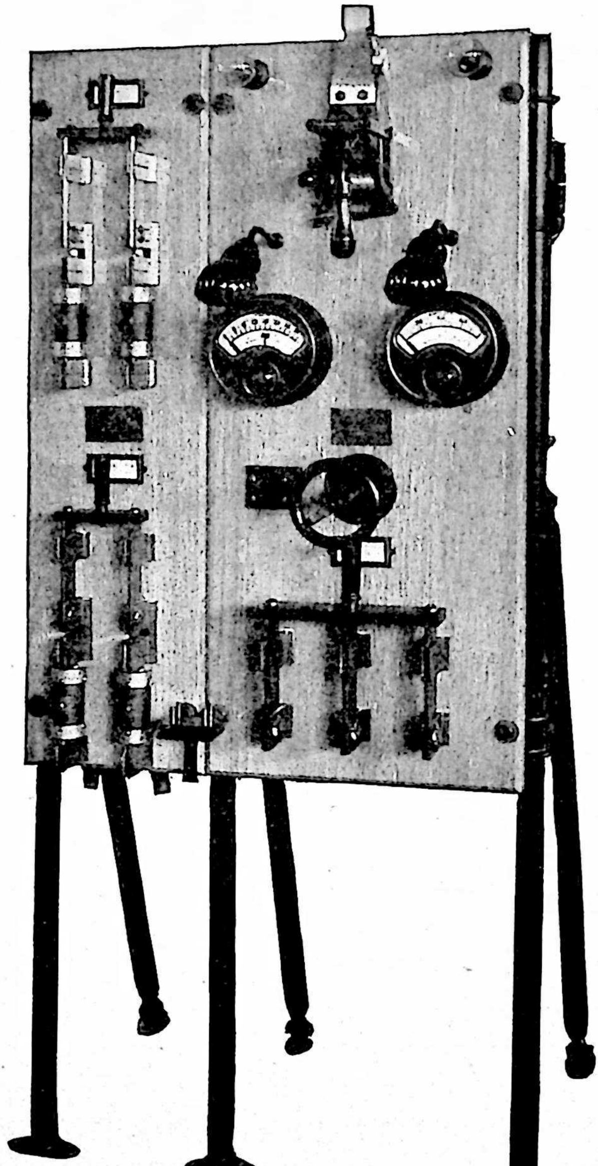
From this table it will be seen that the total illumination required per day is equivalent to burning one lamp for 35 hours. In other words, to operate this plant we will need a storage battery capable of running one lamp for 35 hours or 35 lamps for one hour, or any other equivalent to this. In preparing the above table the lamps were all figured for maximum service, or the longest time they will be in use. In reality they will be used less than half of this, except when there is company in the house or in case of entertainment. But it would not do to put in lamps for ordinary service only. There must be enough power for emergencies.

The Storage Battery

If this plant is to be used for lighting purposes only a low-voltage plant with a storage battery will be best and cheapest. Storage batteries are rated in ampere-hours. An ordinary metal-filament 20-candle-power 20-volt lamp requires a flow of about one ampere at 20 volts to make it burn brightly. To make this lamp burn for 37 hours will require a 40-ampere-hour storage battery. This will give enough, and a little to spare for line losses, etc.

To secure the proper voltage for a 20-volt system several things have to be taken into consideration. There is a considerable loss of pressure, or voltage, in a low-voltage system of this kind. This is especially true where the power-house is located some distance from the house or barns. *The farther the current is carried the greater this loss.* In purchasing the battery this loss must be considered.

Each battery cell will give from 1.8 to 2.5 volts. Fifteen cells will give an average of 30 volts. This is 10 volts more than the lamps require, but these 10 volts will be lost in transmission or can be taken care of by a suitable battery switch.



DIRECT-CURRENT GENERATOR AND FEEDER SWITCHBOARD

The Generator

Remember that only direct current can be stored. So a direct-current generator will have to be purchased. The size of generator necessary is easily figured. A storage battery of 15 cells produces, when charged, 2.2 volts per cell, or 33 volts. This is more than enough to light the 20-volt lamps. But when the cells are only partially charged they give but 1.5 volts each, or 22.5 volts. In charging a battery the current from the generator must be powerful enough to overcome the force of the battery, or the process will be reversed and current will flow from the battery to the generator. To charge a 33-volt battery it will require a 45-volt direct-current generator. Ordinarily a current of five amperes is sufficient to charge a 15-cell 40-ampere-hour battery. It can be charged quicker with a 9-ampere current. If amperes times the volts equal the watts, then $9 \times 45 = 405$ watts, or nearly half a kilowatt. The nearest commercial-size generator is ½-kilowatt, or 500-watt, machine. This will be ample to charge the battery.

It will require a two-horse-power gasolene-engine to drive the generator to capacity, as gasolene-engines seldom give quite as much power as they are rated. A very good one-horse-power engine might drive it, and then again it might not. A large gasolene-engine may be used if it is properly governed. Some of the best engines are throttle-governed so they will produce any amount of power as desired with great fuel economy. The gas-engine should have a large balance-wheel to insure a steady driving-power.

Controlling the Current

This little plant is controlled from a switchboard located near the generator. An adjustable resistance, or rheostat, comes with the dynamo. With this the voltage of the dynamo can be controlled at will so the battery can be charged slowly or fast as desired. Two measuring-instruments are necessary, an ammeter, to measure the current that is being supplied the battery when charging, and a voltmeter, to measure the pressure, or voltage, of the generator. This voltmeter is also arranged to measure the voltage of the battery and the voltage supplied the lamps. The switchboard should also be equipped with an automatic circuit-breaker. The purpose of the circuit-breaker is to prevent any loss of energy in case there is no attendant at the plant when charging and the engine stops. If this should happen the breaker automatically cuts out the current which otherwise would flow from the battery back into the generator, turning it into a motor, and driving the engine backward.

Because the voltage of the battery varies, being higher when fully charged and lower when nearing discharge, a little switch is mounted on the board for cutting in and out the end battery cells. When the battery is fully charged, producing 2.2 volts, the two end cells are cut out, thus bringing the voltage down to 27 volts for the battery. When the battery becomes weaker and produces but 1.8 volts per cell these end cells are cut in, bringing the total voltage back to normal.

The voltmeter is used for three readings. It is switched to the battery, line, or generator with a simple plug-switch at the will of the operator. The location of switches, instruments, etc., is best shown in the drawing of a small switchboard for this plant (Fig. 3).

The Lamp Circuit

The lamps can be operated directly from the generator by using a double-throw switch. Throwing this switch one way puts the battery on the line, throwing it the other way cuts in the generator. The complete wiring plan for this plant is shown in Fig. 4.

A typical layout for the engine-room is shown in Fig. 5. Wires from battery to switchboard and from the switchboard to the armature terminals and from the engine-room to the house should be large enough to carry a maximum current of eight amperes without serious loss. If this distance is not more than 220 feet, No. 8 B. and S. gage copper

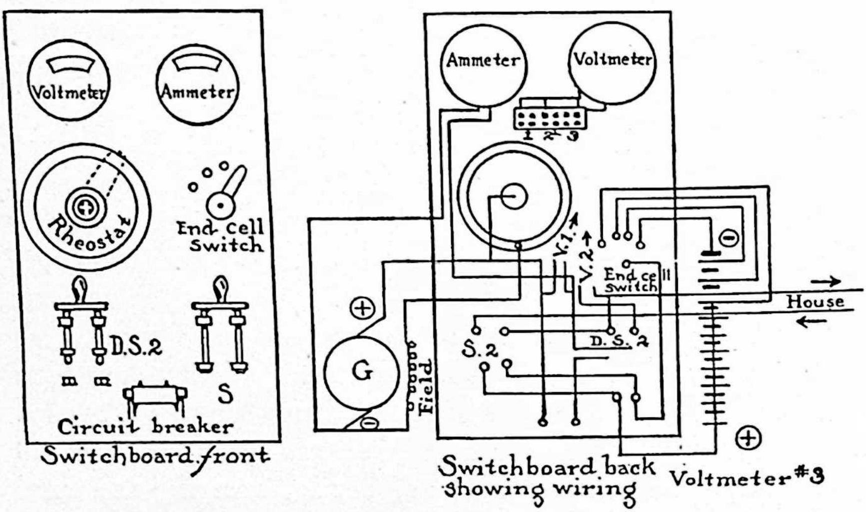


Fig. 3

wire, heavily insulated, should be used. These wires are carried directly to the service-box in the upper floor of the house. The current is distributed about the house on ordinary No. 14 wire for the various branch circuits. These branch circuits will not be asked to carry more than three amperes.

It is better to build a separate fireproof, small concrete building to house the generator, engine, switchboard, etc.

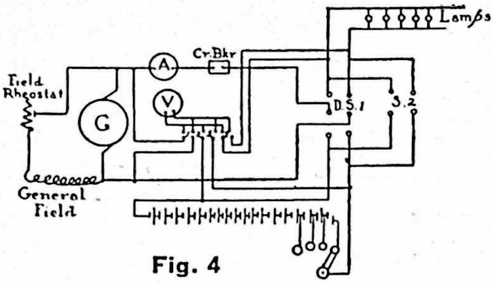


Fig. 4

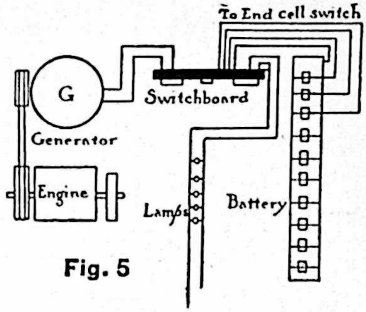


Fig. 5

The engine may be either stationary or portable. Since only a few lights will be burned at a time on all ordinary occasions, the battery will not have to be charged more than once or twice a week, and the engine may as well be pumping water or doing other chores about the premises.

Reducing Cost to Actual Figures

Battery cells cost about $4.80 apiece. At this rate fifteen cells would cost $72, and they will last for several years with very little care.

The cost of the switchboard varies. A good marble board equipped with the best instruments will cost about $95. A slate board and cheaper instruments will lower the cost considerably.

Fifteen-cell battery, 40-ampere-hour	$ 72
Slate switchboard and instruments, etc.	80
Shunt-wound, 45-volt generator, ½ kilowatt	65
Fifteen lamps, metal filament, 25 watts, 20 volts	4.50
1,000 feet No. 14 wire	12
550 feet No. 8 wire	25
Porcelain cleats and tubes	2
Fifteen snap-switches	4.80
Fixtures:	
Living-room, 3 lights	7
Dining-room, 2 lights	6
All others, each $2, total for 8	16
Total	$294.30

Cost of wiring buildings is omitted, it being assumed that any one capable of installing a plant of this size can do the wiring and all the other work necessary about setting up the plant. Full directions for setting up the engine, generator, and battery come with these devices when they are purchased from the manufacturer.

While low-voltage motors are not standard, there is no reason why they cannot be made. Doubtless one could be found among the smaller manufacturers, or they would wind one for a slight increase in cost.

The above figures are given for new material and of the best. If second-hand material is used the cost of the plant can be materially reduced.

Cost of Operation

A two-horse-power gasolene-engine will consume about five cents' worth of gasolene an hour under full load. When running a ½-kilowatt generator direct about .7 horse-power is necessary at a cost of about two cents an hour. The cost of operation for a generator is practically nothing, except for lubricating-oil, if it is given proper care and attention. The storage battery requires no supplies except a little sulphuric acid occasionally. The positive plates ought to last four and one-half years and the negative plates nine years with good care.

A Standard Voltage Plant

If standard voltage is to be used the plant should be considerably larger, as more current will be used when motors and heating-devices are available. The greatest increase will be in the cost for a 55-cell battery at $4.80 a cell. The generator will also cost more, depending on its size.

GLOSSARY OF TECHNICAL TERMS

A

Absorption Coefficient. Surfaces absorb, to a lesser or greater degree, light-rays which fall on them. The percentage absorbed is termed absorption coefficient.

A. C. Abbreviation for alternating current.

Accumulator. Storage battery; because it accumulates, or stores, electricity.

Air Gap. The air space between two conductors, or terminals. The resistance of dry air is about 20,000 volts per inch.

Alternating Current. That form of electric current of which the direction of flow reverses a given number of times per second.

Alternator. A generator which produces an alternating current.

Ammeter. An instrument for measuring electric current.

Ampere. Unit of current. It is the quantity of electricity which will flow through a resistance of one ohm under a potential of one volt.

Ampere-hour. Quantity of electricity passed when electricity flows at the rate of one ampere for one hour.

Anode. The positive terminal in a broken metallic circuit; the terminal connected to the carbon plate of a battery; opposed to cathode.

Arc, Electric. When the current "arches" over an air gap, usually accompanied by great heat and intense light.

Arc-lamp. A lamp which utilizes the intense heat of the electric arc as a source of light. Generally used for street lighting and the illumination of large areas.

Armature. That part of a dynamo or motor which carries the wires that are rotated in the magnetic field.

Armature Coils. The coils of wire in an armature.

Armature Core. The shaft, or soft-iron core, of the armature.

Attraction, Magnetic. Magnetism. The "pull" of a magnet, caused by the shortening of the lines of force.

B

Battery. A generator of electricity by the action of chemicals. The primary battery actually produces electricity; the storage battery merely stores it in the form of chemical energy.

Blow-out. When a fuse burns. A fuse is said to "blow out" when it melts and opens a circuit as a safeguard against dangerous currents.

Branch Conductor. A parallel, or shunt, conductor.

Brush. The collector on a dynamo or motor, which slides over the commutator, or collector-rings, and collects the current for the circuit.

B. T. U. British thermal unit—the unit for measuring heat. The amount of work required to heat one pound of water one degree.

Bus-bars. The heavy copper bars of the switchboard to which the dynamo leads are connected and to which the outgoing lines, measuring-instruments, etc., are connected.

Buzzer. An electric alarm similar to an electric bell, except that the vibrating member makes a buzzing sound instead of ringing a bell.

C

Cable. A heavy conductor. A bundle of insulated conductors protected with a rubber or lead covering.

Candle-hour. Candle-hour represents a definite quantity of light just as a watt-hour represents a quantity of energy. A source of 10 candle-power operated for 1.5 hours would produce a total of 15 candle-hours. If operated for four hours it would produce 40 candle-hours.

Candle-power. A measure of the luminous intensity of a source of light. The light of a standard sperm candle. The standard is known as the international candle, and is common to Great Britain, France, and the United States. The German, or Hefner, unit, is 10 per cent. smaller than the international candle.

Candle-power per Square Foot. Represents usually the ratio of candle-power allotted per square foot of floor-space in approximating illumination values.

Capacity, Electricity. Relative ability of a conductor, or system, to retain an electric charge.

Carbon. A non-metallic element extensively used in batteries and in other electrical devices.

Cathode. The negative pole, or electrode, of a galvanic battery; opposed to anode.

Cell, Battery. A single unit of a galvanic battery; a unit of the storage battery.

Charge. The quantity of electricity present on the surface of a body or conductor.

Chemical Action. The action of the chemicals in a galvanic cell whereby a current of electricity is produced.

Choking-coil. Coil of high self-inductance.

Circuit. Path, or conductor, over which the electric current flows. The house wiring is divided into various circuits. Conducting-path for electric current.

Circuit-breaker. Apparatus for automatically opening a circuit.

Circular Mil. The cross-section of a wire is measured in circular mils. The circular mil is a small circle having a diameter of 1-1,000 of an inch.

Collector-rings. The copper rings on an alternating-current dynamo, or motor, which are connected to the armature wires and over which the brushes slide.

Color. A ray of sunlight consists of numerous waves of different frequencies which, when so combined, produce the so-called white light. If a ray of such light is broken up by a glass prism the spectrum, showing different bands or colors of light, is produced. Different materials appear to have different colors, owing to the fact that all but the color reflected is absorbed.

Commutator. A device for changing the direction of electric currents.

Condenser. Apparatus for storing static electricity.

Conduit. A protective covering for electric wires.

Converter, Rotary. A mechanical device to change alternating current into direct current, or vice versa.

Core. The soft-iron central part of an electromagnet, or armature.

Current. The flow of electricity over a conductor.

Cut-out. Appliance for removing any apparatus from a circuit.

Cycle. Full period of alternation of an alternating-current circuit. From the generator through the circuit to the left, and from the generator through the circuit to the right, constitutes one cycle.

D

D. C. Abbreviation for direct current.

Depolarizers. Chemical agents used to correct the polarizing of galvanic cells. Cells are said to be "polarized" when an excess of nitrogen gas collects on the negative element and prevents a continuation of the chemical action.

Dielectric. A non-conductor.

Dimmer. Resistance device for regulating the intensity of illumination of electric incandescent lamps. Used largely in theaters.

Direct Current. Current which flows continuously in one direction.

Discharge. The equalization of potential difference; opposed to charge.

Dry Cells. Really wet galvanic cells, but the liquid elements are in paste form so they will not flow.

Dynamic Electricity. Electricity in motion; opposed to static electricity.

E

Eddy Currents. Foucault currents, commonly called "eddy currents," because of a fancied likeness to "eddy" currents in a stream of water.

Electric Bell. A small bell operated by an electromagnet and a vibrator.

Electric Furnace. A furnace which utilizes the intense heat produced by electricity.

Electrode. Terminal of an open electric circuit.

Electrolysis. Separation of a chemical compound into its elements by the action of the electric current.

Electrolyte. The chemical solution in a battery.

Electromagnet. A mass of iron which is magnetized by current through a coil of wire wound around the mass but insulated therefrom.

Electromotive Force (E. M. F.). Potential difference which causes current to flow.

Electroscope. Instrument for detecting the presence of an electric charge.

E. M. F. Abbreviation for electromotive force.

F

Farad. Unit of electric capacity.

Faradic Current. Currents produced by induction.

Feeder. A lead from a central station to some center of distribution.

Field. The region of magnetic influence between the poles of a magnet.

Field-coil. A magnetic coil used to produce the magnetism in the field, or between the poles, in a generator, or motor.

Field of Force. The space in the neighborhood of a magnet. Within the influence of magnetic rays.

Filament. The fine wire in an incandescent lamp, now generally made of drawn tungsten wire.

Flaming Arc. A type of arc-lamp in which the luminosity is intensified by using special mineralized electrodes.

Flux. Flux of light pertains to the waves which are emitted or flow from a source of light, and represents output, quantity.

Foot-candle. The unit of intensity of illumination. It is the illumination obtained in a surface one foot from a one-candle-power source; or, expressed otherwise, a foot-candle is the intensity of illumination produced by a standard candle at a distance of one foot, or by a 16-candle-power incandescent lamp when measured in the direction at which it gives 16 candle-power at a distance of 4 feet, as the intensity of light varies inversely as the square of the distance.

Foucault Currents. Correct name for "eddy currents"; stray currents of electricity usually produced by inductive influences.

Frequency of an Alternating Current. Commonly expressed as the number of double reversals in direction in one second. A double reversal is called a cycle, so that frequency is expressed as cycles per second. A 60-cycle circuit indicates that 60 double reversals occur each second.

Friction. The force opposed to mechanical motion; corresponds to resistance as opposed to electrical motion.

Fuse. A short piece of conducting-material of low melting-point which is inserted in a circuit and which will melt and open the circuit when the current reaches a certain value.

G

Galvanic Cell. A chemical generator, or battery, named after Galvani, an Italian scientist, who discovered the battery.

Galvanometer. Instrument for measuring current-strength.

Generator. Rotating-machine for producing electric current; two classes—alternating and direct current machine; many different types of each class.

Gravity Cell. A zinc-and-copper galvanic cell which is kept from polarizing by the force of gravity; copper sulphate, being heavier than the zinc sulphate, settles to the bottom of the cell; generally used for continuous current, such as telegraph work.

Ground. A circuit is said to be "grounded" when one of the conductors is short-circuited to the earth.

H

Helix. A spiral coil of conductor wire.

Horse-power. The unit of mechanical power. The energy required to raise 33,000 pounds one foot in one minute; 746 watts.

Horseshoe-magnet. A type of magnet bent in U-shape to shorten the distance between the two poles.

I

Incandescent Lamp. An electric lamp in which a filament of high resistance is inclosed in a vacuum globe and heated white-hot by the passage of the electric current.

Inductance. The property of an electric circuit to transmit itself through space, due to the lines of force which are developed around the conductor.

Insulator. Any substance impervious to the passage of electricity.

Intrinsic Brilliancy. A measure of the brightness of the light-emitting surface. It is expressed as candle-power per square inch.

J

Joule. Unit for measuring heat. The amount of heat generated by one ampere flowing for one second through a resistance of one ohm.

K

Keeper. A bar of soft iron, correctly called an "armature," laid across the poles of a magnet to retain the magnetism.

Kilowatt. One thousand watts. (See Watt.)

Kilowatt-hour. One thousand watt-hours.

L

Leyden Jar. Form of condenser which will store static electricity.

Lightning-arrester. Device which will permit the high-voltage lightning-current to pass to earth, but will not allow the low-voltage current of the line to escape.

Line. Often used by workmen in place of circuit.

Lines of Force. The invisible magnetic rays which surround every magnet and every conductor carrying a current of electricity.

Load. Work. A generator is said to be at "peak-load" when producing its rated capacity of current. The "load" is the amount of work required.

Lodestone. A natural magnet. Probably derived from "leading-stone."

Lumen. A unit by which the luminous radiation from a source is measured.

Lumens, Effective. The number of lumens falling on a surface, divided by the area of the surface in square feet, will give the illumination in foot-candles; or the number of lumens falling upon a surface, divided by the area of that surface in square meters, will give the illumination on that surface in lux, or meter-candles.

Lux. The illumination produced by one candle at a distance of one meter is called the lux. It is equal to one meter-candle.

M

Magnet. A piece of steel polarized by electricity.

Magnet-coil. The insulated coils of copper wire of an electromagnet.

Magnetic Field. The flow of magnetic rays between the poles of a magnet or magnets.

Magnetism. Theory has it that magnetism is caused by the polarization of the molecules of iron or steel.

Mean Horizontal Candle-power. The average candle-power given by a source in a horizontal plane through its center when it is held with its axis in a vertical position.

Mean Lower Hemispherical Candle-power. The average candle-power given by a source below the horizontal plane through its center.

Mean Spherical Candle-power. The average candle-power given by a source in all directions and is a measure of the total flux of light issuing from the source.

Mean Upper Hemispherical Candle-power. The average candle-power given by a source above the horizontal plane through its center.

Meter. Measure. The common types of electrical measuring-instruments are the voltmeter, the ammeter, and the wattmeter.

Molecule. The smallest part of any material. A molecule is said to be composed of atoms of various materials.

Motor. A device to change electrical energy back to mechanical energy.

Motor-generator. Motor and generator on the same shaft for changing alternating current to direct, and vice versa, or changing current of high voltage and low intensity to current of low voltage and high intensity, and vice versa.

Multiple. Term expressing the connection of several pieces of electric apparatus in parallel with one another.

Multiple Circuits. See Parallel Circuits.

N

Negative. Opposed to positive, usually signified by the minus (−) sign.

Neutral Wire Central wire in a three-wire distribution system.

Non-conductor. Not a conductor of electricity.

North Pole. The positive (+) pole. Opposed to south pole. Named after the north magnetic pole of the earth.

O

Ohm. The common unit of electrical resistance. The resistance of a simple circuit determines the current which a given pressure will produce, and is numerically expressed in ohms as volts divided by amperes. If a pressure of 24 volts causes a current of 4 amperes through an electrical conductor the resistance will be equal to 24 divided by 4, or 6 ohms.

Oscillate. To swing back and forth; to vibrate.

Overload. More than rated capacity. An electric generator, or motor, will carry a heavy "overload" for short periods.

P

Parallel Circuits. Two or more conductors starting at a common point and ending at another common point.

Plating. The process of coating metals by the action of electrolysis.

Plugs. Terminals of a connecting cord which are pushed or "plugged" into a wall receptacle for connecting electric heating-devices.

Polarization. The depriving of a voltaic cell of its proper electromotive force caused by gases which neutralize the chemical action.

Pole. Terminal. A magnet is said to have a north (+) and a south (−) pole.

Potential. The pressure, or voltage, of an electric current; expressed in volts.

Power factor. The power factor of an alternating-current supply indicates the ratio of actual watts to apparent watts which may be delivered. The apparent watts are equal to the product of the volts and amperes, but, owing to possible "phase displacement," the power delivered may be actually less than the apparent power. The power factor is usually expressed as a decimal fraction. If a pressure of 10 volts delivers 2 amperes at a power factor of .8 (or 80 per cent.) the apparent power is 20 watts, while the actual power is .8 times 20, or 16 watts.

Primary. First. A galvanic battery is called a "primary" battery because it produces a current of electricity. A storage battery is called a "secondary" battery because it merely stores, or accumulates, electricity.

Projector. Searchlight; so called because it projects a beam of light.

Push-button. A device which automatically opens an electric circuit, but arranged so it can be closed with a push of the finger.

R

Rectifier. A device for changing alternating current into direct current.

Reflection Coefficient. Surfaces reflect, to a lesser or greater degree, depending upon their nature and the quality of light, light-rays which fall on them. The percentage is termed reflection coefficient.

Reflection, Irregular. If a light-ray strikes a roughened surface, such as, for instance, blotting-paper, it is broken up into a number of component parts, and these parts are reflected in all directions, hence we say that the light is irregularly reflected.

Reflection, Regular. Regular reflection is based on the theory that the angle of incidence of a light-ray equals the angle of reflection, hence we state that when a light-ray strikes a polished surface it is regularly reflected at the same angle at which it is received.

Relay. To pass on. A telegraph relay receives a weak current of electricity and draws upon the local batteries for a strong current to pass the message on to the next relay station.

Remote Control. Controlling electrical apparatus from a distance by the use of magnets, or motors, etc.

Resistance. The quality of an electrical conductor by virtue of which it opposes an electric current. The unit of resistance is the ohm.

Residual Magnetism. The magnetism remaining in a soft-iron core when a current of electricity is not flowing in the magnetizing-coils. The magnetism that is left, or remains.

Rheostat. Resistance device for regulating the amount of current.

Rotary Converter. Machine for changing alternating current to direct current, or vice versa.

Rotating-field. In some generators and motors for various mechanical reasons the field is revolved around the armature instead of turning the armature within the field. Obviously it makes no difference in the flow of current whether the field or the armature is revolved.

S

Secondary Battery. See Storage Battery. A battery whose positive and negative electrodes are deposited by current from a separate source of electricity.

Secondary Current. The current induced in the secondary winding of an induction-coil or transformer.

Self-inductance. Tendency of current in a single circuit to react upon itself and produce a retarding effect similar to inertia in matter.

Series. Arranged in succession, as opposed to parallel or multiple arrangement.

Series Motor. Motor whose field-windings are in series with the armature.

Short Circuit. When the circuit is suddenly shortened by the current escaping through the ground or over another conductor.

Shunt. A by-path in a circuit which is in parallel with the main circuit.

Shunt Motor. Motor whose field-windings are in parallel or shunt with the armature.

Single Phase. A current of one phase, or value.

Snap-switch. A small wall-switch used to snap on and off the current.

Solenoid. An electrical conductor wound in a spiral and forming an electromagnet.

Spark-gap. Space between the two electrodes.

Starting-box. A rheostat, or resistance-box; generally used in starting motors to lower the initial voltage until the machine is running at full speed.

Static Electricity. A high-potential stationary charge of electricity which may exist on insulated bodies; produced by friction; lightning is a form of static electricity.

Stator. The stationary part of an alternating-current generator or motor.

Storage Battery. A device designed for the storage of electrical energy by chemical means.

Switch. A device to open and close a circuit.

Switchboard. A board, or panel, of wood or stone, to hold the switches, instruments, etc., for controlling the distribution of the current.

Synchronize. To be in step, in balance; to work in harmony.

T

Terminal. The end of an open circuit.

Thermostat. Instrument which, when heated, closes or opens an electric current.

Three Phase. An alternating current with three different phases, or values.

Three-wire System. Where three wires, or conductors, are used to distribute the electric current.

Transformer. A device for stepping-up alternating current from low to high voltage, or vice versa.

Transmission. The distribution of electricity over wires, or conductors, often for hundreds of miles.

Trolley. A device for connecting a trolley-car with the overhead trolley-wire.

Turbo-generator. A generator directly connected to a steam-turbine engine.

Two Phase. An alternating current of two phases, or values.

V

Vibrator. A spring device used to "make" and "break" an electric current. Necessary for direct current only.

Volt. Unit of electromotive force, or potential. It is the electromotive force which, if steadily applied to a conductor whose resistance is one ohm, will produce a current of one ampere.

Voltage. Potential difference, or electromotive force.

Voltmeter. Instrument for measuring voltage.

W

Watt. Unit representing the rate of work of electrical energy. It is the rate of work of one ampere under a potential of one volt. Seven hundred and forty-six watts represent one horse-power.

Watt-hour. Electrical unit of work. Represents work done by one watt expended for one hour.

Watts per Candle. Indicate the amount of electrical power necessary to produce unit luminous intensity. When rating incandescent lamps of specific consumption in watts per candle is usually based on the mean horizontal candle-power.

Watts per Square Foot. Represents usually the consumption allotted per square foot of floor-space in approximating illumination values.

Wiring. The wires installed for an electric circuit.

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THE END