LESSON TEXT NO. 1

OF A

Complete Course in Radio Telegraphy and Telephony

General Instructions
History and Development of Radio Telegraphy, Elementary Electricity and Magnetism
Electric Current

TENTH EDITION

NATIONAL RADIO INSTITUTE, Inc.
Established 1914
WASHINGTON, D. C.

CORRESPONDENCE COURSE

N A T I O N A L   R A D I O   I N S T I T U T E

Washington, D. C.

IMPORTANT LESSON CORRECTIONS

BOOK 1.

Page 64 the sixth definition from top should read, "An ELECTRIC MOTOR is a machine for converting electrical energy into mechanical"

BOOK 2.

Page 3 and 4 should read, "These primary rules are relatively few and it will not be difficult for you to understand them and to store them in your memory, etc."

Page 49 the sixth, definition from the top should read Variometer.
A Variometer is composed of two coils, one rotating inside the other, the inductance effects of each winding may be made to assist or practically neutralize each other.

BOOK 3.

Fig. 21-B Page 9.

The arrow C indicates the make and break contact for the vibrator and not the direction of the current flow.

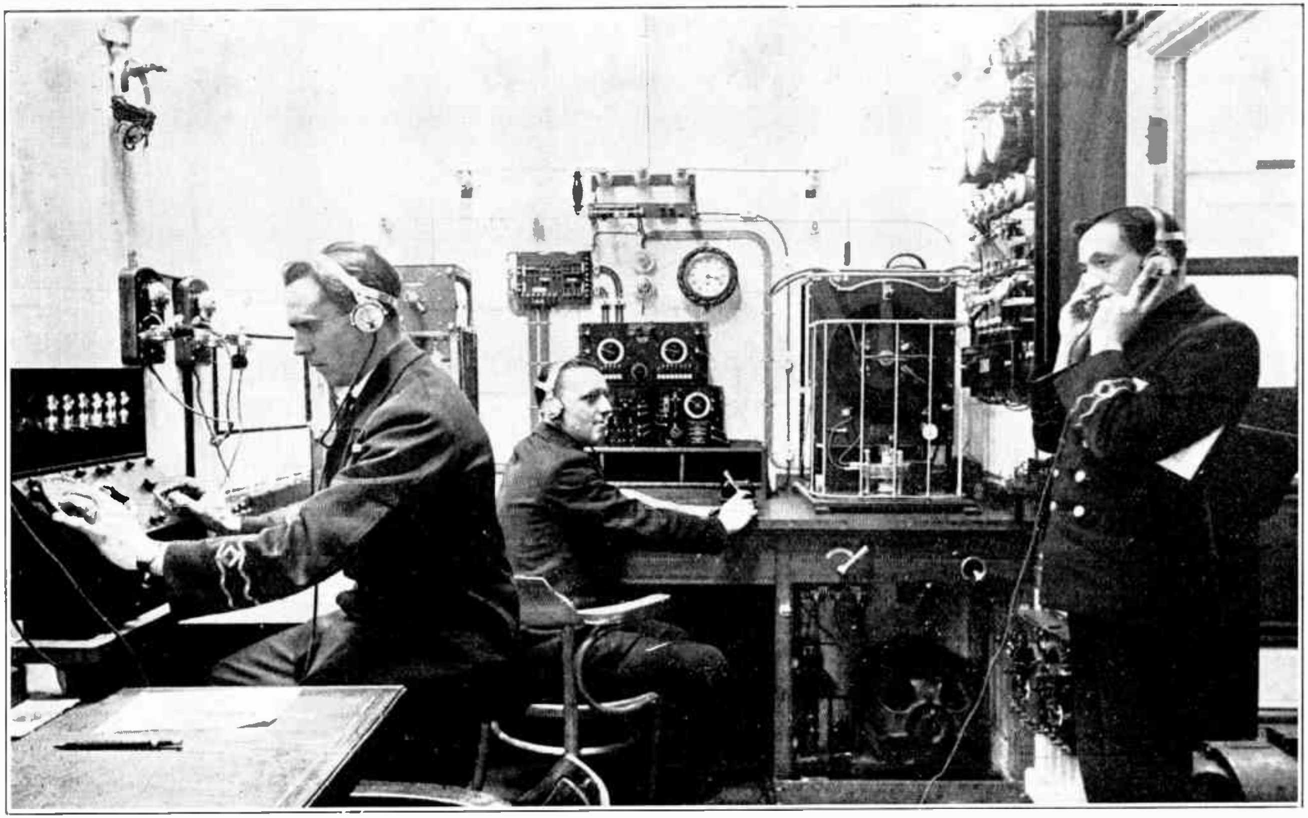
LESSON TEXT No. 1

Complete Course in Radio Telegraphy and Telephony

This course represents the work of Radio experts whose experience and training has been set down in a concise way so that you can profit fully from it within a short period of a few months, provided you apply yourself conscientiously to the work as outlined.

TENTH EDITION

Established 1914
Washington, D. C.



How would you like to be in this comfortable, cozy radio station receiving and sending messages to the world at large? The men in this picture trained themselves and now are rewarded with good-paying positions, clean work, and good surroundings. You are on your way to a position like this now.

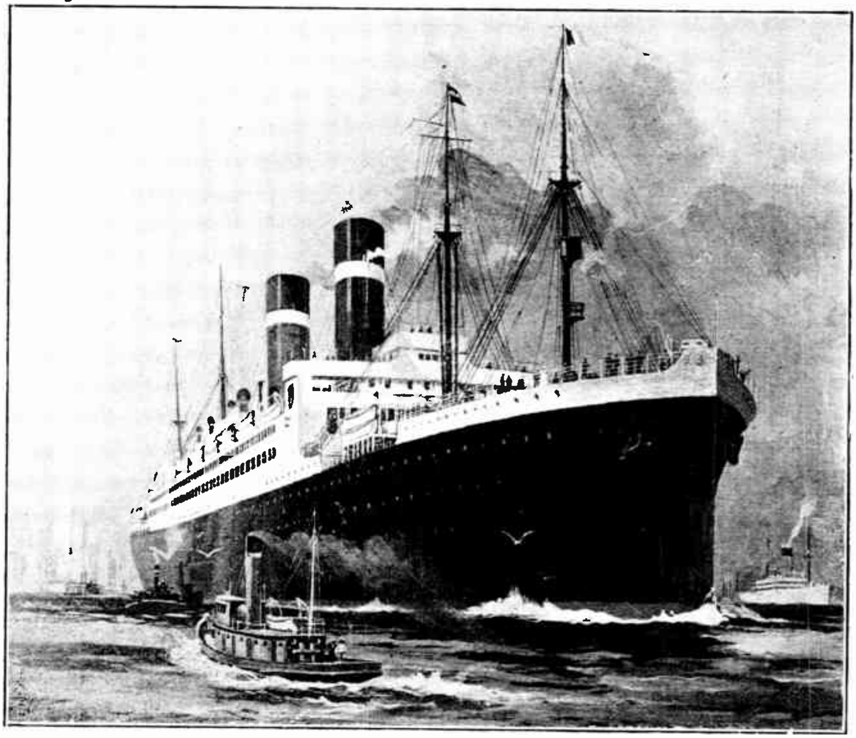
WHERE FORTUNES AWAIT

Unlimited opportunities lie before the radio trained man, with the scientific knowledge for solving the mysteries of radio phenomena. This article points out what some of these mysteries are.*

An eminent doctor recently called on me to ask how he could get a transmitting and receiving radio station.

"Where do you want to transmit to?" I asked.

"Any part of the world," he answered. "Two of my



One of the large Shipping Board vessels of the U. S. Merchant Marine, fully equipped with Radio.

patients are in Paris, one in London, one in Egypt, several at various summer resorts, and two on the Pacific Ocean *en route* to China and Japan. With a radio I can keep in touch with them daily and advise them instantly regarding their health. If I don't prepare for it they'll soon find a more progressive physician."

**By Henry Woodhouse*

I had to admit that the argument was convincing, although I advised him that the matter of transmitting would be too complex for a physician and he should make arrangements with one of the large corporations.

"How many physicians are there in the United States?" I inquired.

"Over one hundred thousand," he answered.

It may seem visionary to state that it will not be long before every physician will have to have a radio telephone. But it is not more visionary than it appeared twenty-five years ago to say that physicians would soon have to have

The Radio Room on one of the Shipping Board steamers, showing transmitting and receiving apparatus.

the telephone. Alexander Graham Bell, the inventor of the telephone, told me that even in his wildest dreams he never dared to think that doctors would ever find it necessary to have telephones in their offices. What would you think now of a physician who did not have a telephone in his office?

The incident is significant. The stupendous spread of interest in radio, by bringing into being a corps of hundreds of thousands of radio experts, professionals and amateurs, has created a world-wide organization, large enough and equipped with the means necessary to attack the most profound problems that have heretofore baffled science, the solving of which will, coincidentally, solve the basic problems that stand in the way of further progress in radio transmission and the fundamental progress of electric art and science.

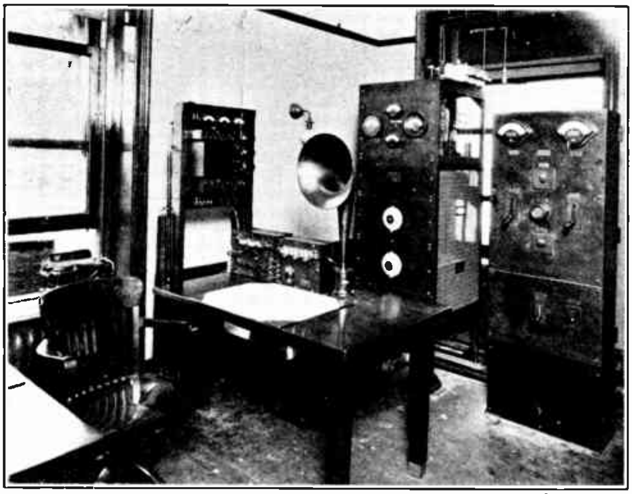
If we can solve these problems radio will become a five-billion dollar industry; the electrical industries will advance until they equal twice as much more. For it is the same group of fundamental mysteries that underlies both radio

The *St. Louis Post Dispatch* has one of the most powerful stations for broadcasting news in the Middle West. Here you see the aerial erected on the top of a high building.

and all the other uses of electricity and magnetism.

The future of radio—to take only this one among the possibilities of electricity—is so immense that it is beyond our power to grasp. The world is ready to adopt radio in every branch of human endeavor, and will do so as soon as ways are found to so control radio waves that a million or more messages can be sent and received simultaneously from as many stations, without mutual interference, and as soon as natural electric, magnetic and atmospheric interferences are eliminated or controlled.

To get an idea of the developments to be expected you must ask yourself what radio can do in co-operation with the hundred or so gigantic industries like the shipping industry, the railroad industry, the automobile industry, the telegraph, telephone and cable industries, the oil industry; in every branch of the commercial world, such as banking, buying, selling, negotiating contracts and concessions; in the transmission of news, photographs and images of events;



This neat Radiophone Transmitter was installed recently by the Union Trust Company, of Cleveland, Ohio. Rapid communication, as well as a means of keeping in constant touch with customers, is vitally necessary for banking institutions. Radio answers the need—nothing else.

in the various professions, and at home and in every phase of daily life.

For instance, in the near future it may be a legal requirement to equip automobiles with radio-telephone receiving instruments, to facilitate the control of interstate traffic. Then there will be a sudden demand for over 13,000,000 receiving instruments, one for each registered auto. This development is dependent upon better control of transmitting and receiving and on the neutralizing of local magnetic and other natural or artificial phenomena created by railway and electric systems, steel buildings and other local conditions.

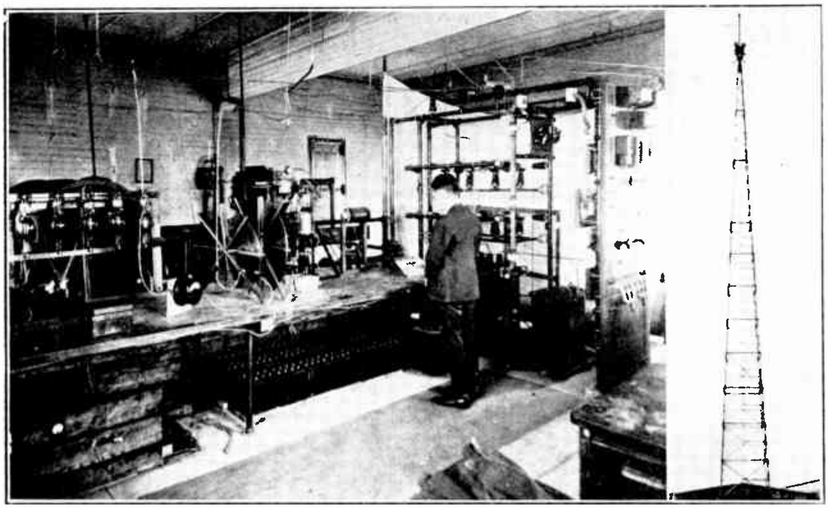
The better control of radio will make it possible for millions of firms and individuals to communicate with their correspondents by radio messages, received on typing machines at the receiving end as fast as they are typed at the sending end.

The solution of these pressing radio problems may make it

possible, also, to realize the task of supplying to air craft, water craft or land craft, as well as to machinery, power from central radio stations—as proposed by Nikola Tesla to me ten years ago.

In the not distant future we may expect that audible broadcasting will be supplemented by visible broadcasting of what we may call radioscapes, through systems that will make it possible to project the pictures of ships and trains in transit and of other events on a screen in any part of the world.

A baseball game in New Zealand will be projected on a screen in a theater or private home in New York or on ships at sea; an opera performance in New York will be seen as well as heard, all over the world; the progress of ships at sea will be shown on the screen at the offices of the shipping companies, or in the homes of friends of persons traveling on the ships; it will be possible to see actions of congressmen



Broadcasting stations are continually being improved. Above you see the interior of the transmitting room of WGY, General Electric Company's Broadcasting Station, Schenectady, N. Y.

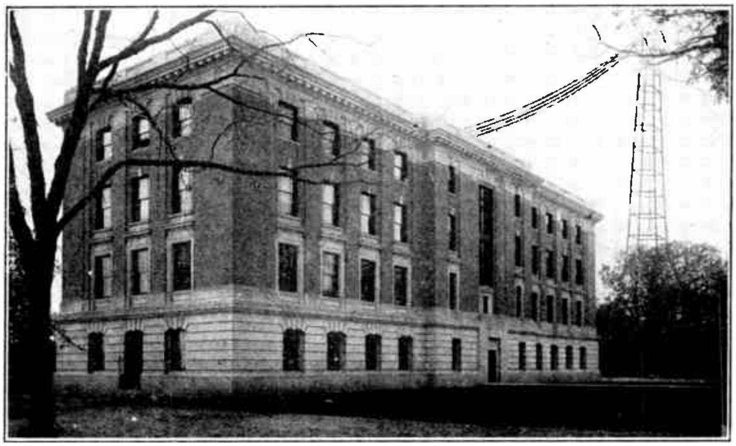
and members of legislatures as well as to hear their addresses' and civic associations will no doubt maintain auditoriums in cities and communities where people may go daily to follow the acts of their legislators; the maneuvers of warships will be projected on screens in Washington, where the naval authorities may follow them; and so on with every public branch of human endeavor.

Radio has always had a keen scientific appeal. But now it is becoming an essential of everyday life, just as has the telephone, which now has over 15,000,000 subscribers in American territory. There are even greater prospects for radio, provided we solve the problems that restrict the volume of radio traffic.

"How can we solve these problems," asks every radio worker who is ambitious to win fame or fortune from his art. So also asks every person who sees a possibility of using radio or electricity to solve some problem of business or of everyday life.

The first step is to see what the problems are.

As a result of twelve years of investigation and contact with leading scientists, who accorded to the writer the rare privilege of stating frankly what we know and what we do not know about fundamentals, the writer has listed over one



BUREAU OF STANDARDS—WASHINGTON, D. C.

One of the finest Radio Laboratories in the world is located in this building. The radio research engineers employed here get rich rewards for their service.

hundred unsolved radio, electric and magnetic mysteries that await solution. The following are a few of them:

1. What are the sources of terrestrial magnetism? If these sources are inherent in the earth, can they be so vast as to supply so enormous an amount of magnetic force for thousands of years, without being capable of being tapped for power to drive our machinery, ships and automobiles?

2. Why is it that both radio and terrestrial magnetism diminish and fade away at the equator? Is it that radio is less strong there because it is unsupported by terrestrial magnetism, or is it that both are diminished by some third mysterious phenomenon about which we do not know anything?

3. Why does the Aurora or polar lights, while disturbing telephone and telegraph service and creating radio dis-

turbance in some regions, improve radio transmission in other regions?

4. By adopting the new theory that ether is a magnetic (or electromagnetic) flux, can we explain the kinetics of the universe, providing a mechanical basis for computations which were limited, heretofore, to mathematical deductions and philosophic conceptions?

5. Do the radio signals from surface vessels, that are picked up by submerged submarines, travel over the surface of the water and then ground where the submarine is? Or do they ground immediately they are transmitted and follow

Radio is used to entertain railroad passengers. This photograph shows equipment installed in one of the coaches of the Pan-American De Luxe Flyer. Passengers can now listen to concerts and other programs while traveling across the country at the rate of 40 to 50 miles per hour.

"hug" the bottom of the ocean? Or do they traverse the whole vertical depth of the water?

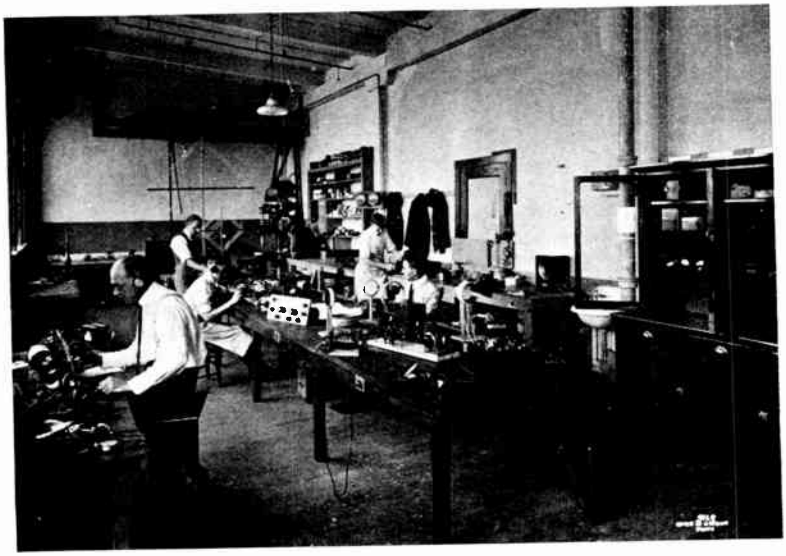
6. Are the phenomena of "static" and "atmospherics" the same below, on and beneath the surface of the earth? Or, to phrase it differently, is ground static the same as atmospheric static or are they entirely different, each requiring different means for its elimination or utilization?

7. Why is it that static disturbances are directional and come mainly from areas located at the magnetic equators, these areas being also the areas of maximum frequency of thunder storms?

8. Are sun spots, magnetic storms, polar lights, magnetic variations and static conditions simultaneous occurrences, interrelated causes and effects all originating from the same source?

9. What is the cause of the mysterious "dead spots" for radio transmission which have been found in the Eastern United States, in Alaska, in Europe, on the oceans, and elsewhere?

10. What forces associated with, or resulting from, the motion of the earth increase or decrease radio conductivity?



REPAIRING AND TESTING SETS

Men in this branch of Radio must be expert. The salaries they earn are in proportion to their expertness.

11. Is the electron responsible for magnetism, or magnetism for the electron, or neither? Is there an ultimate magnetic particle and what is its relation to the ultimate electric particle?

12. What are the effects on the earth of the action of the sun in charging space with electric energy amounting to millions of billions of volts and with light amounting to innumerable billions of candle power?

When these questions, and the scores of others like them, have been answered we shall have gone a long way toward solving the practical problems of radio and of electrical engineering. Practically every one of these problems affords a stupendous opportunity for fame, rewards and distinction to whoever succeeds in finding the answer to it.

An experimenter, a radio amateur provided only with the simplest equipment, may, in seeking the answer to one of these questions, discover some new principle or some new method of application of old principles, some utilization of forces and elements now ignored, just as Edison discovered

Uncle Sam believes in Radio to the extent of spending millions on this new way of communication every year. This photograph shows the Post Office Department Building, Washington, D. C., used in connection with the Aerial Mail Service and also for sending out daily Radio-marketgrams for the benefit of farmers and others interested in market activities. The Radio room is located on the top floor and two aerials are supported by the top of the tower.

many new principles while experimenting to obtain entirely different results, just as Roentgen discovered the X-rays by accident, just as De Forest evolved the revolutionary audion lamp from observing, while experimenting, that the discharge produced by a spark coil affected the intensity of the gas burner in his lodging room, and just as Ampere discovered the principles that brought him fame while working as a village blacksmith.

"Why do we not know these things?" and "Tell me where to begin?" are the two questions I have asked the world's leading scientists—and in turn I have been asked by hundreds who have heard my lectures and read my statements on some of these subjects.

I have space here to mention only a very few of these problems. One of the most alluring of them is that of the nature of magnetism. It is a subject about which we know almost nothing but which probably, nevertheless, is the most important of all to the future of radio and of electricity.

What *is* this mysterious something that we call magnetism that penetrates everything and is to be found every-

AVIATION

Equipment fastened to operator for listening to orders from below and also a phone arrangement for sending messages. This is done in ordinary words and not in code. Here is a new field for the Radio man.

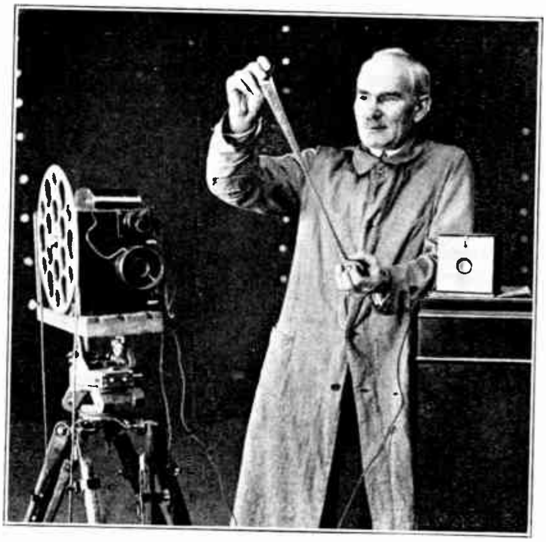
where? Where does it come from? Why is the earth magnetic? What are the magnetic poles? How has it been possible for the magnetic poles to magnetize everything in the earth and, undoubtedly, in the surrounding atmosphere without the source becoming exhausted?

The world cannot answer these questions. Captain Roald Amundsen, who studied magnetism since boyhood and who actually lived over a year in the region of the north magnetic pole in order to study the phenomena there, told me:

"Magnetism is more fundamental and more wonderful than electricity. We know only very little about it."

A small compass, a piece of lodestone, a magnet, a half ounce of iron filings, and a dozen needles, the whole costing about \$3.00, will demonstrate more mysterious phenomena than the collective knowledge of mankind can explain today.

It is a curious commentary upon man's proverbial enterprise that although billions of persons—or an average of two billion every fifty years—have lived and died since the Chinese began using the magnetic compass, about two thousand years ago, only half a dozen men ever tried to follow the compass to the earth's magnetic poles to find out what the



Dr. Lee De Forest, prominent Radio inventor, busy on his latest idea—developing the talking motion pictures. Dr. De Forest is the inventor of the vacuum tube which has been so instrumental in the expansion of Radio. Anyone with an inventive turn of mind could not pick a bigger paying field than Radio.

source of this phenomenon is; and of this half dozen, only one, Captain Amundsen, stayed in the magnetic polar regions a number of months to study the phenomena that occur there.

A number of the most pressing practical problems of radio are related, presumably, to this matter of the earth's magnetism. One example is the frequent phenomenon of variable path of waves in radio transmission. We are reminded by Marconi and other authorities who have opportunity of obtaining continual data of such variations that signals from stations at great distances do not always retain their direction along one great circle, but reach the receiver from either way or various ways around the earth. Marconi reports:

"The observers noted American signals from Radio Central and from Tuckerton coming from a direction which indicated that they preferred to travel a distance of three-quarters of the way around the earth, rather than come by the shortest way round."

Another interesting and extraordinary result was noted on several occasions, according to the report of Mr. Tremallen from Rocky Point, New Zealand, where during last

FOREST SERVICE

Wolf Creek Ranger Station. Station Radio Operator on right. Some of these stations are located 12,000 feet above sea level. These stations take regular observations of the surrounding country by use of power field glasses and report any sign of fire and its location to the proper officers by Radio.

March the signals from Nauen appeared to travel to him *via* the South Pole, whilst those from Hanover, also situated in Germany, and not very far from Nauen, appeared to prefer to travel *via* the North Pole.

Why? Nobody knows, but we may explain the phenomena if fifty thousand radio experimenters report for six months what they hear at different times of the day and night, because when such reports are tabulated they may make evident facts which we do not even suspect at present.

The *Maud*, the ship of the Amundsen Artic Relief Expedition, frozen in the slowly drifting polar ice, is sending two radio weather reports each day from its powerful plant. These are received across the North Pole, at European stations, but, as far as has been ascertained, are not received in Alaska, Canada and the United States.

What is it that prevents the *Maud's* daily radios from reaching the stations on the American continent? It cannot be the ice fields, the frigid air, the arctic storms, because there are more of these north of the *Maud* than south and west of her. The North Magnetic Pole, the center of the earth's magnetic attraction may be the cause, but nobody knows.

It is one of the mysteries that may be solved by the world's radio amateurs if they will listen for the *Maud's* daily radio signals and report whether they hear them or not. And any amateur who succeeds in solving this mystery, or

POLICE DEPARTMENT

Head of Police Service broadcasting news concerning the stolen automobiles for the day. "Every amateur station at least one hundred miles from the city will become a sort of police outpost." Highly trained men in this position are essential.

any other one of the basic radio problems still unsolved, may find that it puts into his hands the key to wealth as well as to scientific distinction.

In May, 1916, when I delivered an address to the New York Electrical Society, I reported my experiences in testing the compass at high altitudes and the possibility of aerial torpedoes and torpedoes mounted on airplanes, directed through the air by radio, and pointed out that the mechanical problems of launching a five-ton load of T. N. T. through the air by radio would be solved before we could solve the problems of directing that load safely.

This is the case today. The Hammond system has demonstrated that even a battleship can be operated by radio, but we dare not venture a full-size airplane, because of the many unsolved problems of radio transmission.

Directing military airplanes by radio cannot be undertaken so long as there is a possibility of interference. While the airplane would carry the load of explosive past a dead spot, which the airplane could easily negotiate, the radio could not cross that spot and the airplane would from that point on be adrift, guideless, a menace to communities below!

This gives an idea of the importance of some of these problems from a military standpoint. Many of them are equally important commercially.

Another one, which may or may not have a magnetic element, is the mystery of the disturbances known popularly as "static" or "atmospherics." Very little is known of these disturbances beyond the fact that they occur. The phenomena may be at times electric, at times magnetic, at times atmospheric. One of the important needs at present is to analyze the disturbances into these or other divisions. Only by learning their nature will we be able to screen them off or to utilize them, the latter being the most likely result, because it is not natural with human beings to let power go unharnessed.

The genius of Tesla, in noticing that the stationary waves caused by a distant storm could be reproduced in the conducting layer of the earth by means of two synchronized oscillators, and utilized to explode submarine mines is an example of how we may utilize all "static" phenomena.

But first we must find out what the disturbances are. Do they originate in the crust of the earth, or in the atmosphere which wraps the earth, or from cosmic sources altogether outside the earth, or from all of these in combination?

This is one of the cardinal questions to be solved.

We must not forget that whatever the nature of these disturbing factors, they use the same conductive media as radio signals, therefore we may learn about both in studying either.

Were it possible for a radio experimenter to view the whole earth whenever his receiving instruments register the clicks and rattlings of static, he would find, probably, that polar lights are flashing their dazzling streamers from points ranging from sixty to one hundred miles above the north and south polar regions and extending skyward, several hundred mlies up.

Why? No one knows. It is one of the many unexplained phenomena which the radio experimenters may help to define, benefiting the art of radio transmission in so doing.

By adding to their radio sets the simplest equipment used for determining magnetic variations, the world's radio experimenters could supply in the course of a year data that might make it possible to establish the connection of the so-called "static" and "atmospheric" disturbances with the polar lights, the connection between polar lights and magnetic storms, the direction and geography of magnetic disturbances and other basic facts.

Radio engineers have been as prodigal with the natural resources available to them as other pioneers have been. Their attitude toward static and atmospheric disturbances is similar to that of the salt miners a century ago who cussed when they struck some stuff called petroleum while mining salt. They are just as wasteful as the railroad people who spent thousands of dollars wearing out brakes in slowing up electric trains going down hill. Now the salt miners who strike oil abandon the salt to take care of the oil, and the railroads use the downward journeys of trains to generate electricity to use to take the same train up the next hill.

The time is coming when what is now grouped under "static" disturbance and cussed by the radio experimenter, will be divided into categories, such as electrics to designate electric phenomena, magnetics to designate magnetic phenomena and atmospherics to designate phenomena caused by atmospheric conditions. Each will be utilized and used not only to advance the cause of radio and electric transmission but also to advance other industries, arts and branches of science.

We may obtain benefits of material value in everyday life, such as means of tapping the natural electric fields for cheaper power to drive machinery and to light the streets and homes of the most isolated communities.

It may come to pass that static and the polar lights, instead of being regarded purely as vagaries of nature that often disrupt the radio and telephone and telegraph service, may become signals that conditions are favorable for tapping the natural electric fields and for storing away electricity to drive our machinery for months to come.

Imagine the world-wide and lasting fame, to say nothing of more tangible rewards, that awaits the man who first succeeds in doing this. Every radio experimenter has unparalleled opportunities of winning fame and wealth by solving one or more of these basic scientific mysteries. There are opportunities for thousands.

Instructions and a Few Helpful Suggestions

You now have in your hands the first lesson of a course of training that is going to make you a radio expert. This is really sort of a fifty-fifty proposition. Half depends upon you and half depends upon us. We know that we can carry out our half of the bargain because we have done so in hundreds of other cases. And we know that you are going to carry out your half of the bargain. We have faith in you. That brings up another point.

HAVE FAITH IN YOURSELF

The man who does not have faith and confidence in himself is in a poor position to forge ahead. **Believe in yourself.** Do not say, "I can't do this; it's too hard for me." Confidence is the spice of life. Lack of confidence and success never travel hand in hand. Remember that. Faith moves worlds and **confidence fattens the salary envelope.**

When Edison was a young man, scientists told him that light without combustion was impossible. He had faith in himself and in his ideas, however, and he plugged ahead and showed these scientists that they were wrong. What if their advice had discouraged him? We would not have the electric light today. There are many men who would bet on their favorite race horse and yet lack the courage and confidence to bet on themselves.

ATTACK THIS COURSE FEARLESSLY

If you are afraid that this course is going to be so difficult that you will be unable to comprehend it, **dispel that fear immediately.** We made this course for men like you. Do not start out like a "gloom" and say, "Gee, this is going to be a tough job." Do it this way: Say to yourself, "Huh, this is going to be the easiest thing I ever tackled." This course is really a "pipe," as the boys say. It cost us thousands of dollars to present this subject of radio in an easy-to-learn manner, but we have succeeded in doing it.

ROLL UP YOUR SLEEVES

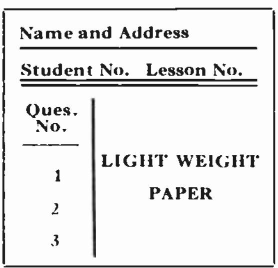
Go into this thing with your sleeves rolled up. **Remember that you will not get any more out of it than you put into it.** Make out a time schedule. Arrange your plans so you can work a definite period each day. Be systematic about it. Keep your notebook at your elbow and jot things down that you want to remember. In fact, jotting things down helps you to remember them. Do your work thoroughly. This is important. No detail is too small to receive your consideration. Skip back over what you have studied and refresh your memory. These little trips into the past will do much toward making the whole thing more comprehensive to you.

Some evenings you may come home not feeling like studying. There is a remedy for this. Put on your hat and coat and take a little walk. Get some fresh air. Then, while you are walking, plan about your future in radio. Think of how proud your folks and friends are going to be when you can show them your certificate and license that Uncle Sam is going to give you to practice the radio profession. When you return to your work you will be all spruced up, primed for action.

We are going to stay with you on this proposition to the last ditch. We will help you in every way possible. **Do not forget that.** We are going to work this thing out together.

A FEW PRELIMINARY INSTRUCTIONS

Every one of our lessons contain instructions pertaining directly to the fundamental principles of radio. A few of the early lessons in the course contain the essential laws and working principles of electricity, for without a knowledge of this modern form of energy we could not make even the first step of progress in Radio. **When submitting your answers for grading, be sure to write your name, address, student and lesson number on every lesson.** You are going to help us a great deal by doing this. Use plain standard writing paper and line it up in the way **shown in the insert.** Try to write as neatly and legibly as possible, **using pen and ink or typewriter. You may use pencil for drawing diagrams.** Do not be like the chap who said there was one thing in this world that he could do that other people could not do, and that was to read his own writing.



Study over the fundamental principles in the text before attempting to answer the questions. Do not cheat yourself by copying definitions out of the text. That will not do you any good. No one ever learned anything that way. Knowledge gained in that way is rarely retained.

The amount of time required for the preparation of a lesson varies with the individual, and the distribution of this time depends necessarily upon what other occupation the student may have. The time devoted should be so planned that one lesson each week may be covered, and the lesson report sent in to us. In most instances this is the ideal standard, and records show that students who maintain this average are the most successful. Yet a student who for some reason finds it impossible to maintain this standard should not by any means become discouraged, as very satisfactory results have been obtained when there has been a longer time between lesson reports. Whatever the rate of work, system and regularity of effort are essential for obtaining the best results, and for this reason the student is urged to make and follow a schedule of study. We would appreciate a few lines from you every time you are detained from sending in your lessons for grading.

Study each lesson until you are sure you have mastered its contents. We are not putting any time limit on you, but we believe you can handle one of these lessons every week if you try. Some of our students complete their course of study in four months, others in six months, and others, who assimilate knowledge slowly, require one year.

When your paper reaches the Institute it will be corrected, graded and returned to you (with new lesson texts) so you can see where your mistakes were made. If your paper is not returned to you within a reasonable time, after it has had time to reach this Institute do not fail to let us know about it. Do not write requests for information or services on your lesson, but do so on a **separate** sheet.

When drawing diagrams always use a ruler; also name each part of apparatus. A pencil can be used for drawings.

Neatness as well as correctness of your answers is considered when grading your papers.

Answers only are required. Do not write the questions.

Lessons, books, instruments, etc., are sent to students according to the schedule in the plan of enrollment.

Be sure to number your answers to correspond with the numbers of the question. This will help us in the correction of your lesson.

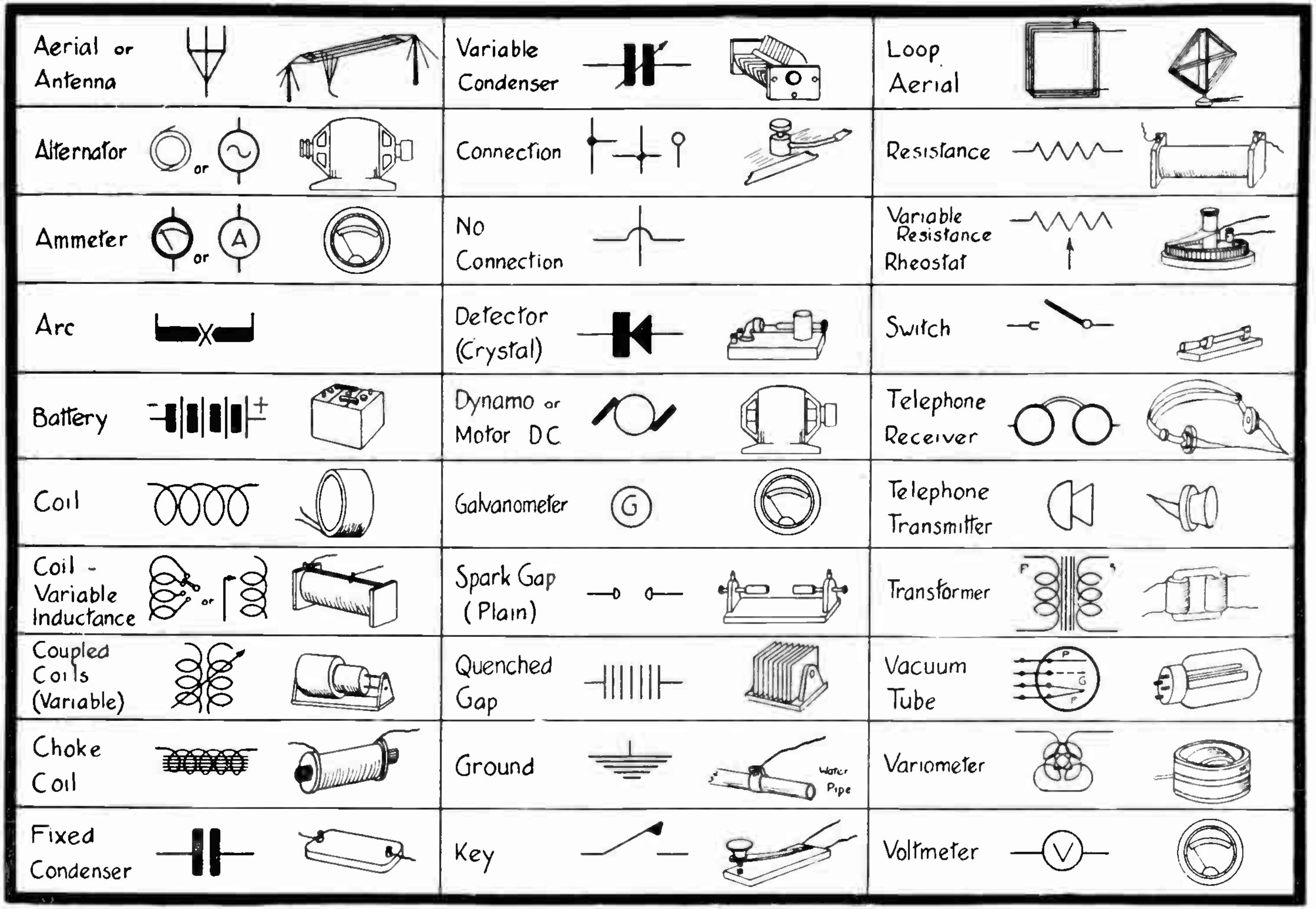
To obtain our diploma, which will mark you as a trained radio expert you must average 75 per cent on your lessons. Honor men must receive marks of 90 per cent or over on their lessons. You can be an honor man.

It is remarkable how much a man can accomplish in the way of improving himself and increasing his earning power by making use of a few spare hours each day. The man who today occupies the front ranks in any trade or profession is the trained man. It is a man's training that counts. Fire and flood can destroy everything you possess, but it cannot take away from you your knowledge and abilities. Then why not make the most of these, your greatest assets?

How our forefathers would have grasped with outstretched arms at the opportunities that lie in wait for every one of us today. All we have to do is to properly prepare ourselves.

The study for your career begins in the next paragraph.

Write all special questions on separate sheet and have the first sheet bear your name, address and student number. All sheets beside the first to have student number on them. Otherwise answer to your questions will be delayed.



Symbols used to illustrate the many parts of a Radio Transmitter or Receiver which will help you to clearly understand many circuit diagrams, as you progress through this radio course.

LESSON No. 1

EARLY METHODS OF COMMUNICATION

The methods used by mankind in the past to transmit intelligence between different points on the earth's surface have been very primitive. History hints vaguely of the possibility that the Chinese used some means of communication, capable of transmitting a considerable distance, but details as to the nature of this are lacking.

The tom tom or drum, still used by the savage tribes of Africa, is probably the most primitive of all methods. The reflection of the sun's rays by means of a mirror was used at the time of the greatest development of Roman civilization. Carrier pigeons have been used for the carrying of messages but furnished a very unreliable and unsatisfactory means of communication. The ability to communicate is one of the greatest factors in the development of civilization. Both domestic and international commerce are dependent upon communication, and the result to the business world, if all communication lines were broken, would be truly disastrous.

The great development in methods of communication came with the invention of the telegraph in 1835 by Samuel Morse. Today it would be difficult to find any considerable portion of the country into which the telegraph lines do not penetrate. The telegraph was followed shortly after by the invention of the cable by Cyrus Field. The cable connects all of the continents, and together with the telegraph has made very extensive the dissemination of news and the development of international commerce.

The development of radio telegraphy within the last fifteen years has brought about communication between continents, and also made it possible for ships to communicate with land and with each other. Cables or telegraph lines may be destroyed by storms or by countries at war, but the maintenance of radio communication is comparatively simple.

HISTORICAL DEVELOPMENT OF RADIO TELEGRAPHY

Wireless telegraphy, or to use a more modern and more accurate term, radio telegraphy, is a special branch of electrical science. The apparatus used in radio communication is quite different in appearance and action from the apparatus used in wire telegraphy. In fact, about the only thing in common is the key employed in breaking the current into the dots and dashes of the International Code.

The discoveries made by scientists, upon which modern radio apparatus is based, date back as far as 1838. In that year Professor Henry, of Princeton University, discovered that a Leyden jar discharge was oscillatory. To make the meaning of this clear to the student we will describe the Leyden jar and explain its action. A jar of glass coated on the inside and outside with tinfoil to about three-quarters of its height may be given a charge of electricity. That is, electricity may be stored in the coatings of the jar. It was given the name of Leyden jar due to the fact that the first one was produced at Leyden, Holland. Professor Henry found that if the Leyden jar is given a charge of electricity and a wire is placed so as to connect the inside and outside surfaces, that the electricity on one coating would discharge to the other coating through the wire and then immediately discharge back again. The discharge from one coating to the other would keep up until the energy stored in the jar was completely dissipated. An action of this nature is termed oscillatory.

In 1853 Lord Kelvin made further investigations of this phenomena, and gave the laws which govern the action of an oscillatory discharge.

James Clerk Maxwell, in 1863, formulated the theory that the discharge of a condenser across a spark gap sets up disturbance in space which traveled at the same speed as light, that is, at about 186,000 miles per second.

In 1888 Heinrich Hertz, a young German scientist, produced experimental proof that Maxwell's theory was correct.

At about this time Sir Oliver Lodge, as well as other scientists, began to study the disturbances set up by the discharge of a Leyden jar, making discoveries of great importance.

In 1880 Professor Branley invented an instrument called a coherer to detect these waves or disturbances and make them audible.

Marconi did not enter the field until about the year 1895. He immediately began to develop the previous discoveries in a practical manner, making his first notable experiment in

England in the year 1896. In 1897 he signaled a distance of about eleven miles between two Italian warships. In the early part of the year 1901 he succeeded in transmitting a distance of 200 miles, and in the latter part of the same year sent his first signal across the Atlantic. This experiment was made between Glace Bay, Nova Scotia, and Cornwall, England, a distance of about 2,200 miles. The power used in this accomplishment was only about fifteen horsepower, which makes it all the more remarkable when one considers the crude instruments used for reception.

In America several inventors began experimenting in 1899, making a number of inventions of importance to the art. Doctor Lee de Forest, Professor R. A. Fessenden, Doctor John Stone, and H. Shoemaker are prominent Americans who have developed successful systems bearing their names.

Since 1901 the development has been very rapid. The apparatus is changing almost daily, and at the present time messages are being sent between points on opposite sides of the earth.

FUNDAMENTALS OF ELECTRICITY

To cover a Radio Telegraphy and Telephony Course completely it is necessary that one start from the very beginning, and that is elementary electricity, taking up this subject very thoroughly, because in it lies the foundation upon which the student must build his study, and the progress in his future work depends upon his knowledge of this subject.

Elementary electricity is where we begin our course. We shall endeavor throughout the entire course to simplify it as much as possible so that the student will have a clear and complete understanding of the many topics we will take up. Not only this, but it is our desire to co-operate with each individual student and assist as much as possible through our instructors. But, of course, we can not do all the work by ourselves. We must have the close co-operation on your part and a willingness to study. You know as well as we that without determination and earnest study one can never gain success, no matter what the undertaking.

Well, here we are at that fascinating subject of electricity. Have you ever watched a trolley car pass you and wondered at the time just what the mysterious force was that was driving it? You are going to learn something about that force now. We are not going to attempt to tell you what it is because that would be impossible. No one knows. We are not going to be like a young man who was asked by his college professor just what electricity was. This young man said, "I knew once but I've forgotten." The old professor said, "Well, young man, you've forgotten something that nobody knows." He turned to another student and asked him the same question. This student replied, "I do not know." The professor smiled and said, "Young man, that's the right answer."

At the outset, let us warn you that you are not setting out to delve into deep mystery. Man does not know what electricity is, but **he does know and understand the laws governing it.** It is through the understanding of these laws that electricity has become man's most potential servant. He holds the whip-hand over this silent, mysterious energy that plays such an important part in the industrial affairs of today.

Many of the laws governing electricity are as simple as ABC. You can learn them with little or no effort, and once learned they will stay with you because the subject is so intensely absorbing.

THERE ARE TWO KINDS OF ELECTRICITY—STATIC AND DYNAMIC

The electricity that flows through the electric light wires in your home is called dynamic or current electricity. Current electricity is the electricity of the workaday world. It is generated in batteries and dynamos. Current electricity always flows through wires. When you see an electric light, an electric motor, a door bell or other electrical device that we use today, always remember that it is operated by current electricity.

Now, there is another kind of electricity that is known as static electricity. If you will refer to the dictionary you will find that static means to remain at rest. It is only in rare cases that static electricity is used in the workaday world. Static electricity is that which sparkles in your hair on a cold winter morning when you comb it with a rubber comb. When you come too close to a rapidly moving leather belt a spark is apt to jump off and give you an unpleasant shock. This is static electricity. We might say that static electricity is "tramp" electricity, because it refuses to work. Tremendous charges of static electricity accumulate in the clouds and it bursts to earth with a terrific roar. That is lightning, which is made up of billions of little charges of static electricity. The poor old house cat is a potential generator of static electricity, especially on cold winter days. Who hasn't played with the cat in a dark room to see its fur generate tiny sparks?

Let us keep these facts in mind:

1. Current or dynamic electricity is electricity in motion.
2. Static electricity is electricity at rest.

MORE ABOUT STATIC ELECTRICITY

You have probably heard the electrical man use such terms as positive and negative. These terms are used both in connection with current and static electricity. If we rub two different substances together, for instance, silk and glass, there will be produced upon the surface of the silk and glass a charge of static electricity. Now, here is where we have to keep our ears and eyes open and put on our thinking cap. There are two different kinds of static electricity. We have positive charges and negative charges of static electricity.

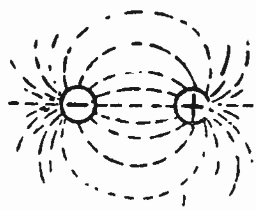


Fig. 1-a—Attraction of Unlike Charges.

After we have electrified the glass and the silk, we would find that the glass had a positive charge and the silk a negative charge. If you were to ask an electrician what a positive charge was, he would put it in this way: A positive charge is a charge of the higher potential, in this case potential meaning voltage or pressure. We are going to thresh out this term voltage later, so we will not stop here to explain it.

Let us imagine that there is a pail of water standing on a chair and that there is another pail of water directly beneath the first pail. The pail on the chair will take the place of the glass rod we used in our experiment, and we will say that this has a positive charge. We know that we can cause the water from the top pail to run into the pail upon the floor. That would be just like having electricity flow from positive (higher potential) to the negative (lower potential). Benjamin Franklin gave us these terms of positive and negative and we have hung on to them ever since. If we were to experiment we would find that we could make the positive charge from our glass rod flow into the silk and neutralize the negative charge there.

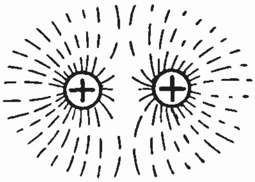


Fig. 1-b—Repulsion of Like Charges.

If you have ever been around a print shop in the winter time you have probably noted how obstinately the paper sticks together at times. The sheets cling as if some mysterious force was holding them together. They are electrified. One sheet of paper will have a positive charge and the next sheet will have a negative charge. This brings us up to an interesting fact and on that we must remember. Unlike charges of electricity attract each other. That is, if we were to charge one sheet of paper with positive electricity and another sheet with negative electricity, these two sheets

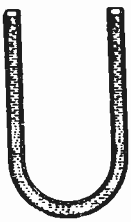


Fig. 2.

would attract one another with considerable force. But what if both pieces of paper were charged with negative electricity or positive electricity? In other words, that if they were both charged with the same kind of electricity? then they would repel one another; they would tend to fly away from one another. It has been found that like charges of electricity repel one another and unlike charges attract each other as shown in Figs. 1-a and 1-b.

There is not a subject in the world of greater interest than current electricity. We are going to learn something about this great force now.

To make matters easy we are going to compare the flow of electric current through a wire with the flow of water through a pipe. That is about the easiest way to get at it. Let us assume that we have water flowing through an iron pipe with an internal diameter of one-half inch. Do not get confused. We are not trying to tell you the electricity is like water; we are merely trying to tell you how easy it is to understand the flow of electricity by comparing it with water.

A long pipe, as shown in Fig. 2, is filled with water. The pipe represents a conductor, and the water illustrates the electricity in the conductor. Both ends of the pipe are held upwards on a level with one another, so that normally there is no difference in pressure acting at each end of the tube, and therefore the water will not flow through the tube.

If, however, we exert a pressure at one end of the pipe by blowing down it, or by increasing the height of one end above the other, or, better still, by connecting a tank of water to it which is situated at a higher level than that on which the experiment is being carried out, as shown in Fig. 3, then the water will immediately flow through the pipe.

By connecting the tank to one end only of the pipe, we exert a difference of pressure on the two ends of the pipe, but if we connect the tank simultaneously to both ends of the pipe, then there is no difference of pressure on the two ends of the pipe, and consequently no water will flow through it.

As the water represents electricity, the flow of water represents an electric current.

What will be the number of gallons of water per minute passing through this half-inch iron pipe depend upon? You know the answer to this. If you do not, put on your thinking cap. One thing it will depend upon is the pressure, is it not? The higher the pressure of the water the more gallons we will receive per minute through the pipe. Now, there is another thing that the delivery of the water depends on. What is that? The size of the pipe. The smaller the pipe the greater the resistance will be offered to the flow of the water. If we had a larger pipe the resistance would be less.

Now, for these words that we have heard so often, volts, amperes and resistance. First, let us say that the pressure of the water in our half-inch pipe represents voltage. We will call the rate of flow gallons per minute of water, amperage or amperes. Then the resistance will depend upon the size of the pipe.

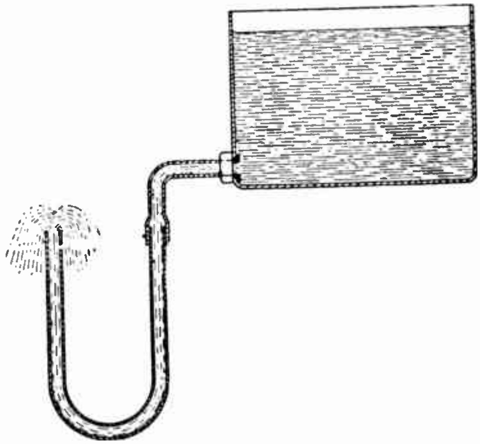


Fig. 3.

Now, let us assume that we have an electric wire with a current of electricity flowing through it. The resistance that this wire offers to the flow of the current will depend upon its size and the metal from which the wire is made. If we had a very small wire the resistance would be great and very few amperes would flow through it. If we increased the voltage (pressure) we could cause more current to flow. If we doubled the size of the wire carrying the current the resistance would be cut in half, giving an increase in current.

We must look upon electrical voltage as pressure, the pushing force that causes the amperes to flow through a wire. Remember that the amperage of an electric current is really the current itself, the working force. Resistance is merely that portion of an electrical conductor that tends to hold the current back. Keep in mind the fact that any moving substance, like a block sliding across the floor or a baseball rolling down a hill, meets with resistance. In fact, we meet with resistance in our daily lives. We must keep plugging along.

Some of us do not have enough pressure, others have too much pressure and not enough amperage.

The next time you hear some one menton a high voltage current, say, for instance, 10,000 volts, do not jump at conclusions and think this is a powerful source of electricity. Voltage is no measure of electric power, it is only the pressure. We could have a very small pipe carrying water under a terrific pressure, but would that pipe deliver more gallons of water per minute? No, it would not. In the same way, we can have an electric current with an extremely high voltage, but the amperage flowing in the current will be small. In the ignition system of automobiles we have an electric current with a voltage as high as 10,000 volts, but the amperage is small.

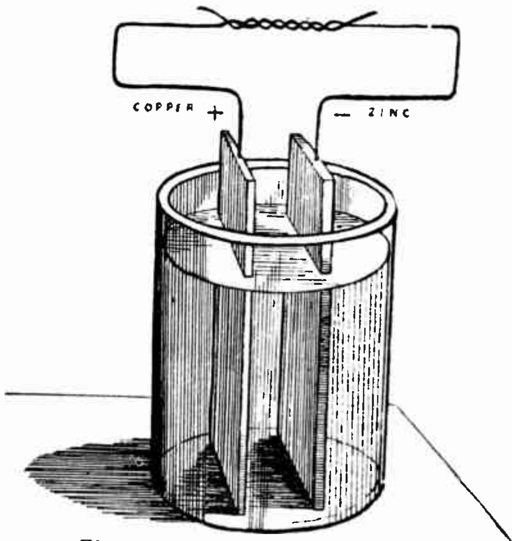


Fig. 3-a—Simple Chemical Cell.

What if we had a very small copper wire running from New York to Philadelphia and wanted to send a current of electricity over this wire? We would have to use a high voltage in the same way that we would have to use a high pressure if we had a very small pipe. As we increased the voltage we would increase the flow of the current and we would receive more amperage at the opposite end.

Voltage alone cannot do the work. An electric current must have considerable amperage before it is able to turn motors, etc.

So far, this has been pretty easy, hasn't it? There is nothing difficult about this subject of electricity. Let us go on. It gets more interesting.

Here we come back to the terms positive and negative again. These terms are associated with current electricity. We must not confuse them with charges. We are all familiar with the ordinary dry cell or dry battery that tingles our door-bell. These little cylinders generate an electrical current by chemical action and this current flows from the positive pole to the negative pole of the battery. For instance, if we had a bell connected up to this dry battery the current would come out of the battery through the positive pole, flow through the wire to the bell, through the bell into the wire again and back into the battery again through the negative pole. We would call the wire, the bell and the battery an electric circuit. The fact we have to keep in mind is this: Current electricity always, without exception, flows from the positive to the negative pole of a dynamo or an electric battery. Get the notebook out again and record this fact. These words positive and negative we might compare to the top and bottom of a hill. We will put a ball at the top of the hill and call it electricity. If we let the ball go it will roll down to the bottom of the hill, but it will never roll up, will it?

THE GENERATION OF CURRENT ELECTRICITY

Now that we have learned what current electricity is we will be interested to know how it is produced. There is no use of stopping half way; we have to make a good job of this proposition. In general, current electricity is produced in two ways: by chemical means and by mechanical means. If we had a glass jar filled with a dilute solution of sulphuric acid and we placed a copper rod and a zinc rod into this solution we would have an electric battery. (See Fig. 3-A.) If we attach a wire to the copper rod (positive) and then touched the zinc rod with it we would notice a tiny spark, proving that there had been an electric current generated.

Electric batteries are used only when small amounts of electricity are to be generated. Electricity is produced in batteries always at the expense of some metal like zinc in the above cell. The metal is eaten away.

INTERNAL CONSTRUCTION OF A DRY CELL

During the last few years what is called a "dry" cell has come to be practically the only type of cell used for open-circuit or intermittent work, such as ringing bells and operating telephones, signal devices, flash lights, and the ignition circuits of gas engines. In this cell the negative plate is a zinc can, which serves as the containing vessel, and the positive plate is a carbon rod, which may be either cylindrical or fluted. The zinc can is lined with an absorbent layer of pulp board or blotting paper which is saturated with a water solution of sal ammoniac and zinc chloride. The space between the lining and the carbon is filled with a paste made of granulated carbon and manganese dioxide soaked in a water solution of sal ammonica. This mixture fills the cell to within about an inch of the top. The top of the cell is generally sealed up with a pitch composition. The outside of the zinc can is frequently lacquered and the cell is always set in a close-fitting cardboard container. The sal ammoniac in this cell takes the place of the sulphuric acid in the simple cell described above.

About 80 per cent of the dry cells manufactured in this country (about fifty million each year) are made with a zinc can 6 inches high and 2.5 inches in diameter. Such a cell when new should give, when tested with an ammeter, at least 15 amperes and not more than 25 amperes and 1.5 volts from the voltmeter test. Figure 5 shows a common type battery testing meter and how it is connected to the dry cell. Some meters have two scales, with two projecting terminals at the bottom, one marked volts and the other amperes. This makes it possible to use the same meter to test the voltage and the current output of a cell. Much smaller dry cells are made for flash lights. Tests with a voltmeter will show that the size of a cell makes no difference in its voltage.

HOW LONG WILL A DRY CELL LAST?

The "life" of a dry cell is not a fixed quantity but depends on the circuit in which it is used. Oftentimes dry cells which are merely standing on a shelf for a year without being used at all will dry up and become practically useless. Sometimes a battery of five dry cells, such as would be used for the ignition of a gas engine which is in pretty constant use, will last for two months. The working life of a dry cell depends on the length of time that its circuit is left closed, but may be extended by arranging circuit so that the current drawn from any one cell will be small.

The use of dry cells for radio purposes has greatly increased the yearly production stated by the figures given above. The audion tube detector (very similar to a small lamp bulb and used in place of a crystal detector) uses dry cells to light the filament and the smaller form cells (flash light) are employed to supply the current for the telephone receivers.

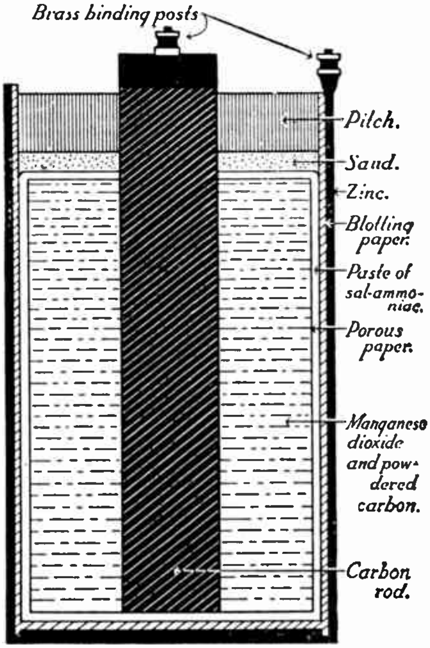


Fig. 4—Inside of a Dry Cell.

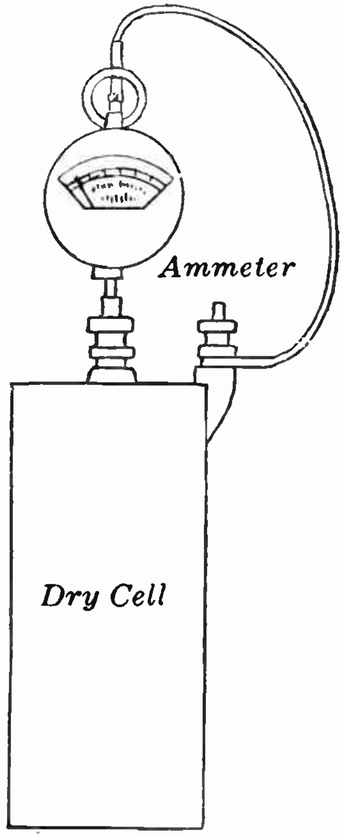


Fig. 5—Testing a Dry Cell.

In an old dry cell, holes will often be found in the zinc can. This means that the metal has been consumed by the chemical change which furnished the energy to drive the electricity through the cell and the external circuit. Thus we see that the zinc acts as a fuel, very much as coal is used to furnish the energy to drive water through pipes. The rate at which this electrical energy is delivered by the cell determines the rate at which the zinc is used up; just as the rate at which steam energy is delivered to a boiler determines the rate of coal consumption. A large cell will naturally last longer than a small cell because it contains more zinc. It is on account of the expense of using zinc as a fuel that we employ cells only as a source of very small electric currents, and use electric generators for supplying power for domestic and commercial purposes.

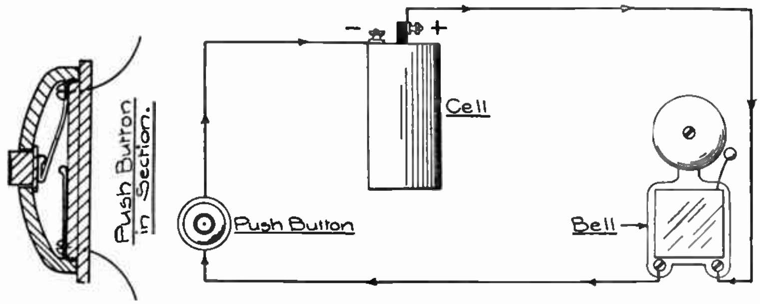


Fig. 5-A—A Simple Electrical Circuit.

POLARIZATION IN DRY CELLS

It was long ago discovered that when a simple electric cell is used by connecting the terminals with a wire, the current does not remain constant, but rapidly becomes weaker. This effect, called polarization, was found to be caused by the formation of a gas, usually hydrogen, on a negative plate. This layer of gas increases the internal resistance of the cell and also sets up an opposing electromotive force. (E. M. F.) In the dry cell the manganese dioxide is put in to act as a depolarizer. Nevertheless, because of this polarization, a dry cell cannot be left on a closed circuit for any length of time.

TERMINAL VOLTAGE OF A CELL

If we connect a voltmeter to a dry cell we find that its e. m. f. is about 1.5 volts. If we connect a coil of high resistance (1,000 ohms) across the terminals, the terminal voltage, as indicated by the voltmeter, is very nearly the same as before. But if we connect a short, thick wire across the terminals (short-circuit the cell) so as to draw a large current, we see by the voltmeter that the terminal voltage is much less than before.

From this experiment it is evident that the terminal voltage of a cell which is delivering current is always less than its electromotive force, or its open-circuit voltage. We may understand this fact if we remember that voltage is used to send the current through the internal resistance of the cell; just as voltage is used to send a current through any other kind of resistance.

Fig. 5-A shows a simple electrical circuit. A cell of the type known as **Dry Cell** is used to furnish the difference in electrical pressure between its terminals. Connection is made from the positive pole of the cell to one side of the bell. The other side of the bell is joined to one side of the push button, while the other side of the push button is brought in connection with the negative pole to complete the circuit. A detailed sketch of the push button is shown on the same sheet. By pressing the button a contact is made between the stationary copper contact and the movable spring. This completes the circuit from pole to pole of the cell. A current may pass from positive to negative. Flowing through the bell it causes ringing of the bell, and upon release of the button the breaking of contact immediately stops the current and ringing.

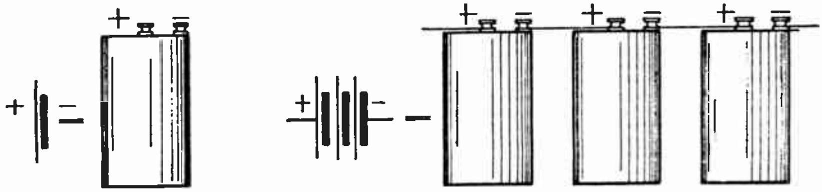


Fig. 5-B Shows three cells connected in series to form a battery.

It would require too much time to indicate cells always in the fashion shown in Fig. 5-A. A much shorter symbol is preferred. In Fig. 5-B we find that the positive pole of a cell is customarily indicated by a long, thin stroke, whereas the negative is shown by a short, heavy stroke. This symbol applies to all types of cells.

SERIES CONNECTION

Various ways to arrange cells, bells and circuits in general exist. For ordinary bell work, batteries are most frequently formed of cells in series. Series connection in all cases means a continuation of apparatus or circuits. There is only one path along which the current may flow. It must pass through one after the other. Applying to cells it means an arrangement in which the positive pole of the first cell connects to the negative of the second, the positive of the second to the negative of the third, and so on. The positive

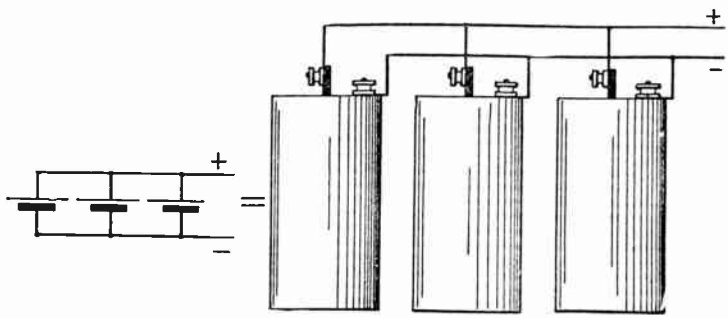


Fig. 5-C—Shows three Dry Cells in parallel.

pole of the last cell in the arrangement and the negative pole of the first cell form the poles of the battery. It is customary to consider a battery a complete self-contained unit after it has been connected. Special reference to the separate cells of a battery is seldom made.

Parallel connection for cells means the same as parallel connection for any other piece of apparatus—separate circuit for each. In Fig. 5-C three cells are connected in parallel to form a battery. The connection is very simple. Join all the positive poles of the cells together and do the same with all the negative poles. The connection is not so frequently used as series connection of cells.

RESISTANCE DEVICES

A simple type of resistance device often used for small currents in radio circuits is shown in Fig. 5-D. This consists usually of a coil german silver wire which has a high resistance to electric currents. It is designed for mounting on a radio receiving panel as indicated at A with a knob B projecting to C and is fastened to a slider D which moves over a coil of high resistance wire E wound on some insulating material and rotates in a circular direction. One terminal F is connected to one battery binding post, the other terminal being connected to the sliding contact D by suitable means.

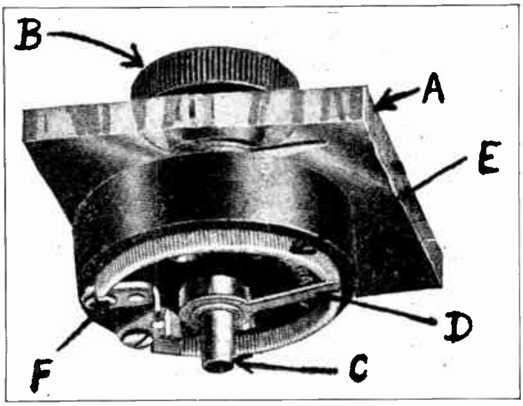


Fig. 5-D—Rheostat or Resistance Device.

The amount of resistance wire between D (slider) and F (terminal) determines the effective resistance of the rheostat in the circuit in which it is used. This device is commonly used to decrease the voltage of the source of current from the battery, so that only a safe current can pass through the filament of the vacuum tube when in operation.

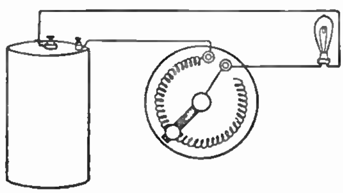


Fig. 5-E—Diagram of Dry Cell with a Rheostat in Series with a tube.

In this type of rheostat the resistance in the circuit may be made to be continuously variable as in practically infinitely small steps, which is a desirable feature in radio receiving sets. A simple circuit diagram showing this rheostat using symbols (see Radio symbols at front of this book) is shown in Fig. 5-E with a dry cell and vacuum tube.

The introduction of the dry cell vacuum tube is one of the foremost developments in recent Radio history. The best known types are the Radiotron WD-11, WD-12 and

UV-199, although there are others on the market. The WD-12 will fit any standard socket. The WD-11 and UV-199 have a different base therefore these tubes require a special socket, although there are special adapters on the market that can be used with these tubes so that they can be used with the standard socket.

Standard Vacuum Tube Socket.

While the WD-12 and WD-11 are one dry cell tubes, the fact remains that if operated for a long time on a single dry cell it will soon exhaust the cell. The best plan is to use two or three dry cells for each tube so that the drain is then shared by each cell. These cells should be connected in parallel (this connection is shown in Fig. 5-C) that is carbon to carbon (positive +) and zinc to zinc (negative—) this maintains the same voltage but doubling the amperage available. The fundamental working principles of all types of vacuum tubes will be taken up in detail in later text books.

Radiotron
WD-12 Dry Cell Tube.

Radiotron
WD-11 Dry Cell Tube.

Radiotron
UV-199.

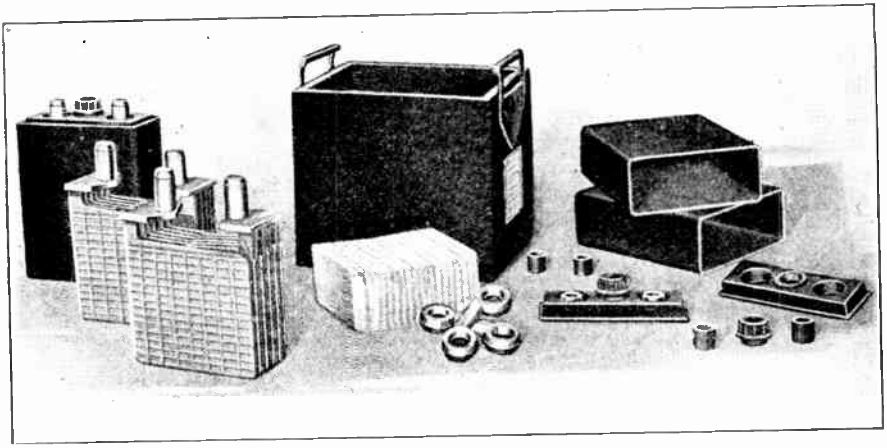


Fig. 5-G—Partly Assembled Lead Storage Battery.

STORAGE BATTERIES

We might compare storage batteries to a phonograph record. A phonograph record stores up music and a storage battery stores up electric current.

The term "storage" applied to this type of electro-chemical cell is not strictly correct, as there is no storage of electricity as in the Leyden jar. A current flowing through a storage cell from an outside source merely changes the chemical composition of the plates in such a manner that it will deliver a current for a time. Although there is no storage of electricity, the effect is the same as if there were. By pass-

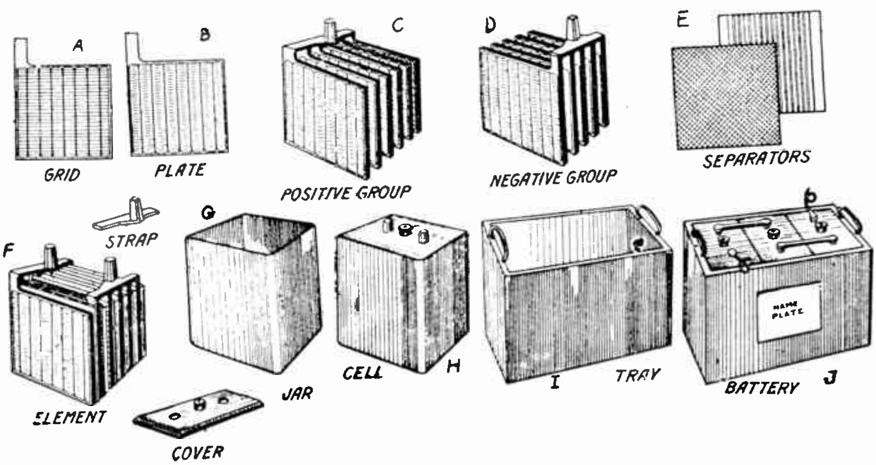


Fig. 5-F—Parts of a Standard Storage Battery.

ing a current through a storage cell (charging) we store up energy which, when we discharge the cell, is delivered to us again. We have inserted Figs. 5-F and 5-G to illustrate the parts of a standard three-cell lead storage battery. This type of battery is used to light the filaments of the six-volt Radio vacuum tubes and is referred to as the A-battery. The same style of battery is found on automobiles for starters and lights. Full information is given on this subject later on in the course under Radio Battery Instructions.

OHM'S LAW

We have now reached a point where we can consider the work of a very great German scientist whose name was Dr. Ohm. Dr. Ohm originated a very simple law. Do not let the word "law" scare you, since nothing could be easier to learn than Ohm's Law.

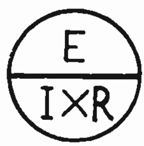


Fig. 6—Ohm's Law in a Nut Shell.

$I = E \div R$, $R = E \div I$, and $E = I \times R$,

I = Amperes R = Ohms, and E = Volts.

A very simple method for using Ohm's law in three forms is to insert the three letters, E, I, R, in a circle, as shown above. If the student wishes to find the value of any one of these quantities he puts his finger over one letter in the circle and reads the value in terms of the other two.

If there is such a thing as electrical resistance, and we know that there is, then we must be able to measure this resistance with some unit just as we measure potatoes by the peck and milk by the quart. There ia a unit now known as the ohm, and this is called the unit of resistance. Electrically speaking, one ohm is the resistance that would allow a current of one ampere to pass under a pressure of one volt. Every piece of wire carrying an electrical current has a different resistance. For instance, a piece of very fine wire might have several ohms resistance to the foot of its length while a piece of large wire would only have a fraction of an ohm resistance per foot of length. The ohmic resistance of a piece of wire depends entirely upon the length and size of the wire and the metal from which it is made. Let us assume that we have an electric circuit with a pressure of 12 volts. We know this because we have measured it with a voltmeter. Let us assume that we have also measured the current with an ammeter and that the current amounts to 6 amperes. Now, let us see how we can use this Ohm's law. We want to know the resistance of this circuit. How will we find it?

In a very simple manner. If we divide the voltage of the current by the number of amperes flowing in the circuit we will have the resistance of the circuit, which in this case would be 2 ohms (12 ÷ 6). This is the first law of Dr. Ohm.

To find the resistance of a circuit, divide the voltage by the amperage.

What if we had the resistance of a circuit and the voltage and wished to find the amperage? Then we would divide the voltage by the resistance and we would obtain the amperage. We can prove this. In our case, we found that the resistance of the circuit was 2 ohms. 12 ÷ 2 6 or the amperage. The second law of Dr. Ohm follows:

To find amperage of a circuit divide the voltage by the resistance.

We know that our imaginary circuit is carrying a current of 6 amperes and has a resistance of 2 ohms. How can we find the voltage with these figures? All we need to do is to multiply the amperes by the resistance (6 × 2) = 12 volts. Then we have the third law of Ohm.

To find the voltage of a circuit multiply the resistance by the amperes of current.

There are two kinds of electricity, one which manifests dynamic itself in the form of a flow of electricity and is called current or electric and another form which is at rest in a dormant state on the surface of a body and is called static electricity. The student is interested in both types of electrical energy and must become familiar with the technical terms and laws governing each.

Current electricity may be divided into three classes, one known as direct current (D. C.). Direct current is one which always flows in the same direction through its path, as for example, the flow of water from a spring, through the brook the river and into the ocean. Another illustration is shown in the top of Fig. 6-A, centrifugal pump C keeps a steady flow of continuing or direct current in the pipe B. This water always flows in the same direction at all times. So it is with the flow of direct current electricity. It always leaves one part of the electric generator or other source of power and flows through the wire in a fixed and definite direction at all

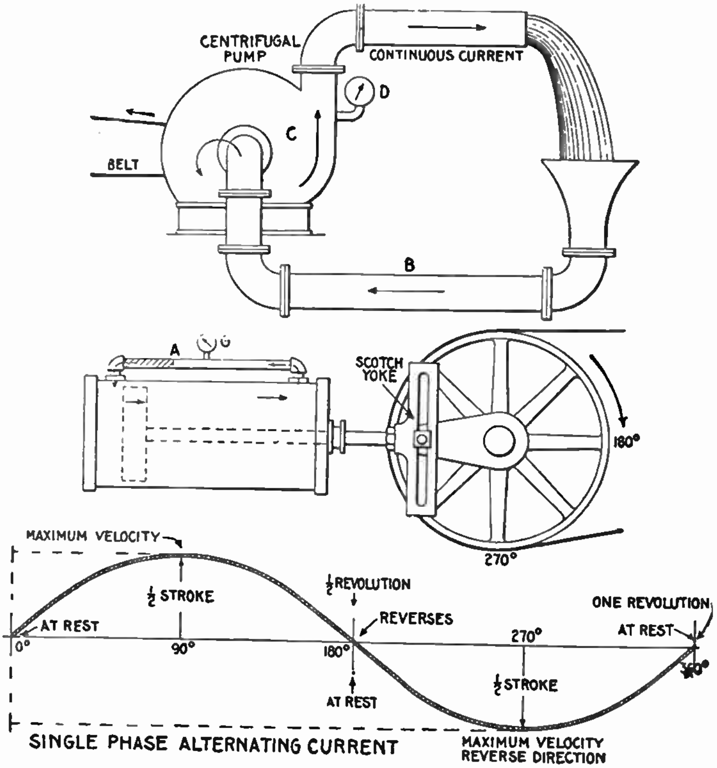


Fig. 6-A.

This diagram illustrates the difference between direct and alternating current. In the above diagram a centrifugal pump C forces water to the upper pipe, from which it falls by gravity to the lower pipe B and re-enters the pump. The water is continuous, always flowing in one direction, that is, it does not reverse its direction. Similarly a direct electric current is constant in direction, though not necessarily constant in value. The center diagram illustrates a double acting cylinder with the ends connected by a pipe A and the piston driven by a crank and a Scotch yoke. If the cylinder and pipe is full of water, a current of water will flow through the pipe in the direction of arrow as the piston begins its stroke increasing to maximum velocity at one quarter revolution of the crank, decreasing at one-half revolution, then reversing and reaching maximum velocity in the reverse direction at three quarters revolutions, and coming to rest again at end of return stroke. If a pressure gauge is inserted as shown in the diagram marked G it will measure a pressure which varies with the current of water. Since alternating electric current undergoes similar changes this simple illustration will explain the single phase alternating current as shown in bottom diagram which will apply equally as well to the pump cycle as to alternating current cycle.

times. Direct current is obtained from a dry cell, storage battery and many forms of direct current generators. This particular type of electricity is most efficient for certain classes of work, for example, the driving of small electric motors, operation of electrical magnets and is necessary in the charging of batteries and electrical chemical processes.

ALTERNATING CURRENT

As the word signifies, it is a flow which changes its direction, alternating first in one direction and then reversing to the opposite direction, going through these changes very rapidly. One might get a clear understanding of this rapidly reversing motion by referring to a water pumping system, such as illustrated in the center of Fig. 6-a. Here a cylinder with a pipe line connected at either end is supplied with water by the action of a piston, which moves back and forth within the walls. One can readily see that the flow of water in the main pipe "A" would be continually reversing in its flow. The curved line at the bottom of the figure shows the change in value and direction for the A. C. flow for one complete change of current. This is called a cycle or 360 electrical degrees.

There are several technical names applying to alternating current terms with which the student should become familiar early in his course. A complete change in the form of the flow of an alternating current is called one cycle. That is to say if the current flows back and forth 25 times in one second we call it a 25 cycle current. The number of these cycles which occur in one second is called the frequency of the current. The common frequencies used by the commercial companies in the United States are 25 and 60 cycles. Approximately 80 per cent of all the power developed in the country is generated at 25 cycle alternating current. This frequency is being adopted for the generation and distribution of electric power over large areas.

During the early stages of electric lighting when carbon filament lamps were used this frequency caused a flicker of the light, and it was deemed unsuitable for the purpose of lighting due to the injurious effect it might have upon the eyes. At that time 60 cycles alternating current was adopted for lighting purposes in our cities and has become a standard lighting frequency. The 25 cycle current is used where large electric motors and other large power devices are employed in the commercial field due to its more efficient results. When the demand for electricity came for the production of radio waves it was found necessary to adopt a new frequency, and 500 cycles became the standard for radio apparatus of this country.

There is another method of expressing frequency in common use by a few large electric companies, and this term is called alternation. An alternation is one-half of the cycle, and the number of alternations are expressed per minute instead of per second as in the case of the cycle.

It is a very simple matter to find the number of alternations for an electric generator as it is equal to the number of poles in the machine times the revolutions per minute. We may reduce the alternations per minute to the term cycles per second, by divid'ng the alternations by 120. This number 120 is derived by the fact that there are 60 seconds to a minute and two alternations to a cycle. The alternating current was used almost exclusively for the production of radio waves during the early advent of this new invention. Recent inventions have made it possible to use direct current for the production of radio waves and at the present time both forms of current are commonly used in the radio transmitting stations.

PULSATING CURRENT

There is also what is known as a pulsating current. This is really an interrupted direct current, used mostly with induction coils. By winding two coils of wire on a soft iron core—using a key and vibrator—and making and breaking the direct current in the primary coil a higher voltage is induced into the secondary coil. This will be taken up in detail in Lesson No. 3 on the subject of induction coils.

MAGNETISM

We have all played with magnets. What boy has not made a trip to the Five-and-Ten-Cent Store to buy a magnet and a package of iron filings. And what a fascinating subject magnetism is. We know the laws of magnetism just as we know the laws of electricity, but the man is yet to be born who will tell us in cold, meaning terms just what magnetism is. We know that there is a very close relationship existing between magnetism and electricity, but what that relationship is we cannot tell. Practically speaking, however, we know that electricity and magnetism are like brother and sister.

If we dip a piece of magnetized steel into a little pile of iron filings the filings will stick out on it like the hair on a man who has just seen a "ghost." We can see that the little pieces of iron arrange themselves in definite lines, just as if they were hanging on an invisible thread. (See Fig. 6-b.) Scientists call these the lines of force.

Fig. 6-b—Poles of a Magnet.

Magnetism is a property possessed by iron and its alloys and was discovered by the Greeks in Asia Minor. The Greeks found an ore in the ground which had the peculiar property of attracting pieces of iron when placed near to it and also

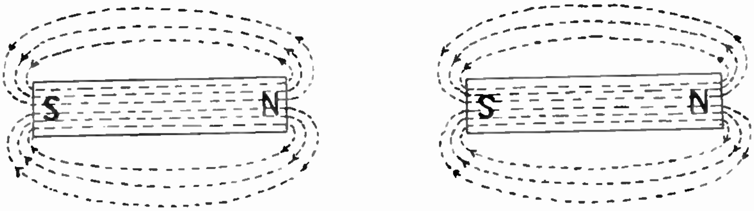


Fig. 6-c—Distribution of Magnetic Lines Around a Bar Magnet.

would turn itself in a definite direction when free to swing upon a string to which it might be fastened. They gave the name Loadstone to this piece of ore, which was afterwards found to be the mineral iron with its impurities. Soon after this loadstone was discovered, means were provided whereby this property could be given to a bar of steel or iron which could be used in the place of the rough crude stone. Bars made in this way and possessing this property were called magnets after the name of the town Magnesia in Asia Minor. One end of this bar or magnet always pointed in a northerly direction and was given the name North Seeking Pole. The other end was called the South Seeking Pole. The word,

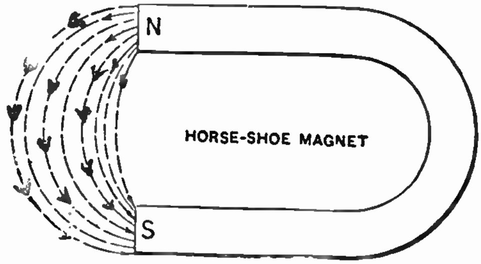


Fig. 6-d—Showing Magnet Lines of Force Around a Horseshoe Magnet.

"seeking," has been omitted, and today the ends of the magnet are known as the North and South Poles. Modern scientists, for the purpose of a clear explanation of the magnetic influence exerted by these magnets, assume that lines of force leave the North Pole of the magnet and enter the South Pole, having a complete path in their travel. Fig. 6-c

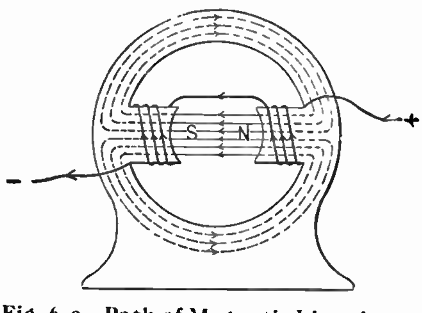


Fig. 6-e—Path of Magnetic Lines in a Modern Two-Pole Generator.

Fig. 6-f—Two-Pole Generator Frame, Showing Pole Pieces and Field Coils.

shows the distribution of magnetic lines around a bar magnet, and Fig. 6-d a horseshoe form of magnet. Magnets may be made in two ways. First, by stroking or rubbing a piece of iron or steel over a magnet or by winding a coil of wire around the bar of iron or steel and passing a current through this wire. There are two classes of magnets. **First,** a permanent magnet, which retains its magnetic effect for a long period of time; that is, for several months to many years. These magnets are made from **very hard steel** and specially treated by secret processes to preserve the strength for long periods of time. The pole pieces of a magneto as used on automobiles, Radio head phones and the magnets of most electrical measuring instruments are of the permanent class. **Second** class, temporary magnets which retain the magnetism only during the time which they are in contact or under the influence of another magnet or are being energized by an electric current. These magnets are **made out of soft iron or a real soft grade of steel.** The iron cores for electro magnets, transformers and the pole pieces for generators and motors are temporary magnets made from wrought iron or soft laminated sheet steel. The space around the magnet is permeated by these magnetic lines of force which attract other iron or steel material placed near them. This space filled with these lines of force is called a magnetic field and the number of lines per unit of area at right angles to the direction of the lines is given the name flux-density and the total number of lines in any given area is called the total flux.

MAGNETIC LAWS

The student may recall the laws regarding the attraction and repulsion of static charges which were as follows: Like charges repel one another and unlike charges attract one another. We have that same law holding true in the case of magnets and may be stated as follows: Like poles of magnets when placed close together repel one another and unlike poles attract one another. For example, if two bar magnets are suspended at the centers by strings and we swing the two magnets by our hand in such position that either the two south poles or the two north poles are close together and let go of them they will swing apart and finally arrange themselves so that the North Pole of one magnet is near to the South Pole of the other magnet. An explanation of this theory perhaps might be well presented by showing the distribution of magnetic lines of force around these two magnets when placed in different positions. Fig. 6-g illustrates two bar magnets so placed that unlike poles are opposite to one another and the distribution of lines of force are as illustrated. The lines leave the North Pole of the left-hand magnet and enter the South Pole of the right-hand magnet passing through both from left to right and dividing at the extreme right-hand end and passing through space at the top and bottom of the magnets over to the extreme left-hand end where they enter the South Pole of the left-hand magnet. We may look at these lines of force for convenience of an explanation as being rubber bands, each line of force representing an elastic band which has been stretched out to the

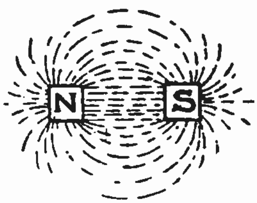


Fig. 6-g—Attraction of Unlike Poles.

length in the figure. One may easily conceive that two substances bound together by rubber bands in this manner would be drawn together with a force which we call in this case magnetic attraction. In Fig. 6-h there is shown the distribution of magnetic lines around the two bar magnets, where two like poles; that is to say, two North Poles are placed opposite to one another. Here the distribution of lines do not merge together between the two bar magnets, but seem to oppose one another and we may consider the

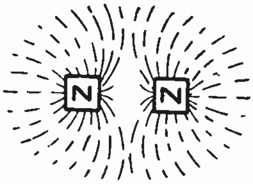


Fig. 6-h—Repulsion of Like Poles.

rubber bands as coming in contact with one another as they expand and pushing each other apart. That is to say, a magnetic repulsion between the two magnets. This same idea may be applied in all cases where magnetic lines are involved.

Fig. 6-e illustrates the distribution of magnetic lines in the frame of a two-pole generator and when the revolving part called the armature is inserted these magnetic lines form an attraction upon this revolving core and offers a resistance

to its movement. A magnetic substance is a material which allows the magnetic lines to pass through it very easily the same as copper allows the electric current to flow through it with much ease. Iron and its many alloys used in the construction of all kinds of electrical machinery and apparatus are magnetic substances. Some alloys of iron which contain small parts of silicon offer much less resistance to the flow of magnetic lines and are, therefore, more efficient for use in electrical machines. Ease with which the lines pass through different kinds of iron as for example cast iron, wrought iron and malleable iron is expressed by the technical term permeability. The permeability of a substance is the ratio of the number of lines which would occur in this substance compared with the number of lines which would be present in air when the same magnetic force is exerted toward producing these lines.

Fig. 6-j—Radio Head Set.

PERMANENT AND TEMPORARY MAGNETS

If you are an observing person you will notice that all good magnets are made of steel. When a good piece of steel is magnetized it insists on holding this magnetism for a great length of time, and therefore we call steel magnets permanent magnets. If we were to magnetize a piece of iron we would find that it would lose its magnetism almost immediately after it had been magnetized. Such a magnet is called a temperary magnet.

Fig. 6-j shows a common type of radio head set. It will be noted that it consists of two receivers of the "watch case" type, mounted on a headband and supplied with a cord which connects the two receivers of the set in series with each other.

Fundamentally, a telephone receiver is a device which makes use of the fluctuations of a current flowing through a small electromagnet so as to cause similar fluctuations of a diaphragm. This diaphragm, by its vibration, causes sound waves to be set up in the air contiguous to it. If the current has originally been varied according to the vibrations of the human voice, the diaphragm, and the sound waves which it sets up, will thus reproduce the human voice.

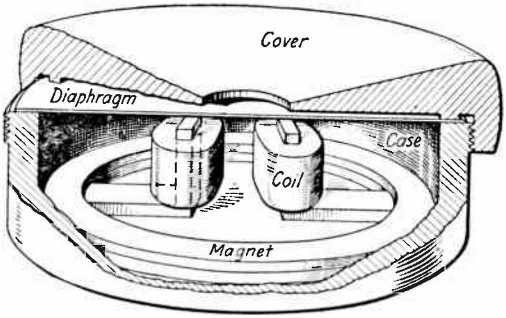


Fig. 6-k—Watch Case Receiver Assembly.

Fig. 6-k shows the watch case form of receiver. The permanent magnet in this type consists of a U-shaped **steel magnet** and there are two electromagnets connected in series.

The watch case receiver has a low reluctance magnetic circuit since the lines of force flow across the minute air gap between the north pole and the diaphragm, through the diaphragm for a short distance, and back across a small air

Fig. 6-l.

path to the south pole of the U magnet. Its light weight and small size make it convenient for headband mounting, however, and we find this type of receiver used by practically all manufacturers whose receivers contain magnetic diaphragms. It is usually assembled in the form shown in Figs. 6-k and 6-l.

GENERATION OF ELECTRICAL CURRENT BY MECHANICAL MEANS

When a coil of wire is moved through a magnetic field and electric current will be generated in the coil of wire. In other words, if we had a little coil of copper wire with its ends attached to a sensitive measuring instrument and we were to move this coil across the pole of a permanent magnet we would find that the measuring instrument would register a current. If we held the coil still in a magnetic field no current would be generated. **It is necessarry to move the coil in the magnetic field to produce a current.**

Do not ask how or why this magnetic field causes a current to exist in the wire; no one knows.

In electric generators, the armature, or moving part of the generator, represents the coil of wire in our experiment. The armature or coil is constantly moving in a magnetic field and a current is therefore produced in it. So much for the principle of the generation of electric current by mechanical means.

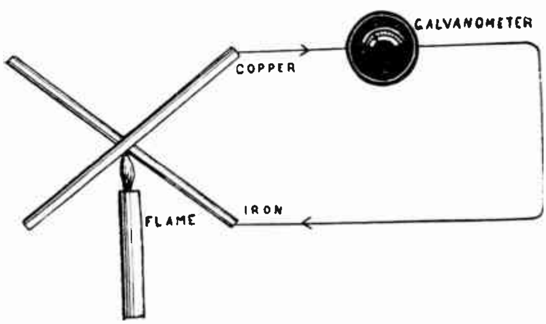


Fig. 7—Thermal Action.

PRODUCTION OF ELECTRICITY BY THERMAL ACTION

The thermal method of producing electricity is of very little practical importance at the present time.

If two unlike metals, such as bismuth and antimony, are soldered together, their terminals connected to a galvanometer (an instrument for the detection of weak currents) and the soldered joint heated, a current will flow from the antimony to the bismuth in the external circuit. Copper and iron may be substituted for the antimony and bismuth, respectively. (See Fig. 7.)

CONDUCTORS AND INSULATORS

An electrical conductor is a substance which will allow a current of electricity to flow through it with ease. The degree of ease with which the current flows through different substances is a measure of its conductivity and varies very widely for different substances. Metals, carbon, acids and alkaline solutions are all conductors of electric current.

The following is a partial list of conducting materials:

silver	platinum	carbon	manganin
copper	iron	water	brass
aluminum	lead	German silver	bronze
zinc	mercury	platinum silver	phosphor bronze

Silver is the best known conductor, affording a path of lower resistance than any other substance. Copper is next, being about 93 per cent as good a conductor. Iron, nickel and steel have a much higher resistance than either silver or copper, and for that reason are seldom used as conductors. Some substances, such as cotton, dry wood and paper, are termed partial conductors, but they possess such high resistance that they are used as insulators in many cases. The earth is a good conductor and is made use of by rural telephone companies as a return circuit for the telephone lines. Electrical companies encounter much trouble in preventing the current in wires from short-circuiting to the ground or to another part of the circuit.

Temperature causes changes in the resistance of conductors. Heating a metallic substance increases its resistance, but fluids when heated have their resistance lowered.

An insulator may be defined as a substance which offers great resistance to the passage of an electric current. Electricity always seeks the easiest path back to the source of current. Hence, insulating materials are used to prevent the current in a circuit from escaping to the earth or to another portion of the circuit. To insulate wires for prevention of leakage several different methods are used. A very common method is to give a wire a coating of silk or cotton thread. Another type of insulated conductor is made by covering bare wire with a layer of soft rubber, on top of which there is placed another layer of braided cotton or silk. A third method of insulation is to cover the bare wire with a thin layer of liquid enamel, which solidifies, producing an insulated conductor, which, for certain purposes, has advantages over wire insulated by other means.

The following is a list of insulating subatances:

oils	asphaltum	cotton	paper	glass
shellac	wool	resin	asbestos	air
varnish	silks	mica	slate	amber
porcelain	rubber	paraffin	ebonite	wax

In the transmission of electrical power, porcelain, glass or electrose insulators are used to insulate the transmission wires from the supporting masts. Glass has been used as an insulation for telegraph and telephone lines for many years. Mica is a very good insulator, being used extensively in the manufacture of electrical machinery. Pure water is practically an insulator, becoming a better conductor when impurities are added to it.

You have now successfully completed the first lesson in Radio and we know you have enjoyed learning about some of the fundamental facts which form the foundation and the stepping stones to this marvellous new science. You have been told of many of the industries which are in deep need of Radio to expand their facilities for better serving humanity, and have also been told about the many avenues open for improvement in this great new invention.

The lesson just studied by you has presented the very fundamental principles of electricity upon which all progress and future development in Radio must depend. From the very first discoveries of Radio when Hertz and Marconi endeavored to make a wireless wave, electricity was the sole source from which the supply of energy could be obtained.

We could not enter any type of radio station today without seeing at first glance some piece of electrical machinery which is developing the power for this wonderful new form of communication. Let us impress upon you at this time that the future text matter will show you clearly the application of electricity to radio communication and the more efficient you can become in adopting electrical laws and principles to the radio science, the more successful you will be in your future career.

The second lesson tells the wonderful story about electrical units and how they are measured with the same degree of accuracy as our common household articles as sugar, milk and potatoes. It is due to the fact that electricity has been so thoroughly developed in the past 25 years that scientists have been able to make such wonderful developments in the radio art.

Now we want you to turn your thoughts back to Lesson No. 1, and answer the 20 following questions on the regular lesson paper which has been sent to you, using much care and neatness in writing your answers. Please answer these questions right now, while the text matter is fresh in your mind, since it will save you time and trouble in reading over again this subject matter.

Remember that we are anxiously awaiting these first answers on your course and we hope they will be worthy of a high grade mark to cheer you on the way to better things in Radio.

We want to assure you that it will be as much a pleasure to us to record a 90% or better grade on your record card in our office as it will for you to receive it. Let us both start now working together for the better things in life which make for success in every way. Please answer these questions now and send them in to us by the next mail.

QUESTIONS—LESSON 1

When writing or answering questions put your NAME, ADDRESS and STUDENT NUMBER, also the NUMBER of your lesson at the top of the page. **Don't fail to do this,** otherwise your papers will be delayed.

Use plain paper, preferably letter size (8½x11). Write your answers with INK or with a TYPEWRITER. Don't send answers to less than one lesson (all questions) at a time.

1. Why is it necessary for students of Radio telegraphy to have a knowledge of elementary electricity and magnetism?
2. Into what two general divisions may eletricity be divided?
3. Define two kinds.
4. Describe the production of static electricity.
5. What is meant by a positive charge?
6. Give the law for the action of electric charges.
7. Is static electricity of much practical value?
8. Into what three kinds of current can dynamic electricity be divided?
9. Describe the action of a simple cell.
10. What is the difference between a dry cell and a storage battery?
11. Does the size of a cell make any difference in the voltage of a cell?
12. Make a drawing, showing three dry cells connected in series, with a rheostat in series to light the filament of a vacuum tube.
13. What two methods are used to produce dynamic electricity?
14. If we have 110 volts and 10 amperes in a circuit what would be the resistance in ohms?
15. Describe what is a cycle of current.
16. Describe the action of a bar magnet made of steel.
17. What law governs the action of like and unlike poles?
18. What is the difference in the action of permanent and temporary magnets?
19. What is meant by the magnetic field of a magnet?
20. Is pure water a conductor?

Definitions of Radio Terms

The definitions of Radio Terms given below will be very helpful to the student as he progresses with this course.

Absorption: That portion of the total loss of radiated energy due to atmospheric conductivity.

Aerial: A system of wires insulated from and suspended at a certain height above ground but generally being connected through suitable apparatus to earth. Used to radiate energy in form of electro-magnetic waves from oscillations flowing along it and to receive energy in form of oscillations from ether waves passing across it.

Aerial Tuning Inductance is a number of turns (in the form of a helix or spiral) of wire which can be adjusted to radiate waves longer than the fundamental wave length.

Aerial Tuning Condenser: Variable condenser in aerial circuit. Used to vary oscillation constant of receiver.

An Alternating Current is one which gradually rises in value from zero to a maximum in one direction, then goes through the same changes but in the opposite direction.

An Alternation of current is one-half cycle, or a change from zero to maximum and back to zero in one direciton.

An Alternator is a machine with a rotating element for the production of an alternating current.

Ampere is the unit of flow and is that value of current which is maintained in a circuit having a resistance of one ohm by an electro-motive force of one volt.

The Ampere Hour is the unit for expressing the quantity of current passing through a given circuit, or amperes flowing for one hour of time. Amperes times hours equals ampere hours.

Ampere Turns: Expressed by the product of number of turns of, and the number of amperes flowing through, the coils of an electro-magnet. Thus one ampere turn would be one ampere flowing through one turn.

Amplifier: Audio frequency. A device for increasing signal strength at audible frequencies, namely, after the current has passed through the detector. Composed of a three element vacuum tube, a rheostat, a socket, and "A" and "B" batteries, together with an audio frequency amplifier transformer. Operates at all wave lengths with the same transformer.

Amplifier: Radio frequency. A device for increasing signal strength at radio frequencies. Used before the incoming current reaches the detector. Comprises a three element vacuum tube, a rheostat, a socket, "A" and "B" batteries and a radio frequency transformer suitable for the particular wave length desired—generally equipped also with a potentiometer.

The **Amplitude** of an alternating current is the maximum value or the highest point reached during an alternation.

The **Antenna** or **Aerial** is one or more conductors insulated from the earth, employed to radiate electromagnetic waves, or to absorb energy from a passing electromagnetic wave.

Anode of a cell: The positive pole of the cell.

Arc: The passage of an electric current of relatively high density through a gas in which the material of one or both electrodes is volatilized and takes part in the conduction to the current, whether continuous or alternating.

Audibility: Measure of signal strength. Unit audibility being strength of received signals which just enables dots and dashes to be distinguished.

Audion: A relay operated by electrostatic control of currents flowing across a gaseous medium. It consists of three electrodes in an evacuated bulb, one of these being a heated filament, the second a grid-like electrode, and the third a metal plate.

Brush or **Coronal Losses:** This is due to leakage of electric currents through a gaseous medium.

Brushes: Fixed carbon blocks held in a position that makes contact with the commutator of a dynamo or motor for the purpose of collecting current generated by or supplying current to the machine when running.

Capacity: Power of containing. A condenser has unit capacity (farad) when a charge of one coulomb creates a difference of potential of one volt between its terminals. This farad being too large for practical purposes the microfarad is used.

Choke Coils: Coils wound to have great self-induction. Usually wound over an iron core which is generally composed of a bundle of wires or luminated sheets insulated each other to prevent eddy currents. The function is to check by reaction the amount of current flowing in the circuit.

A Changeover Switch or **Transfer Switch** is a device to transfer the aerial connection from the sending to the receiving apparatus or vice versa.

A Circuit Breaker: A device to open or break a circuit when the current reaches a certain value.

Compass Radio: A radio transmitting device for determining the direction of maximum radiation; also direction in which maximum energy is received.

Commutator: On a dynomo or motor refers to a number of copper strips fixed on a cylinder of insulator and parallel to the axis of armature shaft to which are affixed the ends of armature windings.

A Condenser consists of two or more conductors separated by an insulator and is used to store up electricity in electrostatic form and then discharged in the form of radio frequency oscillations.

A Continuous Wave: One whose amplitude does not decrease as it travels (undamped).

Converter: A machine similar in construction to a motor but being supplied with slip rings in addition to a commutator. Used to convert D. C. to A. C., or vice versa.

Conventional Symbols: Conventional Symbols are sets of easily drawn representations adopted to indicate various pieces of apparatus in circuit diagrams.

Crystal Detector: A device used to rectify the oscillating currents to direct impulses which affect the telephone receiver and makes it possible to detect wireless waves.

Counterpoise is a large amount of sheet metal or wires spread out in space and insulated from the ground, and acts as a ground to form one plate of the condenser, with the aerial as the other.

Coulomb is the unit of quantity of electricity and is the amount of electricity past a point in a circuit when current of one ampere flows for one second.

Coupling: A measure of the mutual inductance between two oscillatory circuits. The connecting of two oscillatory circuits.

Cymometer: An instrument to determine the frequency of oscillations.

A Cycle is a complete change of current, or two alternations.

Damped Oscillations are those consisting of a series of oscillations which gradually decrease in amplitude.

The Damping Factor is the ratio of the amplitude of current in one oscillation to that of the next succeeding oscillation in a damped wave train.

Decremeter: An instrument for measuring the logarithmic decrement of a circuit or of a train of electromagnetic waves.

The Logarithmic Decrement is the Naperian Logarithm of the ratio of the amplitude of one oscillation to that of the next oscillation in the same direction in a damped wave train.

Diaphragm: A thin plate used in telephone receivers, the vibration of which produces audible signals.

Dielectric: The insulator between the plates of a condenser. Every insulator is a dielectric, even the rubber covering of a wire.

Direct Current (D. C.): Current flowing continuously in one direction.

Discharge: To dissipate electric energy from a cell, condenser, or any other charged body.

Edison Effect: Flow of energy in the space surrounding the filament of an incandescent lamp bulb.

Eddy Currents: Useless currents in the armature, pole pieces and magnetic cores or dynamos or other masses of metals.

Electromagnetic Lines of Force are those lines of force about the poles of a permanent magnet; an electromagnet, or a wire carrying electric current.

Electrolytic Detector consists of a fine platinum wire just touching an electrolyte contained in a small platinum cup. Current from a battery which is connected to cup and point keeps point covered with small bubbles owing to electrolysis. Passing oscillations break through these bubbles, destroying their insulation and permit momentary current to flow through phones.

An **Electric Generator** or **Dynamo** is a machine to convert mechanical energy into electrical energy. The term generator may be applied to both direct and alternating current machines, while the term dynamo is usually applied to a direct current machine. The generator or dynamo operates on the principle of electromagnetic induction. It consists of a magnetic field, a revolving coil or wire, called an armature, a commutator or collector rings and a supporting frame and shaft. The magnetic field is produced by electromagnets arranged in the form of a circle, in the center of which the armature revolves. The revolving armature cuts the lines of force between the field poles and has a current induced in its turns. Brushes bearing on the commutator or collector rings collect the current thus induced.

An **Electrical Oscillation** is an alternating current of high frequency, usually 10,000 cycles or greater.

Electron: Ultimate or final particle of negative electricity. An atom plus an electron is a negative ion. An atom minus an electron is a positive ion.

An **Electromagnetic Wave** is an electromagnetic disturbance traveling through space.

Exciter: Small auxiliary dynamo used to excite magnetic field of some type of generators.

Farad is the unit of capacity; a condenser of such dimensions that it will hold one coulomb of electricity when a pressure of one volt is applied across it, will have a capacity of one farad.

Fading Signals whose strength slowly decrease though power at transmitting station is not varied. Is due to atmospheric changes.

Filament: A fibre or thread made of carbon or fine metallic wire which glows when current passing through it heats it sufficiently.

A Field Rheostat is a variable resistance employed to regulate the flow of current in the field windings of a motor or a generator.

The **Frequency** of an alternating current is the term employed to express the number of complete changes or cycles taking place per second of time.

Fundamental Wave Length is the wave length which the aerial and ground alone, without any added inductance or capacity will send out.

Flux Density is the total of a number of lines of force (electrostatic or electromagnetic per unit of area—per sq. cm. or per sq. in.)

Flux is the term which designates the total number of static or magnetic lines of force in a given space.

Galvanometer: An instrument used for detecting the presence of and ascertaining the force and direction of current in a circuit.

Gaskets: The insulating discs used to separate discharge discs of a quenched gap.

Grid: The frame of wire gauze or perferated metal tube placed between and insulated from the plate and filament of a valve, amplifier.

Ground: An electrical connection (usually of low resistance) to the earth.

Henry is the unit of inductance. A circuit is said to have inductance of one henry when one volt of pressure is required to make a change of one ampere in one second of time.

Heterodyne: A method of detecting received oscillations usually undamped by causing them to interact with other locally produced sustained oscillations of slightly different frequency and generally of greater amplitude. The beat or resultant note is the difference between the frequencies of the two independent oscillations.

A High Frequency Current is one where several thousand or more oscillations take place in a second of time.

Hysteresis: Slowness or lagging behind when a change of condition is taking place in an electromagnetic circuit.

Impedance is the term applied to express the total opposition of a circuit to a varying current, due to the ohmic resistance and reactance of the circuit.

Inductance may be defined as the property of an electrical circuit which opposes a change of current in the circuit.

Induction Coil: An instrument for producing high voltage impulses from low voltage current.

Insulator: A material through which electricity will only pass when under great pressure of voltage.

Interrupter: An apparatus for breaking up a D. C. into a series of impulses, thus producing an intermittent current. See Induction Coil.

Ionization: The splitting up of molecules into ions. Ionised air or gas becomes conductive.

Joule: Unit of electrical work. Work done by one coulomb flowing under a pressure of one volt.

Logarithim (Log): In the case of common logarithim (com log) is the power of ten (the base) which produces the number in question, **e. g.,** Log 100 equals 2, since 100 equals 10^2, 2 being the required power of 10 to produce 100 (10X10—100).

Loop Aerial: One similar to a frame aerial having several turns of wire wound in series on a frame, which form a closed circuit, part of which may be the ground.

A Low Frequency Current is generally considered one where no more than, say, 60 to 500 cycles take place in a second of time.

Magnetic Field: The whole space over which a magnet exerts its magnetic influence.

Magnetic Flux is the total number of lines of force in a magnetic circuit.

Microphone: A sound magnifier. Varying pressure imposed by sound waves cause a diaphragm to equally vary its normal pressure or suitable conductors, this, in turn, equally varying the electrical resistance of the points of contact, thus permitting a current whose strength varies as the imposed sound waves to pass into a telephone.

Molecule: The smallest group of atoms of an element or compound which can exist by themselves.

An **Electric Motor** is a machine for converting mechanical energy into electrical energy.

A Motor Generator consists of two machines joined together mechanically for changing electricity from one form to another.

Mutual Induction is the production of an electric pressure in one circuit by another circuit close to it.

Non-Synchronous: When two or more things are not in a similar condition or position at the same time.

Ohm is the unit of resistance which an electric circuit offers to the flow of an electric current. A circuit which allows one ampere to flow through it by a pressure of one volt is said to have one ohm of resistance.

Oscillatory Circuit is one which allows the free flow of electric oscillation and generally consists of a few turns of wire in series with a condenser, the entire circuit having a minimum value of resistance.

The Oscillation Constant of an oscillatory circuit is the numerical value obtained from the square root of the product of its inductance multiplied by its capacity.

Oscillatory Currents are alternating currents of very high frequency ranging from ten thousand to several million per second, and are used in radio telegraphy.

An **Oscillation Transformer** consists of one or two coils of wire placed near to one another for transferring the energy from the closed circuit to the open or radiating circuit.

These definitions are continued in the next textbook

LESSON TEXT NO. 2

OF A

Complete Course in Radio Telegraphy and Telephony

Electrical Units and Circuits
The Electric Current
Switches, Insulators, Conductors and Circuit Breakers

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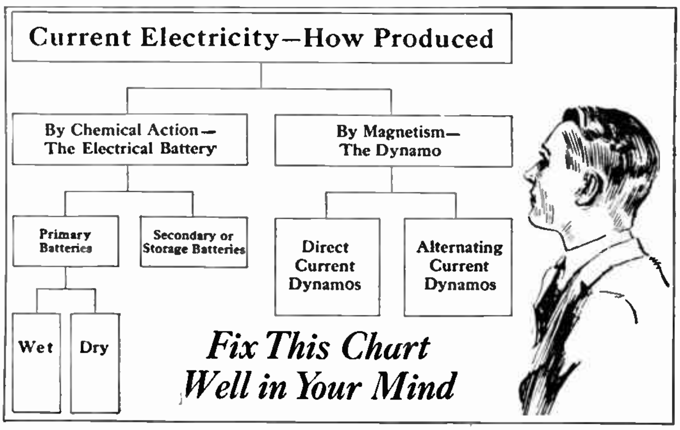
LESSON No. 2

FUNDAMENTAL PRINCIPLES

Well, here we are at the second lesson. It is going to be just as easy as the first one; just as necessary and interesting also. Sweep everything else out of your mind and try to prevent anything from interrupting you while you are at work. You must not think that too much stress and importance is being put upon the elementary electrical principles. Do you realize that more dry cells are being used for Radio purposes than in any single branch of the electrical industry? The largest electrical manufacturers of our country (General Electric Company, Westinghouse Electric & Mfg. Company and others) are building large factories for production of electrical apparatus for Radio stations.

Electricity is the very foundation, the real life food on which Radio lives, and without it could not endure. Therefore let us each one feel that we are mastering the greatest things in Radio in these early books. Without this knowledge we cannot progress to a true understanding of Radio science. Study the picture and chart given below and it will refresh your memory concerning the production of current electricity.



HOW TO GET THE MOST FROM THIS COURSE

Look for the main points—the laws, the principles, the rules of the thing studied. These primary rules are relatively to store them in your memory for use when needed. The man who knows how to apply the principles has mastered the sub-few, and it will not be difficult for you to understand them and ject.

WHAT IS ELECTRICITY?

Have you ever considered the tremendous work which electricity is doing in the world today? Electrical energy drives our machinery, lights our houses and buildings, transmits messages from one part of the world to the other. It makes possible the automobile, the street car, the subway and elevated trains.

While we are able to recognize it by its properties, to measure it, and to harness it to do our work, what electricity really is, is not definitely known.

There have been many theories advanced. The greater part of these have been discarded. But a consideration of one or two of these theories will be helpful.

For example, one theory held that electricity was a fluid which pervaded all matter. While this theory has been discarded it helps us to picture the nature of electricity.

The latest theory holds that "electricity is a rapid vibration of the molecules of the conductor and in the space immediately surrounding the conductor." A molecule is one of the tiny particles of which all matter is composed, and is the smallest particle of matter which can exist by itself. The exact nature of these vibrations are similar to light and heat, and travel at the same speed as light; that is, 186,000 miles per second.

In this course we will concern ourselves especially with the properties of electricity, a knowledge of which has made its commercial application a reality, and we will see how these properties are applied in practice to the art of Radio communication.

Before we get down into the bone of this particular lesson let us consider for a moment the drawing of electric circuits. Let us assume that you are an operator and that you wish to make a diagram of connections—you want to show how a certain set of apparatus is "hooked up." This "hook up" is a little phrase that radio operators always use. Most every operator has a pet "hook up."

If you were an experienced radio man you would not make a drawing of every instrument that you wanted to show in the diagram of connections. That would be a long and tedious job

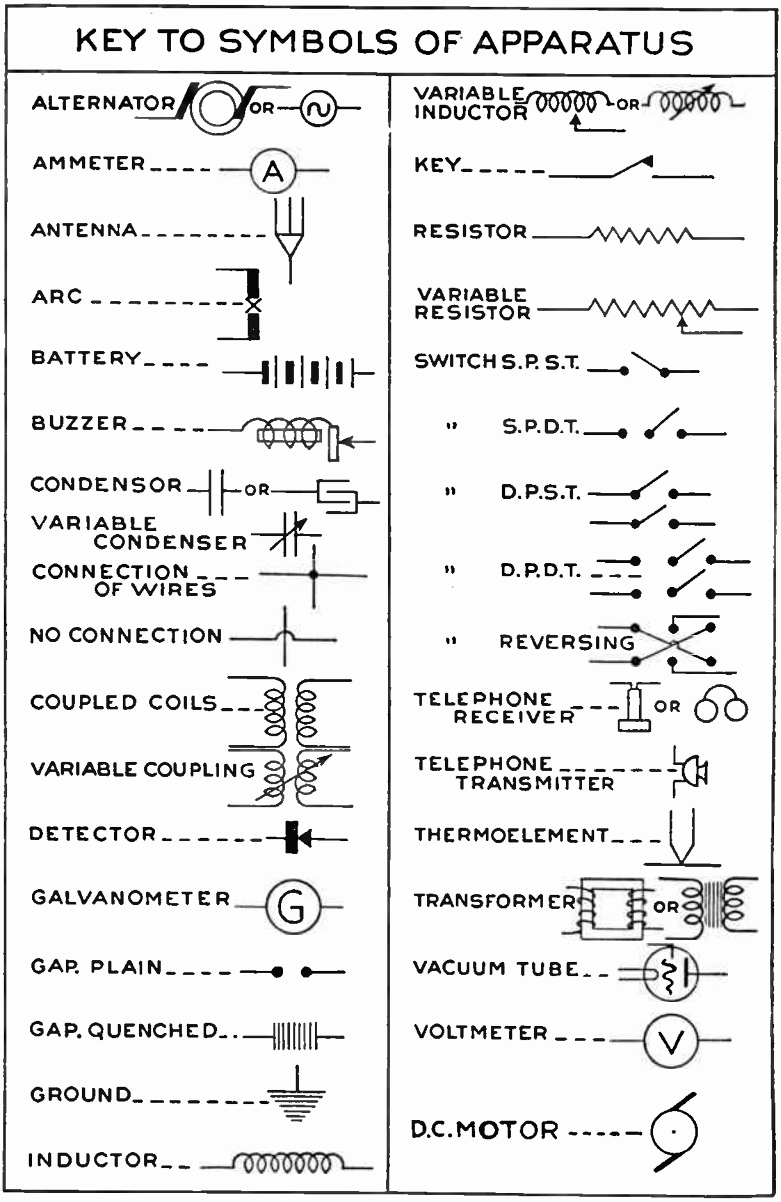
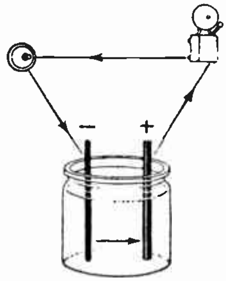


Fig. 5

Switch S P S T Abbreviation for Single Pole Single Throw
Switch S P D T Abbreviation for Single Pole Double Throw
Switch D P S T Abbreviation for Double Pole Single Throw
Switch D P D T Abbreviation for Double Pole Double Throw

and wholly unnecessary. The radio man has a little diagram that he uses to represent each instrument. He uses sort of a "short hand" just as the chemist does when he outlines certain chemical processes by well-recognized symbols.



Showing how a circuit is formed on an ordinary push-button bell outfit

Fig. 5-A

On the following page you will notice all of the symbols used in radio "hooks ups" (Fig. 5). A careful examination of this page will show you that each diagram is really a crude little sketch which shows the principle of the piece of apparatus referred to. Examine each one of these sketches carefully. Register them in your mind. Sketch them out in your note-book and draw and redraw each one until you are sure you can recall it at any time you wish to do so. Do not look upon this as a big job. There is nothing to it. In fact, do not look upon any part of this course as a big job because it is not. It is simply an outline of instruction that any school boy could follow with perfect ease.

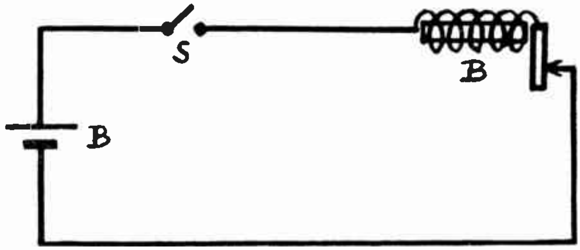


Fig. 5-B—Showing the same circuit as Fig. 5-A using symbols

Let us see in what way these symbols may help in the work before us. Suppose one wanted to show some person how to connect the wires for installing an electric door bell. The inexperienced or untrained man would spend one-half hour or more in making an elaborate drawing (as the things really look) as shown in Fig. 5-A. The electrical man in one-tenth (1/10) the time would make the diagram shown in Fig. 5-B.

The saving of time means efficiency to the engineer and the study of any branch of engineering is for the purpose of accumulating knowledge that will make one more saving of time, material and power.

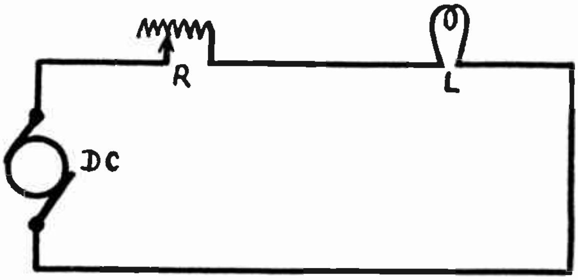


Fig. 6—Circuit diagram using symbols showing D. C. Generator, Variable resistance and an electric lamp in the circuit

WHAT IS MEANT BY A CIRCUIT?

The path along and in which electricity flows is known as a circuit. In flowing over this path or circuit the current electricity naturally follows a certain direction, which direction is, of course, always out from the point of highest pressure. In any device generating current electricity, there are always two poles, as hereinafter shown, which are known as the positive and negative poles. The student should note that this has nothing to do with the positive and negative charges which we have seen to exist in static electricity. In current electricity, positive and negative current refer only to the direction of flow from or to the source of supply. The pole from which the current flows out is known as the positive pole, or the pole of high pressure. The negative pole is the pole through which the current returns to the source of supply and is the pole of low pressure. A circuit may now be more fully defined as that path over which the electric current flows from its starting point, or positive pole, out over its path and again back to its source, or negative pole.

MORE ABOUT ELECTRIC CIRCUITS

Do you find this subject of electricity opening up to you as it should? Isn't it really a pleasure to come to understand this fascinating subject?

The subject of electric circuits is of the utmost importance;

therefore we have decided to come back to it. Fig. 7 illustrates a very simple electric circuit. You will notice that the current

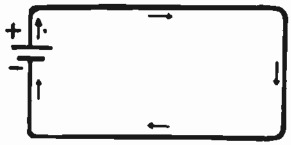


Fig. 7—A circuit

starts at the positive pole of the battery and flows in the direction of the arrows back to the negative pole. An electric circuit is simply a complete path for the flow of electricity from one point to another. The circuit shown in Fig. 7 is called a closed circuit. You do not see a gap in it, do you? Therefore it is closed.

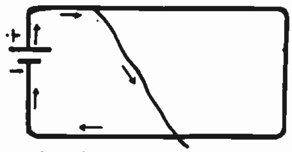


Fig. 8—A short circuit

A short circuit is shown in Fig. 8. Did you ever play with the electric-light circuit when you were a boy and blow out all the fuses in the house? You had some experience with short circuits then, but you probably did not know it. By referring to Fig. 8 you will see that a piece of wire extends from one point of the circuit directly across to another point and that the current follows this piece of wire instead of going through the entire circuit as shown in Fig. 7. This is called a short circuit. Electricity always takes the path of least resistance.

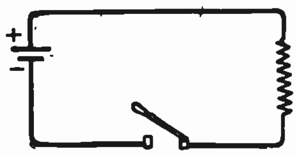


Fig. 9—An open circuit

Many human beings are like this, but they do not succeed as well as electricity does. Electricity always takes the shortest way back to the negative pole of the battery or generator that is producing it. You could not fool it if you tried. The majestic law of electrical currents has never been violated.

When we cause a short circuit in the electric-light system of our home we give the current an occasion to act rather strange. This happens because too much of the current is allowed to pass through the circuit, and this great volume of current, having little work to do, must occupy itself in heating up the circuit. Then the fuse blows out and somebody goes hunting for the candle.

What is an open circuit? We were told that the circuit shown in Fig. 7 was a closed circuit. The circuit shown in Fig. 9 is an open circuit. Why is it open? Because there is a gap of air across which the current can not pass. If we had a very high potential we could make the current jump this gap, overcoming the tremendous resistance offered by the air, but in this case we are dealing with a low potential current and when we interrupt the circuit by an electric switch as shown no electricity will flow in the circuit. An electric switch, then,

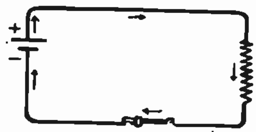


Fig. 10—A closed circuit

functions like a valve in the water pipe. It breaks the flow of electricity.

The open circuit shown in Fig. 9 is shown closed at Fig. 10. We notice that this circuit contains some resistance which is represented by zigzag lines. Of course, every circuit contains some resistance because the conducting medium or the wire represents resistance. The zigzag lines represent what we might call resistance. It is generally imposed in a circuit to control the current. For instance, if we want to hold some of the current back we would put a resistance coil in the circuit. This resistance coil would be made up of what is known as high-resistance wire, like Nichrome or German silver wire.

In Fig. 11 we have a divided circuit. There are two wires

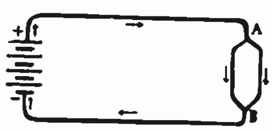


Fig. 11—Divided circuit

between the points A and B. What would happen here? We would find that the current would divide itself, part going down one wire and part down the other. If both wires were of the same length and size the current would divide in half, one-half going through each wire.

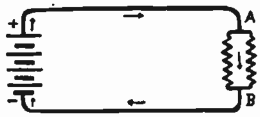


Fig. 12—Resistance in parallel

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

Let us now consider another example of connecting these coils of resistance wire. Join one end of all coils together and connect these joined ends to one binding post of four dry cells (joined in series). Then connect the other ends of the coil together and connect these by a wire to the other binding post of the four dry cells, as shown in Fig. 12. These coils are now said to be connected in parallel. If the student will study for a moment the action that will take place in the flow of electricity, or, if we turn our thought to the case of the coils representing water pipes, one may readily see that the water will divide when it reaches the joining points of the pipes and a small part of the entire water will flow through each one of the pipes. The flow of electricity will be divided in the same manner and a small part of the total current will flow through each one of the coils. The total current flowing in a parallel circuit is found by adding together the current flowing in each one of the several branches, while the pressure upon each one of the several branches of a parallel circuit is equal in amount as measured in volts. One may make a circuit combining these two arrangements and call it a series-parallel circuit, as shown in Fig. 13.

Now let us try to apply in a practical way what we have digested in the previous paragraphs. We must come to understand that knowledge for knowledge's sake is absolutely useless. We must be able to use what we put into our heads; otherwise the knowledge is useless. In this course we have included only those things that are going to be of value to you in your radio career.

Let us solve this problem: Suppose that we desire to obtain 6 volts of electric pressure to be used in lighting an automobile lamp. This we desire to do by the use of dry cells. A single dry cell is able to produce a voltage of 1½. Let us digress for a moment at this point. On one hand, we will assume that we have a dry battery the size of a thimble and, on the other hand, a dry battery the size of a barrel. Will the voltage increase in proportion to the size of the battery? You will probably be surprised to learn that it will not. The voltage of the tiny battery and that of the big battery will be exactly the same, 1½. But what about the amperes or the current of the battery? Will that increase? The answer is yes. The amperage of a dry cell increases with its size.

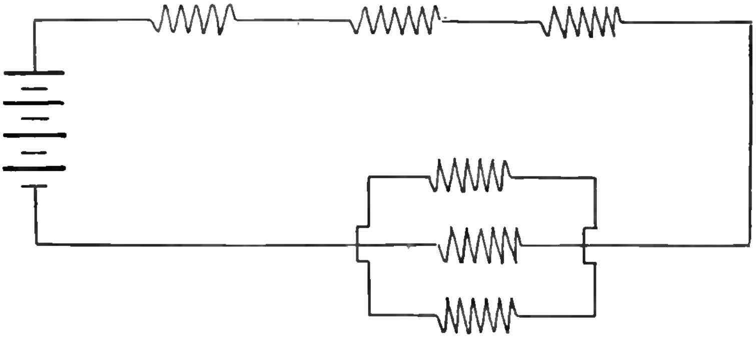


Fig. 13

Well, let's go back to our original problem. If we wish to obtain 6 volts we must use 4 dry cells, since 4 times 1½ equals 6.

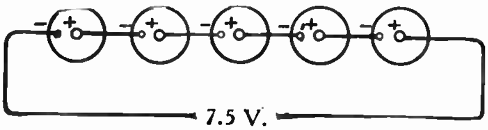


Fig. 14—Dry cells in series

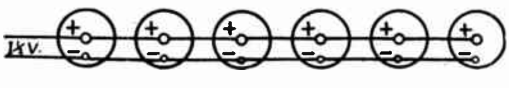


Fig. 15—Dry cells in parallel

Do not make the mistake of calling a single dry cell a battery. A battery refers to a number of dry cells used in combination.

We will now consider the method of connecting up dry cells. The method of connecting them usually depends upon the duty they are to perform and upon the amount of current or voltage we require for our use. Fig. 14 shows how dry cells are connected in series. They are simply connected in a single

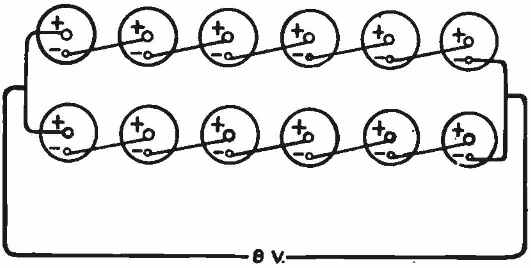


Fig. 16—Dry cells in series-parallel

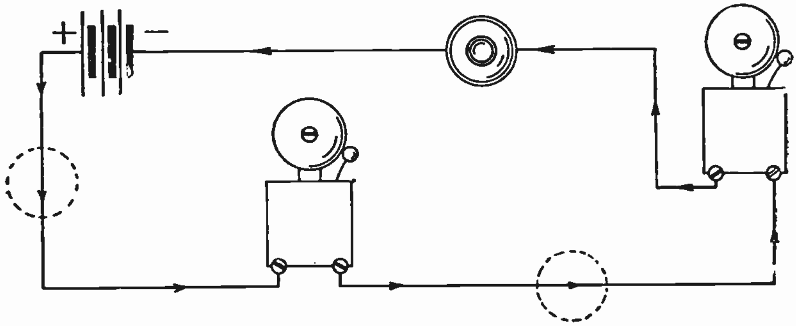
line, but do not be too hasty here. Notice how the poles are connected together. We could not connect two positive poles together and expect the battery to function properly. If we look close we will notice that the positive pole of one cell is connected to the negative pole of the next, and so on. We notice that the potential of the cells as they are connected in Fig. 14 is 7½ volts. In other words, it is 5×1½, because we have five cells and each cell produces 1½ volts. Dry cells of standard size produce a current of about 20 amperes. What will the current of this battery amount to? In this series connection the current will be the amperage of one cell.

If we needed a heavy amperage and a low voltage we would connect the dry cells in parallel as illustrated in Fig. 15. Here we would connect all the positive poles together and all the negative poles together so that, as far as the voltage was connected, all the cells would act like one large single cell and the voltage would be 1½. However, the amperage would be 6 times 20, or 120 amperes.

Fig. 16 shows what is known as a series parallel connection of dry cells. You will notice that this is a combination of the first two methods. The two sets of cells are called banks, and when cells are connected in this way we must have an equal number of cells in each bank. (One student wrote in and told us if we did not, we would have a lop-sided current). The voltage of a series parallel is equal to the voltage of one cell multiplied by the number of cells in one bank, and the amperage is equal to the amperes of one cell multiplied by the number of banks.

Let us now turn our attention to a few practical applications of these various types of circuits as applies to the wiring of push-buttons and bells in our home.

The definition of series connection is the same for other apparatus as for cells. Several lamps or bells may have to be connected to the same circuit. They may be arranged in series, applying the same principle. Fig. 16-A shows a circuit in which two bells are operated from one push button. The bells are connected in series with each other and also with the button.



Pushbutton may be placed in either of dotted-in positions instead of in location shown.
Fig. 16-A—Two bells connected in series.

The current must flow through the one before it can flow through the other. There is no other path for the current from positive pole to negative pole. It is immaterial on which side of the bells the push button is located. An interruption of the circuit at any point means a cessation of current. But the bells require the current in order to ring. It is likewise just as good to have the current flow through the bell in one direction as in the other. With the exception of special apparatus the direction of current through an instrument is of no importance. As long as the bell is in working order and a current of sufficient strength is passing through it, it will ring.

Whenever the necessity arises for connecting any piece of electrical apparatus, no matter how simple the connection may be or appear, it is a good scheme to work out the connection on paper first.

Parallel Connection—The proper way to connect vibrating bells is in parallel with each other. This means a connection where each device may be traced out separately from pole to pole of the battery. There is more than one path for the current to reach the negative pole after flowing from the positive. Divisions of current take place. The connection may be best understood by a specific example, Fig. 16-B. Two bells are to be operated by one push-button. The button, in order to make or break the circuit for each bell as desired must be in series with each. But, as can easily be traced from the drawing, it is possible to start out from positive, go through either bell No. 1 or bell No. 2 and from there through the push-button in completing the circuit to the negative pole. Right at the point where a wire branches off towards bell No. 2 the current divides.

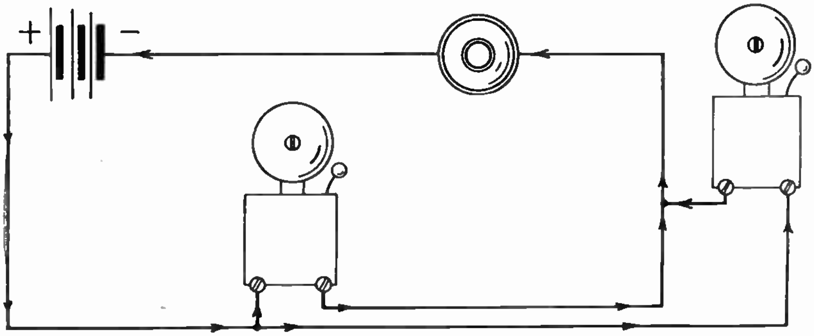


Fig. 16-B—Two bells connected in parallel.

Later, after flowing through the bells the currents again join and flow together back to the negative pole of the battery. Each one of the bells is connected to the battery and push-button independently of the other. Should we desire to cut the wire of either bell somewhere behind the branch-off and before the re-junction we could do so without any interference. Having two buttons in series means that the circuit is open normally at two points. Pressing one button does not close the other open circuit. But you could not very well press the vestibule button and the one on the top floor at the same time. That is exactly what would be required to close the circuit if the buttons were in series with each other. That leaves only parallel

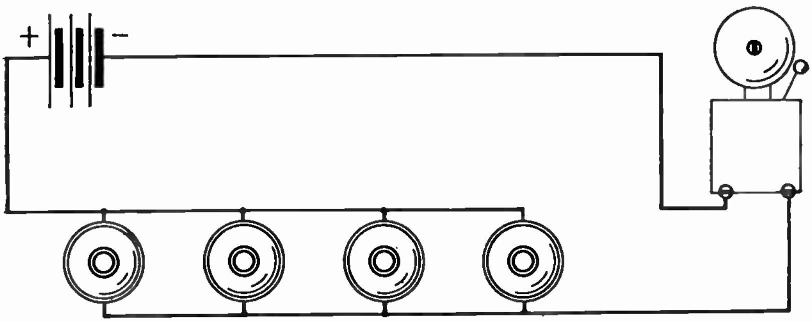


Fig. 16-C—A number of pushbuttons to operate one bell.

connection. Fig. 16-C will tell you how. Tracing from positive to negative you will find each button to be in series with the bell—one after the other. But you can also trace out a separate, independent circuit for bell and each individual button without having any use for the others at that time.

We may conclude that devices which we wish to work independent of others connected to the same circuit, should be in parallel with the others; while devices which should always and without fail operate simultaneously with others in the same circuit should all be in series with each other. There are modifications at times but not as a rule.

In Fig. 16-D we see two bells and two push-buttons connected to the same battery of four cells in series. Each button is in series with its bell. Each button operates only one of the bells. They have nothing in common except the battery. The two independent bell problems, each being fundamentally the same as the one in Fig. 5-A, Book I, are therefore connected in parallel with each other.

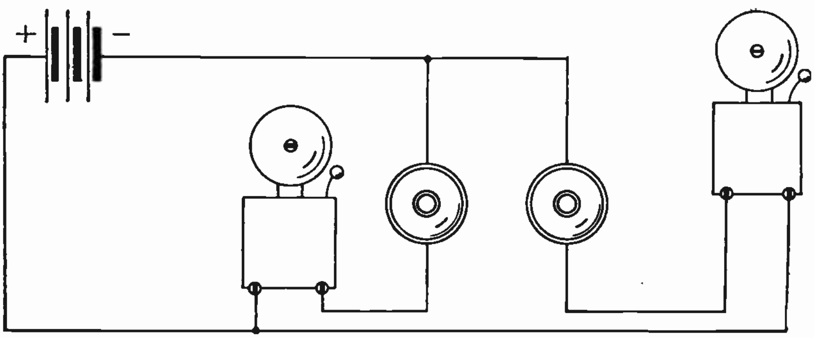


Fig. 16-D—Two independent bell circuits connected to the same battery.

Series-Parallel and Parallel-Series Connections—It often happens that several devices are connected in parallel with each other, but that they do not represent the total number of apparatus in the circuit. Others may in turn be added to them in series. Or groups of apparatus in series may be arranged in parallel with each other. The expressions series-parallel and parallel-series apply to such combinations. No well defined distinction is made between the two terms. They are often used interchangeably.

Let us now attempt to test our ability to understand circuits and apply it to a simple radio diagram as shown in Fig. 16-E.

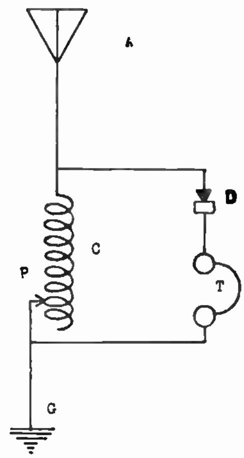


Fig. 16-E—Showing a very simple radio circuit

You will see at once that there are five pieces of apparatus, an antenna, tuning coil, a detector, telephone receiver and a ground. Furthermore you notice that the detector and telephone receiver are connected in series. Now isn't it really simple after you have studied it in the right way?

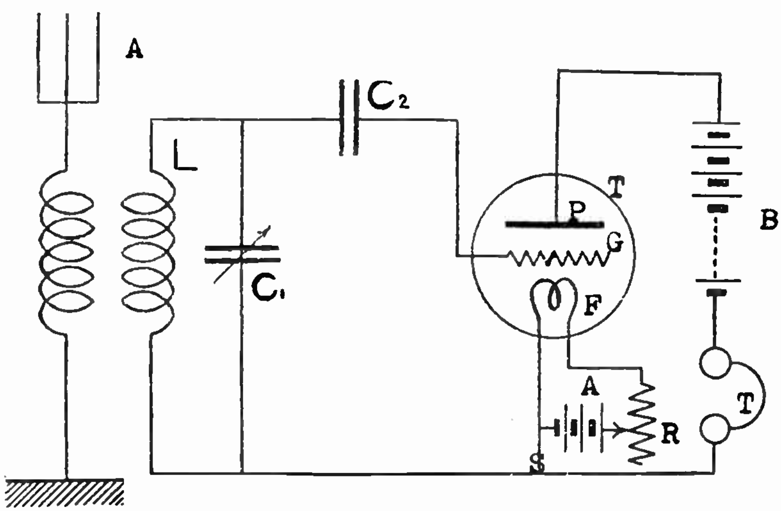


Fig. 17—A diagram of a straight vacuum radio receiver circuit

Now let us study the circuit diagram of a straight vacuum tube radio receiving circuit as shown in Fig. 17. This is the standard diagram for a straight vacuum tube radio receiving circuit. Now if you have studied the key to the symbols of the apparatus, you will first pick out the instruments that are used in this circuit. Referring to the upper left hand portion of the diagram, we find the aerial symbol. Directly below it, we find the symbol for the coupling coils, which can be loose coupler or variable coils and below this we find the symbol for the ground. Then connected across the secondary of the tuned coil marked "L", we find the symbol for a variable condenser, marked C1. In the center of the diagram, we find a symbol for vacuum tube. Connected between the grid (G) and the coil L we find the symbol C2, a fixed condenser just below the filament (F) of the tube we see the symbol (A) three cells connected in series called the A battery and the variable resistance (R) called the filament rheostat. At the right of (R) we see the symbols for the telephone headset (T) and above these the symbol for several cells in series called the B battery. From this diagram, therefore, we learn that we need the following parts to make the set:

1. A loose coupler or variocoupler
2. 1 variable condenser
3. 1 grid condenser
4. 1 vacuum tube
5. 1 vacuum tube socket.
6. 1 filament rheostat
7. 1 "A" battery for lighting the filament.
8. 1 pair of headphones
9. 1 "B" battery for supplying the plate current.

Details of all types of Radio Receiving circuits will be taken up in lesson texts 9 and 10.

Let us reflect our thought for a few minutes on the distribution of water to the many homes in a city. The main water pipe runs underground through the streets and a pipe leading from each house to the street is connected to the water main so the water may be conducted to the several water faucets inside the house.

This is the same in the distribution of electricity for the homes except for the fact that there are two wires in the street one wire brings the current to the house, and the other returns it to the power house.

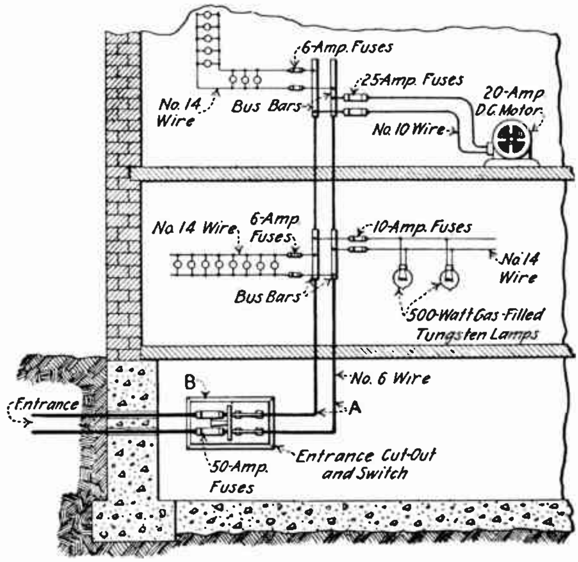


Fig. 17-A—Distributing circuits for the two floors of a building

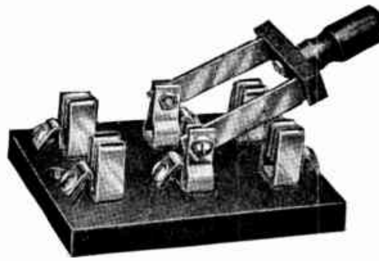
Figure 17-A illustrates the distributing circuits for the two floors of a building. The entrance wires for the main circuit come through the concrete cellar wall, pass through the main fused switch and then run to the first and second floors. The first floor has two circuits. One circuit with two large lamps running to the right and a second circuit with 8 small lamps on the left side. The second floor also has two circuits, one being a motor circuit extending to the right and the other has 8 small lamps on the left side.

Now we must find some way to open and close these circuits just as we open and close a faucet in our sink so as to let the water flow. The term switch applies to the device used to open and close the electric or radio circuits. There are many different types of switches, some of which will be described here.

Single Pole Single Throw

Single Pole Double Throw

Double Pole Single Throw



Double Pole Double Throw

Fig. 17-B—Four Types of knife blade switches

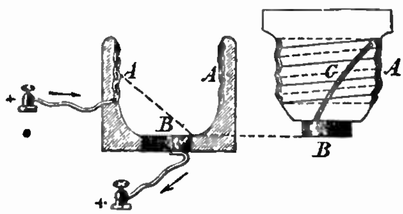
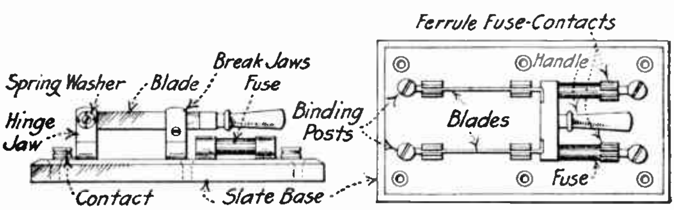


Fig. 17-C—Details of construction of a plug fuse



I - Elevation II - Plan View

Fig. 17-D—Diagram of D P S T cartridge fused switch

Fig. 17-B illustrates four types of knife blade switches and are named according to their constructive features and the purpose they serve. All electric light and power circuits for radio installations must, according to the National Board of Fire Underwriters, be protected from having too much current pass

through them. The fuse is the more common type of protection device and as shown by Fig. 17-C, it consists of a small insulated plug having a brass screw shell which fits into an ordinary Edison lamp socket. Between the brass shell A and the other brass tip B there is a piece of fuse wire (c) through which the current must pass on its way into the circuit (to be protected).

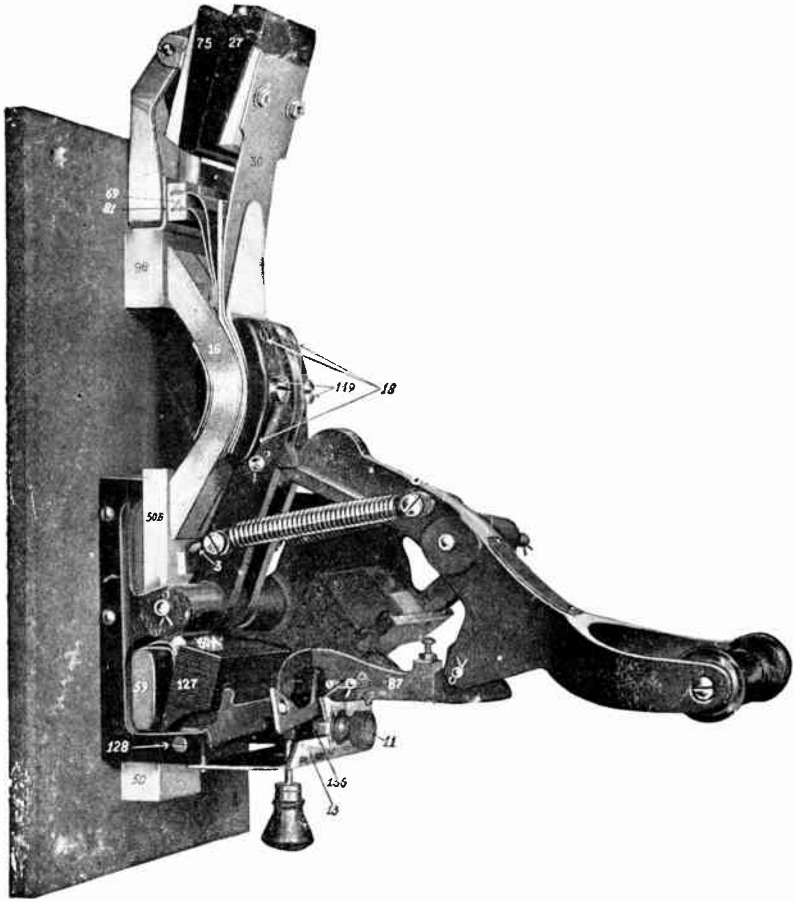


Fig. 17-E

When the amperes of current exceed the capacity of the fuse wire it is melted and the circuit broken. There are other ways of making the larger fuses as the cartridge form, and the knife form fuses but they all have the fuse metal strip which is melted by the excessive current. Fig. 17-D shows a D. P. S. T. cartridge fused switch.

Another form of protective device very much used in modern radio and electrical installations is the circuit-breaker. This device shown in Fig. 17-E is a piece of mechanical apparatus so designed and constructed that when too much current flows through it, a latch 87 in the Fig. 17-E is pulled down by this large current, releasing the handle just above it and thus allow the sheet copper arm or bridge 16 (fastened onto 18) to move outward suddenly under the pulling action of the coiled spring which in turn opens the electric circuit in two places between 50-B and 16 also between 16 and 98. In other words the U shaped copper member 16 acts as an automatic switch blade in a S. P. S. T. switch to open and close a circuit between the copper blocks 50-B and 98.

Suppose this to be the circuit-breaker illustrated in Fig. 17-G then the path of the current would be from the + wire of the Direct Current Generator in the Generating Station to the copper block 50 (Fig. 17-E) then through a coil of large wire wound on the magnet 59 then on to the copper block 50-B through the arm or bridge 16 (if it were closed) to the block 98 then to the trolley wire through the trolley pole to the motor under the car and back to the negative side (—) through the rails or the ground.

When the circuit-breaker opens the actual stopping or arcing of the current takes place between the two blocks of carbons 75 and 27 provided at the top for this purpose. The arm 16 is made from many thin sheets of spring copper and moves about a hinge just below 3. As the bridge moves to the right a gap is first made between 98 and 16, the lower end of 16 keeping in contact with 50-B by the spring action in the copper sheets. Now the current cannot flow directly from 16 to 98 but takes the longer path from 16 to the carbon block 27 to the block 75 and then down to 98. As the arm 16 moves further out to the right it separates the carbon blocks 27 and 75 and this causes the final breaking or arcing of the current. If the carbon blocks are burned by long use they may be easily replaced at a very small expense.

The wires of the circuit are fastened to the copper blocks 50 and 98 by copper bolts extending through the slate or marble back, and then held firm by copper nuts.

In many cases, double-pole circuit-breakers are shown in Fig. 17-F, are used in order to protect each wire of a circuit

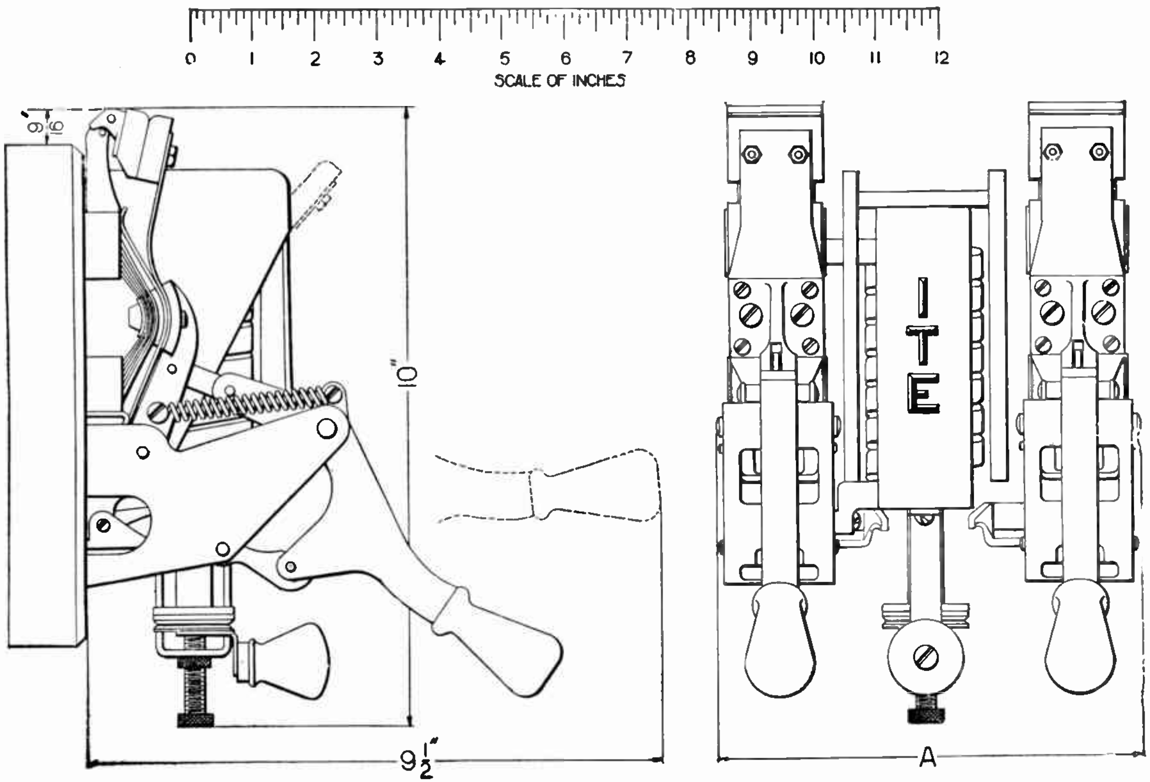


Fig. 17-F

just the same arrangement as shown by the D. P. S. T. fused switch shown in Fig. 17-D. Plan view.

The first cost of a circuit-breaker is much greater than the fuse but on the other hand it offers a greater protection in many cases and is practically no expense after installation. When the fuse is melted then a new one must be purchased and put in place. In case of the circuit-breaker we have only to close it by the handle. The fuse requires time to melt it before the circuit opens while the circuit-breaker opens instantaneously thus affording greater protection.

Figure 17-G shows how a single pole circuit-breaker is inserted in the supply wire for a 550 volt electric car circuit. In most cases each one of the cars are supplied with a circuit-breaker. This protects the motors on the car from being burned out by too great a load. Modern radio stations have all the power circuits carefully protected by circuit-breakers or fuses.

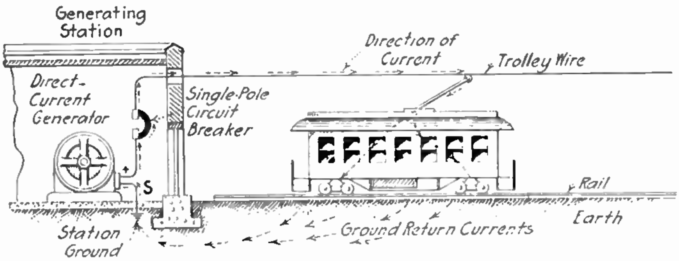


Fig. 17-G—Diagram of a single pole circuit-breaker inserted in an electric car circuit

TRANSMITTING ELECTRICITY FROM ONE PLACE TO ANOTHER

It is not always convenient for electricity to be used where it is generated as in the case of waterfalls, so it must be transmitted or conducted long distances, as is the case from Niagara Falls, from where it is transmitted many hundreds of miles.

Today the power is transmitted at a very high voltage from a power house to sub-stations, from where it is stepped down by means of transformers, to a lower voltage suitable for commercial use. (The theory and use of transformers will be, thoroughly explained in a later lesson).

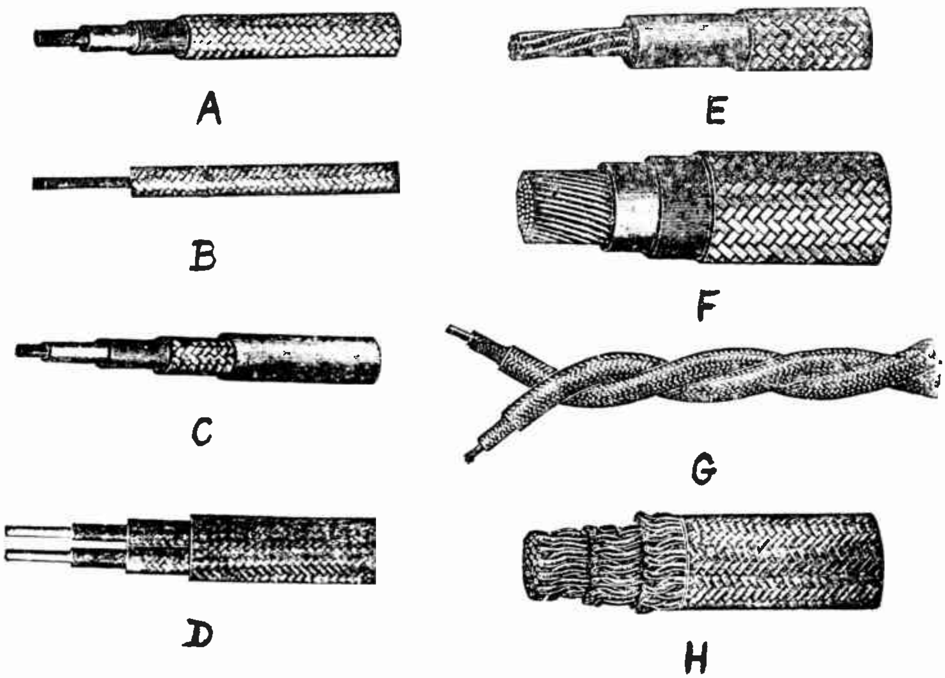


Fig. 17-H

COPPER WIRE

Copper is the principal conductor used for electrical conductors. Most of the copper in this country is found around Lake Superior and in the Rocky Mountains. It is usually found at a great depth and is expensive to mine. After taken out of the mine, the copper ore is sent to the stamp mill where it is crushed and then to the smelters where it is purified. After the copper is purified, it is molded into bars and is ready to be made into articles for general use. That which is to be made into wire is drawn through tapering holes in steel plates which get smaller and smaller till the wire is drawn to the size desired. The wire is then annealed by heating which makes it pliable and soft.

Remember, the different insulations and the letters, which stand for them. Single cotton covered, S. C. C.; double cotton covered, D. C. C.; single silk covered, S. S. C.; double silk covered, D. S. C.

Very often copper wire is covered with a black enamel for insulation purposes. This is called enameled wire and is cheaper than cotton covered. For some purposes it is better than other insulations.

Annunciator wire is used in wiring annunciators, electric bells, burglar alarms and other devices which do not require much power. It is insulated with two layers of cotton, and then soaked in paraffin which makes it more durable. This kind of wire usually comes on spools.

Rubber covered wire is used in connecting motors and lights. This wire has one or more layers of cotton braid over the rubber covering. A double braid is shown in Fig. A. A single braid wire is shown in Fig. B, and a double braid lead covered wire in Fig. C.

Fig. D is called a "duplex" and is used for lighting and power purposes.

Fig. E is a piece of stranded wire single braid rubber covered. Fig. F shows a piece of flexible cable. This is made of a number of strands wire and covered with several thicknesses of insulation. Fig. G is a rubber covered telephone wire.

Fig. H shows a piece of rubber insulated telephone cable. These are plain rubber insulated wires, twisted in pairs and covered with saturated tape and braid.

A LIST OF DIFFERENT KINDS OF WIRE USED FOR AERIALS

Solid copper (No. 14 or No. 16) with enamel cover

Solid Hard-Drawn Copperweld Aerial Wire—Copperweld wire is a non-corroding electrical conductor having an exterior copper coating or covering welded to a steel core, and has a distinct advantage on account of its additional tensile strength.

Solid Hard-Drawn Copper Aerial Wire—Many amateurs prefer this wire on account of its high conductivity. It is not, however, as easy to work as stranded wire.

Stranded Copper Aerial Wire Not Tinned—A flexible wire of high conductivity standard size is No. 14, which is composed of 7 strands of No. 20 B. and S. Gauge.

Stranded Copper Aerial Wire Tinned—This wire is selected by the discriminating amateur and is very efficient for aerial purposes.

Aluminum Aerial Wire—This wire has the advantage of being very light in weight and will not corrode.

Stranded Phosphor Bronze Aerial Wire—A very strong wire of high conductivity, used by nearly all commercial wireless stations and the government for high power installation.

Silicon Bronze Aerial Wire—A wire similar in appearance to Phosphor Bronze Wire with slightly less strength and conductivity but more suitable for a long span than copper.

LITZENDRAHT WIRE

This wire is used to advantage for winding inductances with a low resistance. This wire is composed of a number of enameled copper magnet wires separately insulated from each other, and braided, the whole covered by a single braided silk wrapper. (It is also used for loop aerials).

LOOP AERIAL WIRE

For indoor use for all ordinary purposes the wire used for a coil antenna may be No. 20 or No. 22 ordinary insulated copper wire, with solid conductor.

CONDUCTION

In theory, all bodies conduct electricity to a greater or lesser extent. It follows, therefore, stating the matter the other way, that all bodies resist the passage of electricity to a lesser or greater extent. **Substances which allow electricity to pass through them readily are known as conductors.** Those which materially resist the passage of electricity are known as non-conductors or insulators, as hereinafter described.

Metals are the best conductors and are never classed as non-conductors or insulators. In order to give you an idea as to the relative resistance of different metals, we will tabulate a few. In this table, silver for a given size or shape (not weight) is shown as having the least resistance, and therefore, is the best conductor. For the purpose of comparison we have taken silver as "1." By referring to this table, you will see that mercury, though a metal, has over 62 times the resistance of silver; or, silver has more than 62 times the conductivity of mercury:

Silver	1.000	Iron	6.160
Copper	1.086	Nickel	7.628
Gold	1.393	Tin	8.091
Aluminum	1.935	Lead	13.050
Zinc	3.741	Antimony	21.645
Platinum	6.022	Mercury	62.730

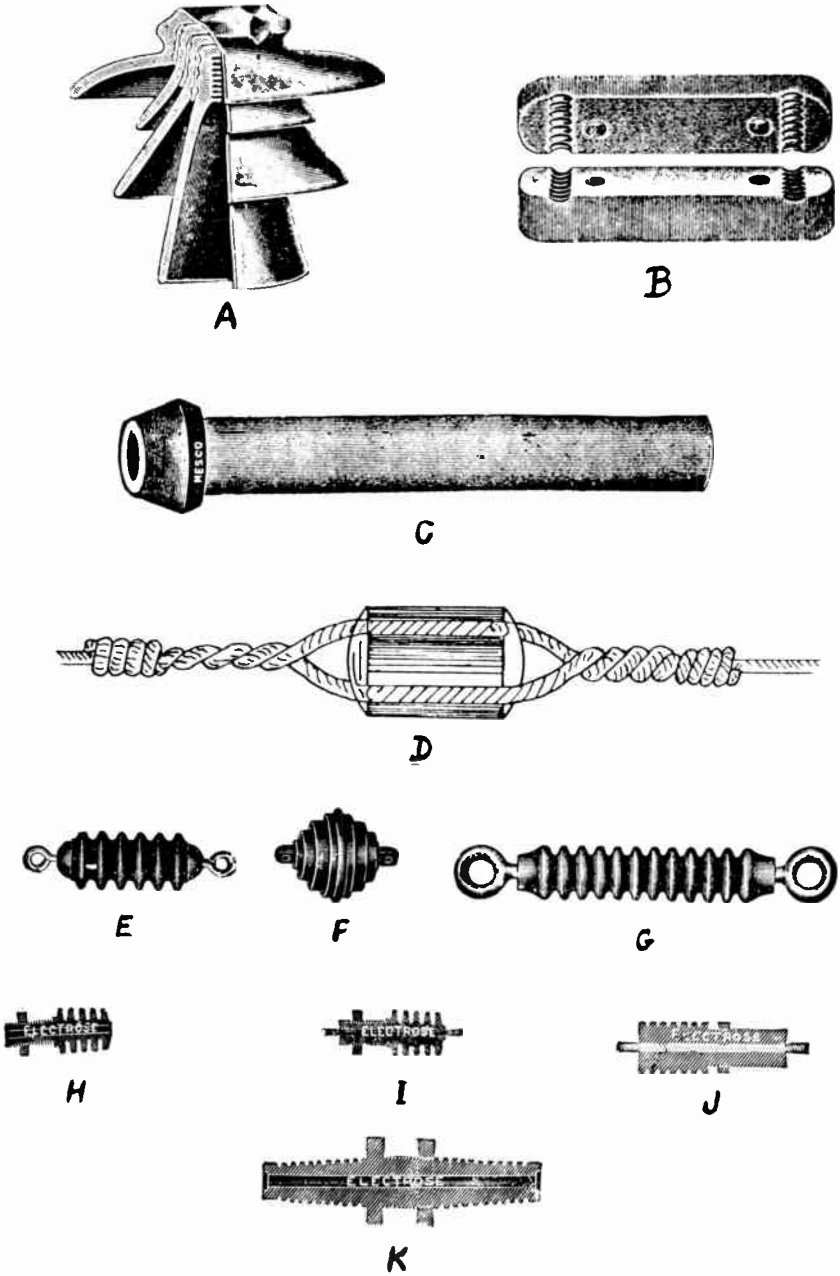


Fig. 17-K

For commercial purposes copper is generally used, as it is almost as good a conductor as silver and is much lower in cost, and its great ductility permits it to be drawn out into wire.

INSULATORS

Glass and various kinds of clay insulators are mostly used for all classes of electrical work. The clay insulators usually have a glazed finished surface made of silica. Fibre is used a great deal as an insulator and has proved very satisfactory. Rubber is also a good insulator and is used a great deal in covering electric wires of large size.

Figure A shows one of the types of insulators such as is used on high voltage transmission lines. They are made in sections, each section being called a petticoat. These insulators are now made with as many as four petticoats.

Other styles of insulators are shown in Figs. B, C and D.

Figure B shows a standard two wire porcelain cleat. These are used in general wiring in such places as they are permitted. They are also used by some amateurs for aerial insulators.

Figure C is a porcelain tube through which wires are carried when they pass through walls or partitions.

Figure D shows Guy strain porcelain insulators. These are used on electric lighting lines and have proved to be very satisfactory. Note in the illustration, the grooves in which the wires are placed to prevent them from slipping.

Figures E, F, C, are different types of aerial insulators. These insulators will stand considerable tension, also unaffected by ordinary degrees of heat and cold, moisture and acids, and have the highest insulating properties. Fig. F is most generally used for small stations.

Figures H, I, J, K, show different types of electrose lead in insulators. The insulators are used for leading the aerial wires through the walls of a building. Perfect insulation is absolutely necessary at this point if long distance transmission or reception of messages is an object. They are made of molded composition insulating material Figs. H and K have a hole through the center for carrying the wires Figs. I and J have a brass rod embedded, with a screw thread at each end, for connection to the wires by means of nuts and washers.

The Deck Insulator. Many different forms of deck insulators are in use. This device is employed to connect the apparatus in the radio cabin with the aerial lead-in. Owing to the high voltage produced by the transmitter the deck insulator must withstand 30,000 volts potential. The American Marconi Company employs two types, called the Bradfield Tube and the Electrose deck insulator. The first type, shown in Fig. 17-L, is a hard rubber tube about 2 inches in outside diameter and several feet in length. A brass rod extends through the hard rubber tube and is threaded on both ends. A funnel-shaped metal hood is placed over the top of the tube and serves to protect it from moisture. The brass rod extends through this hood and is connected to the lead-in by means of a nut. At the point where the tube goes through the deck, it is threaded and is held in place by two wooden blocks screwed on the threaded tube, one above and the other below deck.

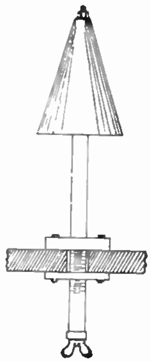


Fig. 17-L—Bradfield Deck Tube

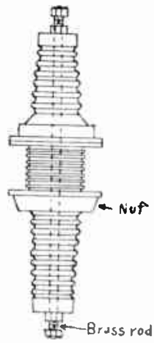


Fig. 17-M—Electrose Deck Insulator

The electrose deck insulator, shown in Fig. 17-M, is molded about a brass rod and has a corrugated surface. It is held to the deck in a similar manner to the Bradfield Tube, a threaded electrose nut being used instead of wood to clamp it to the deck. On account of the extensive surface supplied by the corrugations, it is difficult for leakage to occur over the surface of the insulator to the deck.

ELECTRICAL UNITS

Here we are again at the subject of electrical units. In Lesson No. 1 we have covered such important units as volts, amperes and ohms. We have decided to come back to this subject because it is so important to you, and we are now going to take up other units which you should have in mind. These units are just as important to you as pecks, bushels and pounds are to the grocer, and grams, ounces and liters to the druggist.

Let's brush through Ohm's Law again for the sake of practice. We are going to consider the mathematical expressions that are in common use to signify the various operations in Ohm's Law. The following letters are used to denote amperes, volts and resistance respectively: You will recall how these letters were put within a circle and referred to as Ohm's Law in a nut shell.

I=Current or amperes,
E=Volts or electro-motive force,
R=Resistance or ohms.

The three operations of Ohm's Law are then expressed in this way:

$$I = \frac{E}{R} \text{ or Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$R = \frac{E}{I} \text{ or Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

$$E = R \times 1 \text{ or Volts} = \text{Ohms} \times \text{Amperes}$$

Do not let these simple little formulas scare you. You will find here an occasion to use merely the simplest form of arithmetic. In the case of the first formula $\frac{E}{R}$ simply means to divide the numerator E by the denominator R. For instance, if R = 22 ohms and E = 110 volts, then we will have 110 divided by 22, or 5 amperes. Nothing hard about that, is there? You will note that we said in a previous paragraph that voltage is sometimes referred to as electro-motive force. This is abbreviated to E. M. F. Then voltage is also referred to as potential. We have high potential currents and low potential currents. Now let us get this thing straight once and for all.

$$\text{voltage} \begin{cases} \text{pressure} \\ \text{E. M. F.} \\ \text{potential} \end{cases}$$

We must keep in mind that potential is the force that causes a current to move through a wire. Could we have current without potential? Now we must not ask silly questions. Could we have water flowing through a pipe without any pressure? Certainly not. Could we have electric potential without cur-

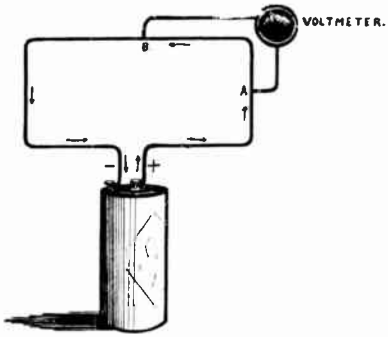


Fig. 17-N—Difference of potential

rent? This would be like asking if we could have water flowing in a pipe without water. It simply resolves down to this: Where there is potential acting on a closed circuit, there is current, and where there is current, there is potential. We can not have smoke without fire, or fire without smoke.

Now while we are dwelling on this subject of potential or voltage, let us consider Fig. 17-N for a moment. Here we have a simple dry cell forming part of an electric circuit. If we took a small voltmeter and connected it at A and B as shown, the voltmeter would measure what is known as the fall in potential or the fall of voltage between the points A and B. This is interesting. Let's hear more about it. Why does the voltage drop between these points? Let's go back to the water analogy. We will assume that a stream of water is flowing through this circuit under a pressure of ten pounds, per square inch. Now, in passing through the pipe the water meets resistance, does it not? Part of the pressure of the stream is going to be used up in overcoming this resistance and as the water travels on its pressure will grow less. This is as plain as the nose on your face. Electric current does exactly the same thing. As it passes through the wire or circuit the pressure drops, and if we bridge a voltmeter over part of the circuit, as shown in Fig. 6, we can measure this voltage drop. If a very small wire formed part of the circuit we would find there would be a considerable voltage drop because there would be lots of resistance. A drop in potential is often referred to as a difference in potential between two points of an electric circuit. This expression is usually abbreviated to P. D. (potential difference).

THE COULOMB

The coulomb is another unit of electricity that we must include in our vocabulary. Sort of an odd name, isn't it? One might expect to find it on the menu of a French restaurant. Nevertheless the coulomb is an important little unit and we must understand it. It may be defined as that quantity of electricity passing a given point in a circuit when one amperes flows for one second (coulombs equals ampere, times seconds). For instance, if the current in a circuit is 1/10 of an amperes and it flows for 10 seconds the product of the amperes and seconds will equal one. In other words, a quantity of electricity equal to one coulomb will pass a given point in the circuit. You will observe that we must consider both amperes and time in seconds to produce coulombs.

UNITS OF MEASUREMENT

In this lesson we will also deal with the way electricity is **measured.**

It seems strange that we do not know what electricity really is, and yet we can measure it very accurately.

In order to get a fairly clear idea as to how electricity is measured, let us liken the flow of electricty to the flow of water.

Suppose that you had a big reservoir of water up in the mountains, and were studying ways to bring that water down into the valley in order to irrigate your farm.

THE UNIT OF CURRENT STRENGTH—THE AMPERE

One of the first things you would have to decide would be how large a **flow** you needed. Whether you would want much water or only a small quantity to be flowing.

If you wanted much water, you would dig a large ditch to carry it. If you wanted only a little water, you would dig a small ditch.

In other words, one of the things you would have to decide would be the **rate of flow** of the water.

Now, just as there can be a certain rate of flow of water in a ditch, so there can be a definite **rate of flow of electric current** along a wire.

The **rate of flow** of the current, also known as the strength of the current, can be measured. The unit of measurement is called the **ampere.**

Just as, with a current of water, you can say that there are so many gallons per minute coming through, so with electricity you can say that there are so many amperes coming through.

To give you some idea of the amount of current an ampere represents: The ordinary 25-watt incandescent Mazda lamp (on the usual 110 volt circuit) has a current flowing through it of about ¼ of an ampere; a 50-watt Mazda lamp, about ½ of an ampere.

WHAT MAKES CURRENT STRENGTH—PRESSURE DIVIDED BY RESISTANCE

But you readily see, do you not, that the strength of any current depends on two other factors—the amount of pressure behind the current driving it forward, and the amount of resistance in the path of the current, trying to stop it.

Let us give an illustration:

Suppose you have a current of water flowing through an inch pipe. Then suppose you fill that pipe with buckshot. What happens? Why, the current slows up. Just as in our previous illustration if we had filled the ditch with stones. The buckshot is a resistance. In effect, it reduce the size of the pipe. The greater you make the resistance, the less current you get.

But now suppose that you put a force pump on that pipe in order to bring force or pressure on that current of water. What happens? The current increases. The greater the pressure, or force, the greater the strength of your current.

Let us illustrate this with a little arithmetic:

Suppose you had a current of water flowing through a trough at the rate of 100 gallons a minute.

If you double the pressure or force behind that water, you will get 2 times 100 or 200 gallons a minute.

But then if you should double the resistance of those 200 gallons, you would cut the current in two. You would have one-half of 200 gallons, or 100 gallons.

So here is the formula that you should fasten in your memory:

The strength of the current equals the pressure divided by the resistance. (This is known as Ohm's Law).

ELECTRIC RESISTANCE

We have learned in the first lesson that substances differ in the readiness with which they will permit electric current to be conducted along them, and we have classified them as good or poor conductors according to their ability to conduct current. **The opposition which a conductor offers, tending to retard or restrict the flow of the electric current, is called the resistance.**

RESISTANCE DEPENDS UPON VARIOUS FACTORS

The resistance which a conductor (of uniform shape) offers depends primarily upon **length** and the **area** of its **cross section;** in the case of round or square conductors, therefore, upon length and the square of their diameter. (You learned in arithmetic that the areas of squares and circles vary as the square of their diameters). For example, a conductor twenty feet in length will offer twice as much resistance to an electric current as a conductor ten feet long, all other things being equal. Similarly the greater the diameter of the wire, the less resistance it offers, just as a large waterpipe offers less resistance to the flow of water than a small pipe.

Although by illustration we have compared electricity to water, electricity of course, is not a liquid and does not "flow" like water. But the analogy is helpful to the student.

We have pointed out that **the resistance offered is directly proportional to the length.** Now then, the amount of **resistance is also inversely proportional to the square of the diameter** of the conductor. For example: No. 21 wire has a diameter of .02 inch, No. 30 wire has a diameter of .01 inch or one-half of the diameter of No. 21 wire. It takes 39 feet of No. 21 copper wire to give a resistance of one unit, but it takes only 9.7 feet of No. 30 wire, or one-fourth as much to offer the same amount of resistance. In other words by halving the diameter of a wire we increase the resistance four times. So we see that the larger the wire, the less resistance it offers to the current.

The amount of resistance offered by a wire depends also upon the **material** of which it is made. For example: only 2.2 feet of No. 21 nickel-steel wire will offer a resistance of one unit, whereas it takes 39 feet of No. 24 copper wire to give the same resistance. Copper is the best commercial conductor; hence, wires for carrying electric current are almost universally made of copper.

Temperature (of the conductor) also is a factor in the resistance offered. Of this we will speak in a later lesson.

THE UNIT OF RESISTANCE—THE OHM

The unit of resistance is called an ohm, and one ohm may be defined **as the amount of resistance that allows a current strength of one ampere to flow when there is a pressure of one volt.** (The resistance of a copper wire one and one-fifth inch long and one-thousandth of an inch in diameter is about one ohm. The resistance of 528 feet of iron wire one-third of an inch in diameter is also about one ohm).

In many instances resistance is an undesirable factor as it retards electric current and uses up power; but we shall see as we progress that it is largely because of resistance that we can develop the heat which is the necessary factor in all electrical heating appliances. We merely call this point to your attention here and will treat of it more fully in a later lesson.

THE UNIT OF ELECTRICAL PRESSURE—THE VOLT

The driving force which produces a flow of electricity is known as the electromotive force. It is electrical pressure, just as we speak of water pressure. The unit of electromotive force, or pressure, is known as a volt. The volt accordingly may be considered as the unit by which electrical pressure is measured. **It is defined as that force which will cause a current strength of one ampere to flow through a resistance of one ohm.**

So that you may obtain an idea of about how much electric pressure a volt is, we might mention that the electric pressure in the ordinary dry battery runs from 1.1 to 1.5 volts and that the usual lighting circuit in this country operates at 110 volts. In many foreign countries the lighting circuit operates at 220 volts.

THERE IS A DEFINITE RELATION BETWEEN THE UNITS OF MEASUREMENT

You remember the formula that we gave a few paragraphs back—"The strength of the current equals the pressure divided by the resistance."

Now let us express this in electrical terms, as follows:

AMPERES EQUAL THE VOLTS DIVIDED BY THE OHMS

Or, if we let "I" stand for amperes, "E" for volts, and "R" for ohms, we may express this relation by the following equation:

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

or, if we say, I = 4, E = 160, and R = 40, then we have—

$$4 \text{ (amperes)} = \frac{160 \text{ (volts)}}{40 \text{ (ohms)}}$$

But if $4 = \frac{160}{40}$ then it is also true that $4 \times 40 = 160$.

Using the same arithmetical rule with our letters, we can say that if $I = \frac{E}{R}$ then $I \times R = E$ and $R = \frac{E}{I}$

As a practical illustration take the standard radio emergency battery 110 volts: pressure and 21.1 resistance, then

$$\text{Amperes} = \frac{110 \text{ (volts)}}{21.1 \text{ (ohms)}} = 5.25 \text{ (approx.)}$$

From these equations you will see that if two of the three units are known, the third is easily found by substituting the figures known in the equation and then solving for the unknown quantity.

For example, let us assume that we have a pressure of 150 volts and a resistance of 30 ohms and desire to find the current which is flowing in amperes. Substituting the known quantities in the equation we find that $I = \frac{150}{30}$ or $I = 5$ amperes.

In other words, there are 5 amperes of current flowing.

Again, let us assume that we have a current strength of 7 amperes and a resistance of 20 ohms, and we wish to find the amount of pressure in volts. Applying our formula again we find that

$$E = 7 \times 20 \text{ or } E = 140$$

In other words the electrical pressure is 140 volts. And so in every instance where two units are known, the third is easily found.

THE UNIT OF POWER—THE WATT

We have now considered the measurement of electrical flow, pressure and resistance, which we have learned are measured by units known as the ampere, the volt, and the ohm, respectively. There is another factor the measure of which is highly important—power, or **rate** of doing work. **The unit of measurement of electrical power is known as the watt,** just as the unit of mechanical power is the horsepower; 746 watts is equivalent to one horsepower.

Let us get clearly in mind this question of rate of doing work, or activity, or power, of which a watt is the measure.

Rate of work is found by dividing the work done by the time consumed in the process.

The expression "Sixty miles per hour" expresses a rate of speed; you do not know how far the train will go or how long it will take—you only have the **rate.** It takes an engine of a certain **power** to pull a certain length of train at that rate of speed. The power represents the rate of doing work; the actual amount of energy expended or work done in making the trip may be measured by the coal used up or the steam used, or something else.

Now we will come back to a hydraulic analogy. A current or stream of water is capable of running a water wheel or a water motor and doing work. Its power, or rate of doing work, depends on the "strength" of its current (i. e., the amount of flow in a given time), and its "force" as measured by its pressure or head.

Suppose you lived somewhere where there was no electricity and you connected a water motor to your kitchen faucet to run a washing machine. There would be a certain flow from the faucet which is under a certain pressure, say 50 pounds per square inch, and you get a certain power, or rate of doing work. Now, if you had a larger faucet and feed pipe, you would get a large flow and you would expect more power or a faster rate of work. Or, if you kept to the original faucet but the town water pressure was increased, you would also expect more power. **The power would be proportional to both the flow and the pressure.**

So the power, or rate of doing work, in an electric circuit depends upon the same two factors: First, the strength of flow, or amperage; Second, the electric pressure, or voltage. In fact, the electric power is the **product** of these two factors.

A watt then is that unit of power produced when one ampere flows in a circuit under a pressure of one volt.

The watts may accordingly be found by simply multiplying the volts by the amperes as expressed in the following equation:

$$W = V \times A \text{ or } W = E \times I$$

For example: a standard radio emergency battery is rated at 110 volts and 15 amperes. Then the

Watts = E (110) $\times$ I (15) = 1650

The corresponding battery built to be used on a 220 volt circuit, which is common in foreign countries, would be rated at 7½ amperes. And the product of the volts and the amperes in this case would be 220 $\times$ 7½ = 1650 watts—which gives the same product and wattage as that of the 110 volt battery.

THE WATT-HOUR

We have been dealing with a measure of the rate of doing work,—the unit of power which is the watt. We need now to have a measure of the work actually done, or the electrical energy expended, and this introduces the factor of time—**the work done as measured by the length of time the power is applied.**

If we apply a watt of power for one hour, we have a unit of work done which is called the watt-hour. The watt-hour may be defined then as the **equivalent of one watt used for one hour.** It may be only a half-watt used for two hours, or two watts used for only one-half hour; in fact, any **combination** that equals one watt for one hour.

It is easy to understand that two watts applied for one-half hour will do the same work as one watt applied for one hour, just as two men might unload a carload of coal on a siding in one-half day, and one man would do the same job in a whole day. The **work done would be the same in both cases.**

If H equals hours, or the length of time the power is applied, then

$$WH = W \times H$$

or the power multiplied by the length of time.

We have seen, however, that the power W is the product of the pressure and the current, or the volts times the amperes. Therefore

$$WH = E \times I \times H$$

which is saying that the work done, or the energy expended, depends on the length of time that a current is applied under a certain pressure.

To illustrate: A motor of 4 amperes, 110 volts consumes 440 watts, that is, its **rate** of using power; if operated for one hour, it uses 440 watt-hours; for one-half hour, 220 watt-hours; for two hours, 880 watt-hours—that is, watt-hours is the measure of the **work done.**

For example:

$$WH = E\ (=110) \times I\ (=4) \times H\ (=\ 1) = 440$$
$$WH = E\ (=110) \times I\ (=4) \times H\ (=\tfrac{1}{2}) = 220$$
$$WH = E\ (=110) \times I\ (=4) \times H\ (=\ 2) = 880$$

Work and Energy. Horse Power-hour. Kilowatt-hour.—When a man buys mechanical power to run his shop he has to pay not only according to the horse power he used but also according to the number of hours he uses the power. For instance, he may use 40 horse power for 1 hour and pay $1.20 for it, that is, at the rate of 3 cents for each horse power-hour. If he uses 40 horse power for 2 hours he would have to pay twice as much, because he has used the same power twice as long. Another way of stating the same fact is to say that he used twice as many horse power-hours. For in the first instance he used 40 × 1, or 40 horse power-hours, and in the second 40 × 2, or 80 horse power-hours. In other words, he did twice as much work in the second case as he did in the first, or received twice as much energy. The unit of work or energy then is the **horse power-hour,** and is the work done in one hour by a one-horse power machine.

Example—How much work is done by a machine delivering 15 h.p. when it is run for 8 hours?

1 h.p. in 1 hr. does 1 h.p.-hr.,
15 h.p. in 1 hr. does 15 h.p.-hr.,
15 h.p. in 8 hr. does 8 × 15, or 120 h.p.-hr.,

or work = horse power × hours,

15 × 8 = 120 h.p. hr.

Example—At 3 cents per horse power-hour how much does it cost to run a 200-h.p. engine for 12 hours?

Horse power-hours = 200 × 12
= 2400 h.p.-hours.

Cost = 3 cents × 2400 = $72.00

A watt is a measure of the **rate** of doing work. A watt-hour is the measure of energy actually expended, or amount of **work done.**

Since the watt is a unit of power too small to conveniently express the output of modern electrical machinery, a unit called the **Kilowatt,** equal to 1,000 watts, is generally used.

Thus:

Example.—What power does a motor consume which takes 20 amperes at 220 volts?

$$\text{Watts} = 20 \times 220$$
$$= 4400 \text{ watts.}$$
$$\text{Kilowatts} = \frac{4400}{1000} = 4.4 \text{ kw.}$$

Since a kilowatt is a unit of power it can be reduced to horse power.

$$1 \text{ kilowatt} = 1\tfrac{1}{3} \text{ horse power, (approx.)}$$

or

$$1 \text{ horse power} = \tfrac{3}{4} \text{ kilowatt, (approx.)}$$

Example—What horse power does the motor of the above example consume?

$$1 \text{ kw.} = 1\tfrac{1}{3} \text{ h.p.}$$
$$4.4 \text{ kw.} = 4.4 \times 1\tfrac{1}{3} \text{ h.p.}$$
$$= 5.87 \text{ h.p.}$$

THE KILOWATT-HOUR

In commercial practice we do not use the watt-hour to measure electrical energy because it is so small. We have accordingly adopted a unit of measurement which is 1,000 watt-hours, called the kilowatt-hour, expressed KWH.

The word kilo means 1,000 and so **the kilowatt-hour** is a thousand watts for one hour, or 250 watts for four hours, or 2,000 watts for one-half, or one watt for 1,000 hours; or **any combination which is the equivalent of 1,000 watts for one hour.** This will explain what is meant when a bill for electricity reads 18 KWH @ 10c = $1.80.

Electric power is sold by the **kilo-watt-hour.** This unit is the work or energy delivered in one hour by a 1-kilowatt machine.

Example—A generator delivers 2 kilowatts to a consumer for 40 hours. How much electrical energy is consumed by the customer?

$$\text{Kilowatt-hours} = \text{kilowatt} \times \text{hours}$$
$$= 2 \times 40 = 80 \text{ kw-hr.}$$

Since kilowatt-hours are made up of hours and kilowatts, which in turn are made up of volts and amperes, it is always possible to find the electric energy when the **volts, amperes** and **hours** are known. Thus:

How much electrical energy is taken in 10 hours by a 110-volt motor which takes 6 amp.?

$$\begin{aligned} \text{Watts} &= \text{volts} \times \text{amperes} \\ &= 110 \times 6 = 660 \text{ watts} \\ &= 0.66 \text{ kw.} \\ \text{Kw-hr.} &= \text{kilowatts} \times \text{hours} \\ &= 0.66 \times 10 = 6.6 \text{ kw-hr.} \end{aligned}$$

EXAMPLES OF WATTAGE OR POWER

You may easily apply what you have learned about watts by observing the markings on the name plates of electric appliances. Sometimes the amperes and volts are given, but usually the watts and volts are given.

In the first instance, if a name plate on the appliance is marked "5 amperes 110 volts," then you get the watts, of course, by multiplying 5x110, which will give you 550. Usually the manufacturer's catalogs give the wattage and in this way you can check the ratings with the published information.

The modern tendency, however, is to mark the watts directly on the name plate because that is what the user is most interested in. The amperes were formerly marked for the benefit of the electrician, who wanted to know the size of wire, which is determined by the amount of current and not by the

> To find the power in watts of any electric device marked with amperes and volts use the following method:
>
> **AMPERES × VOLTS = WATTS**
>
> **For example:**
>
> **3 AMPERES × 110 VOLTS = 330 WATTS**
>
> Therefore, such a device will consume 330 watt-hours of electricity if operated continuously for one hour.

power in watts. However, if a name plate is marked "600 watts and 110 volts," then if we wanted to find the amperes, our rule would be to divide the watts by the volts according to the formula:

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

and in this case I would equal 5.45 amperes.

While the voltage is always marked on a name plate, we might have some case where we have the watts and the amperes and wanted to find the volts. The formula would then be:

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

and if the watts were 600 and the amperes 6, of course, the voltage would be 100.

Another practical point is brought out by what we have learned about power. If you take any electrical apparatus marked 110 volts and connect it on a 220-volt circuit, such as is occasionally found in this country, you get **four times** the power of watts and will probably destroy the article.

The resistance remains constant, because it is a definite quality of the design of the appliance, but doubling the voltage **also** doubles the current which flows through the apparatus—and the watts is the **product** of the two—hence you get four times the watts.

WATT-HOUR METER

The watt-hour meter is a wonderful instrument for measuring with great accuracy the amount of electrical energy which is being used by the circuits connected to it.

It consists of four essential parts which are shown in Fig. 17-P and described in the following manner. The first two parts, the revolving armature revolving on a shaft (with a damping disc on the lower end) and second the magnet field made by many turns of copper ribbon in two coils and called the series or field coils, form a little electric motor. The speed of this motor depends on the strength of the current through the armature wires (see Fig. 17-R) which is supplied by the voltage on the circuit and the current and also the strength of current through the field coils which is the main current being used in the circuit.

Thus one can see that the speed of the revolving armature will change as the volts and amperes in the circuit change. In order to determine how long the current and volts act, the third part is added, a recording device which indicates the number of revolution of the armature shaft is attached at the top of the instrument.

Figure 17-P—Westinghouse type CW-6 watt-hour meter with cover off. This meter is of the commutator type without iron in the magnetic circuit. The spherical armature is closely

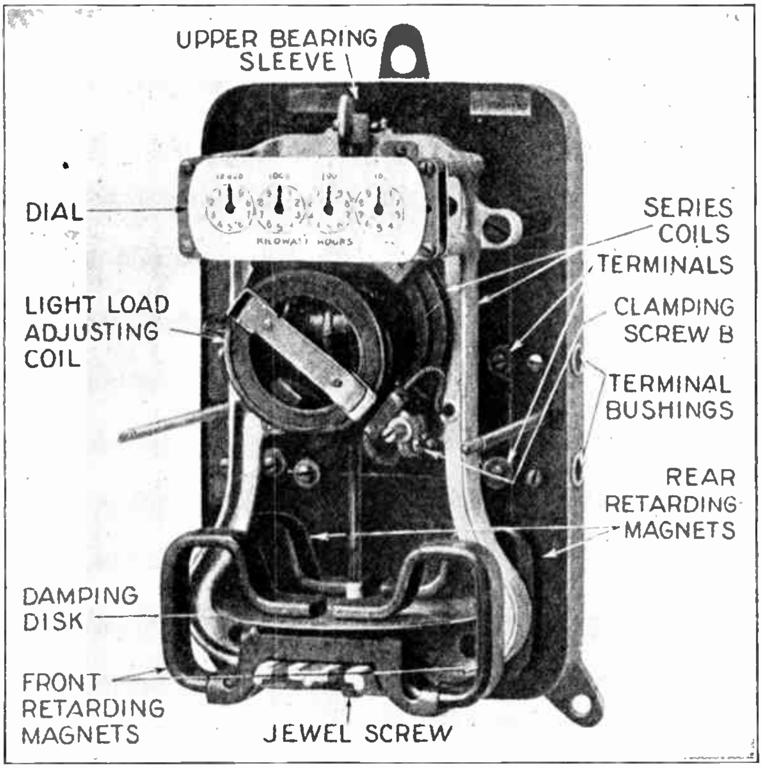


Fig. 17-P

surrounded by circular field coils which provide the shortest magnetic path and smallest magnetic leakage, thus securing high torque with small consumption of energy. The armature winding is wound on a hollow sphere of prepared paper which is molded in corrugated form to secure strength. Uniform brush tension is maintained by gravity. Each brush consists of two small round wires placed side by side and held against the commutator by a small counterweight whose distance from the fulcrum is adjustable. The current winding consists of two flat coils of strap copper one clamped rigidly on either side of the central mounting frame which supports the armature bearings. These coils are connected either in series or parallel, depending on the capacity. In three wire meters one of the coils is connected in series with each side of the line. The retarding element consists of a light aluminum disc rotating between two pairs of permanent magnets. The magnets are prepared by a special aging process to insure permanence. Full load adjustment is made by shifting the position of the permanent magnets. Ample light load adjustment or friction compensation is provided by means of the movable coil, which can be shifted horizontally or radially on loosening one screw. The meter registers directly in kilowatt hours.

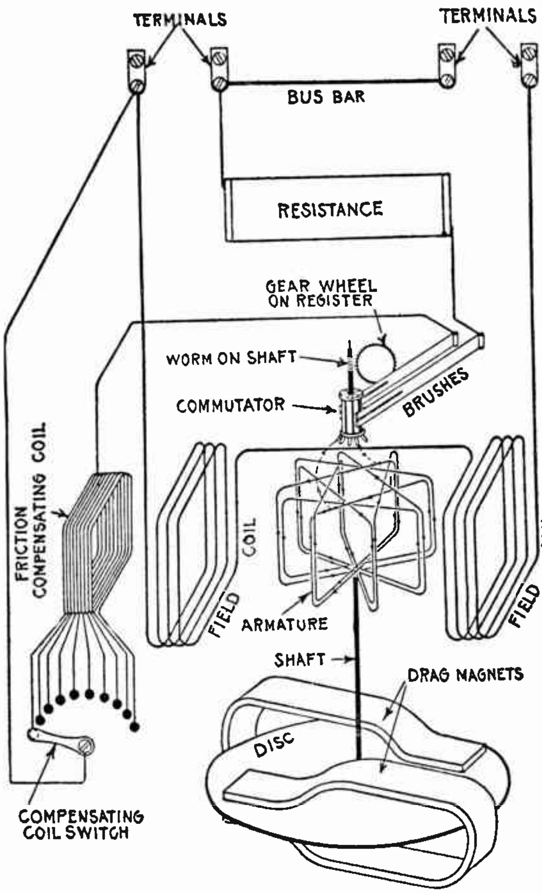


Fig. 17-R

Figure 17-R—Diagram showing internal connections of the watt-hour meter. Its operation depends upon the principle of

the well known electro-dynamometer, in which the electro-magnetic action between the currents in the field coils and an armature produces motion in the latter. It also embodies the other two necessary watt-hour meter elements required for the speed control and registration of the revolutions of the armature, these being embodied in the drag magnet and disc, and the meter register respectively. The motion of the armature is converted into continuous rotation by the aid of a commutator and brushes, the commutator being connected to the armature coils and carried on the same spindle therewith.

The fourth essential part is the drag magnets acting on the copper disc at the bottom of the armature shaft. These drag magnets exerts a force on the disc as it turns and tends to stop it thus bringing the armature at rest (stopping it) the same as the spring on spring balance brings the pointer to the zero or resting mark when the weight is removed from the balances. The application of this instrument to practical service will now be explained.

THE COST OF OPERATION AND ITS MEASUREMENT

Do you know how to read an electric meter? Do you know how to calculate the cost of operating any electrical appliance for any given length of time?

These are points which may come up any time during your radio work. Suppose the director of a radio station called you to his office and said: Our bills for electricity are very unreasonable. I don't know how the company figures them, but I know I do not use as much current as the company charges us for. How do they figure those bills?" Could you answer him satisfactorily? Could you take him to the electric meter in the station and show him how to figure his own bills?

Let us take another point. Suppose during the process of charging a storage battery you were asked to figure the cost of energy supplied by the Power Company.

Could you figure the exact cost of charging the battery?

These are the important points covered by this lesson. Let us first take the electric meter.

THE ELECTRIC METER

(Watt-hour Meter)

We have learned what very definite units there are by which electricity may be measured; and that the watt-hour, or rather, the kilowatt-hour, is the measure by which electricity is sold. (KWH = Kilowatt-hour = 1,000 watt-hours). It measures the energy used, which is in exact proportion to the work done by the electric current. The various units of measurement of electricity can be very accurately recorded in commercial instruments, or meters.

In this lesson when we speak of the "meter," we will refer only to the watt-hour meter,* which is the meter installed and connected in all premises that are wired for electric service.

In principle, the electric meter is really only a small electric motor driving a set of dials, the motor being so designed as to revolve at a speed exactly proportional to the amount of electric energy being used.

In the standard type of meters, the speed of the motor is regulated by a horizontal metal disc which revolves on jewel bearings between horseshoe magnets. Most meters are marked with the value in watt-hours for each revolution of the disc. This figure may be found on the name plate or marked on the disc.

In most types you can see this disc revolve. For example assume that one revolution of disc measures one watt-hour. If one watt of electricity were being used, the disc would revolve once an hour. When a 50-watt Mazda lamp is being used the disc will make 50 revolutions in an hour. Or, if the lamp were on for one-fiftieth of an hour, the disc would revolve once and the meter would register one watt-hour, or one one-thousandth of a kilowatt-hour (KWH). (Such a very small amount, of course, could not actually be observed on the dials of the ordinary meter).

Thus the moment an electric lamp, or any other current-consuming appliance connected on the circuit is switched on, this little motor begins to revolve, and at a speed in keeping with the wattage consumption of the appliance or appliances connected on the circuit.

This motor has no work to do, except to revolve the metal disc referred to, and to move the little hands on the dials of the meter, which leave a record of the exact amount of electricity consumed.

*NOTE:—There are other meters for measuring electricity, such as Ammeters, or Ampere meters, for measuring the flow of current; Voltmeters for measuring the pressure, or voltage; Wattmeters for measuring the rate of power used, etc.

ACCURACY OF ELECTRIC METER

It is because this motor (unlike motors for operating sewing machines, washing machines, etc.) has practically no work to perform, that it can be very delicately and accurately made, and the weight of its rotating part is so small, and the bearings so delicate, that no measurable amount of energy is consumed in operating it.

One peculiarity of the electric meter is that only dust and friction are at all likely to affect its accuracy, and both of these necessarily have a retarding effect, causing it to register less current than has been used. The chances of its registering more are remote indeed.

Meters in use in stations are often tested in large numbers, and it is exceedingly seldom that one is found that is appreciably inaccurate.

HOW TO READ A METER

Let us now turn to the dials of the meter and learn to read them, and be able at any time to determine how much electricity has been consumed in a given period. The meter is made to read in kilowatt hours.

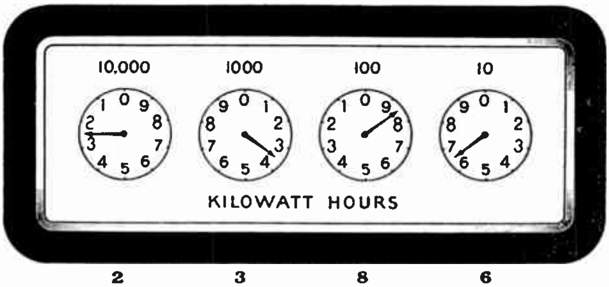


Fig. 17-S

A meter usually has four dials, as illustrated above. The dial at the right registers from one to ten, the **units**; the hand on this dial moves from one number to the next for each KWH and makes a complete revolution for every ten kilowatt hours.

The second dial from the right indicates the **tens**, and its hand moves from one number to the next for each **ten** kilowatt hours used, and makes a complete circle for every one hundred kilowatt hours.

The third dial from the right registers the **hundreds**, and the dial at the left, **thousands.**

The little figures above the dials indicate the complete quantity which each dial registers. For example: We have stated that the second dial from the right measures **ten,** while the figure above the dial is "100." This means that the dial will measure ten for each division and 100 when the hand goes completely around the circle.

When the hand is **approaching** 0, it is approaching 100 in value; when it is **leaving** 0, it is leaving zero in value; the hand on the next dial to the left—the **hundreds** hand—has moved around to the next figure and added a hundred more to the meter record, so that the **tens** hand begins at zero again, and starts recording tens to make up the next hundred.

So with the **units** hand: it measures up to ten, and the instant it touches 0 it measures zero again, and starts to record the next ten. The ten just measured is now recorded by the **tens** hand.

To read the meter, it is only necessary to write down the numbers registered on the dials, writing them in the same order as the dials on the meter, and always taking the smaller of the two numbers between which each hand points. We have applied this to the illustration and placed the number below each dial, showing the meter registers 2,386.

Sometimes the hand on the dial will apparently rest directly over the figure and yet, in some cases, the next small figure should be used. Take the following illustration:

Suppose the hand is on top of the number 4 in the dial under 1,000 mark, do not put down that number unless the hand on the dial to the RIGHT of it has passed 0. If it has not, as is the case here, put down the next lower number which is 3.

You will readily understand why this is correct. For instance, on any dial (except the one at the extreme right end, of course) the hand travels only one-tenth as fast as the hand on the dial to its right. Because of this slower movement, it is almost impossible to tell whether the hand has actually passed, or not quite passed the number it rests over. You will readily see that in the case of the third dial from the right, any error in judging the position of the hand would mean an error of 100 kilowatt hours.

But in every case, even should the hand be slightly misplaced, and actually have passed the center of the number over which it is found, you can definitely determine which number to put down by noting the position of the hand at the right of it.

There is another point about reading a meter which must now be brought out; that is, the registration on the dials of the meter gives a record of the **total** kilowatt hours **since the meter started from zero.**

Take the meter dials in the illustration in Fig. 17-B which show that 2,386 KWH have passed through the meter since the meter started from zero. Let us assume for illustration that the average family's consumption of electricity is 30 kilowatt hours a month (if we assume the lighting rate is 10 cents per kilowatt hour, this would represent a bill of $3.00 per month). In this meter, then, we have the total kilowatt hours consumed by such a station for 79½ months, or more than six years. This meter will register until 10,000 kilowatt hours have been used, when it will continue to register but starting over again from zero.

If we now assume that the meter man has just visited a station where this meter is installed, he will put down in his book the reading, 2,386 kilowatt hours. The next time he comes around to read the meter we will assume that the dials then read 2,417, which will show that 31 kilowatt hours have been used during the month. In other words, IT IS THE DIFFERENCE in monthly readings that is paid for.

IN METER READING IT IS ONLY THE DIFFERENCE THAT COUNTS

If, at one reading, the meter dials register 2,386 and if one month later they are found to register 2,398, then the amount of electricity consumed for the month is 2,398—2,386 or 12 KWH.

To find out how much electricity has been used then, it is necessary to take **two readings**—at the beginning and at the end of the period which it is desired to measure; it may be an hour, a day, a week, or a month.

We have learned that the reading of the meter at any one time has nothing to do with the current consumed. Whether a new meter which may be installed registers 36 or 4,628 is of no significance, as it is always the difference between two readings which represents the consumption of electricity.

It is accordingly on this difference as shown on the meter readings that the power company bases its bills.

HOW TO DETERMINE THE ELECTRICITY USED OR THE WATTS IN A CIRCUIT

If it is desired to determine either the watts of a lamp or of an appliance, or the electricity used in a given time, it is only necessary to connect such lamp or appliance on a circuit to which a meter is connected and operate it over a given period of time.

Suppose you wanted to know the amount of electricity consumed by a standard radio transmitter, you would first make sure that there were not lights or other electric motors connected in the station. You can check this by looking at the meter and observing that the revolving disc on the meter is stationary. You would then switch on your transmitter and make a note of the time and the reading on the meter dials.

Let us assume that the meter reading is 2,386 kilowatt hours. Let us suppose that you continued transmitting for two hours. At the end of this time you would read the meter and might find that it registered 2,387 KWH, which would show that the transmitter had consumed one KWH during the period of two hours' sending. (In this test only the hand on the dial on the right end would have moved perceptibly; i. e., from 6 to 7; the hand on the next dial would have moved only one-tenth as much; and the hand on the third dial one one-hundredth as much, and of course, could not be observed). If you had used the transmitter for only one hour, you would have used only one-half KWH.

To find the wattage of an appliance by means of the meter, it is only necessary to have it register continuously on the meter **for one hour**, in which case the reading changed into watt-hours is the measure of watts.

If the electrical appliance is operated **more** than an hour, take the reading in kilowatt hours and change it into watt-hours and divide by the number of hours the device is in operation.

DETERMINING THE COST OF OPERATION

When we have the meter readings, we find the cost of operation by multiplying the KWH by the rate charged per KWH.

Throughout this course we will assume the rate charged by the Power Company to be 10 cents per KWH, which makes easy figuring (and as a matter of fact, is the rate usually charged for lighting purposes). It must be pointed out, however, that some companies have to charge more, while some can charge less, and some small companies and those which operate for a short season of the year have to charge 15 and 20 cents per KWH, and even more.

Many companies make a special rate for charging batteries of 3, 4 or 5 cents because it is "OFF PEAK" business, somewhat on the same principle that a lower charge is made for a matinee compared with an evening show.

In the previous pages we have learned how to find the watts from the name plate marking on an electrical device, and, when we have the watts, to find the watt-hours by multiplying the watts by the hours the appliance is in use, or rather, the hours the electricity is actually flowing through it. From this we can estimate or determine the COST of operation by multiplying by the rate charged per KWH—in all our lessons, assumed to be 10 cents.

Let us take a few more illustrations:

Mazda lamps are rated in watts. Therefore, if a Mazda lamp is marked 25 watts you will know that in one hour this lamp consumes 25 watt-hours or 1-40 kilowatt-hours (25 divided by 1,000). Therefore such a lamp would need to burn 40 hours to consume one kilowatt-hour of electricity.

Again consider an electric radiator stamped 500 watts. Such a radiator will according consume 500-1,000 or .5 kilowatt-hours in one hour. With electricity at 10 cents per KWH the cost of operating this radiator would be .5 $\times$ 10 or 5 cents per hour.

Many appliances, in place of being stamped in watts, have the voltage at which they are designed to operate and the amperage which they require stamped on them. As has been previously pointed out, to find the watts of such an appliance it is only necessary to multiply the number of volts by the number of amperes. For example, a two (2) horse-power (H.P.) motor stamped 110 volts 16 amperes would have a power of 1,760 watts per hour or approximately 1.8 KWH per hour. With the cost of current at 10 cents per KWH the cost of operating this motor would be 18 cents per hour if the current were on continuously.

> **To find the watts multiply amperes by volts: 3 amperes × 110 volts = 330 watts or amount of current iron will consume if operated continuously for one hour.**

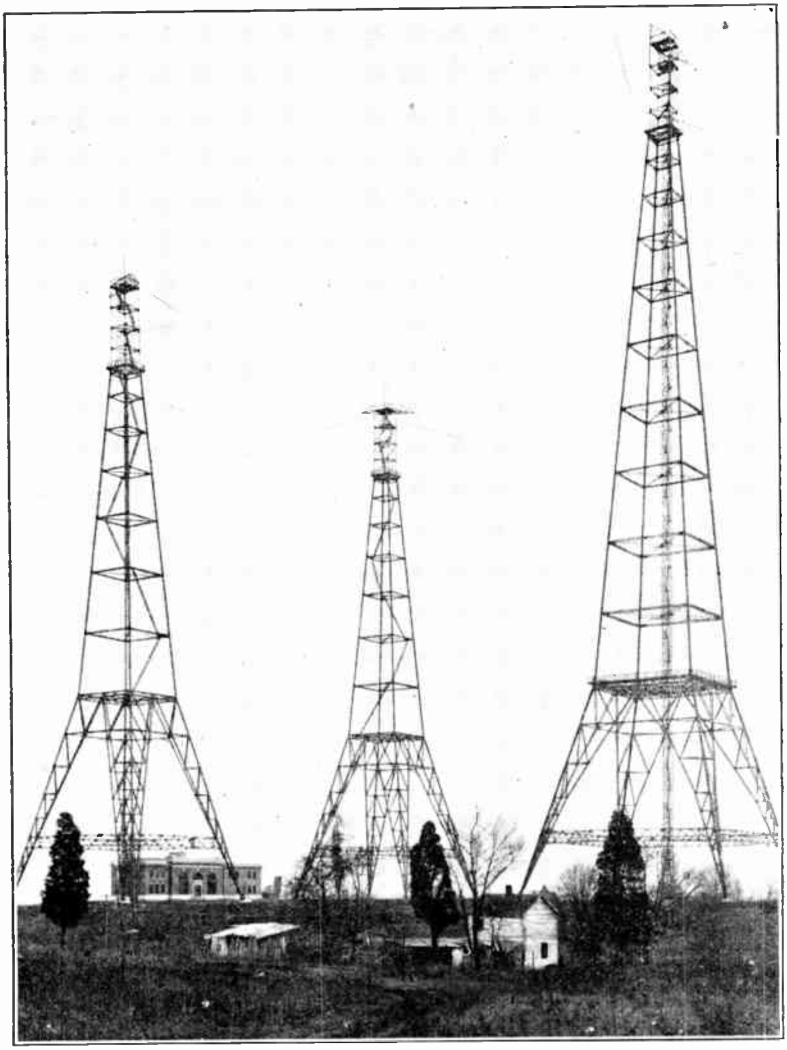
Now that you have finished Lesson Two, lay down the papers for a moment and review in your mind what you have read. Recall the three fundamental measurements of electricity, the ampere, the ohm, the volt. What do each of these represent? Go over the lesson mentally as far as possible. Then take up the lesson again, and be sure you have not missed any of the important principles, particularly those which are most essential—they are the key to the whole lesson. Now you are ready to answer the question sheet.

QUESTIONS LESSON No. 2

21. What two things are necessary before a current will flow in a circuit?
22. What forms the conducting path of an electric current?
23. What complete quantities or units are used in dealing with electricity?
24. What is a complete circuit?
25. Define closed circuit, open circuit, and short circuit.
26. Name some common conductors.
27. How are current carrying wires insulated?
28. Name five insulating materials.
29. What is meant by potential?
30. Name the different terms used to represent electromotive force?
31. What is the unit of electrical quantity?
32. How does it differ from the unit of current strength?
33. What is an ohm?
34. What is a divided circuit?

(Continued on next page)

35. Explain Ohm's Law.
36. What is a kilowatt?
37. What three methods are used in connecting cells?
38. A battery has three cells in series, each cell having an E. M. F. of 1.5 volts. What is the total voltage or E. M. F. of the battery?
39. What is a horsepower expressed electrically?
40. How do you calculate the power consumed in an electrical circuit?



How would you like to be Chief Operator of a big land station like this? Chief operators have from two to ten operators under their direction. The chief operator is a well-paid man. He is really the director of the station. Such a job is open to you, and when you have completed your training with us there is nothing to prevent you from stepping into a big paying job. Keep your good work up.

Your training has increased greatly since the first lesson. Are you aware of that fact? Don't you feel proud to have this new knowledge at your command? Knowledge is the most powerful thing in the world. What a man puts into his mind no one can take out. It is there forever. Knowledge is training, and training increases the value of every man in this world. The world recognizes and honors the trained man. The world also pays the trained man.

Lesson No. 3 is going to tell you how the great generators in the power stations produce their current. Did you ever stop and peek into a power-house and watch the monstrous dynamos whirling around? At that time didn't you feel that you would like to know how these things worked? Probably you thought that only engineers of high training could know this. In this you were sadly mistaken. The third lesson of our course will tell you exactly how they work so the next time you see one you can probably say to yourself, "Well, that thing is no mystery to me, thanks to the old N. R. I." What man would not be filled with pride when he realized that this knowledge was his? Obtained by studying for a short time each day on these lessons.

Definitions of Radio Terms

Continued From Book 1

The **Period** of an alternating current is the time required for one cycle or one complete change to take place.

Phase: An A. C. is in phase when maximum E. M. F. and current are reached at same moment.

Phosphor Bronze: An alloy of phosphorous with copper and tin. Has great strength and can be hammered or rolled while cold. Largely used for aerial wire.

Pliotron: An amplifier or three electrode values whose bulb is as near an absolute vacuum as possible, and is used for high power transmission.

Polarization: The partial changing of the polarity of a cell, due to hydrogen bubbles forming on the negative plate.

A Potentiometer is a resistance joined across a direct current source of power, and having two lead wires, one a variable connection for supplying a desired potential or pressure to another circuit, a receiving detector circuit in radio and telephony.

A Protective Resistance Rod is a high resistance made of carbon, graphite or other material in the shape of a small rod. The ends of the rod are connected across the power circuit and the center of the rod is connected to earth. This device allows the high pressure electrical surges to find their way to earth and prevent grounding of the power apparatus and instruments.

Pulsating Current: A current rising and falling regularly remains on one side of the zero line; that is, one which, though varying in intensity, always retains its characteristic, being continuously positive or negative throughout its motion.

Quenched Gap: A spark gap consisting of a number of metal discs separated by insulating washers.

Reactance is the term applied to express the opposition which a circuit offers to the flow of current through the capacitance and inductance in it.

A Reactance Coil is a coil of wire, wound on an iron core, arranged so that either the number of turns can be varied or so the position of the iron core can be adjusted, thus varying the reactance in the circuit. It is employed to regulate the power input in a radio transmitter.

A Receiving Detector is a device to change the character of incoming electrical oscillations, so as to make them audible in the head telephones of a receiving set.

A Receiving Tuner is an oscillation transformer for transferring the energy absorbed by the receiving aerial from a passing electromagnetic wave to a local detector circuit, where it is made audible. It also allows the receiving operator to differentiate between and adjust to electromagnetic waves of different lengths, thereby avoiding interference.

Reflex: A trade name for a set in which the incoming current is first amplified at radio frequency, then passed through the detector and there rectified, and then passed through the tubes again to be amplified at audio frequency. The tubes serve as both radio and audio frequency amplifiers at the same time.

Rectifier: A device for converting alternating current into pulsating direct current.

Regenerative Circuit: A regenerative circuit is an electron tube circuit in which additional amplification is produced by feeding back some of the energy in the plate circuit into the grid circuit.

Relay: A device consisting of an electromagnet and two contacts, one of which is mounted on a movable arm and makes contact with the other when a current is flowing through the magnet coil.

Resistance is that property of a conductor which tends to oppose the flow of electric current, the spent energy being consumed in the form of heat.

A Resonant Circuit is one having a definite time period of oscillation for any particular adjustment of inductance and capacity, and which can be adjusted so that capacity reactance and inductance reactance neutralize for any particular impressed frequency.

Rotor: The moving part of an induction motor.

Self Induction is the term applied to the phenomena resulting from the rise and fall of a magnetic field around a coil of wire through which a current is flowing. Self induction is defined as the property of an electrical circuit which tends to prevent a change of the electric current established in it.

Series Connection: A number of instruments or cells connected up in a circuit having no shunts; that is, current must pass through each conductor successively.

A Short Wave or **Series Condenser** is used to adjust the antenna system to period of oscillation corresponding to a wave length, less than the natural wave length of the aerial.

Shunt-Parallel: An alternate path for the current to pass in a circuit.

Silicon Detector: A crystal detector in which a cat-whisker makes contact with a piece of silicon.

Skin Effect: The increased resistance of a conductor to high frequency currents to that offered to low frequency ones is due to the fact that H. F. C. travel on the surface of conductor, while the L. F. C. use the whole of the metal or "soak in."

Socket: A socket is a receptacle, or support, into which some piece of apparatus may be inserted for convenient connection to a circuit or circuits.

Solenoid: A coil of wire having the property of an electromagnet. An electromagnet without a core.

Solder: Solder is an alloy or mixture of lead and tin. It has a low melting point.

Soldering Flux: Soldering flux is a chemical preparation to assist in cleaning the surfaces to be soldered, and to help the solder to stick properly.

Spark Gap: A mechanical device to allow the discharge of the transmitting condenser at regular intervals and to stop the flow of current between discharge intervals, thus permitting the condenser to receive a full charge.

Spark Frequency may be defined as the number of sets of sparks discharges taking place across a spark gap per second of time.

Specific Gravity: The density of a solution as compared to water. It shows how many times heavier the substance is than an equal volume of water.

Static Charge: An electric charge at rest on the surface of a body.

A Starting Box is a variable resistance to regulate the flow of current into an electric motor during the starting period.

Stator: The stationary part of an electric motor or generator.

A Stopping Condenser is a small low-voltage condenser used in the detector circuit to store up the small impulses of current in a wave train and then give this energy out in one discharge to the telephone receivers for operating the diaphragm.

Syntonic Circuits are circuits having same time periods or natural frequency of oscillation and are said to be in tune with one another.

A Telegraph Key is made of a small lever supported on a base by two cone-shaped bearings. On one end of the lever is mounted a round, smooth button, which can be operated up and down by the hand, causing a make and break of contact points fastened to the lever and base. This action interrups the flow of current for making dots and dashes in the telegraph code.

Telephone Jack and Plug: A telephone jack is a special type of connection device into which a telephone plug may be inserted to make an electrical connection.

A Thermo Ammeter employs the principle that a heated junction of two similar metals sets up an E. M. F. which in this case is measured by a D. C. voltmeter.

Thermo-Couple: A junction of two dissimilar metals.

A Tickler Coil is placed in the plate circuit of a vacuum tube receiver to transfer part of the energy of the oscillating plate current back into the grid circuit in order to produce amplification and to enable the tube to generate oscillations of high frequency.

Tikker: A device for interrupting the current induced in the receiving set and is usually placed in the secondary circuit at the rate of 600 to 1,000 times per second. Used with crystal detector for reception of undamped waves.

Tone Frequency is the same as **Spark Frequency.**

A Transformer consists of two coils of wire insulated from one another and wound upon an iron core. Current flow pressure (110 or 220 volts) is supplied to one coil and high pressures or voltages (5,000 or 30,000 volts) are induced in the other coil for charging the transmitting condensers.

Tuning: The process of securing the maximum indication by adjusting the time period of a driven element.

Ultraudion: By DeForest Radio Telephone and Telegraph Company. The Ultraudion is an audion used in a circuit having a type of energy coupling so that a powerful relay action, or the production of sustained oscillations, may be obtained. In one of its present commercial forms its elements are connected in two circuits, so arranged that the energy coupling may be obtained through a bridging condenser in its plate-filament circuit.

Vacuum Tube: Name usually given to a glass tube exhausted of air with filament, plate and grid inside used for detectors in radio work.

Valve Amplifier: A three-electrode vacuum tube of the Audion type is used to amplify either the incoming high frequency currents after rectification, or both rectification and magnification may be performed by the one tube.

Vernier Attachment: A device to be attached to a coupler or condenser to obtain very fine tuning. Generally engages the dial.

Volt: The unit of electric pressure. It is that pressure which forces one ampere through a resistance of one ohm.

Variocoupler: A variocoupler is composed of two coils, one rotating inside the other, the outer one is tapped off so the inductance can be varied, the inside one varies the coupling between the different circuits.

Variocoupler: A variocoupler is composed of two coils, one rotating inductance effects of each winding may be made to assist or practically neutralize each other.

Watt: The unit of power. A pressure of one volt causing a flow of one ampere is one watt of electric work. or power Volt times amperes equals watts.

Wave Changer: A switch by means of which the wave of a transmitter may be rapidly changed from one wave length to another.

Wave Length: The distance one wave travels before the next starts from the point of origin.

Wave Train Frequency is the term applied to designate the total number of wave trains being produced or acting per second in wireless transmission or reception.

Wave Meter: An instrument for measuring the wave lengths of radio transmitters and receivers.

Wiring Diagram: A wiring diagram is a sketch or figure showing where wire connections are to be made in a circuit.

LESSON TEXT NO. 3

OF A

Complete Course in Radio Telegraphy and Telephony

Magnetic Induction
Part I

TENTH EDITION

Established 1914
WASHINGTON, D. C.

Additional Information on
Question 42, Lesson No. 3.

A solenoid has the same properties as a bar magnet. When referring to the polarity of a solenoid, we mean which end is the north pole or which is the south pole. The lines of force always flow out of the north pole end of a solenoid and in at the south pole end. Therefore, we can find the polarity of a solenoid by applying any of the rules pertaining to the direction of the lines of force, such as, the "corkscrew" or "right hand" rule, or by testing with a compass.

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FOREWORD

This Lesson Text should be read thoroughly and then studied intensely, a few pages at a time. Do not expect to grasp the subject merely by reading it over. If you do not understand a certain explanation, read it again, and if necessary review preceding instruction books or consult the dictionary of radio terms in lesson text Nos. 1 and 2.

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

It is a common saying, that the value of a thing is in direct proportion to the difficulty encountered in attaining it. Therefore, if you find trouble in mastering any part of this course of lessons, you may rest assured that you are improving yourself.

Note:—The word, through, when used in this book in regard to the current flowing in a wire or conductor should not be interpreted as such in its strict sense, because in dealing with the high frequency Radio currents the current actually flows along the outer surface of the conductor.

ELECTROMAGNETIC INDUCTION

PART I.

We must come back to the subject of induction. Our previous mention of the subject only scratched the surface. This time we are going to dig a little deeper. We are going to come to understand what a really tremendously important subject it is. In fact, electricity is largely a study of electromagnetic induction and its attending phenomena.

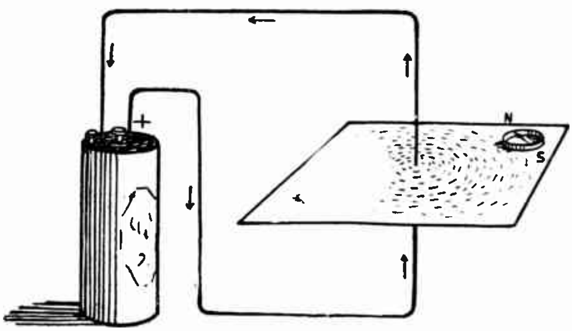


Fig. 18—Lines of Force about a Current-carrying Wire

The phrase "electromagnetic induction" would be very apt to scare the ordinary layman but do not let it scare you. There is nothing mysterious about it. Electro means electric; magnetic relates to magnetism and this combination of the terms means electric current produced by magnetic lines. That leads us up to an important point. There is a magnetic field about every wire that carries an electric current. Again we are brought face to face with this mysterious connection which appears to exist between electric current and magnetism. We must be satisfied by just saying that when an electric current flows through a wire that wire will be surrounded by a magnetic field that will be exactly like the magnetic field produced by a permanent magnet.

How can we prove this, you ask? That is simple enough. Let us refer to Fig. 18. Here we will see an electric current-carrying wire passing through a small piece of cardboard. Iron filings are sprinkled upon this cardboard and we notice that they have arranged themselves in concentric circles. This awe-inspiring force of magnetism grips each little particle and holds it helpless. This experiment proves beyond all possible question that there is a magnetic field existing about a wire carrying electric current. The pocket compass resting on the cardboard strengthen this proof because the needle is affected. If we look closely at the drawing we will notice that the lines of force start with the wire as a center and they spread out from this center, becoming weaker and weaker as they do so. If we had an extremely sensitive recording instrument we would be able to detect these lines of force across a room.

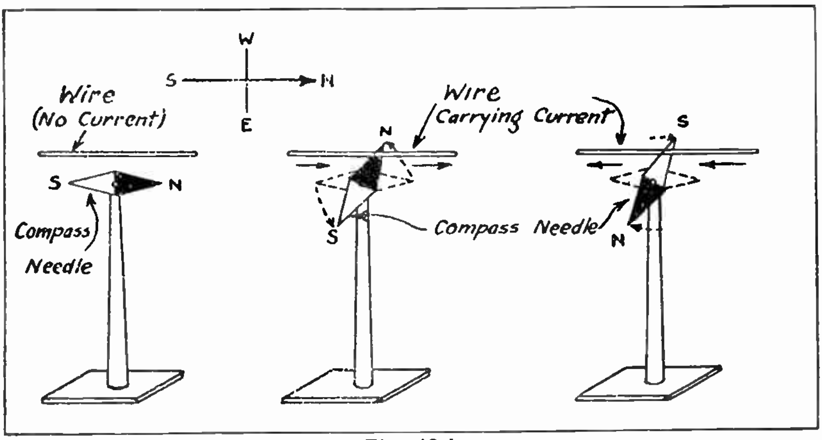


Fig. 18-A

Put a compass underneath a wire carrying an electric current. The needle is deflected. Note in which direction the north pole moves. Move the compass to a position above the wire. Note in which direction the needle is deflected. Figure 19 will show you the method and results of doing this.

You have seen that there is a definite relation between the direction of the current and the direction of the lines of force, which result from that current. Here is a simple rule which will enable you to tell the direction of the lines of force, or will enable you to tell the direction of the current if you know the direction of the lines of force. If you grasp a wire carrying a current with your right hand so that the thumb points in the direction of the current, the fingers will point in the direction of the magnetic field (lines of force). This rule is very useful and should be memorized. Try it out.

Problem—You wish to attach an instrument to the electric light wires which are in your house. They carry a direct current, and it is necessary to know in which direction the current is flowing, so that the instrument may be attached correctly. How would you find out the direction of the current? Suggestion: Use a compass and the rule stated above.

Does the strength of the lines of force existing about a wire depend upon the strength of the current flowing through the wire? It most certainly does. A powerful current will produce powerful lines of force and a weak current will produce correspondingly weak lines of force.

When the current flowing through a wire stops at the time the circuit is opened the magnetic field collapses instantaneously. If we had placed a variable electric resistance in the circuit we would find that the magnetic lines of force would vary depending upon the amount of resistance in the circuit. We know that the resistance placed in a circuit can control either the voltage or the amperage.

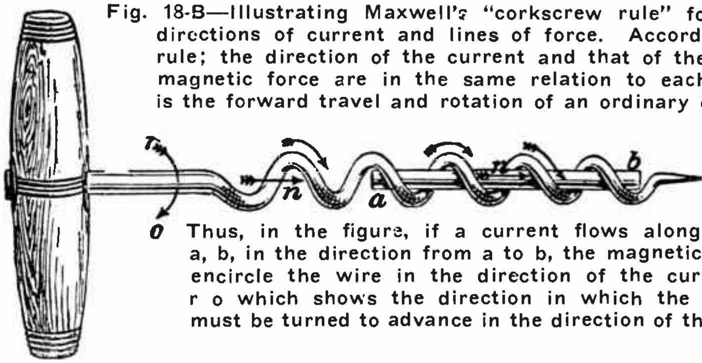


Fig. 18-B—Illustrating Maxwell's "corkscrew rule" for relative directions of current and lines of force. According to the rule; the direction of the current and that of the resulting magnetic force are in the same relation to each other as is the forward travel and rotation of an ordinary corkscrew.

Thus, in the figure, if a current flows along the wire a, b, in the direction from a to b, the magnetic lines will encircle the wire in the direction of the curved arrow r o which shows the direction in which the corkscrew must be turned to advance in the direction of the arrow n.

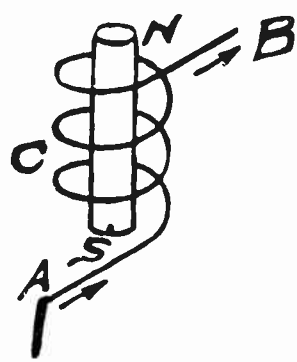
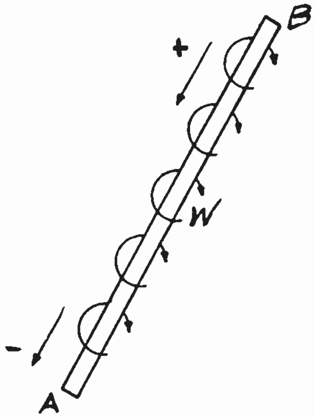


Fig. 18-C

There is another important thing about the lines of force. The direction taken by the lines of force will depend upon the direction the current is flowing through the wire. If we reverse the current we reverse the direction of the lines of force automatically.



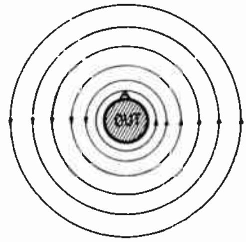


Fig. 18-D—Showing lines of force around a conductor with current flowing towards reader

Cork Screw Rule

This rule may be applied either to find the direction of flow of the magnetic lines when the direction of current flow is known, or it may be used to find the direction of the current when the direction of the magnetic lines are known. See Fig. 18-C.

Assume we have a coil of wire C forming a solenoid and that the current enter at A, flows around the coil in a right-hand (clock wise) direction. Now in applying the cork screw rule we assume that we place the sharp point of the cork screw (shown in Fig. 18-B), at the center of the coil on an end (point S in Fig. 18-C), and turn the cork screw in the direction of the flow of current (right-hand or clock-wise), and direction which the screw moved (in or out of the coil C) represents the direction of the magnetic lines.

In the example given the screw would move into the coil at the end marked S. This shows that the magnetic lines flow in at S and through the center of the coil and out at the far end N. In other words, N is the north Pole of the solenoid. If a core or iron or soft steel were put inside the coil it would become an electro-magnet and N would be the North Pole and S the South Pole. Now if the current were reversed, that is to say, it enters at B and out at A, the direction of flow around the coil would be in a left-hand or counter-clockwise direction (looking at the end S) and if we turn the cork screw counter-clockwise at S it will move toward us or out of the end S, therefore the lines are coming out of the end S and would be the North Pole of the solenoid.

Reversing the current reverses the polarity as shown in Fig. 18-D. Put the sharp end of a cork screw at the center of the A end of the wire and turn it to the left (counter-clockwise direction), and it will move out or toward you showing the current comes toward you or out at A. Therefore, the current flows from B to A.

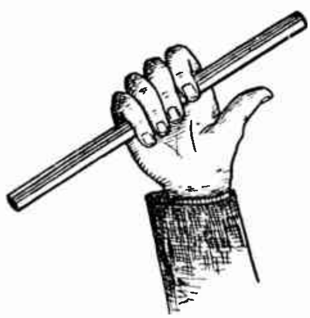


Fig. 19—Right Hand Rule for Direction of Current Flow

Let us now apply this rule to a real practical problem. Assume we want to determine which direction the current must flow in the two magnet coils in Fig. 25. The lines (as indicated by the N pole to the left) come out (move down) the bottom of the left coil. Now if the point of a cork screw is placed at the lower end of this coil we must turn it to the left (or counter-clockwise) to make it move down or out; therefore, the current must flow around the coil of wire in a counter-clockwise direction (looking at the bottom end). Now when we consider the right-hand coil (just above the S pole) the lines are entering the bottom end or moving up in it. In order to make a cork screw move up (when sharp point is placed against the lower end), we must turn it clockwise, therefore, the current flow around the right-hand coil in a clockwise direction looking at the bottom end.

Cork Screw Rule

How to determine the flow of current when the direction of the magnetic lines are known:

Assume we had a wire, Fig. 18-C, with D. C. flowing through it and we place a compass needle above it and the North Pole points to the left as we look at the end A of the wire. Now if we place the needle below the wire it will point to the right. This shows that the lines are moving around the wire in a counter-clockwise (left-hand), direction. Apply the cork screw to end A and turn it to the left, it moves out of A, showing the current is from B to A. We recommend the cork screw rule in all cases, but include a second method used by many school and college text books.

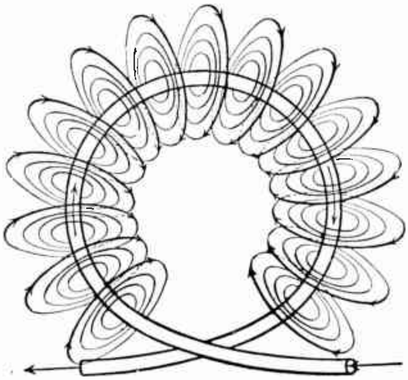


Fig. 19-A—Field about a Single Loop Carrying a Current

Let us refer to Fig. 19. There is illustrated here another method of finding the direction of the lines of force about a wire if we know the direction of the current. The wire is grasped in the hand so that the thumb is pointing in the direction in which the current is flowing. The fingers about the wire will then point in the direction taken by the lines of force. There is one little moral about this rule. Do not put your fingers about a bare wire until you know how much current and voltage it is carrying and be sure that you are standing on a dry surface. If you were to come in contact with a real live wire you would certainly dance a merry jig and the direction of the lines of force would not interest you for some time. Remember that electricity is no respecter of persons. It strikes quickly and without warning.

But how are we to know in what direction the current is traveling? That is no problem at all. If we know the positive and negative pole of the source we know that the current is traveling from positive to negative, do we not? What if it is alternating current? In that case this rule does not apply. It applies in a way, but you would have a hard time keeping pace with the current because of its numerous reversals during a second of time.

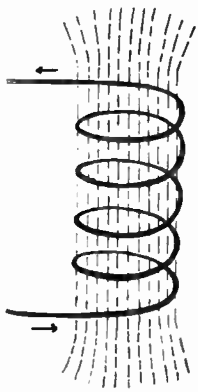


Fig. 20—Lines of Force about a Solenoid

Refer to Fig. 19-A. There you will see how the magnetic lines of force cluster about a loop of wire carrying-current. Above all, do not let this picture of magnetic lines of force sink in too deeply in your imagination. This is really a crude picture that will give you the idea in a very general way. These lines of force exist about every section of the wire. They are not arranged in pie-like form, as we have shown them. We could not hope to give you a drawing that would show these lines of force as they actually exist.

The loop of wire shown in Fig. 19-A might be called a solenoid with a single turn of wire. What is a solenoid? A solenoid is a coil of wire arranged in the form of a hollow cylinder. Let's take a long wire and wind it around a broomstick, placing the turns close together. We will then take the wire off the stick and connect it up to an electric battery. What have we done to the lines of force that will exist around this wire when a current is passed through it? If the wire formed a part of a circuit and was in a long straight line the magnetic field would extend from one end of the wire to the other, would it not? But now we have the wire wound in a coil. Will this concentrate the magnetic field, so to speak? It surely will. All the little magnetic lines of force will be bundled together and a fairly powerful field will be produced.

We have seen now that a wire carrying a current is surrounded by a magnetic field. If we make the wire in a continuous coil (not have the wire doubled back on itself) the total magnetic effect is the effect of each turn of the coil added to the effect of the other turns. If we measure the strength of the magnetic field as we change the current we will find that the stronger the current the stronger the magnetic field. So if we wanted to make a very strong magnet (this is called an electromagnet because it is made by a current through a wire) we would have many turns of wire and have a large current.

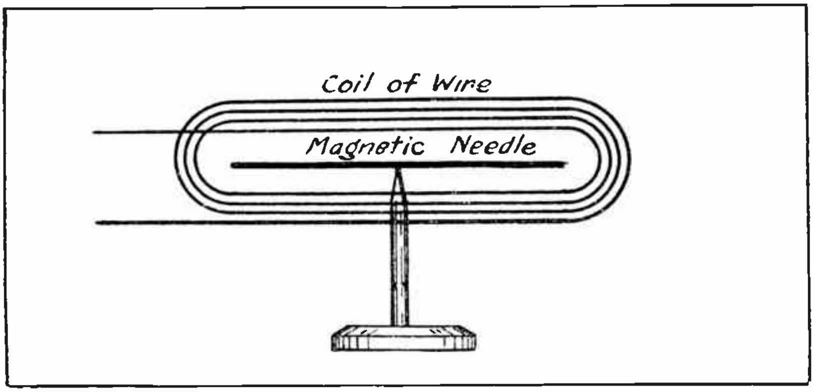


Fig. 21-A

The fact that a current of electricity produces a magnetic field around it is used in making most of the instruments used in measuring electricity. Figure 21-A shows a **galvanometer** (galvanic electricity is an old term used to mean current electricity, hence a measurer of current).

A current passing through the wire will deflect the compass needle. The stronger the current, the further the deflection of the needle. Make one of these galvanometers and test it. A piece of cardboard makes a good frame around which to wrap the wire. The voltmeter and ammeter that you have been using (except hot-wire ammeter) are modified forms of such a galvanometer.

To illustrate how an electric current is made to work through its magnetic field, let us study the door bell. Figure 21-B shows a simple diagram of it. It does not show the framework.

Let us study this. The current starts from the battery, goes through the wire **b**, through a screw **c**, through a spring **ds**, through the electromagnet **mm**, and back to the battery through the wire **g**. Thus we have a complete circuit. The current flows and **mm** becomes a magnet and pulls the flat piece of iron **e** toward it. The flat piece of iron moving toward the magnet pulls the spring **ds** away from the point on **c**, and the striker hits the bell. This breaks the circuit at this point (between **c** and **ds**), and the current stops flowing. With no current flowing **mm** is no longer a magnet, and so no longer attracts the flat piece of iron **e**. The spring **ds** pulls itself and the flat piece of iron away from **mm**, and **ds** makes contact with **e**. The circuit is made, the current flows, and events repeat themselves. This keeps up as long as the battery is connected.

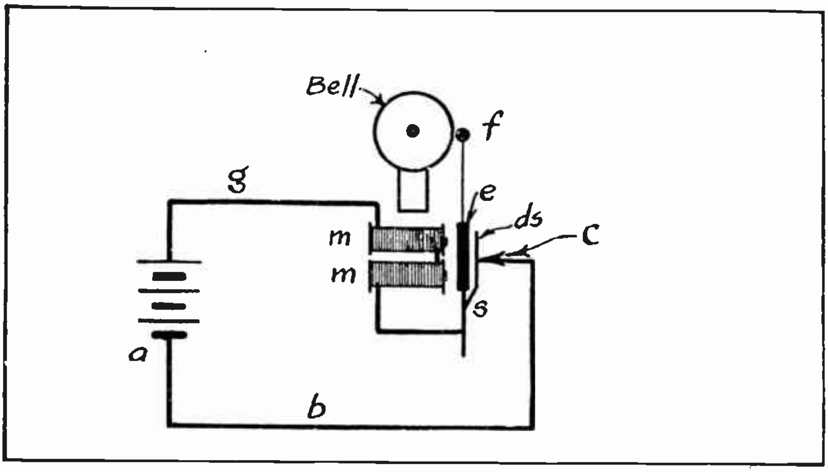


Fig. 21-B

You should study the above thoroughly. You should be able to make the diagram and explain it without any help at all. This arrangement is used in many instruments.

We have seen that a current of electricity produces a magnetic field. Will a magnetic field produce a current? It will. Moving electrons (electric current) make a magnetic field. A moving magnetic field will produce a current. It is by this method that current is produced in large amounts. Magnetos, induction coils, and dynamos produce currents by making use of the fact that a moving magnetic field will produce a current.

What would happen if we were to place a piece of iron in the center of the solenoid? The magnetic lines of force would be increased and the iron itself would become strongly magnetized while the current was flowing through the wire. In fact, we would find that the solenoid would actually attract the iron and if a heavy current was flowing through the wire the iron would be removed with great difficulty. We would find that the magnetic lines of force would produce sort of a sucking action on the iron core. In your work as a Radio operator you will come across many solenoids as they are used for many different purposes.

When we place the iron core in our solenoid we change its name. We must remember that a solenoid must have a hollow center. When we placed the iron in it, it no longer had a hollow center. At that moment it became what is known as an electromagnet. An electromagnet is a coil of wire wound around an iron core.

Let us glance at Fig. 20 to obtain a final impression of a solenoid. It might be just a bit surprising to find that a solenoid has a north and south pole just like a permanent magnet.

We learned heretofore that the strength of a magnetic field produced by a current will depend upon the strength of the current. We have an addition to make to this. The strength of a magnetic field produced by a solenoid will depend upon the number of ampere turns in the solenoid or electromagnet. For example, an electromagnet with twenty turns of wire and carrying 5 amperes would have the same strength as 100 turns carrying one ampere if they were placed on the core. In both cases the magnet would have 100 ampere turns. We find then that the ampere turns are simply the number of turns of wire multiplied by the amperes flowing through the coil.

Now that we have assimilated everything of importance on the subject of solenoids and electromagnets, let us turn our attention to electromagnetic induction. In a previous lesson we came to understand that a current would be generated in a coil of wire if that coil of wire was moved in a magnetic field.

In 1831 Michael Faraday discovered **the principle of electromagnetic induction.** In one of his experiments, he wrapped a coil of wire about a block of wood and connected the terminals to a galvanometer. Another coil was wrapped about the first and connected to a battery. He found, that upon closing the circuit of the coil in series with the battery, that the needle of the galvanometer was momentarily deflected, and upon opening the circuit that the needle was again deflected, but in the opposite direction.

This experiment opened up a new field of investigation in electrical science, and the principle deduced from it is of very great importance, due to it being the basic principle of the production of electricity by mechanical motion.

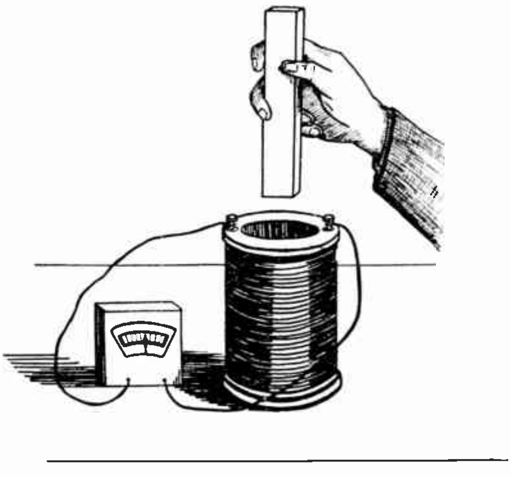


Fig. 21—Electromagnetic Induction

There is a interesting experiment in this connection which is pictured in Fig. 21. A small sensitive voltmeter is connected to a solenoid which is formed by winding a piece of wire around a cardboard cylinder. If we were to take a permanent magnet in our hand and move it up and down in the solenoid we would find that the voltmeter would register, proving that an E. M. F. had been produced in the coil. What if we were to hold the magnet still? Would a current be produced? Not at all. We cannot fool nature. There is an inflexible law that states that work must be done to create energy. This is the law of the conservation of energy. We could hold the magnet still in the center of the solenoid until Dooms Day but not a bit of current would be generated. If we move the magnet up and down, however, the little voltmeter will register faithfully and we will see that the needle jogs back and forth following the direction of the magnet. When we move the magnet in one direction and then move it back in the opposite direction the current will be reversed.

Here we have in a nutshell the principle of the generation of the electrical power that is used today. Will the current in the solenoid depend upon the power in the magnet? Yes it will. It will depend upon the power of the magnet and the speed with which we move the magnet. If we move the magnet rapidly we cause more work to be performed and the current generated will be greater. We might put it in this way. The strength of the current flowing in the solenoid will depend upon the number of lines of force cut by the solenoid per minute. We use the word "cut" here in rather a peculiar way. Of course we would not cut the lines of force with a knife or even with a good safety razor blade in the generally accepted sense of the term.

There is an interesting experiment illustrated in Fig. 22. Here we have two independent electric circuits. Trace the two circuits through to prove this point. You will notice that one circuit contains a small key or switch, a solenoid and a battery. The other circuit contains another solenoid larger than the first and a small voltmeter. The small solenoid fits within the large one. If we close the circuit with the switch and place the small solenoid within the large one we will notice that the voltmeter will move, proving that there is E. M. F. produced in the second circuit. This is easy to understand. It is simply another case of electromagnetic induction. The small solenoid will generate a concentrated magnetic field when a current is flowing through it and these magnetic lines of force will cut the second solenoid and a current will be produced in the second circuit. If the small coil is allowed to run slow in the center of the larger one the current will be generated only at the moment the key is pressed and the magnetic lines of force spread outward. If the circuit is kept closed a current will be produced in the larger coil if we keep the larger coil moving. Therefore the three ways a current can be induced in a coil of wire are:

(1) By making a magnet enter a coil of wire and connecting the two ends of the coil together. A current of electricity will flow through the coil.

(2) By replacing the magnet by a coil of wire through which a current is kept flowing and making this coil enter another coil of wire. The effects then produced are known as those of **mutual induction.** See Fig. 22.

(3) By leaving one coil inside of the other and making and breaking the battery circuit by means of a switch in the last two cases the battery circuit is called the Primary Coil, and

the coil in which the current is induced is called the Secondary Coil. See Fig. 23, Induction Coil.

The point to remember here is this: The magnetic lines of force have to be constantly cut to produce a current in the secondary circuit. When the first circuit is closed the magnetic lines of force spread outward and in this spreading movement they are cut, but once they are established they remain stationary and then we must move one of the coils within the other to make a current flow in the second circuit.

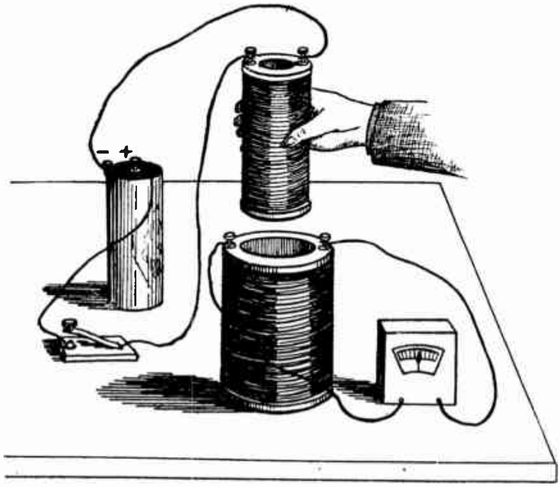


Fig. 22—Electromagnetic Induction

In the little experiment shown in Fig. 22 we used direct current. What if we had taken the battery out of the circuit and replaced it with an alternating current generator? Now put on your thinking cap. What would happen? Think hard. We know that an alternating current falls to zero a number of times each second and if the current falls to zero then the magnetic field must collapse with it and rise with it when the current builds itself up again. We picture, then, an alternating magnetic field as having sort of a breathing effect. It rises and falls like the waves of the sea. It is constantly in motion where the magnetic lines of force produced by a direct current are at rest after they are once produced. If there is an alternating magnetic field about the little solenoid the larger solenoid will constantly cut through these magnetic lines of force, or, we might say, the magnetic lines of force will cut through the big solenoid and a current will be generated in it.

This is the principle of electric transformation. We have all heard of electrical transformers. They are contained in the big black boxes mounted on the top of electric light poles.

Could there be such a thing as a direct current transformer? Surely you would not make the sad mistake of saying that there could be. If we wished to use this principle of transformation with a direct current it would be necessary to interrupt the direct current many times a second so that its lines of force would be constantly expanding and contracting; building up and collapsing.

Let us refer again to Fig. 22. The first circuit containing the small coil would be called the primary circuit. The second circuit would be called the secondary circuit. The primary circuit then always contains the original current and the secondary circuit contains the induced or transformed current. Nothing confusing about that, is there?

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

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

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

There is nothing difficult about the foregoing if we think in a straight line. Concentrate a little and you will get it straight. By concentrating we mean, do not let your thoughts jump all over the lot, so to speak. You cannot think of your best girl, the show you saw last night and electromagnetic induction all at the same time.

Self-induction is sometimes referred to as counter E M. F., the counter E. M F. being a current that flows in a direction opposite to the original current. The value of this extra or self-induction depends upon the number of turns of wire in the solenoid and the nature and strength of the inducing current.

The subject of mutual induction will now be considered. By this time we must have come to understand that this subject of induction has many ramifications, and that the thing taken as a whole is simple enough. The laws are by no means difficult to learn. When two electric circuits are close to one another the current flowing in one will be induced into the other. This is called mutual induction.

The Induction Coil

The principle of self-induction is made use of in a device called **a primary induction coil.** See Fig. 22-A. It consists of an iron core, upon which is wound one or more layers of fairly large insulated wire. Due to the great permeability of the iron

Gas-Engine Ignition. Make-and-Break System

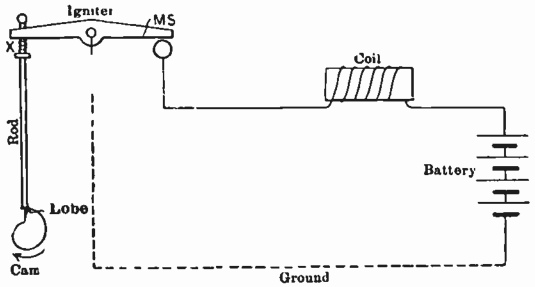


Fig. 22 A—Primary Induction Coil Make and Break System of Gas-engine Ignition Using Batteries and a Single Coil and Iron Core

core, the magnetic field about the coil for a given current is much greater than that produced by the same coil having an air core. The purpose of a primary induction coil is to produce a fat, hot spark when the circuit is broken and is used in some types of gasoline engines to ignite the mixture of gas and air in the cylinder. In these engines the point of make and break is located in the cylinder.

The principle of mutual induction is used in another device called the **secondary induction coil.** See Fig. 23. This type of coil consists of an iron core of soft iron wire, a primary with layers of heavy, insulated wire, and a secondary of many hundreds of turns of small insulated wire. The primary is wound about the iron core, over this a hard rubber tube or other insulating material is placed, and the secondary wound about the tube. The number of turns and the size of the wire used in the secondary are both dependent upon the desired voltage at the secondary terminals.

We have seen that when an electric circuit containing a coil with iron core is broken, a spark jumps across the gap. Use of this is made in exploding the gas in the cylinder of a gas engine (see Fig. 22-A). As the engine shaft revolves, it turns the cam in the direction marked. This gradually pushes up the rod so that the points M and S of the ignitor touch each other and a current flows in the circuit thus made. When the "lobe" of the cam passes by the rod, the spring S suddenly pulls the rod down and separates the points M and S, and a spark jumps across the gap. These two points are situated inside of the cylinder of the gas engine. The break is so timed that the spark comes when the cylinder is full of compressed gas, which is thus exploded, and furnishes the force to drive the piston. This is called the make-and-break system of ignition.

The diagram shown in Fig. 23 represents what is commonly known as an induction coil. If you have ever received a shock from the ignition system of an automobile you have probably had experience with an induction coil unless that particular car was equipped with a magneto.

The induction coil is a device with which an extremely high voltage can be generated. By way of analogy we may look upon the induction coil as a high pressure pump—a pump capable of creating a tremendous pressure with very little volume of water. If you have ever received a shock from an induction coil you probably thought that you were kicked by a mule, and at the same time it probably occurred to you that about all the current that had ever been generated in the world was passing through your body. However, we can easily understand why high voltage gives a person a terrific shock. The body interposes a certain amount of resistance in the circuit and when it comes in contact with a high voltage the resistance offered by the body is immediately broken down and a very uncomfortable shock results. High voltage shocks, however, unless accompanied by considerable current strength, are not necessarily dangerous when generated by small induction coils. However, current produced Radio transformers are things to be avoided.

Let us refer again to the diagram in Fig. 23. Do not let this diagram intimidate you. Take your pencil and trace the connections through. We see that there are two coils of wire about an iron core. If we examine the drawing closely we will see that one coil is wound over the other and that this coil forms part of an incomplete circuit which is broken by a spark gap. What is a spark gap? A spark gap is simply an air gap. All right. That accounts for part of the diagram. Now let us trace the heavy wire which is wound under the other coil and directly next to the iron core. We see that one end of this winding is connected to a key or switch. Then it passes through the battery and then it goes to a contact point. Let us for a moment forget the condenser as this is really an auxiliary device. From the contact point the current passes to the vibrator. Now this vibrator is a spring-like device capable of

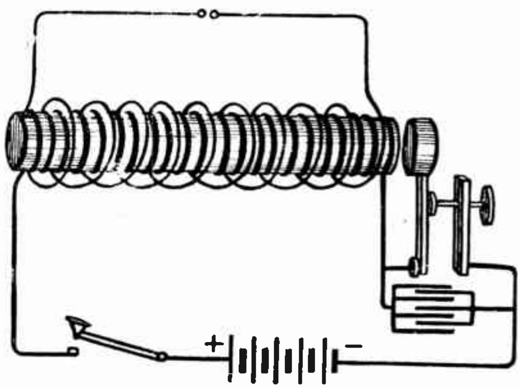


Fig. 23—Secondary Type of Induction Coil

oscillating to and fro. The current passes through the vibrator and back into the winding, thereby completing the circuit. So far, so good. Now what is going to happen when we close this circuit by pressing the key down? The iron core will become magnetized, will it not? And when the iron core becomes magnetized it is going to pull the iron vibrator to it. Then what happens? When the iron vibrator is pulled forward it pulls away from the contact point and this opens the circuit. That will readily be seen. Now, when the circuit is opened the magnetic field collapses, the iron core loses its magnetism and back goes the vibrator to the contact point. It no sooner strikes the contact point than the circuit is completed again, the magnetic field is built up and the vibrator is again pulled forward to break the circuit again. The poor vibrator has a very busy time of it. First it is pulled forward and then jumps back. In modern terms, it oscillates with a vengeance. It vibrates to and fro many times a second. Of course, the rapidity of the vibrations will depend upon the tension of the spring and the proximity of the contact point, which, by the way, is adjustable.

We find here that the circuit containing the key, the battery and the interrupter is interrupted a great number of times per second and we have as a result a pulsating current or an intermittent current. We also see that this magnetic field is going to build itself up and collapse every time the circuit is made or broken. The magnetic field, in fact, follows the interruptions of the vibrator.

With these few simple facts in mind, we can readily see that there is going to be a current generated in the first coil that we considered which is wound over the one which we have just treated. But, if you are a close observer, you will say: "Here, aren't we getting ahead of our story? How can there be a current in the second coil when the circuit is open, said opening being formed by the spark gap?" That leads up to another interesting story.

A current with an extremely high voltage is produced in the second coil. So high, in fact, that it breaks down the resistance of this air gap and flows across it in a brilliant little spark. Remember, when we started out we said that we were going to consider a high pressure pump. The average spark coils produces a secondary voltage ranging from 5,000 to 35,000 volts. A terrific potential, we must admit.

The coil which is wound about the iron core and which forms a part of the circuit with the battery, the vibrator and the key, makes up what is known as the primary circuit. We have considered primary and secondary circuits before. The primary coil in this case is made up of a few turns of comparatively heavy copper wire. Heavy copper wire is used so that there will be little resistance offered to the current produced by the battery and a maximum magnetic field will be created.

The secondary coil is wound over the primary coil and contains thousands of turns of very, very small thread-like copper wire. It might be well to mention at this point that the size of copper wire is gauged in numbers ranging from 00 to 50. The No. 00 is the weight they use for trolley wires and it ranged from this point up to No. 50, which is so fine it can barely be seen with the naked eye. The wire used on the secondary of the induction coil ranges from No. 30 to No. 36, which is very small. Having cleared up this point let's see how it can be used in radio stations.

A SIMPLE TRANSMITTING SYSTEM

Figure 23-A shows the simplest type of transmitting equipment for broadcasting electromagnetic waves. It consists of an induction coil, primary and secondary windings with vibrator (not shown in Fig. 23-A but can be seen in Fig. 23), battery, key, spark gap, aerial and ground.

This is the type of transmitter originally used by Marconi in his earlier commercial apparatus, later used aboard ships for an emergency set, and is at the present time used by a good many amateurs.

A telegraph key is inserted in the primary coil in series with battery so that the circuit may be made and broken to form the dots and dashes for the forming of the code signals.

The aerial and ground wires are connected to both sides of the spark gap. The spark gap is adjusted so that the spark is smooth and fills the entire gap with a solid discharge. If the gap is too far apart the discharge becomes broken up and each spark weak and stringy, the oscillations produced in the aerial being likewise broken up and not readable at the receiving station. In this type of transmitter the wave sent out is a broad wave. We mean by this statement that the radiated energy is not carried by a single wave-length but is carried by a broad band of wave-lengths. For this reason and others this transmitter is not used very much nowadays only by some amateurs (we have only just mentioned this now because we have just learned about the principle of an induction coil). It is very desirable to radiate all the energy at a single wave-length which will be taken up and explained later on in other text-books.

The production of an impure wave (a broad band of wave-lengths is sometimes spoken of as an impure wave), is not uncommon. A person gets a cold and becomes hoarse. His voice sounds hoarse because his vocal cords produce an impure wave. A man who is not a musician blows a cornet and produces a disagreeable sound. He has an impure wave. Training and practice will enable him to produce a pure wave. If you allow a bell to fall to the ground, it makes a noise, that is, it gives forth an impure sound wave. Strike the bell with a clapper, and it gives forth a clear musical sound; that it what you might call a pure wave. The types of transmitters that produce pure waves will be taken up later. We cannot expect to grasp everything at once.

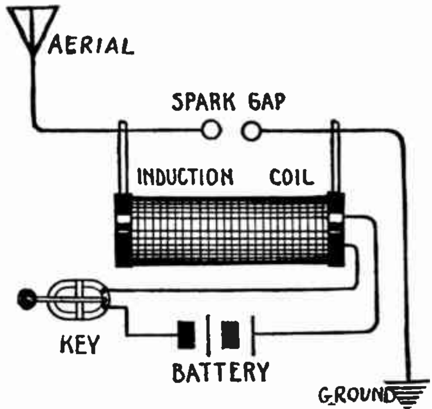


Fig. 23-A—A Simple Type of Spark Transmitter

We are now interested in knowing how this tremendously high voltage is produced in the secondary coil. To digest this point thoroughly, let us return to the experiment shown in Fig. 22. We know that a current will be generated in the secondary circuit shown. When you were considering this experiment did it occur to you that the voltage and amperage generated in the secondary circuit might depend upon the number of turns of wire in the secondary coil? Keep your eyes open at this point, because we are now considering basic principles that are of utmost importance. To be sure, the voltage produced in the secondary circuit depends absolutely upon the number of turns of wire contained in the circuit. If our secondary coil was made up of a great number of turns of fine wire a very high voltage would be produced and this voltage would increase with every turn of wire. We can put this simple rule in our minds. The voltage and amperage produced in the secondary circuit of an induction coil depends upon the size and number of turns of wire contained in it. In fact, we can adjust the voltage and amperage nicely by simply adjusting the number of turns of wire.

Here is an important point. Can we increase the amperage and the voltage at the same time? You would not want to be accused of trying to invent perpetual motion, would you? You know that is impossible. If that is so, how could we increase the voltage and amperage at the same time? That would be cheating nature and nature absolutely refuses to be cheated. If we could do this we would only need to build an induction coil, connect it up with a dry battery, increase the power of the battery a couple of hundred times and run our electric automobile with it. That would certainly be good sport, but, unfortunately, it can't be done.

In transforming current by the use of the induction coil we actually lose energy through the resistance of the wire. To be sure, we can increase the voltage, but what would happen to the amperage? The amperage falls to an insignificant value. Therefore, we find that in order to increase the voltage we must sacrifice amperage and therefore we gain nothing. If we were to put 30 watts of energy into the primary of the coil we would not be able to get 30 watts out of the secondary. The voltage may be 5,000 or 6,000, but remember that this would be multiplied by a very small fraction which would represent the amperage.

An induction coil or step-up transformer operates the principle that two separate insulated coils of wire are wound on the same iron core and that as the current passes through one it produces magnetic lines in the iron which cut the turns of the second coil and induces in the second coil a pressure or voltage which is proportional in value to the ratio of the number of turns in the secondary coil to those in the primary coil. That is to say, if the primary coil had twenty-five turns and the secondary coils 2,500 turns, then the voltage in the secondary would be 100 times as much as that in the primary, due to the fact that there are 100 times as many turns, so if there is a voltage of ten applied to the primary then there would be a voltage of 100 times 10 or 1,000 produced in the secondary coil.

The voltage of the secondary current can easily be calculated if we know the ratio that exists between the secondary and primary winding. If the number of turns in the primary is 100 and the number of turns in the secondary 10,000, and the voltage of the primary is 10, then the voltage of the secondary will be calculated as follows:

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

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

X must equal 1,000 volts. In other words, 10,000 divided by 100 equals 100 then multiplied by 10 = 1,000.

There is nothing difficult about this formula, is there? Look it over carefully and you will find that it is merely a matter of simple arithmetic. So many people get frightened when they see formulas.

Let us go back to the study of our induction coil. The current in the primary has induced a current in the secondary. There has been a change from a low voltage and a large current in the primary to a high voltage and smaller current in the secondary. How large a current have we in the secondary? A very small one, for the number of watts in the secondary coil is not greater than the number in the primary coil. This is the same thing as saying that the work done by anything is not greater than the work done on that same thing. In other words, to get work from a machine one must do work on a machine and the work taken from the machine can not be greater than the work put into the machine.

So in the induction coil, the wattage (work) in the secondary is not greater than the wattage (work) in the primary. Let us say that there were two amperes in the primary under a pressure of 10 volts. The wattage was 20 watts. Now the wattage in the secondary would be 20 watts if there were no loss. Suppose we found that there were 1,200 volts in the secondary. Then the current would be $\frac{\text{watts}}{\text{volts}}$ which is $\frac{20}{1200} = \frac{1}{60}$ of an ampere.

Now that we have come to understand the general operation of an induction coil, let us turn our attention to the electrastatic condenser that is bridged across the contacts of the interrupting device. Due to the current flowing through the primary of the coil and to the counter E. M. F. that is developed by the coil there is considerable sparking at the contact points. This sparking is disastrous inasmuch as it burns the contact points away. It is the purpose of the condenser to absorb part of this sparking and thereby prevent injury to the contact points.

Induction coils were used to a great extent during the early history of wireless, but today they are used only in an auxiliary set which is employed in emergency cases. The more reliable transformer is now employed and it will be our pleasure to consider this apparatus at a later time.

Generation of Electric Current

Let us refer for a moment to Fig. 24. The dotted lines represent a magnetic field. The arrows show the direction of the lines of force. Located in this magnetic field we have a small coil. It moves downward in the direction of the large arrow. When this happens there is generated within the coil an electric current that will flow in the direction of the two small arrows.

This leads up to an explanation of the simple dynamo alternator shown in Fig. 25.

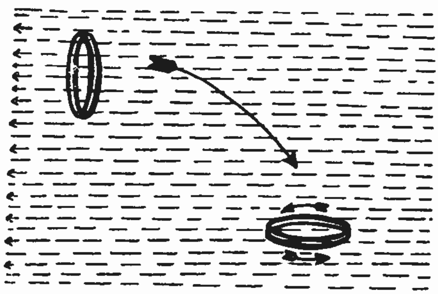


Fig. 24—Electromagnetic Induction

The Dynamo—We may briefly define the dynamo as a machine for converting mechanical energy into electrical energy by the principle of electromagnetic induction. But unlike the simple battery or storage cell the dynamo may generate either **direct** or **alternating** current. Alternating current dynamos are frequently called **alternators.** The student can nearly always distinguish between the two machines by observing the part of the dynamo at which the current is collected. If the brushes rest on a commutator made up of a number of copper segments separated by insulating material, it will be a direct current dynamo, but if the brushes simply rest on two brass rings, it will be an alternating current dynamo.

The fundamental principle of the dynamo follows: Whenever a coil of wire rotates through a magnetic field of uniform strength in such a way that the number of lines of force enclosed by the coil increase or diminish uniformly, a current of electricity will be induced in the coil, the strength of which at any instant is proportional to the rate of the change of flux.

Hence the essentials of a dynamo are:

(1) A magnetic field of constant strength;

(2) A number of coils mourted on a shaft and rotated in such a way as to cut through the magnetic field;

(3) Means for conducting the current induced in the rotating coils to an outside circuit.

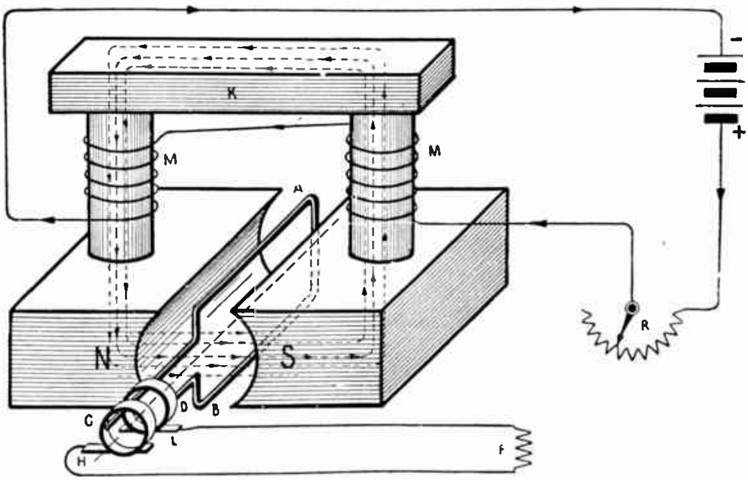


Fig. 25—Fundamental Diagram of Simple Alternator

A diagram of an elemenetary alternator appears in Fig. 25. A uniform magnetic field is set up between the magnetic poles N and S by the current from battery B-1 which flows through the magnet windings M, M. The rectangle of wire A, B is mounted on a shaft which rotates clockwise. Two brass rings, C, D, are mounted on the shaft but insulated from it. The copper brushes H and L make contact with these rings, and the circuit is completed through F (any current absorbing apparatus).

According to the principle just explained, if A, B, rotates around its axis, an E. M. F. will be induced in the loop, the magnitude of which depends on the rate of change of the number of lines of force threading through the loop. When in the vertical position of Fig. 25 the loop encloses the maximum number of lines of force, but when side A goes underneath the S pole and side B goes under near the end pole, as in Fig. 25-A, the rectangle will enclose the minimum number of lines of force when it has moved 90 degrees or in a horizontal position. As A moves out of the field of the south pole and B out of the field of the north pole, the rectangle reaches another vertical position (but with the two sides of the rectangle reversed) and again encloses the maximum number of lines of force. As the rotation of A, B, continues, side A goes into the field of the N pole and side B goes into the field of the S pole, where for a second time the minimum number of lines of force are enclosed after which the loop returns to the position mentioned at the beginning.

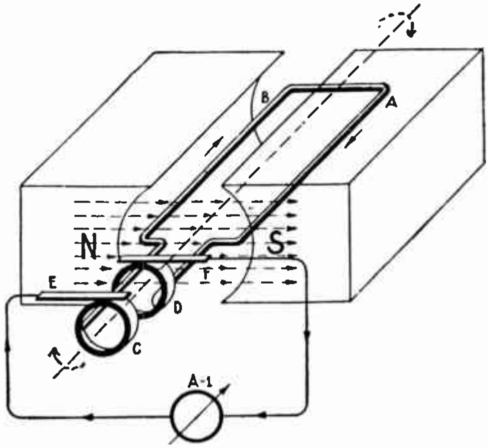


Fig. 25-A—Showing Position of Armature Conductors for Maximum Cutting

Now, according to the rule which governs the direction of the flow of current in a conductor cutting through a magnetic field, when A, B, is in the position of Fig. 25-A, a current will flow towards the rear of the rectangle in the left hand side, and towards the front of the rectangle on the right hand side. Then if A, B, continues ½ revolution, so that side A is cutting through the N field and side B through the S field, current will flow in A, B, in the opposite direction. It is clear that in a complete revolution, A, B, undergoes two changes of current which flows first in one direction around the rectangle and then in the opposite direction. The current is said to have gone through a complete **cycle.**

We see that during the first quarter revolution of loop A, B, or from 0° to 90°, the E. M. F. increases from zero to maximum; from 90° to 180° the E. M. F. decreases from maximum to zero; from 180° to 270° the current reverses and the E. M. F. increases from zero to maximum, and from 270° to 360° the E. M. F. again decreases from maximum to zero.

The changes in the strength of the current induced in A, B, can be shown by a wave-like curve in Fig. 25-C.

Field and Armature.—The magnets which produce the magnetic field of an alternator are called the "field magnets." If there is but one north and one south pole, the machine is said to be "bipolar;" if there are several pairs of poles the machine is "multipolar."

The conductors in which the electromotive forces are induced constitute the "armature winding." The winding is supported, usually by being embedded in slots, well insulated, on an iron core.

When a wire or revolving conductor passes one pole piece it induces a pressure varying from zero to maximum and back to zero in one direction and as this same conductor passes the next pole piece a light variation in voltage occurs, but in the opposite direction. These two variations in voltage, that is, first in one direction and then the other, is repeated as it passes each two or each pair of pole pieces. Therefore, for every two pole pieces passed per second we have one cycle. Therefore, the number of pairs of pole pieces per second will give us the frequency of the generator in cycles per second.

Cycle, Period, Frequency.—A regularly recurring series of values of electromotive force, from any point in the series to the corresponding point in the next series, is called a "cycle." The time required for one cycle is the "period." The number of cycles per second is called the "frequency."

In American commercial practice, 60 and 25 cycles per second are the most common frequencies for alternating current circuits. The corresponding periods are 1/60 and 1/25 of a second.

As is customary, the speed of the generator is given in revolutions per minute, so we must divide the revolutions per minute by 60 to get the revolutions per second. Multiply the revolutions per second by the number of pole pieces and divide by two and we have the cycles per second, bearing in mind that two pole pieces are required to be passed in order to make one complete cycle.

There is nothing difficult about the foregoing. It should be as simple as A, B, C, considering the facts we already have in mind concerning electromagnetic induction. Analyzing this alternator we find that it merely consists of magnets, revolving coil, collector rings, and brushes. The magnetic field may be produced by permanent magnets and by electromagnets. The number of poles of the machine may also vary but they must always be even in number. We could have a machine with ten poles, and if this was the case, we would readily see that we would have more than one alternation of current produced in one revolution of the machine. With a machine of this nature the frequency of the current will depend upon the number of poles and the speed of the rotor or armature. The frequency of a current produced by an alternator is equivalent to the number of cycles produced per second. The following simple formula is used in determining the frequency:

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

Where F = frequency in cycles per second.
N = number of poles.
S = revolutions per second.

The passing of each pair of poles, $\frac{N}{2}$ in number gives rise to one cycle. If there are **n** revolutions per second, the number of cycles per second is therefore $\frac{N}{2} \times S$. The second form of the equation is given, because the speed is commonly given in revolutions per minute.

For example: What frequency will a 12-pole alternator give when running at 5,000 r.p.m.?

With 12 poles, each revolution gives 6 cycles. In a minute there will be $6 \times 5{,}000 = 30{,}000$ cycles. In a second there are $30{,}000 \div 60 = 500$ cycles. The machine gives 500 cycles per second. By the second formula we get the same answer

$$F = \frac{12 \times 5000}{120} = 500 \text{ cycles per second.}$$

Commercial frequencies are used that range from 25 cycles to 60, 120, 240, 480, 500, 600, etc. Ordinary electric lighting circuits usually have a frequency of 60 and at times 25.

We will digress a moment and consider the simple rule shown in Fig. 25-B. This shows how the direction of the current can be indicated if the direction of the lines of force is known.

This is known as the right hand rule. If the thumb points in the directions of the lines of force and the fingers point in the direction the conductor is moving, the index finger will point in the direction the current is flowing in the conductor.

The drawing at Fig. 25-C will now receive our undivided attention. This may look horribly complicated. If we examine this closely we will see that we have another alternator here and at the side of this alternator we have a little drawing showing how the current acts during one complete cycle or one complete revolution of the armature. We might say that we actually

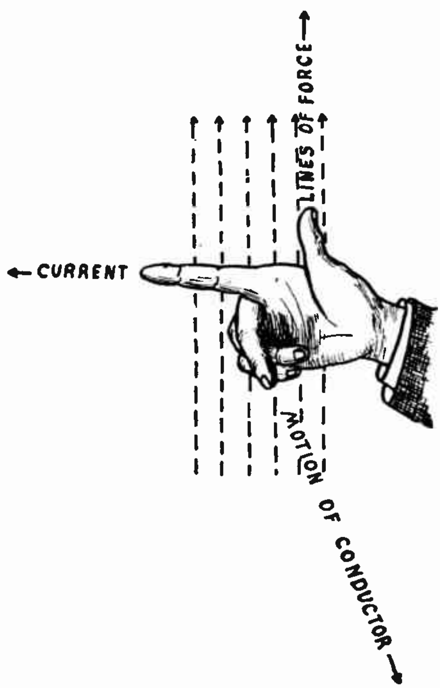


Fig. 25-B—Right Hand Rule for Determining Direction of Induced Current

have a picture here of the current. Let us start at the left hand side of this curved line where the line starts moving upward. In this case let us assume that the rotor or armature is in the position shown when the zero current will be flowing through it. As the armature moves from this position the current will build itself up. The line that we have drawn here actually represents the current and you will notice that it goes upward until it reaches a peak or the top of the curve. Then, when it reaches the peak it starts to drop following the motion of the armature. It drops to zero. Then the current reverses and does the same thing in the opposite direction. The line that we have drawn, then, shows one complete cycle.

If we wish to increase the facilities of the current produced by an alternator we must increase the speed. In the case of a simple two-pole laboratory machine we could do this, but large machines developed for commercial service are made to run at a consistent speed and for the production of a current of definite cycle.

Study the drawing in Fig. 25-C very carefully and if you do not find that you have these facts about alternators clearly in mind, go back over them and then, if you do not have the thought, communicate with us. Remember that we have obligated ourselves to help you in this matter and it is part of our service to see that you understand every fact contained in the course. However, the matter just covered is easily understood.

Inductance may be defined as that property of an electrical circuit by which energy may be stored up in electromagnetic form. Inductance, or the co-efficient and self-induction, may also be defined as the property of an electric circuit by which it produces induction within itself. Inductance and self-inductance are practically synonomous. The unit of inductance is the henry, which is that inductance possessed by a circuit which has an induced E. M . F. of one volt. when the current is changing at the rate of one ampere per second.

That is, if the current increases from zero to a value of one ampere through a coil of wire having an inductance of one henry during one second of time, the change in the number of lines of force set up about it will cause an induced pressure of one volt. The henry is too large a unit for practical use, except in special cases, so a smaller unit called the millihenry is used. The millihenry is one thousandth of a henry. Another subdivision in the microhenry, which is one millionth of a henry.

Electrical Capacity

Well, we are about ready now to sample electrical capacity, and it is not going to taste bitter at all. Capacity is a much-used word in radio and, of course, we have to familiarize ourselves with all these "much-used" words.

Briefly, we might say that capacity is the property of an electric circuit by which electrical energy is stored up in electrostatic form. The meaning of this word electrostatic should be perfectly clear to us. Electro always means electrical or electricity. The addition of "static" means, in this case, at rest. Therefore, we may say that capacity is the property of an electrical circuit in which electricity is stored at rest.

How do you store electricity in this way— that is, what kind of a device or instrument do we use? We use what is known as a condenser. A condenser is a sort of an electrical reservoir in which we store electrical energy through the property of electro-static capacity possessed by the condenser. Read that last sentence over again to be sure that you get all the good in it.

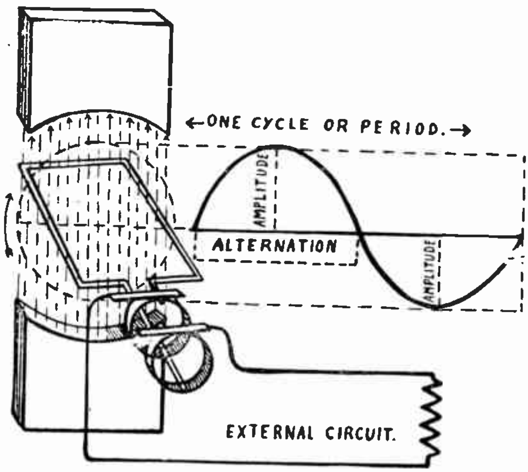


Fig. 25-C—Production of One Cycle of Current in an Alternator

How are condensers made? We might say that a condenser is formed by two conducting surfaces separated by a non-conducting or insulating medium. Say we took a nice clean piece of window glass and pasted a piece of tinfoil on each side. We would have a condenser. In other words, we would have the glass plate which is an insulating medium, separating two tinfoil or conducting surfaces. What would happen if we were to insert this condenser into an electric circuit? We would not expect the electrical current to jump through the glass plate, would we? When the current found itself baffled by the interposition of the glass plate it would immediately begin to build up electric charges on the conducting surfaces of the condenser. The condenser would only have a certain definite capacity to hold these charges. At the moment the condenser became "full" it would discharge just like a barrel would overflow when too much water was placed in it. However, the condenser differs from the barrel in this respect. The condenser would empty itself completely once it started to discharge.

You must remember that electrical current works with great haste—faster than our imagination. When an alternating electric current runs into the electrical condenser it charges it in the infinitessimal part of a second. And then what happens? After the current charges the condenser to its maximum value the condenser in turn discharges into the electrical circuit, thus creating high frequency oscillations for making Radio waves. The capacity of an electrical condenser depends upon the following: The size of the condenser surface, thickness and number of the insulating plates and the quality of the insulating material: The size and number of the conducting surfaces and the distance the plates are placed apart.

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

The dielectric constant of any substance may then be defined as the ratio of the capacity of a condenser using this substance as the dielectric, to the capacity of the same condenser with air as the dielectric. This ratio is seen to be the factor by which the capacity of an air condenser must be multiplied in order to find the capacity of the same condenser when the new substance is used. Some values are given on page 32.

Dielectric Constants

Substances	Values of dielectric constant
Air	1.0
Glass	4 to 10
Mica	4 to 8
Hard rubber	2 to 4
Paraffin	2 to 3
Paper, dry	1.5 to 3.0
Paper (treated as used in cables)	2.5 to 4.0
Porcelain, unglazed	5 to 7
Sulphur	3.0 to 4.2
Marble	9 to 12
Shellac	3.0 to 3.7
Beeswax	3.2
Silk	4.6
Celluloid	7 to 10
Wood, maple, dry	3.0 to 4.5
Wood, oak, dry	3.0 to 6.0
Molded insulating material, shellac base	4 to 7
Molded insulating material, phenolic base ("bakelite")	5.0 to 7.5
Vulcanized fibre	5 to 8
Castor Oil	4.7
Transformer oil	2.5
Water, distilled	81.0
Cottonseed oil	3.1

A wide variation is seen in the value given for some substances. The different grades and kinds of different materials vary considerably in many of their physical properties, including their electric properties. For instance, there are a very large number of kinds of glass made for different purposes, having very different properties. Many substances absorb a small amount of water very easily, and in some substances the presence of a small amount of water will considerably increase the dielectric constant. The value of the dielectric constant also depends on the kind of voltage applied and the manner in which it is applied. If the current is supplied by a source of direct current, such as a battery, the values of the dielectric constant found when the condenser is charged slowly will differ considerably from the values found when the condenser is charged rapidly. If the voltage applied is from a source of alternating current, the values of the dielectric constant may differ considerably from the values for direct current. This is particularly true if the alternating current has a very high frequency, such as is used in radio communication. For accurate results the conditions under which the material is to be used must be stated.

Dielectric materials are not perfect insulators, but do have a very small electric conductivity.

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

Energy Relations in Inductive Circuits

In mechanics it is well known that a piece of matter cannot set itself in motion and that energy must be supplied from outside. So in the electric circuit a current cannot set itself in motion, and energy must be supplied by some form of generator (source of E. M. F.) It has already been explained how a magnetic field arises about electric circuit. When this field collapses or disappears, the energy stored in the field is returned to the circuit.

Illustration of Inductance

When a nail is forced into a piece of wood the mere weight of the hammer as it rests on the head of the nail will produce but little effect. However, by raising the hammer and letting it acquire considerable speed, the kinetic energy stored is large, and when the motion of the hammer is stopped this energy is used in forcing the nail into the wood. In the electric circuit a cell with its small E. M. F. can cause only a feeble spark. By including a piece of wire with many turns in the circuit, however, energy is stored. A small current will enable a large amount of energy to be stored in the magnetic field, if the inductance is large. Then when the circuit is broken and the field collapses this large amount of energy is released suddenly, and a hot spark of considerable length is the result.

The close relations between capacity, inductance, and resistance will be more fully discussed below.

Resistance—Reactance—Impedence

In Books 1 and 2, we have been dealing with direct current and we have been satisfied with this type of current for our lights, heating devices, motors, telegraph instruments and many other pieces of electrical apparatus. Ohms law gave us a means of determining the value of E, I and W accurately. As progress was made in the method of producing electrical energy by machinery the engineer found he was held back in the development of high voltages and large amounts of power in direct current types of generators, due to limitations of the commutator not being able to withstand the higher pressures along with the inability of the brushes to collect or take away from the rapidly moving commutator bars large volumes of current.

Alternating current generators, commonly called alternators, were invented and the early type of construction (revolving armature) has been briefly explained in this book. Rapid improvements have been made in advancing the design of alternating current machinery due to certain advantages which this new type or form of electric energy possessed. But like all other big developments in modern life, alternating current brought with itself new problems to be solved.

Now let us turn our attention to one of the first problems the engineer had to meet in this advance. He found that Ohms law I equals $\frac{E}{R}$ did not seem to hold true for alternating current. This was a hard blow.

After long and exhaustive experimentation new properties showed their effect to the flow of this constantly changing type of alternating current. I dislike, at this point, just after you have mastered a clear understanding of that simple rule (Ohms Law in a Nutshell) to lay it aside as useless in solving our measurement problems. No, we'll not do that, but we will add to it the new properties which electric circuits have toward obstructing the flow of these rapidly reversing currents and let it stand in the original form but with a new letter in the place of R, that is, I equals $\frac{E}{Z}$. Z is the total resistance offered to the flow of alternating current and is called impedence. We must have a new name for a new letter to avoid confusion. Don't let this new word "impedence" add trouble. You have often heard of impediment of speech. It means an obstruction and again we have heard of impeding progress which means to hinder or stand in the way of progress. Now we have a good idea of what impedence does in a circuit. It obstructs, hinders, on stands in the way of the current as it tries to flow through the circuit. Yes, just as there are more ways than one to impede progress so it is true that there is more than one way to hinder the flow of alternating current.

Resistance we know about. It is like friction which water meets with as it flows through a cast iron pipe with rough sides. If we could make a pipe of the same size from smooth rolled sheet copper or brass, how much easier it would be for the water to flow and a larger volume of water or current would flow. Now that is the way with resistance in an electric circuit; iron wire we say is like the rough pipe, while copper wire offers less resistance and more current will flow.

Next, we approach the two new things which came about from a change of direct current to alternating current. First, is the effect of inductance on the flow of this new kind of curment. Now what is inductance? Just a simple definition in what we want. Inductance is that property of an electric circuit which objects to a change in current. Stop for a moment and get the true meaning of that thought. What? A property; Of what? An electric circuit; For what? Objecting to a change of flow. Let us see what that means. No current is flowing in a circuit when we apply a pressure to it, say a dry cell or storage battery. What are the natural results? A current tries to flow but this property of inductance objects to this flow of current, due to the fact that there is a change in value from no current to some amount of current. The current increases we will say to two or three amperes and then we attempt to stop the current by opening the circuit with a switch and this property of inductance objects to the current stopping its flow and tries to continue to have a flow in the same direction and same amount and we notice that a large spark occurs in the points of breaking the circuit with the switch, which would not have occurred had there been no inductance in that circuit.

Let us turn our attention to a close analogy of this which occurs in everyday life. And in order that we may hold to the same idea of the flowing water in the pipe, let us assume a large pipe several inches in diameter with a pump connected to it and start the water to flow through this line of pipe. Of course, we are going to meet with the resistance due to any roughness inside of the pipe, but if we add a new obstruction to the pipe line in the form of, we will say, twenty, thirty or forty turns made up in the form of a coil of pipe about, say eight or ten feet in diameter, we will find that the pump will have to have more power supplied to it in order to start the water to flowing through this coil than it would if the same number of feet of pipe were out in a straight line.

Another good illustration is suppose that you were running in a race and the distance was say one-fourth of a mile, you can readily see that you would have less obstruction and would run the distance in a much quicker time if you had a straight way course instead of a round track where you had to make one or two laps in completing the one-quarter mile distance. This is very similar to the new obstruction inductance which the current meets with in flowing through electric circuits and we must not treat this matter with too much vagueness since we can readily see like examples in our everyday life.

Figure 26 illustrates the holding-back effect which inductance has upon a circuit when 100 volts of constant pressure is placed upon it. The resistance of this circuit is ten ohms and the inductance is .2 of a henry. The value of current in amperes is represented by the vertical line and starts with zero and has a maximum value of ten; while on the horizontal line we have a time represented in hundredths of a second.

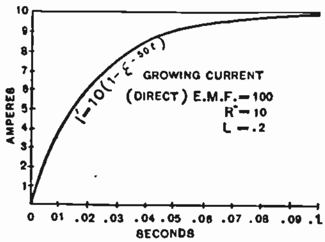


Fig. 26—Increase of Currents in an Inductive Circuit

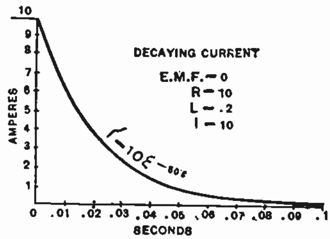


Fig. 26-A—Decrease of Current in an Inductive Circuit

You will see from the curve that in one-hundredths (.01) of a second after the voltage is applied the current reaches the value of nearly four amperes and in two-hundredths (.02) of a second between six and seven amperes, and in five-hundredths (.05) of a second, very nearly its maximum value or nine amperes.

From a study of this curve you can readily see that in the case of an alternating current of very great frequency that the current might never reach this maximum value due to the rapid change of pressure taking place.

Figure 26-A represents the decrease of current when the pressure on the circuit is immediately removed. One can readily realize that if a certain quantity of water was started to flow in a pipe line, that even after you had taken the force away, the water, due to its weight or inertia would continue to flow for

some period of time and this is true in an electric circuit where we have inductance.

The vertical line represents amperes as in the previous figure (Fig. 26) and the horizontal line represents time in one-hundredths of a second. One-hundredths of a second after the pressure is removed, the current has died down to approximately six amperes or the same amount that the current increased during the first one-hundredths of a second and in five-hundedths of a second it has reduced to about one ampere, and the next five-hundredths of a second or at the end of one-tenth second the current has practically reached zero value.

This well illustrates the effect of inductance upon a change of current in the circuit where it is placed.

Now that we have a working knowledge of this new obstruction, inductance, let us pass to the next property which is added to the alternating current, which we call capacity. Likewise, let us get clearly in mind what capacity is. Capacity is the property of an electric circuit which is able to store electrical energy in the static form. Static meaning stationary or at rest. We have already studied about different properties of capacity. Condensers are made up of sheets of metal separated from one another by an insulator. These are the devices which are placed in electric and radio circuits for the purpose of giving to these circuits this property of storing up energy, but we must not forget that even a few feet of wire in an electric circuit has to a very small extent, the ability to store electric energy and, therefore, all wire and different parts of apparatus has a certain amount of capacity effect due to the fact that they are made up of metal.

Now let us see what is going to be the reaction of this capacity effect as the alternating current starts to flow in a circuit which contains a condenser. This condenser is very much like a storage tank with one end covered by heavy rubber diaphragm which can be stretched out as the water fills it up and presses outward on it, and when a pressure of water is placed upon this pipe line it will find an easy space into which it may run and especially is this true if we could have a vacuum in this tank like they have on some fire engines and the effect will be to sort of aid the flow of water as it first starts and help it to increase its flow due to this suction action coming from the empty space within the large storage tank.

Now in turn this is the effect which a condenser has upon the flow of electric current in a circuit in which it is placed when the pressure is first placed on it. Even before the pressure has a chance to increase to any large extent the current flow will be increased very rapidly due to this suction action which the condenser has upon the flow in the circuit where it is placed. We have discussed this problem from the viewpoint of the current starting to flow or we might say increasing its flow or even stopping its flow in an electric circuit. But now let's see what happens when the current starts and stops and reverses its direction many times in a second. I think we are true in saying many times in a second, are we not? When we think of 500 cycles of alternating current which starts and stops 1,000 times in a second and then if you will go a step further and think of oscillating currents which make radio waves which even start and stop as rapidly as 1,000,000 or more times in a second.

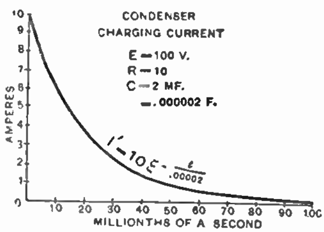


Fig. 26-B—Decrease of Current in a Circuit Containing a Condenser

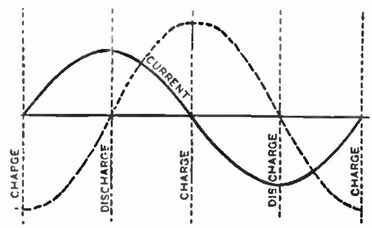


Fig. 26-C—Curves Showing Change of Current and Voltage in Circuit with Capacity

Figure 26-B represents the change in the current which takes place in a circuit containing a condenser of 2 M. F. (microfarads) capacity and resistance of 10 ohms when a pressure of 100 volts is placed upon it. The student should notice that the same method of representing the ampere along the vertical lines and the seconds on the horizontal line has been employed, but instead of hundredths of a second we have the value in millionths of a second.

Particular emphasis is laid upon the fact that the current starts at nearly its maximum value and the amount of flow decreases as the pressure has a chance to act upon the circuit. This is due to the fact that as the condenser fills up it reacts on the incoming pressure to reduce the flow of current very much like a rubber balloon would react on a person's mouth when blowing air into it. You will readily recall that as the balloon is filled up it is much harder to blow air into it and that the amount of air going in is much less than when you first started to blow.

Now Fig. 26-C is a method of representing the change in the flow of current in a circuit containing a condenser as the electric pressure placed upon this circuit changes. Starting with the pressure of maximum in the negative direction as represented by the lower end of the dotted line on the left hand side you notice that as this pressure decreases in value to zero, the current flow in the condenser increases from zero to z maximum, and during the next quarter of a cycle as the pressure increases from zero to maximum in a positive direction, the condenser changing current decreases from a maximum to zero, which has been well represented by the previous Fig. 26-B.

The student may continue to follow these two curves throughout the cycle and obtain a good idea of just how the current and pressure are related to one another throughout the complete cycle.

Now will it make any difference regarding the effect which these two properties, inductance and capacity, have on the flow of currents, as relates to the rapidity with which they change in a second of time. That is to say, does the inductance and capacity effect offer different values of obstruction as the frequencies of the current change. Stop for a moment and reflect on the obstructing effect which a coil of pipe might have on water which was started 100 times a minute instead of ten times a minute, an iron ball which is pushing back and forth 100 times a minute instead of ten times a minute. I know you are going to say right away that it is going to take more power to make these larger number of changes per minute and that really means that there is more obstruction offered to these rapid changes and, therefore, we come to the conclusion that there is more impedence offered to the flow of alternating currents as the frequency increases.

Now that leads us to the finding of the true values of these obstructing properties to the flow of alternating currents. You will recall in this early discussion that we used Z to signify the total resistance or the impedence to the flow of this new current. And furthermore, we have three different quantities which were obstructing the flow of this change in current. First, resistance; second, effect of inductance; third, effect of capacity. These two new properties, capacity and inductance, do not act in a manner so that they can be added directly to the value of resistance, and therefore, must be treated in a special manner. They have a reacting effect. First, inductance to sort of offer a force opposite to the pressure trying to start the flow of electricity, and second, the capacity which seems to suck or draw along the current as the pressure starts to act. Furthermore, we found that these two effects are going to change as the frequency changes and so the engineer has devised two new terms, one called inductive reactance and the other called capacity reactance. The mathematical treatment of this subject will be taken up in a later book.

Now we will recall from discussing the effect of the coil of pipe as compared with the tank containing a vacuum the effects of these two devices were just opposite to the starting of a flow of current. That is to say the coil of pipe seemed to have a holding back effect on the water starting while the vacuum tank seemed to suck the water or draw it along. This is true of the effects of capacity and inductance in an electric circuit, or in other words, they act just opposite to one another and if they were equal in amounts they would neutralize or destroy one another's effects and thus a circuit having inductive reactance and capacity reactance of the same amount would act like a circuit which had no inductance or capacity in it at all.

We have carefully discussed the values of inductive reactance, capacity reactance and resistance which are the three obstructing or hindering properties in a circuit through which alternating or oscillating currents are flowing.

We have been dealing with this problem from the viewpoint of finding their impeding effect on a flow of current in circuits. We will now turn our attention to their effect upon the phase relation between the pressure and the current which flows as a result of this pressure.

There are three possible relations that may exist between the current and the E. M. F. which causes the flow and will be described as follows:

First, the pressure and the current may be in phase with one another, that is to say they may be acting in unison with each other. This can better be explained by saying that when the pressure is zero the current is zero, and when the pressure reaches a maximum value the current has reached maximum value, and the current changes in exactly the same way as the pressure and exactly the same instant.

This is well illustrated by Fig. 26-D. The E. M. F. is shown by the light line while the current is represented by the heavy line. The student should notice that the current and pressure reach a maximum value at 90 degrees and both decrease to zero at 180 degrees. The same like changes occur when the pressure is exerted in the reverse direction and both values continue to change in this manner for each cycle that takes place in the circuit.

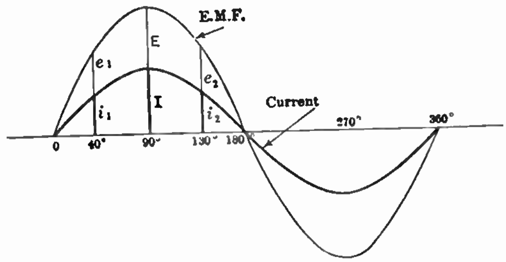


Fig. 26-D—Shows Changing Value of Current and E. M. F. When in Phase With Each Other

The second possible relation is where the current lags behind the pressure and is caused by inductance being placed in a circuit. This is illustrated in Fig. 26-E, and the student will notice that the current is zero even after the pressure has increased to a value of nearly three-fourths of its maximum value, that is to say fifth degrees while when the pressure is maximum the current has reached about one-half its maximum value and after the pressure begins to die down to about one-half of its maximum value, the current then has reached its maximum value.

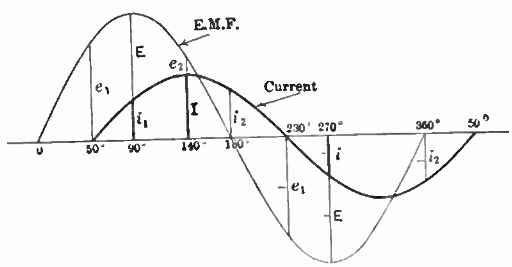


Fig. 26-E—Shows Changing Values of Current and E. M. F. for a Lagging Action Due to Inductance in the Circuit

Follow these two curves throughout the cycle and familiarize yourself with the relations which they are bearing to one another in a circuit containing inductance.

If we could have the circuit with pure inductance alone, with no resistance or capacity, the current would lag 90 degrees behind the pressure at all times. If you stop and meditate for a moment you will see that when the pressure is maximum the current would be zero and according to that we would have practically no power in the circuit. That is one reason why in a great many electric circuits we have quite a bit of pressure and current flowing but the watt meter registers a small amount, due to the fact that these two are not acting together and are not accomplishing very much work. Very much like two boys working together and instead of helping one another they hinder one another and therefore do not succeed in doing much work.

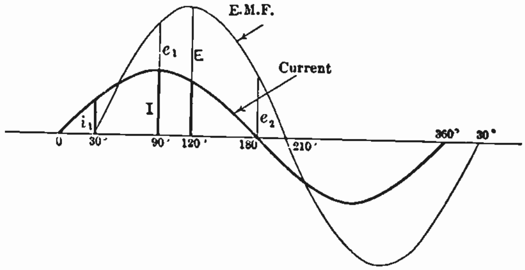


Fig. 26-F—Shows change of Current and E. M. F. for a Leading Action due to Capacity in the Circuits

The further and last possible relation is where the current leads the pressure and this is represented in Fig. 26-F. This takes place in a circuit containing capacity along with resistance. You recall in a previous explanation of capacity reactance that it was the property whereby it seemed to pull the current into a vacant space and thus cause a sort of suction, and it is also illustrated in the curve showing the charging of a condenser after the voltage is applied. And so we notice from this curve 26-F that the current really gets started before any pressure has been exerted and sometime after the current gets to flowing the pressure starts to increase, and it is some time after the current reaches maximum value that the pressure attains its maximum value, and it continues throughout the cycle, that is to say the current always being ahead in its relation to that of the pressure which is supposed to be causing it to flow in the circuit.

If we could have a circuit containing pure capacity alone without any resistance or inductance we would have the current leading the pressure by an angle of 90 degrees and there would be no power in the circuit under these conditions since we would say there is a wattless current flowing or a current flowing without any pressure.

You will recall that work is made up of two things—force and distance. If you push against an object that does not move you would not be doing any work; while if an object would move without any force being applied you would not be doing any work, so you must have the two, that is, you must have force acting through distance.

In an electric circuit you must have an electric pressure acting along with the flow of current in order to have it accomplish work and furnish energy.

This principle will be discussed in a more detailed manner in one of the latter text-books, but it is hoped that the student will get a working knowledge of the effects of capacity and inductance in radio circuits so that he may better understand the theory of tuning both for transmitting and receiving apparatus.

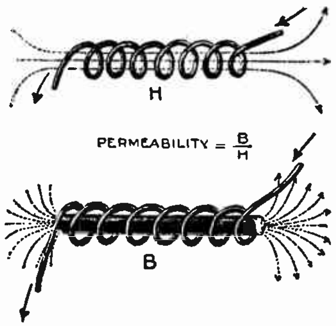


Fig. 27-A—Illustrating the effect of introducing an iron core into a solenoid. in the upper figure, the air space or "air core" surrounded by the solenoid offers considerable resistance to the passage of magnetic lines allowing only a small number to pass through. If a piece of iron be introduced, as in the lower figure, the number of lines will be greatly increased. The number of line B passing through a unit cross section of the iron core divided by the number of line H, passing through a unit cross section of the air core is called the permeability.

Interesting facts about iron as a conductor of magnetic lines and also similar actions of glass and other insulators for conducting static lines.

Let us first refer to Fig. 27-A, which shows two coils of wire. Both of these coils have the same current in amperes flowing through them and therefore in both there is the same force trying to produce magnetic lines in the center of each coil. The top coil has air as a core and the number of lines per unit of area is represented by the letter H (called field intensity), or in other words, the number of lines produced per square inch or per square centimeter in air by a magnetizing force (coil of wire or magnet), is given the name field intensity (H).

Now the lower coil (may be the same coil as shown in the top picture), has a round iron core put into it. Due to the fact that magnetic lines flow through iron much easier than in air, the same magnetizing force supplied by the coil will cause several hundred times as many lines in the iron core as there was in the air before the iron was put into it. The number of lines per unit of area in the iron (or any magnetic substance) is given a new name magnetic density represented by the letter B.

The value of B divided by H expressed in the form of a number is called the Permeability of the iron. The term Permeability means how much easier it is for the magnetic lines to permeate (pass through) a magnetic material than through air.

For example, if there were 3 lines of force per square inch in the air core of the top coil, Fig. 27-A, and 1,200 lines per square inch in the iron core of the lower coil then the following method would be used to compute the permeability:

H equals 3 B equals 1200

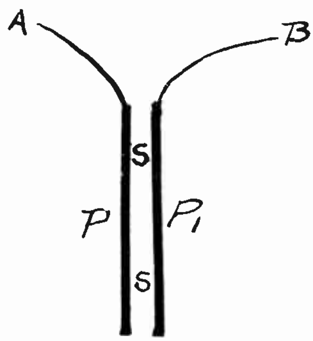


Fig. 27-B—Constructive Feature of a Simple Condenser

Permeability equals B divided by H or equals 1,200 divided by 3, equals 400. Therefore, the Permeability of this iron is 400. Now, if another piece of iron, say a piece of cast iron were placed inside the coil there would be a different number of magnetic lines produced per square inch and therefore the permeability of the iron would be different.

This value of permeability for different grades of iron and steel as used in Radio apparatus is of deep interest to the Radio Engineer.

The iron is said to have **permeability** because it carries lines of force well. Different kinds of iron have different degrees of permeability, so that some kinds of iron will carry more magnetic lines of force than others. Wrought iron has a very large permeability. All other substances are poor conductors of magnetic lines of force. They are said to have **reluctance**, because they do not readily admit magnetic lines of force. There is no known substance which will not carry lines of force at all, so that we can not insulate a magnetic circuit as we do an electric circuit. Figure 27-A will give you a good idea of how iron affects the magnetic lines of force. Note that the lines of force seem to gather at the iron.

The fact that iron is permeable is made use of in several ways. Whenever we need a strong magnetic field, we use iron; thus it is used in dynamos and other machines which depend upon electromagnetic induction. Iron can be used to shield delicate instruments from magnetic effects by inclosing them in a box or cage made of iron.

The fact that there is no known "insulator" of magnetic lines of force means that always some of the lines are leaking away from the path we want them to follow. This **leakage** can not be prevented altogether. It can be reduced by making the magnetic circuit out of all iron, and having this iron path as large as possible.

Now let us turn our attention to Fig. 27-B, which shows the constructive features of a simple condenser. P and P1 are two plates of sheet copper with wires attached to their tops and separate from one another about ⅛ of an inch. Assume that these two plates of copper insulated from each other by the air in the space S-S to form a condenser. Now connect the two wires at the top of the plates to a 110 volts source of direct current. The condenser will receive a charge in proportionate to its capacity.

Now discharge the condenser by connecting it to a galvanometer, whose reading indicates the extent of the charge. Next place a plate of glass between the copper pieces so as to fill the space S-S.

Again connect the condenser (with glass as an insulator or dielectric) to the 110 volt source for charging it. On discharging it through the same galvanometer the reading will indicate from 6 to 8 times the value indicated when air was used in the condenser.

The value obtained by dividing the capacity of a condenser with a certain material as a dielectric by the capacity of the same condenser with air as a dielectric is called, the dielectric constant of that material. (See table at the top of page 32 for these values).

QUESTIONS

Electromagnetic Induction—Part I.

41. How do we know that a current is accompanied by a magnetic field?
42. How may the polarity of a solenoid be determined?
43. What effect does an iron core have on a solenoid?
44. Give three methods of inducing a current in a coil of wire.
45. How does mutual induction differ from self-induction?
46. Name and describe briefly each of the two types of induction coils. Draw one that can be used for a Radio Transmitter.
47. Define mutual induction.
48. What is the purpose of the condenser connected across the vibrator contacts?
49. What is the function of the collector rings in an alternator?
50. Name the principal parts of an alternator.
51. Define alternating current.
52. What is frequency? Alternation? Cycle?
53. Give the rule for determining the frequency of an alternator.
54. What is the unit of inductance?
55. What is electrical capacity?
56. What is the unit of capacity?
57. What is meant by dielectric constant?
58. What does the capacity of a condenser depend upon?
59. Define reactance.
60. What effect does capacity reactance and inductance reactance have upon a circuit?

LESSON TEXT NO. 4.

OF A

Complete Course in Radio Telegraphy and Telephony

Electromagnetic Induction
Part II

TENTH EDITION

NATIONAL RADIO INSTITUTE, Inc.
Established 1914
WASHINGTON, D. C.

LESSON TEXT NO. 4

OF A

Complete Course in Radio Telegraphy and Telephony

Electromagnetic Induction

Part II

TENTH EDITION

Established 1914
WASHINGTON, D. C.

Fundamental Principles Lesson No. 4

ELECTROMAGNETIC INDUCTION

We are now digging down into the very heart of Radio and we are going to consider in this lesson a number of important things which a full-fledged radio man must understand. Don't you feel your knowledge increasing? Isn't it nice to really know something about such a fascinating subject as radio? Someone has said that "Knowledge Is Power," and there was never a more truthful statement made.

We have arrived again at the subject of electromagnetic induction because it is such a vitally important one. First we are going to consider transformers. The induction coil that we considered in a previous lesson is really a crude sort of a transformer inasmuch as it has a primary and secondary and a core and all transformers have these. However, the induction coil is not really an efficient transformer. It not only wastes energy lavishly, but it also gives trouble when higher powers are used. In the early days of Radio transmission the induction coil was quite important, but it became obsolete as the art progressed. When heavy D. C. current is sent through induction coils the contacts are badly and gradually burn away.

To start our understanding of transformers, we might say that the main difference between a transformer and an induction coil is the absence of a vibrator on the former. Now let us be wary, rest on our oars a moment and survey the outlook. What is a vibrator used for in an induction coil? To interrupt the D. C. current because a uniform current flowing in the primary will not induce a current in the secondary. Now, if we screwed the vibrator up tight on an induction coil so that it could not move and then sent an alternating current through its primary we would have a transformer. We would find that there would be a current induced in the secondary **because the alternating current would be constantly changing in value.** Unfortunately, an ordinary induction coil would not act very efficiently when used with alternating current because it would not be designed for such a purpose. For that reason we have transformers designed especially for use with alternating current.

There are really two principal types of transformers. We have **step-up** transformers and **step-down** transformers. The **step-up** transformer **always increases the voltage.** The **step-down** transformer **always decreases the voltage.** Step-up transformers are used in Radio transmission. They increase the voltage from 110, 220 or 550 to from 5,000 to 50,000 volts. Our interest will now be centered on step-up transformers.

Step-up transformers are divided into four distinct classes. Of course, the operating principle is based on the same laws of electromagnetic induction. We have what is known as the open-core transformer, the close-core transformer, the air-core and the auto transformer. We might compare an open core transformer to an induction coil. Its primary and secondary are wound together on a long core made up of laminated sheet iron or bundled soft iron wires. A diagram of an open core transformer is given in Fig. 28. It should be understood that the primary is wound directly over the core and that the secondary is wound over the primary. In other words, if we took a broom handle and wound some wire around it and then covered that wire with paper and wound some more wire over the paper, we would have a crude imitation of an open core transformer.

Open core transformers are not used a great deal these days because they are not as efficient as closed core transformers which we will consider next.

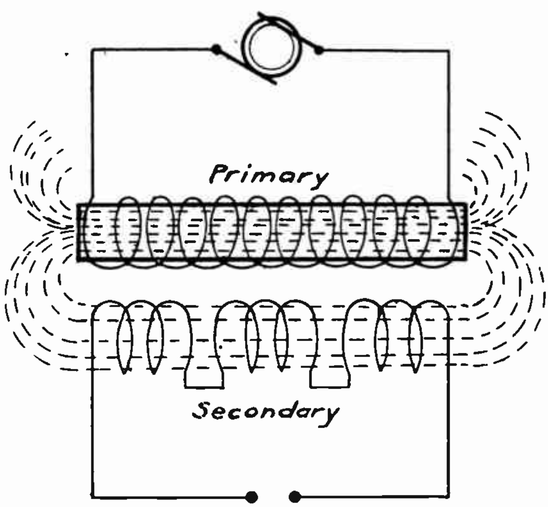


Fig. 28—Diagram of Open Core Transformer.

A very good idea of the construction of a closed core transformer will be had by carefully studying Fig. 29. Here we see that the primary and secondary are separated from one another. We will also notice that the core is arranged in the form of a square. In other words the core is "closed." The dotted lines shown in the diagram represent the part of the magnetic lines of force or the magnetic flux produced by the primary. We have been told that iron is a much better conductor of the magnetic lines of force than air, and, therefore, laminated sheet iron is always used in the construction of closed core transformers.

The term laminated cores refers to a core made up of a thin sheet of iron or soft steel varying in thickness from .001 to .025, according to the frequency employed. The thicker sheets (called laminae) are used for commercial power frequency of 25 and 60 cycles and the very thinnest sheets of .001 (1 mil.) are used for radio frequencies about 10,000. These sheets of iron have an insulating material on the outer surfaces, usually formed by dipping it in a liquid which rapidly dries. The object of having the thick laminae insulated from each other is to prevent the flow of eddy currents (induced currents flowing in a circular path and in a plane at right angle to the lines) created about the changing lines of force.

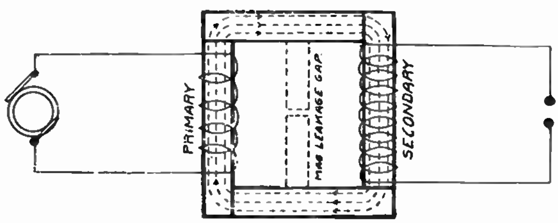


Fig. 29—Diagram of Closed Core Transformer.

Figures 30-A and 30-B illustrate the use of laminae in modern transformer constructions.

Now, let us see if we have everything straight in our minds. An open core transformer has a core that can be likened to a section of a broom handle, while the closed core transformer would need for its construction a core made up of four sections of a broom handle arranged in the form of a square. Each one of these sections of broom handle would be called a leg of a closed core transformer. The primary would be wound on one leg and the secondary on another leg.

In the case of these powerful step-up transformers, the winding on the primary consists of two or more layers of very coarse wire, such as No. 10 or No. 12 gauge. Now, if we are going to step the current up how must the secondary differ from the primary? Let us think this out. The secondary must be composed of a number of turns of very fine wire, No. 28, No. 30 or No. 36.

When the core of a closed core transformer is built up the strips of sheet iron used are insulated from each other with shellac. This reduces what is known as the eddy currents which tend to heat up the core and reduce the efficiency of the transformer.

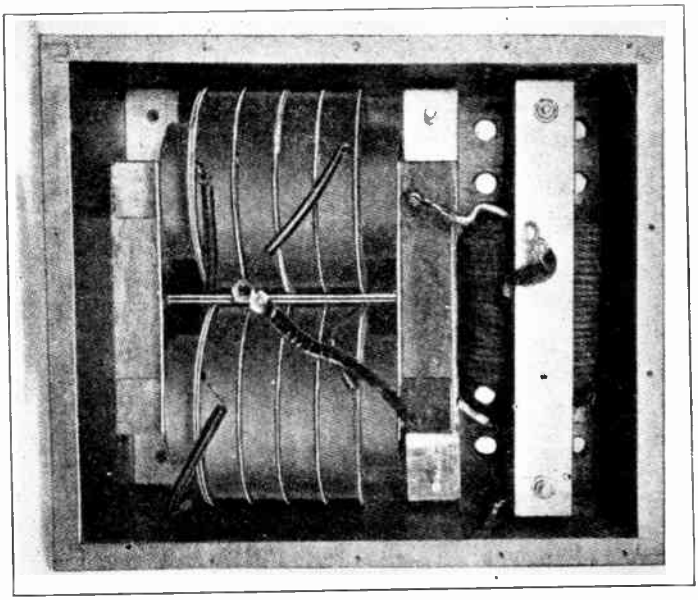


Fig. 29-a—Closed Core Transformer.

If we examined the diagram at Fig. 29 closely and carefully, we noticed a magnetic leakage gap. This gap is used so that the transformer will deliver a uniform current and so that the magnetic reaction set up in the secondary will be dissipated without effecting the primary winding.

Leakage—All of the magnetic flux due to the current flowing in one winding and linked with that winding is not also linked with the other winding. The path of a certain part of the flux is through the air, outside of the core. This part of the flux due to one winding which is not linked with the other winding is called its "leakage" flux. In well-designed transformers this leakage flux is quite small. The leakage flux obviously is not effective in transferring energy from one winding to the other. Leakage may be reduced by offering to the magnetic flux a complete path of high permeability. (Small reluctance or magnetic resistance to lines flowing). One way to do this is to use a closed core, so that the path of the magnetic flux is entirely through iron; in the open-core transformer part of the path of the magnetic flux is through air, and considerable leakage necessarily results. Another way is to use a core of large cross section, so that the iron is worked at low flux densities. Leakage is also reduced by bringing the coils close together and making them approach coincidence. This may be done by winding one winding right on top of the other; very little magnetic flux can then be linked with one winding and not with the other.

Losses—The transformer is one of the most efficient kinds of electrical apparatus. The efficiency of well-designed transformers is usually from about 91 to 98 per cent, according to size, the larger units being the more efficient. There are "copper" losses in primary and secondary windings, equal to the resistance times the square of the current. There are "eddy current" losses due to the currents induced in the iron core. If the iron core were solid, currents would be set up in the whole cross section of the core in the same plane as the plane of a turn of winding. By using thin sheets of iron the path of the eddy currents is reduced, and hence the eddy-current loss. At comparatively low frequencies the eddy-current loss is proportional to the square of the frequency and also to the square of the thickness of the sheets or laminations. At radio frequencies other effects must be taken into consideration, and these relations do not hold. At high frequencies it is important to have the laminations as thin as possible. In transformers for commercial frequencies the thickness of the laminations is usually between 0.010 inch and 0.030 inch. If a solid core were used in a transformer for handling any considerable amount of power, enough heat might be quickly evolved by the eddy currents in the core to destroy the unit. There is also another loss in the iron, called the "hysteresis" loss. Hysteresis losses are caused by reversals of the magnetism of the core and represent the energy required to change the direction of the lines (the positions of the molecules of the iron core). At comparatively low frequencies hysteresis losses are directly proportional to the frequency and are greater the higher the flux density at which the iron is worked. Hysteresis losses at radio frequencies are discussed in the pages mentioned at the close of this section. The sum of the eddy-current losses and the hysteresis losses is known as the "core losses" or "iron losses." The core losses occur as long as a voltage is applied to the primary and are nearly the same whether the secondary is delivering a load current or not. The current taken by the primary when the secondary circuit is open supplies these losses in the iron. It is therefore very important to design transformers so that the eddy-current losses and hysteresis losses are small. This is particularly important in transformers which are connected to the line all the time but supply a load during only a small part of the day, as transformers on electric-light systems, and is less important on transformers supplying full load secondary current all day, as transformers in a power house.

The cores of most transformers and other apparatus for alternating currents **are now made of silicon steel instead of soft iron or a mild steel.** One advantage of silicon steel is that when subjected to heat it does not age appreciably; that is, its permeability does not decrease with use. Ordinary soft iron will age rapidly with heat. Therefore a transformer with core of silicon steel can be operated at a higher temperature than a transformer with soft-iron core. Another important advantage of silicon steel is that its ohmic resistivity for electric currents is much higher than soft iron, and therefore in a given transformer the eddy-current losses will be less with a silicon-steel core than with a soft-iron core. The permeability of silicon steel is about the same as the permeability of the soft iron which has been used for transformers. Practically all core transformers used for radio apparatus, for either transmitting or receiving, have cores made of silicon steel.

Cooling—The losses represent electrical energy converted into heat. Some means must be provided for dissipating this heat, or the temperature of the transformer may rise until it is destroyed. Small sizes, including most of those found in radio stations of moderate size, may be cooled by simply being exposed to the air. The exposed surface of the windings must be sufficient to dissipate the heat. In larger sizes an air blast may be blown through the transformer. Large transformers are also cooled by immersing the windings in oil, which is kept cool by circulation. (Sometimes the oil is cooled by circulating through pipe immersed in cold running water).

If a tap is brought out from an intermediate point of the winding of an inductance coil, a part of the voltage applied at the terminals may be tapped off between one terminal and the intermediate tap. This can be considered to be a transformer in which one winding serves as both primary and secondary. It is simple and cheap, but has the disadvantage that the two windings are not insulated and the voltage to ground of the high-voltage winding also exists in the low-voltage circuit. Its use is confined for the most part to small sizes. This device is often called an "auto-transformer."

For bell ringing and similar work in which low-voltage alternating currents can be used, use is now made of small transformers rated at only a few watts, which are connected to the A. C. electric supply and deliver about 10 volts at their secondary terminals.

In radio apparatus the load on the secondary of a transformer usually includes a capacity. It may become desirable to adjust the system consisting of the A. C. generator, transformer, and secondary condenser so that the impedance of the primary circuit is a minimum; that is, so that the condition of "resonance" exists. This arrangement is called a "resonance transformer." With such an arrangement it is possible to obtain very high voltages. One type of transformer employing resonant circuits is sometimes called a "Tesla coil" and may be made to produce spectacular high-voltage effects.

The air-core transformer is used a great deal in radio circuits in sending and receiving. The air-core type of radio receiving transformers will be discussed under paragraph in this book of Radio Frequency Transformers.

Now, let us tackle the auto transformer. Fig. 30 will give us a very good idea of just how an auto transformer is made up. It is a single winding over an iron core, and it is used to reduce alternating current to lower voltage. Some years ago auto transformers were used to a great extent in radio, but today they are obsolete and, therefore, we will not need to bother ourselves about them.

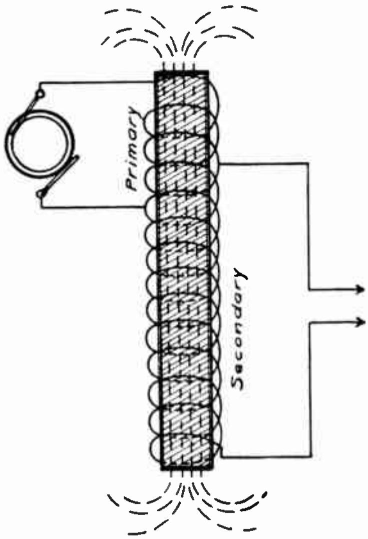


Fig. 29-b—Diagram of Auto Transformer.

Figure 29-B will serve to illustrate the construction features of the open core transformer. The only change would be to have two separate windings on the core instead of using the same coil for both primary and secondary.

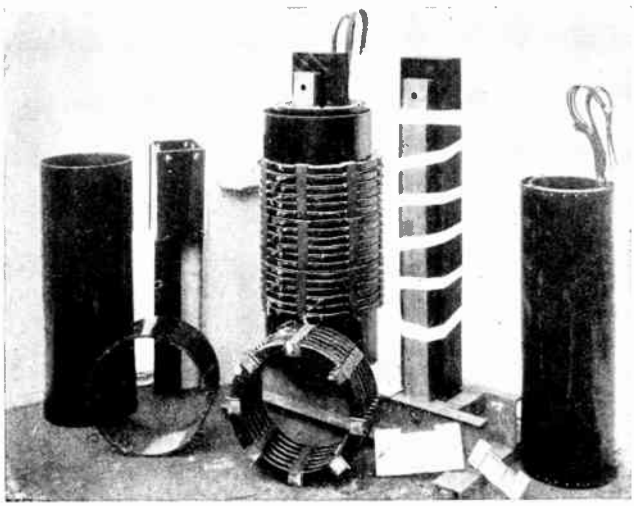


Fig. 29-c—Unassembled Parts for a Closed Core Transformer.
Courtesy of Westinghouse Elec. & Mfg. Co.

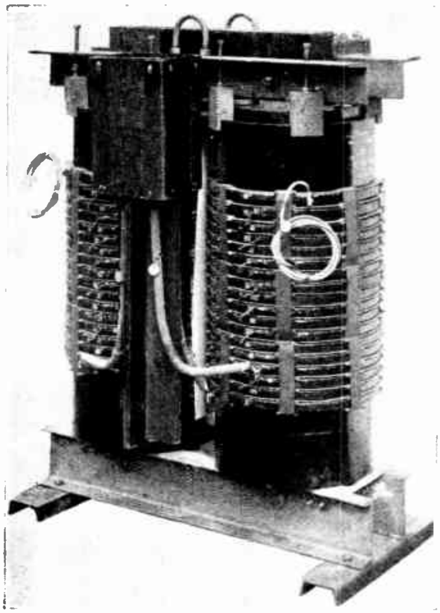


Fig. 29-d—Assembled Parts of a Closed Core Transformer.
Courtesy of W. E. & M. Co.

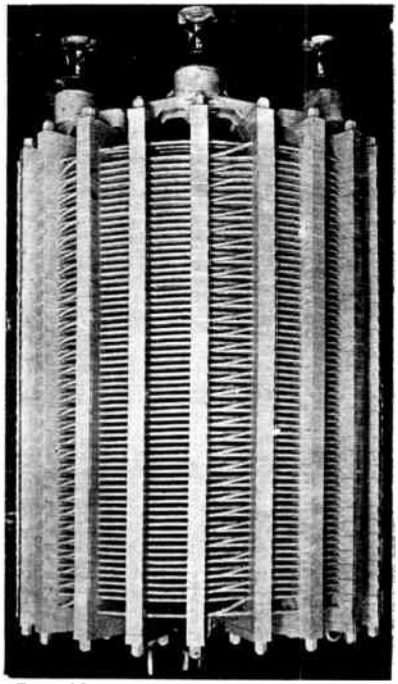


Fig. 30—Winding for an Open Core Transformer.
Courtesy of W. E. & M. Co.

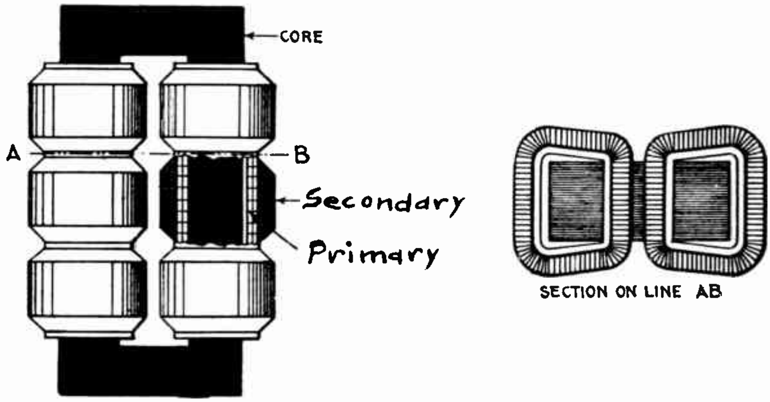


Fig. 30-a—Core Type of Transformer.

Figure 30-A shows the core type construction. Here the windings are divided into six coils or sections which are usually connected in series, but for lower voltages and larger currents could be connected in parallel or series parallel to suit the

requirement of voltage increase. The primary or low tension winding is made up of fewer turns of large wire wound next to the iron core with the proper insulating material between them.

Figure 30-B represents the shell type of construction. The method requires less copper and more iron. The sheets are made in two parts by cutting them along the dotted lines shown in the picture. Then in assembling them around the coils, every other complete sheet is turned around (180°) so that joins overlap each other. The path for the magnetic flux during ½ cycle (flowing of current in one direction) is shown by the lines with arrow on them. The magnetic lines divide as the come-on of the center of the coil, one-half going to one side and the other half to the opposite side.

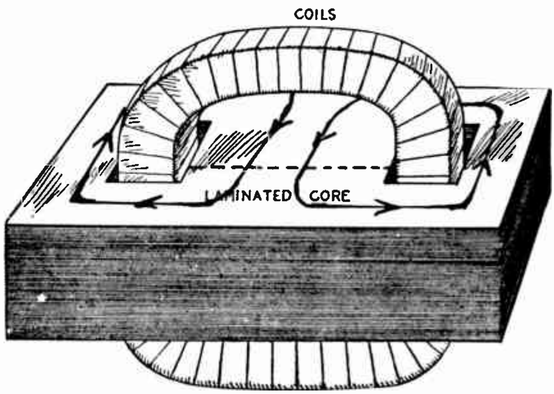


Fig. 30-b—Shell Type Transformer, Showing Laminated Core and Coil.

Transformers used in radio stations usually obtain their current from what is known as a motor generator. What does motor generator mean? This is very simple. A motor generator means the combination of a motor and a generator. Let us assume that we are faced with this problem: We have a supply of direct current which we wish to use to operate a transformer. How are we going to do it? A direct current cannot be used. There is only one thing to do. We must get a direct current motor connected to the direct current power line and then allow this motor to drive an alternating current generator. In this way we are able to change direct current to alternating current. Since direct current is used almost exclusively on ships motor A. C. generators must be employed.

Alternating current is fed into transformers at various frequencies ranging from 60 to 500 cycles. We must not lose sight of the fact that a transformer must be constructed for use with a certain frequency. We would not want to make the sad mistake of trying to operate a 500-cycle transformer on a 60-cycle circuit. There would be trouble right from the start.

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

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

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

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

$$\frac{10}{10,000} = \frac{100}{T1}$$

Therefore, T1 would need to be 1,000 times 100, or 100,000 turns in the secondary.

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

If the current in the primary is 10 amperes, and the voltage 10, the power would be 10x10 or 100 watts.

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

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

RADIO FREQUENCY TRANSFORMERS

Amplification in radio receiving refers to increased strength of signals. The amount of energy available at the telephone receiver or loud speaker, when receiving from distant transmitting stations (200 to 2,000 miles), is not always sufficient to operate them. The radio frequency transformer with an iron core has proven to be a much more efficient method of transfer of energy from the aerial circuit to the detector or amplifying circuit.

Modern radio frequency amplifiers consist of a group of two or three vacuum tubes in cascade interconnected by the specially designed radio frequency transformers. When the current for long distance reception is too weak to properly operate the detector then the radio frequency transformer with its improved efficiency will greatly increase the energy and make the operation suitable for further amplification by the audio-frequency transformers. The important feature in the design of radio frequency transformers is to obtain a fairly good working range in wave lengths. Many makes of transformers will operate efficiently on one wave length. For example, a transformer built for 360 meters would give very poor (if any results) on 300-meter wave length. By skillful designed features, radio frequency transformers are built with a working range of 200-600 meters, or 600-1,000 meters. It should be remembered that the tubes used for radio frequency amplification do not have the grid condenser or grid leak resistance.

The radio frequency transformer has been designed along the three common lines—air core, open iron core and the closed iron core. It is hard to predict at this time which type of construction will best serve the radio field.

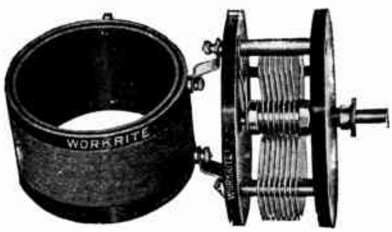


Fig. 30-c—Neutroformer.

The modern use of radio frequency amplification has brought into use the famous Hazletin Tuned Radio Frequency Rereceiver. The Neutrodyne is one of the newest radio circuits and has met with great favor wherever it has been tried out. Several tubes are used as amplifiers and the energy is transferred from plate circuit of one tube to the grid circuit of the next amplifying tube by means of a radio frequency transformer, employing an air core.

An illustration of such a transformer is shown in Fig. 30-C. The reader will observe that it consists of two windings placed on insulating tubes, one arranged within the other very much like the old type of loose coupler.

The figure also shows a condenser attached to one of the windings for tuning this circuit to the proper frequency. Many of the manufacturers of the regular radio frequency transformers have eliminated the iron entirely, using air as a core. The student should bear in mind that this greatly reduces the losses and thus improve the efficiency of the apparatus.

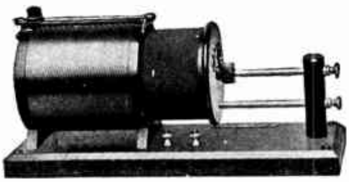


Fig. 30-d—Receiving Transformer (Loose Coupler).

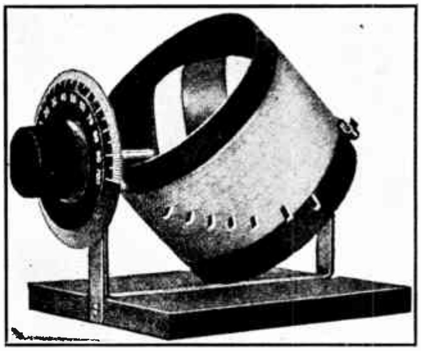


Fig. 30-e—Receiving Transformer, a Vario-coupler with 180° Coupling Showing Dial Attached.

Two other types of air core transformers used in radio receiving sets are shown in Figs. 30-D and 30-E.

The first one is sometimes called a loose coupler or tuner. The larger coil (primary) is connected directly in the aerial circuit, the other coil (secondary) is of a smaller diameter and may be moved into or out of primary coil by sliding it along stationary rods which support it. By using this arrangement the amount of coupling can be varied over a considerable range.

The second one is another type of receiving transformer called a variocoupler. This type is used a great deal nowadays and installed inside of modern radio receiving panels. The outer coil is stationary and wound so that a number of taps are taken off this coil for varying the induction.

The inside coil has a fixed number of turns and is so mounted that it may be rotated within the primary coil.

The knob is fixed at end of shaft that passes through both coils and supports the inner coil.

Figure 30-F shows a common air core type of oscillation transformer used in transmitting sets. The windings of this transformer are made of heavy copper wire and the adjustments are made by allowing the secondary to be moved in or out of primary coil. If the secondary coil is moved away from the primary there will be fewer lines of force cutting. Therefore, the energy transmitted to the secondary coil will be much less.

In order to vary the number of turns in the coils there are clips (as shown in Fig. 30-F), which are attached to the end of the wires leading to the transformer.

These connectors are clipped on to the turns at the proper points to give the right amount of inductance in the circuits.

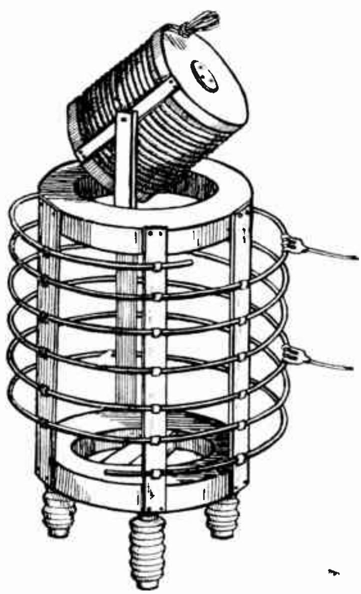


Fig. 30-f—Helix Type Oscillation Transformer.
Used in Radio Transmitting Circuits.

Figure 30-G shows one of the type of Iron Core Radio Frequeny Transformers used in radio receiving sets. Fig. 30-H is the base it is mounted on, showing binding posts for connection to + B-battery, filament plate and grid circuits. Fig. 30-J shows the transformer already mounted on base.

Fig. 30-h—R. F. Transformer Base.

Fig. 30-g—R. F. Transformer.

Fig. 30-j—R. F. Transformer attached to base and binding posts.

RADIO FREQUENCY AMPLIFYING TRANSFORMERS

The scheme of amplification at two different frequencies, namely first, at the radio frequency as it exists before the signal current is rectified by the detector and at the voice frequencies (called audio frequency) as they exist after rectification by the detector is doubly well suited to the characteristics of the cascade amyplifying scheme and rectification by such detectors as cystals and vacuum tubes. This comes about through the fact that while the number of cascade steps of amplification at any frequency is quite definitely limited by the "howling" which results from the use of too many stages, it is quite possible to amplify the unrectified radio frequency currents with several cascade steps of tube-transformer combinations and then after the signal currents have been rectified by the detector to amplify the voice frequency currents without series interaction between the radio frequency amplification and voice frequency amplification systems so that as many stages of voice frequency amplification may be used as when no radio frequency amplification is used. The Radio Frequency Amplifier therefore, allows us to secure additional amplification which may be used either with or without the well established methods of voice frequency amplification. Another and exceedingly important advantage arises from the fact that in the use of the vacuum tube and a detector the response in the telephones in the plate circuit for a given signal voltage applied to the grid, is not directly proportional to the voltage applied to the grid but, on the other hand, for grid voltages less than a certain limiting value no response resnlts in the telephones while for voltages somewhat in excess of this "threshold value" the response is more nearly proportional to the square or some higher power of this voltage. That is, if by radio frequency amplification between the antenna circuit and the detector tube the voltage made available to the grid of the detector tube is doubled, the telephone response is not doubled, but is increased to four or more times its original value.

Thus not only is it possible to secure greater amplification without serious unstability and "howling" through the use of R. F. amplification by its means it is possible to make available signals of such insignificant intensity as would be quite indistinguishable without it and where signals of noticeable intensity are available to take advantage of the square law of the detector by amplifying before rectifying.

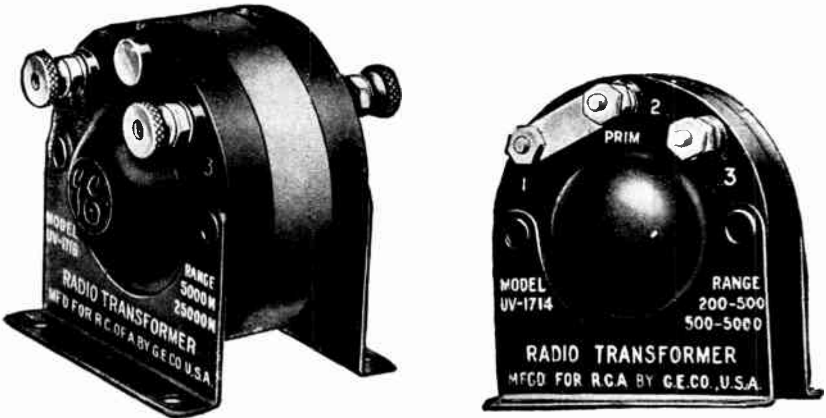
These several fundamental principles have been taken advantage of, to the maximum, in the Federal R. F. Transformers when used with this tube, all connections being cared for especially for use with the U. V. 201 Radiotron. These transformers have been made as short and as direct as possible, will give satisfactory operation over the wave length between 175 and 300 meters; 275 and 550 meters; 500 and 1,000 meters, and 1,000 to 3,000 meters.

All these types of Radio Receiving Transformers will be taken up and discussed in later text books on different types of Radio Receiving Sets.

Standard radio frequency transformers are built with a 1 to 1 ratio (same number of turns on primary and secondary), B. & S. gauge No. 38 to No. 14 wire is used in both windings.

Figures 30-K and 30-L represent the open core type of radio frequency transformer, manufactured by the General Electric Co. and sold by the Radio Corporation of America. The one shown in Fig. 30-K is for long waves, 5,000 to 25,000-meter range, which means a lower frequency current and, therefore, the use of more iron in the core. A shell type of radio frequency transformer has been designed by Mr. C. A. Brigham (a teacher in our institute), and it is being manufactured by the Dublier Condenser and Radio Corporation.

The use of radio frequency transformer makes it possible to use small loop aerials for reception, which eliminate a large amount of the static disturbances. Another added feature is that it may be built complete in a unit ready to receive. It can be used on moving objects or in an apartment where the construction of an aerial might be prohibited.

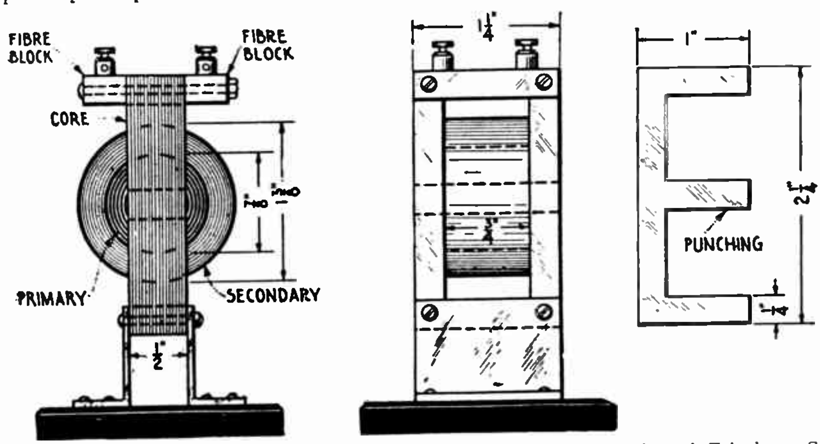


Courtesy of General Electric Co.

Figs. 30-k and 30-l—Radio Frequency Transformers.

AUDIO FREQUENCY TRANSFORMERS

Audio frequency transformers (sometimes called intervalve transformers) have been designed to transfer the audio frequency impulses from one tube to another for amplification of



Courtesy of Federal Telegraph and Telephone Co.

Fig. 30-m—Dimensions and Constructional Details of the Shell Type of Transformer.

the signals. After the radio frequency has been rectified by any form of detector (tube or crystal) the amplifying process may be carried on through many stages, but common practice has been to use 2 or 3 stages. This is particularly desirable where long distance concerts are to operate a loud-speaking device.

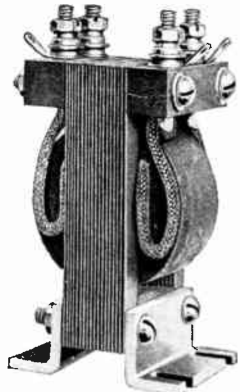


Fig. 30-n—A. F. Transformer.

Fig. 30-p—A. F. Transformer

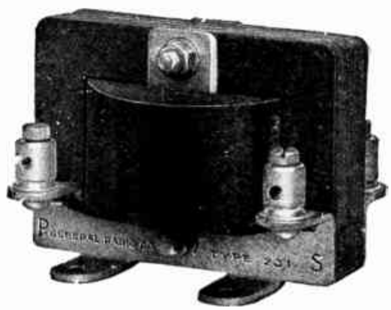


Fig. 30-q—A. F. Transformer.

Audio frequency transformers are wound with a step-up ratio of turns, varying from 3 to 1 to 10 to 1, thus increasing the pressure or voltage in the grid circuit of the next amplifying tube. The laminae (sheets of iron) are from .025 to .005 inches in thickness and the sizes of wire in the windings are from No. 36 to No. 14 B. & S. gauge.

Figure 30-M illustrates the design feature of an Audio frequency transformer. There are several types of Audio Fre-

quency Transformers. Four of these are shown in Figs. 30-N, P, Q, R.

The first three are of the iron core shell-type. The fourth is the open core type.

Figure 30-P—This transformer has been designed to eliminate the objections that have so limited the beauty and faithfulness of reproduction in the past. Its design and construction is of such a nature that the notes of the bass viol, the kettle drum, the piano brass are carried through the system with a completeness and roundness that is amazing.

It is of such construction that each note that enters it is passed on to the vacuum tube with exactly the same roundness and without a suggestion of any added tones, whether dissonant or not. And when used with vacuum tubes.

UV-201 UV-201-A WD-12 UV-199

or any of the other commonly available tubes, the degree of exceptionally satisfactory amplification exceeds that which has yet been available with any A. F. Transformer.

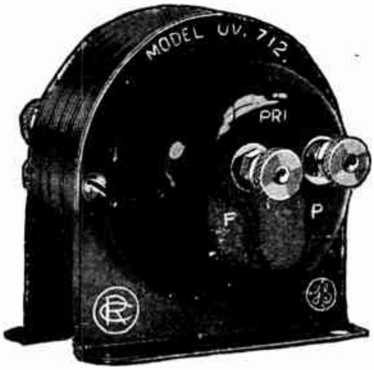


Fig. 30-r—Open Core Type of Audio Frequency Transformer UV-712.

When two transformers are connected in a two-stage amplifier, they should be, if possible, separated from each other, by five or six inches at least, and when convenient placed so that their windings are at right angles to each other. This prevents induction from one transformer to the other which will cause howling also other noises reducing efficiency of the receiving set.

Audio frequency amplifiers have four binding posts usually marked P and S that is for two to be connected to primary circuit and two to be connected to the secondary.

The primary P should be connected to the plate circuit and the secondary S should be connected to the filament and grid circuit. All these connections and different types of radio receiving circuits will be taken up in lesson texts numbers 9 and 10.

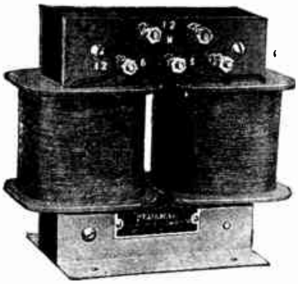


Fig. 30-s—Filament Light Transformer for Tube Transmitters.

Special transformer for reducing the house current voltage 110 (25 and 60 cycle A. C.) to 6 and 8 volts for lighting the filament of the audion tube are being used. The same idea in design has been applied to transformers to change the voltage of the house current, so it may be applied for the plate voltage of tubes in the place of the B-batteries.

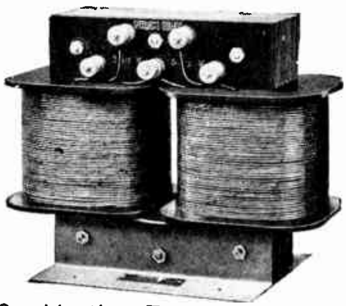


Fig. 30-t—Power Combination Transformer for Tube Transmitter.

This transformer is designed to give a secondary voltage of 12 volts when connected to a 110-volt, 60-cycle source of supply. It has two 12-volt windings and is used to heat both the filaments of the transmitting and rectifying tubes where a motor generator set is used to supply the plate potential.

Its use takes the place of a storage battery and furnishes a more economical current supply for the standard transmitter and rectifying tube filaments. Capacity, 150 watts.

This transformer is designed to economically replace the usual motor generator set as a source of 500-volt supply for plate potential. It eliminates the maintenance of motor generator sets and gives a constant reliable source of current for plate voltage of transmitter tubes.

The combination consisting of two standard rectifier tubes, two No. 1,000-W condensers, two filter coils and one combination transformer, will give 500 volts (D. C.) when the primary of the transformer is connected to a 110-volt, 60-cycle supply.

The filter coils and condensers are designed to reduce the A. C. fluctuations to a minimum.

In an addition to the 500-volt supply, two other current supplies are provided for filament heating.

(A) 12-volt supply for two 12-volt rectifier tube filaments.

(B) 12-volt supply for the transmitting tube filaments.

The low voltage supply eliminates the use of storage batteries and their upkeep, and gives a constant current supply for the filament on the transmitter tubes.

Modulation and microphone transformers are coming into rapid use. In ordering any transformer one should be very careful to specify the voltage, frequency and kind of current.

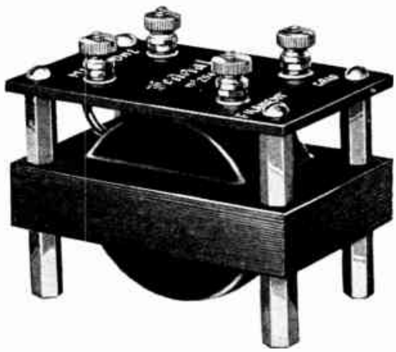


Fig. 30-w—Modulation Transformer

The Modulation Transformer as shown in Fig. 30-W is designed particularly for grid modulation for use in connection with Microphones to properly modulate the voice frequencies and produce clear speech.

This transformer has proven its efficiency in radiophone transmitters.

It is the shell core type, ratio 9 to 1 turns and provided with an insulating panel on which are mounted convenient nickel binding posts and lugs. The operation of Vacuum Tube Transmitters will be taken up in Lesson No. 13.

In Lesson No. 3 we touched briefly on the subject of the electric generator. We are coming back to that subject because it is such an important one. When we ride in the street car, go up in an elevator or turn on the electric light it is an electric generator that is supplying the current. In fact, every commercial radio installation receives its current from a generator.

GENERATORS AND MOTORS

Generator—a machine delivering electric power when mechanical power is put into it.

Motor— a machine delivering mechanical power when electric power is put into it.

Dynamo—a term which includes both motor and generator. The same machine may be used either as a motor or as a generator.

Voltage is generated by wires wound on the armature cutting through a magnetic field; the brushes merely convey it to the outside line.

Magnetic Fields are produced by winding soft iron or steel with coils and sending an electric current through the coils. These fields are composed of magnetic force lines, which leave the North poles and enter the South poles, returning to the North poles through the iron or steel yoke of the machine.

Direction of the current in the field coil determines the polarity of any pole. The rule for finding polarity is: Grasp the coil with the right hand so that the fingers point in the direction of the current in the coil and the thumb will point to the North pole.

The Poles of a machine should be alternately North and South around the frame, and their strength depends upon the number of **Ampere-Turns** in the coils.

Field may be either:

- **Separately Excited**—when the field current comes from some outside source. This type is rarely used.
- **Self-Excited**—when the field current comes from the armature of the machine itself.

Self-excited generators are divided into:

- **Shunt**—when only a small part of the current going through the armature goes through the field coils.
- **Series**—when all the current going through the armature flows through the field as well as the line.

Compound—when two coils are used on each pole, one a series coil, and the other a shunt coil. This is the most common type of generator.

Motors are classified in the same manner as self-excited generators. Shunt motors are in most common use except for traction work.

Voltage of a Generator must be "built up" from the small amount of residual magnetism left in the frame since last used. The voltage of a shunt generator can be controlled by means of an adjustable resistance inserted in the field circuit, which varies the field current and therefore the magnetic strength. When once "built up" and set at proper value by field resistance, the voltage of a shunt generator is nearly constant. It can be made absolutely constant by means of series coils in addition to the shunt coils.

Commutating Poles are small poles on both generators and motors. These poles are not to generate power in the armature but merely to keep the brushes from sparking on heavy loads or high speeds. The coils on these poles consist of a few turns of heavy wire, and are always placed in series with the armature so that the same current flows through them as through the armature.

The polarity of commutating poles is determined as follows: Determine the polarity of the main poles; then place your hand on one pole after another in order, around the frame, in the direction in which the armature is to rotate. Every commutating pole will have the same polarity as the main pole which follows it, if the machine is a generator; or as the main pole just behind it, if the machine is a motor.

A machine generally has the same number of brushes as poles, not counting commutating poles. All (+) brushes are in parallel and all (−) brushes are in parallel.

We learned in Instruction Book No. 3 that an alternating current is produced by a dynamo or a generator when the current is taken from the armature by means of slip rings. Now, we are going to learn how direct current is produced with the same kind of a machine. It is interesting to know that to obtain direct current we need only replace the slip rings with what is known as a commutator. A machine equipped with a commutator is called a dynamo and it produces current that flows in one direction only. It might be said that the function of the commutator of a dynamo is to vary the connection of the brushes to the armature coils in such a way that the current in the external circuit flows in one direction only.

An examination of Fig. 31 will reveal the differences existing between slip rings and a commutator, or, in other words, between an alternating and direct current machine. In Fig. 31

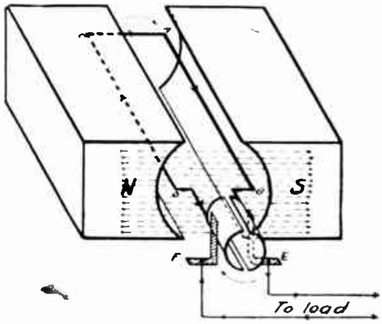


Fig. 31—Diagram Showing Function of Simple Commutator.

we notice that the commutator is made up of two semi-circular segments. Only two are used because there is but one coil in the armature. As the number of coils increase, the number of

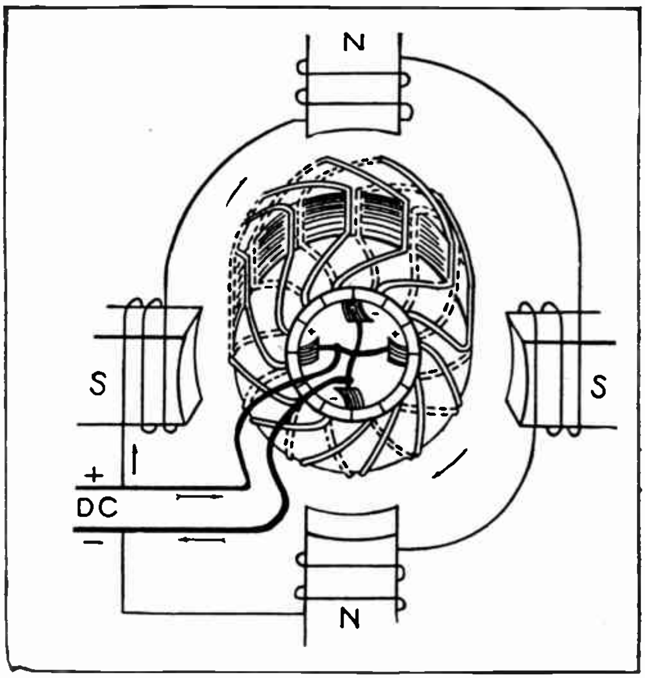


Fig. 31-a—Diagram of Circuits of a 4-pole Shunt Motor.

segments used must increase. Of course the segments must be insulated from one another to prevent short-circuiting.

The principal parts of the little dynamo shown in Fig. 31 are:

1. Field magnets. 2. Armature. 3. Commutator. 4. Brushes which bear against the commutator.

Only toy dynamos are made without field windings and in the larger machine we would have to add field windings to the list of principal parts mentioned above.

Fig. 31-A illustrates the four important parts of a generator and also the method of winding the coils on the pole (field) pieces and on the armatures. The field coils are joined in series so that the strength of magnetizing force (ampere turns) will be the same in each pole piece. This insures uniform pole strength. The iron core for the armature is made up of thin sheets of iron (laminated) .03 to .01 inch thickness according to the frequency (25 to 500 cycles), the thinner laminae being used for the higher frequencies.

Every dynamo produces an alternating current within its armature, but this current can be rectified at the commutator into a current flowing in one direction. If slip rings are used the current is led forth from the armature in exactly the way in which it is generated.

In the larger machines the commutators have 150 or more segments and the armature consists of many loops of coils wound over a laminated iron core. Such machines are called multipolar dynamos since they have more than two poles.

This study of dynamos and generators is intensely absorbing because it strikes deep into the fundamentals of electric current as it is used today. We must keep our eyes and ears open to make sure that we do not lose any of the important essentials of this side of our training. When we acquaint ourselves with the details of the electric generation of power we know something that the average electrician is astonishingly ignorant of.

Let's come back again to the subject of the armature. There are two principal types, the ring wound and the drum wound. The ring wound armature is used very little in the generation designed for Radio work, therefore we will not need to devote a great deal of attention to it. It merely consists of a ring of iron about which is wound the coils of the armature.

Let us pass on to the drum wound type (illustrated in Fig. 31-A), which is used in modern dynamos and motors. An examination of such an armature shows that all of the wire is

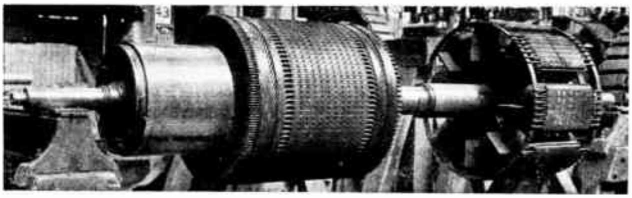


Fig. 31-b—A. C. Motor Armature (to left) and D. C. Generator Armature Inverted on same Shaft.

Courtesy of W. E. & M. Co.

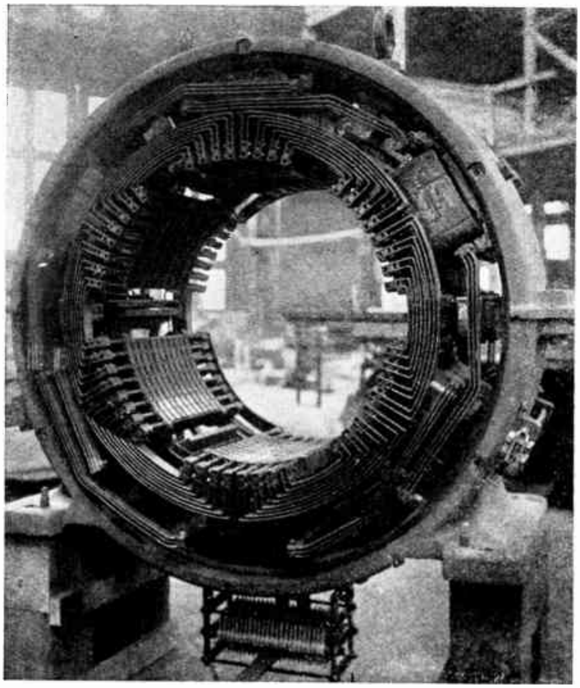


Fig. 31-c—Construction Features of a D. C. Generator Stator.

Courtesy of W. E. & M. Co.

placed in slots cut in the outer surface of the iron core. The distinguishing feature of the drum winding is that two branches of each turn of wire lie under the adjacent field poles. The core is made up of soft sheet iron stampings insulated from one another by shellac. The stampings are bolted together tightly so that they form practically one piece of metal.

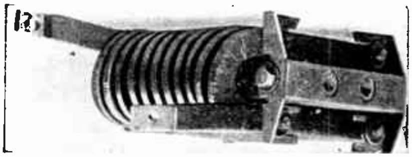


Fig. 31-d—Inter-pole Field Coil for D. C. Generator.
Courtesy of W. E. & M. Co.

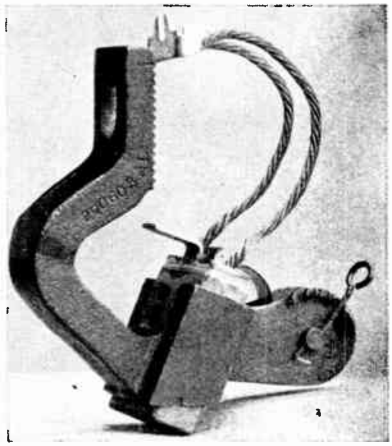


Fig. 31-e—Brush Holder Showing Adjustment of Spring Tension on the Carbon Brush
Courtesy of Westinghouse Elec. & Mfg. Co.

If we stop and think hard for a moment we will come to understand that the voltage generated in a dynamo depends on —just what? You will know if you think hard enough. What did the voltage generated in the coil mentioned in Lesson No. 2 depend upon? The amount of wire that was used, to be sure. The same holds true of the dynamo. The amount of pressure it generates depends upon its winding. Then, of course, you must also remember that a dynamo or generator designed to produce, let us say, one horsepower must be driven by a steam engine, water wheel or other power producing unit that will develop over one horsepower. If we want to get a horsepower of electric energy out of a generator we have to supply it with a little bit more than a horsepower, the "little bit more" being thrown in for good measure to account for the inefficiency of the dynamo. We can never get something for nothing. That is one of the fundamental laws of nature.

The brushes which rest on the commutator are usually made of carbon. On smaller machines they are sometimes made of copper gauze. They are brought to bear at a slight angle on large machines. The adjustment of the brushes is important, and undue pressure must be prevented. On most dynamos the brushes are held by what is known as a rocker arm. This device is merely a holder which allows the shifting of the brushes from one point to another so that they can be adjusted to a critical position, called the neutral point. In the neutral point there is a minimum of sparking, due to the fact that the coils connected to the segments, on which the brush is bearing at this point, in their revolution, have little or no current induced in them.

Dynamos are divided into three classes, i. e., shunt wound, series wound and compound wound. We do not want to neglect any part of our electrical education, so we are going to spend a few moments considering these three machines.

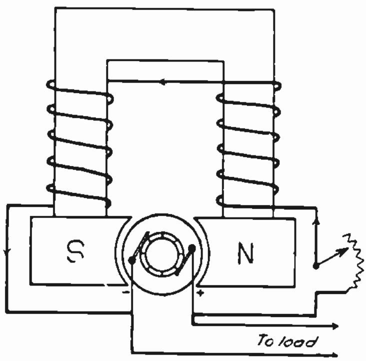


Fig. 32—Diagram of Shunt Wound Generator.

Figure 32 is a diagram of a shunt wound dynamo. Let us take our pencil and trace the winding through. In fact, it would be a good idea to sketch the winding diagram of these three different generators down in our note books. In Fig. 32 we notice that the field winding is placed in shunt to the armature winding. By the phrase "in shunt" we mean that it is placed across the armature winding or in parallel. Each end of the field winding is connected to one of the brushes. The field winding is in series with a rheostat of variable resistance. This method of connection causes part of the current flowing through the armature to pass through the field windings and this current flowing through the field windings helps to build up the strength of the magnetic field to its proper value. When such a dynamo is started the magnetic field is very low in value, but as the armature is turned current is sent through the field windings and this, in turn, builds up a stronger magnetic field. This, in turn, helps the revolving armature to generate more voltage and so on until the full voltage is supplied.

"How is all the current generated by the armature prevented from flowing through the field?" you ask. That is indeed a very intelligent question and one that would naturally come up. To prevent too much current from flowing in the field winding its resistance must be made rather high, and the resistance of the external circuit, or the circuit which the dynamo is supplying with current, must be lower than the resistance of the field, otherwise too much current will flow through the field. The field rheostat is used to control the voltage through regulating the strength of the current passing through the field.

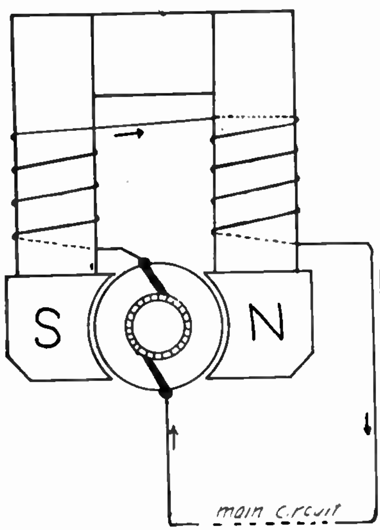


Fig 33—Diagram Showing Connections of Series Wound Generator.

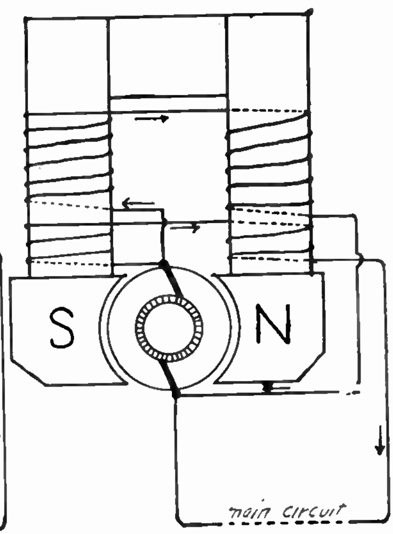


Fig. 34—Diagram Showing Connections of Compound Wound Generator.

Figure 33 shows us the winding of a series wound dynamo. This is very simple in construction. If we trace the winding through with our pencil, we will see that the armature is connected in series with the field. We will not tarry long with the series wound machine because it is practically obsolete. It will be seen that all the current generated in the armature must flow through the field winding. Therefore, the field winding must have a low resistance.

The compound wound machine is illustrated at Fig. 34. If we look closely and trace the winding diagram through we will notice that this type of dynamo is provided with two field windings. One winding is in series with the armature and the other is placed in shunt with the armature. The series coil is of large wire and its function is to increase the magnetic field when the load varies. When a heavier load is put on the dynamo the increased flow of current will, in flowing through this series winding, increase the number of lines of force cut by the armature and thus maintain the voltage.

The voltage of dynamos may be regulated by a field rheostat or by varying speed. The former method is more commonly used.

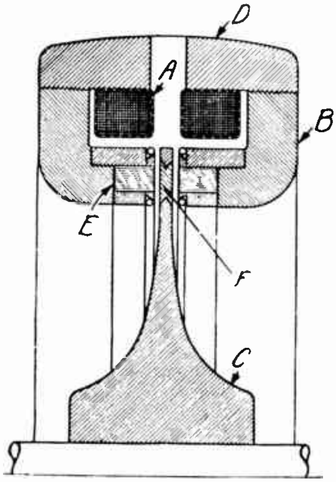


Fig. 35-a—(left)—Section of Alexanderson Alternator, Showing Rotor.

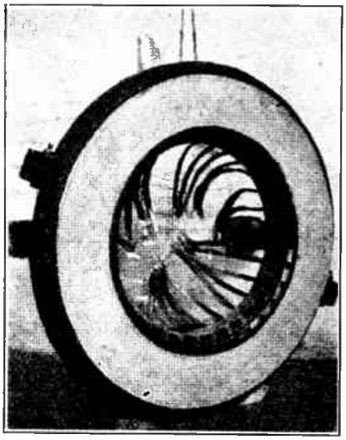


Fig. 35-b—(right)—Front View of Armature Used in 200 KW. Alexanderson Alternator.

The demand for high frequency currents (500 to 100,000 cycles) for radio purposes has created many new features in the design and construction of generators. Notably among these are the Alexanderson high speed inductor type alternator. Fig. 35-A will serve to illustrate the working principles of this machine.

The rotor consists of a steel disk with a thin rim and a much thicker hub shaped for maximum strength. Instead of having teeth on the edge, slots are cut on each side of the rotor very near the edge and may not extend entirely through the rotor disk. The spokes of steel which remain form the inductors, and a solid rim of steel is left. To cut down the friction of the air at the high speed at which the disk is operated. the slots are filled with a non-magnetic material, such as phosphor bronze, finished off smoothly with the face of the disk.

The armature conductors are laid zig-zag in small straight open slots in the flat face of the stator core, this face being perpendicular to the shaft. Fig. 35-A shows a cross section of a part of a small Alexanderson alternator. C is the rotor disk, and A the field windings. The armatures are shown at B, and the armature conductors, which are carried in laminations, at E. The field flux passes through the iron frame D, the laminated armature, and the disk. The slot filled with non-magnetic material is shown at F. The usual air gap is 0.015 inch, so that a very slight defect in construction will cause a serious accident.

In the radio station at New Brunswick, N. J., there is an Alexanderson alternator having a rated output of 200 Kw. generated at a frequency of about 22,100 cycles per second when the alternator is running about 2,170 r. p. m. Similar alternators are in use at Tuckerton, N. J., and Marion, Mass.

An uninitiated person could not tell the difference between a dynamo and a motor because they are almost identical in construction. In fact, most dynamos will run as motors if we feed current in to them through the same path that the current takes which is generated by them. The electric motor converts electrical energy into mechanical energy, just as the gas engine converts chemical energy into mechanical energy.

The principle of the electric motor is simple enough and no deep thought will be necessary to understand it. Here it is: If a conductor (wire) has a current flowing through it, a magnetic field will be produced about it. If this conductor is free to move in another stationary magnetic field the reaction of these two fields causes the conductor to move in a certain direction, depending upon the direction of the current flow.

Let us refer to Fig. 35. Here we will see the effect of a magnetic field on a current carrying conductor. We must take more than a glance at this drawing because it is important. The lines of force we see are more dense on one side of the conductor, thus causing a distortion of the lines of force existing between the north and south poles. The lines of force in trying to straighten exert a pressure on the conductor causing it to move in a certain direction.

The simple machine shown back in Fig. 31 can be connected to act as a motor. The function of the commutator would be to maintain the polarity of the armature loop in such relation to the field poles that there will be a constant attraction and repulsion which will bring about rotation. The function of the commutator is to keep the current flowing through the coils of the armature in such a direction that the lines of force between the poles will exert a pressure on the armature windings thus causing rotation.

Simply and briefly, this is the principle of the electric motor. We might say that the magnetic fields of the armature or the field conflict in such a way that a twisting motion is produced and this twisting motion whirls the armature around and produces power. Of course, the twisting motion depends upon the amount of current fed into the machine.

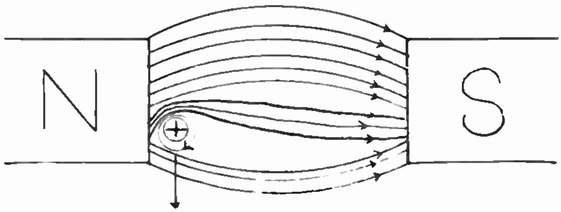


Fig. 35—Diagram Showing Effect of Magnetic Field on Current Carrying Conductor.

Some of us are going to ask if a motor does not generate a current while its armature is revolving. This question, of course, would be suggested by the fact that there is very little difference between a direct current motor and a dynamo. It probably will not surprise us to learn that a direct current motor in operation does generate a voltage, and the troublesome part of this matter is that the voltage generated acts in a direction opposite to that of the voltage driving the machine. We might say that a battle is wagered between the two voltages, and, of course, the stronger one overpowers the weaker one. In such cases the stronger voltage is the voltage that drives the motor and, therefore, it wins. The opposing voltage is called the counter e. m. f., or counter voltage. If it reached the same value as the voltage driving the motor, the motor would stop. However, motors are designed so that this cannot happen.

We can readily see that this counter e. m. f. reduces the current of a motor because it imposes reacting force in the path of the driving current. It would be just like putting a pressure water pump on both ends of an iron pipe. The larger pump would overcome the effect of the smaller one, but the smaller one would prevent the larger one from working at full load.

How is the speed of motors controlled? In the case of the dynamo we learned that a variable resistance is inserted in the field windings to vary the voltage at the terminals. A variable resistance is also used in the motor field windings to regulate the value of the counter e. m. f. If the counter e. m. f. is increased by allowing more current to flow through the field windings, the current entering the armature will be reduced in value and, therefore, the motor will slow down. When a larger current flows through the fields the number of lines of force cut by the armature is greater, inducing a larger counter e. m. f. This counter e. m. f. will oppose the applied e. m. f. from the source of power that is driving the motor and a reduction in speed will be effected.

What an interesting subject this makes. Everywhere we go we see electric motors in operation and the next time we see one we will take more interest in it than we have in the past. We will go up to it and look it over. How nice it feels to know that we understand how it operates.

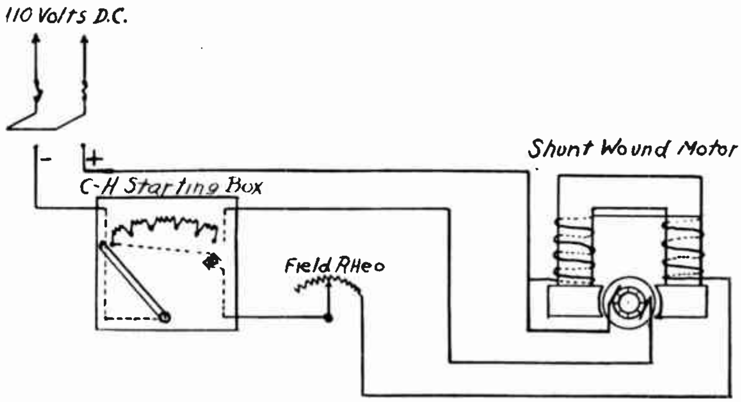


Fig. 36—Diagram of Cutler Hammer Starting Box with Connections to Motor.

Figure 36 shows how a starting box is connected with a shunt wound motor. The starting box is, in the final analysis, merely a variable resistance. If the current was fed directly into the armature of the motor before it had come to full speed too much current would pass, heavy sparking at the commutator would occur and the armature might burn out. To prevent such a disaster a starting box is employed, being connected as shown. As the handle of the starting box is moved across the contact points the resistance of the circuit is gradually decreased. This controls the current passing through the armature. Very little passes first and the armature revolves slowly. As the handle of the starter is pulled over more resistance is cut out and more current is allowed to pass through the windings of the armature. As the motor gains in speed the counter e. m. f. increases in value and offers resistance to the applied voltage tending to choke it back. Thus, as the speed of the machine increases the resistance of the starting box is unnecessary.

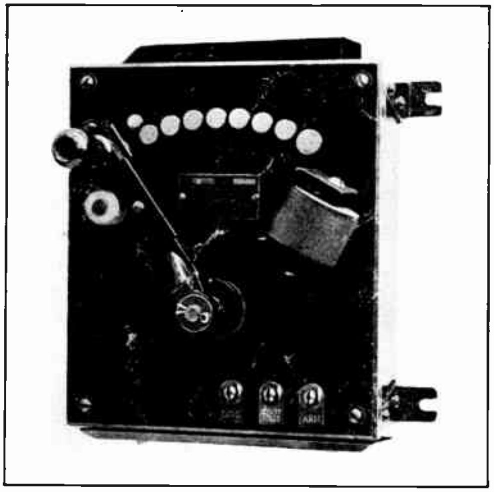


Fig. 36-a—Cutler Hammer Hand Motor Starting Box

Rating; Name Plate Data.—Practically all electrical apparatus, whether for alternating or for direct-current generator, motor, or other device, is designed for certain definite conditions of operation. It is standard commercial practice to attach firmly to every electrical machine before it leaves the factory a brass information tag called a "name plate." This usually gives the serial number by which the machine can be identified; tells the maker's name; states whether the machine is a generator or a motor; what is the maximum continuous power output; whether for direct or alternating current; if alternating, for what frequency and how many phases; at what speed it is to be operated; at what voltage; the maximum current for continuous operation. Some of these items are at times omitted, but most of them are essential. A person who wishes to become familiar with electrical machinery should form the habit of examining the name plate of every machine to which he has access and note the differences in size, construction, and use.

It has been previously said that electrical power is measured in watts (or kilowatts, "kw.," when large). In a direct-current circuit watts are the product of volts times amperes. With alternating current something else has to be taken into account, and to get the average power we must multiply the volts-times-amperes by the "power" factor." Power factor is, in fact, the number by which we must multiply volt-amperes to get true watts. It is commonly expressed in per cent. It can not be over 100 per cent and is usually less. It depends entirely on the sort of circuit that happens to be connected to the generator, since this as well as the generator itself controls the phase difference existing between volts and amperes. We might expect to find a.c. machines rated in watts or kilowatts, if we look at the name plate of a generator we are likely to find the letters "kva." (kilovolt-amperes). That is, instead of actual watts the permissible output is expressed as a product of amperes times volts divided by 1000. The reason is plain, if we remember that the whole question of what an electric machine will stand hinges altogether on the heating.

The heating of the field coils and armature core depends upon the voltage generated, because that is determined by the strength of the magnetic field, which in turn depends on the current in the field coils. The heating of the armature conductor is determined by the armature current; whether or not that is in phase with the emf. makes no difference. The total heating, then, depends on the volts and the amperes, regardless of the power output, which may be large or small, depending on the phase relation between the two.

Direct-current generators are usually rated in kilowatts and, as just stated, alternating-current generators in kilovolt-amperes. Motors, either d.c. or a.c., are often rated in units of horsepower (1 horsepower=746 watts). When an a.c. motor is rated in horsepower, a particular power factor is, of course, assumed.

Efficiency.—The ratio of the useful output of a device to its input, is called its "efficiency."

In all kinds of machinery it is impossible to avoid some losses of power, so the output is less than the input and the efficiency is less than 100 per cent. It is lower for small electrical machines than for large ones, and for a given machine it varies with the extent to which the machine is loaded. Certain losses go on regardless of the load; those are the mechanical losses, field excitation, and core losses. Others increase with the load; the armature copper loss rapidly, some additional core losses and a portion of the excitation loss more slowly. When the output is small, most of the power input is used up in the constant losses, and the efficiency is low. With very large outputs the variable losses become excessive, again lowering the efficiency. For some intermediate load, usually not far from the rated load given on the name plate, the efficiency is a maximum. At full load, and for the usual designs, it may range from 80 per cent for a 1-kw. generator to 95 per cent for a 1000-kw. generator.

Regulation.—Electric generators are, with few exceptions, intended to be operated at constant or nearly constant speed. Assuming that the speed is constant, and that the field excitation is also constant, the generated voltage would likewise be constant, regardless of the current output, if it were not for certain disturbing influences. A generator operating under these conditions is often called a "constant potential" or "constant voltage" machine.

The current output depends on what is going on in the external circuit. In a city it might depend on the number of lamps turned on. In the case of a generator supplying energy to a spark gap, it would depend largely on the adjustment of the gap. The term "load" is commonly used in this connection. Sometimes it means the devices themselves, which are connected to the line, and sometimes the current taken by them. There is generally no trouble in knowing which is meant.

Suppose we have a certain voltage generated when the load is zero. Then, if the machine is made to supply current to a circuit, the voltage at its terminals will in general be lowered and the greater the current, the more will the voltage be reduced. The term by which the behavior of a generator is described in this respect is called the "regulation." It is found by subtracting the voltage at full load from the voltage at no load, dividing by the full load voltage and multiplying by 100 to get the result in per cent.

Expressed as a formula—

$$\text{Regulation}=\left(\frac{V_o-V_f}{V_f}\right)\times 100 \text{ per cent.}$$

where V_o=voltage at no lead and

V_f=voltage at full load.

A small percentage regulation means that the voltage remains very nearly constant when the load is changed.

Armature Impedance and Armature Reaction.—There are two reasons why the voltage of a generator is lower when it is supplying current than when it is not supplying current, even if the speed is entirely steady and the direct current flowing around the field magnets is the same.

(a) The armature windings are bound to have some resistance and some reactance. It requires an emf. to send current through the armature, therefore. This emf., called the armature impedance drop, has to be subtracted from the emf. generated to get the emf. left to send current through the external circuit. The greater the current, the greater the armature impedance drop and the less the emf. left for the external circuit.

(b) The armature winding and core constitute an electromagnet. When current flows in the windings, the magnetic field caused by it is combined with the magnetic field due to field strength, with consequent decrease in armature voltage, since the resultant magnetic field is what determines the generated emf.

The change in the field flux by reason of the current flowing in the armature is called "armature reaction." Armature reaction occurs in direct current as well as in alternating current machines, and in motors as well as generators.

Effect of Power Factor on Regulation.—The reduction of terminal voltage due to the current flowing in the armature depends not only on the magnitude of the current but also on its phase relation to the emf., which is indicated by the power factor. A lagging current causes a greater reduction in terminal voltage than the same number of amperes in phase, the effect increasing with the lag. Thus, at 80 per cent power factor it may be twice as great as at 100 per cent. Conversely, a leading current, such as is taken by condensers, improves the regulation, so that the terminal voltage may actually be higher when current is flowing than when there is none.

Effect of Speed on Regulation.—Since the emf. is proportional to the rate of cutting of flux, it follows that fluctuations of speed are attended with proportional fluctuations of voltage, provided the field excitation is not changed at the same time.

Voltage Control.—The simplest way to control the voltage of a generator is by adjusting the strength of the magnetic field by means of the field current. For this purpose an adjustable resistance is inserted in the circuit of the latter, called a field rheostat.

One kind consists of a quantity of wire of an alloy having a comparatively high resistance, mounted on insulating supports in a perforated iron box with a slate face, or embedded in an insulating enamel. A handle is provided for making contact with any one of a number of brass studs attached to the resistance wire at various points, so that more or less of it can be in circuit. Terminals are provided for connecting the rheostat to the field circuit.

Small alternators for field use in radio telegraphy are often used without a field rheostat. The voltage is kept steady enough for practical purposes by driving the machine at the right speed

We are going to come back again to the subject of starting boxes, generators and motors, but for the time being kept the facts in mind that we have just covered.

MEASURING INSTRUMENTS

The electrician and Radio operator must know how to measure current with instruments just as a civil engineer learns to measure distance and the grocery man to measure his goods. We have water meters, gas meters, speedometers, and we also have electric meters for various purposes. Electric meters are in most cases used to tell us what is happening in an electric circuit. For instance, the Radio operator takes an occasional glance at the meters on his switchboard to see that everything is behaving properly. When there is something wrong his meters show it and he immediately hunts for the trouble.

Let us first consider the galvanometer. This is one of the most elementary measuring instruments. Every boy who fusses around with electricity makes a galvanometer. Long, long ago galvanometers were extensively used in measuring electricity, but today they are used only for very special purposes in indicating the resistance of extremely weak current. They are used for this purpose because of their extreme sensitivity. Some carefully made types are capable of measuring as little as one-millionth of an ampere.

A simple galvanometer is shown in Fig. 37. Here we see a coil of wire suspended between the poles of a permanent magnet. Those of us who are alert will say, "Why that is just like an electric motor." Quite true, a galvanometer is in a way an electric motor. If a very small current passes through the

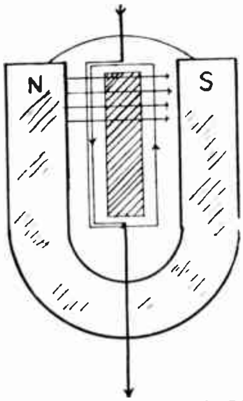


Fig. 37—Diagram of Simple Galvanometer.

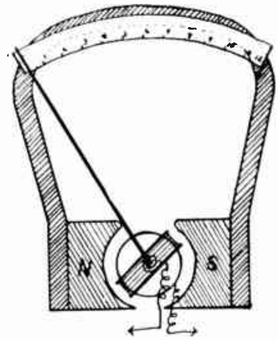


Fig. 38—Diagram of Voltmeter or Ammeter.

armature of the delicately suspended coil the coil will tend to move; a twisting force will be exerted upon it and this twisting force will depend upon the strength of the magnetic field produced by the magnets and the strength of the current flowing through the coil. If a pointer is fastened to a moving coil and used in connection with a calibrated scale the amount of current flow through that instrument can be measured. In expensive galvanometers agate bearings are used and precision workmanship is necessary to produce a refined instrument.

Figure 38 shows the schematic arrangement of a voltmeter or ammeter. The cautious student will at once recognize the similarity that exists between this type of instrument and the galvanometer. The operating principle is really the same. There is only a difference in design. The scale is carefully calibrated at the factory to read in volts or in amperes. Some instruments are combined volt and ammeters depending upon the manner in which they are connected to the circuit. And that, by the way, is important. The voltmeter measures the pressure of potential between two points of a circuit. **A voltmeter is never connected in series with a circuit.** Keep that in mind. It is always used in shunt to a circuit. A high resistance coil is placed in series with the coil of the voltmeter to keep the current flow at a low value.

An ammeter is connected in series with the circuit. It has a low resistance moving coil connected in shunt to a path of low resistance. Only a very small amount of current is necessary to actuate the instrument and for this reason a shunt is placed about the moving coil to carry the greater portion of the current.

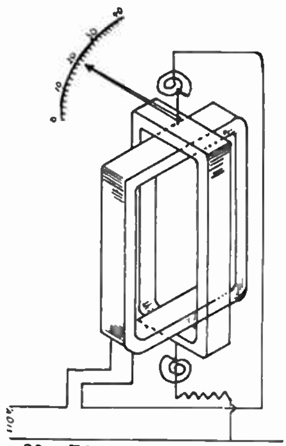


Fig. 39—Diagram of Wattmeter.

The wattmeter is used to measure the power flowing in a circuit. There is a wattmeter in every home equipped with electric current. If we have one in our home it is well that we climb up on a chair and look it over. In ordinary direct current work, the product of volts and amperes, or volts x amperes equals the watts. This is not true, however, in alternating current due to the fact that the amplitude of the current may lag behind the amplitude of the potential. "Ohm's law does not hold true for alternating currents then," you ask? That is a very sensible question and it shows thought. It is true that Ohm's law is changed when applied to alternating currents. However, we will not dwell upon this subject now since we are considering wattmeters. Every modern Radio transmitting set is provided with a wattmeter. One type of wattmeter is illustrated in Fig. 39. It consists of two coils, one of which is connected in series in the line, while the other is in series with the high resistance connected across the line. The wattmeter is really an ammeter and voltmeter combined. The voltage coil is arranged to be movable, while the current coil is stationary. Fig. 39 shows that the spiral spring is used on the voltmeter coil to keep the handle at zero when no power is being used. When current is flowing the magnetic fields set up in the two coils react on each other in such a manner that the movable coil tends to move into a parallel position with the stationary coil. The pointer on the voltage coil moves over a calibrated scale so as to measure either watts or kilowatts.

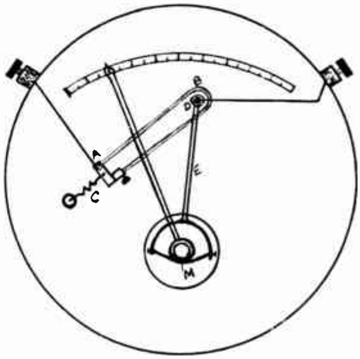


Fig. 40—Diagram of Hot Wire Ammeter.

There is an interesting story told about a stingy New York merchant who was told by an electrical inspector to keep the dust off the watthour meter, since it would interfere with its proper functioning. Thereupon, the crafty old man moved his ash barrel under the meter and sifted all his ashes there, hoping to see a difference on his electric light bill. Another story is told of a man who tore a meter apart looking for a blown fuse.

The hot wire ammeter is an instrument designed to utilize the heating effect caused by the current to be measured, when it passes through the wire. When we come across this term "hot wire ammeter" we must not make the wire too hot in our imagination. We are not referring to a red hot wire, but simply to a wire that has its temperature raised to an appreciable extent. Hot wire ammeters are usually employed in measuring the amount of energy flowing into a wireless aerial from the transmitting set. "Why cannot an ordinary ammeter be used," you suggest. Because the high frequency currents with their high voltage would cause an ordinary ammeter to function very inaccurately.

We all know that a wire will expand when it becomes hot. In fact it does not even need to become hot. When its temperature arises it expands although in some cases the expansion is too small to be noticed. This is the principle of the hot wire ammeter. Reference to Fig. 40 will show how the elements are arranged with the meter. We might say that the length of the wire increases in direct proportion to the amount of current flowing through it. Could anything be more simple than that? Of course, the scale used is calibrated to read in amperes or milliamperes. As shown in Fig. 40 the current flows on the wire from A to B. The spring at C produces a tension on the two wires extending over pulley D. If the current flows and expands the wire from A to B, the pulley D must rotate to make both branches the same length. This causes the arm E, attached to the pulley, to move to the left. Between the prongs of this arm a silk thread, which passed around the shaft M, is stretched. As the arm E moves, the silk thread must move the shaft carrying the pointer over the scale.

Other types of hot wire ammeters use a thermocouple as the essential element.

Thermoelectric Ammeter—The heat developed in the hot wire may be indicated by means of a thermocouple, placed very near or in contact with the wire. The electromotive force produced by the heating of the thermocouple is measured by a suitable direct-current instrument. The indications depend upon the temperature at one point only of the hot wire instead of upon the heating effect throughout the whole wire as in the expansion ammeter.

A diagram of the simple type is shown in Fig. 40-A. The fine wire marked Hot wire carries the high frequency current. The copper-constantan thermocouple is hard soldered to it and connected to the binding posts and thence to a galvanometer. Such an instrument is easily constructed for laboratory use for currents up to 2 amperes. Commercial instruments are made by combining the hot wire, thermocouple, and a pointer-type microammeter into a single instrument.

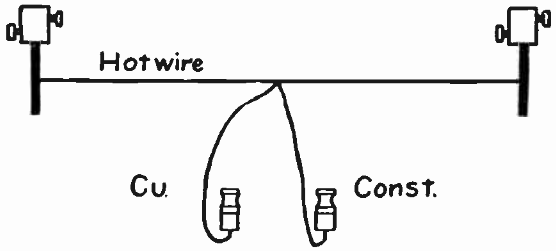


Fig. 40-a—Simple Hot Wire Ammeter with Thermoelectric Indicating Device

Frequency meters are used to indicate the frequency of an alternating current. In one common type a number of reeds, having various vibrating frequencies, are arranged in such a manner that an alternating current flowing through it will cause the reed having a corresponding frequency to vibrate. The frequency of the current flowing in the circuit is indicated on the dial.

In our next lesson we will come back to the subject of motor generators. You are going to like this lesson because the facts are given in such a simple, fascinating way. After all, there is nothing difficult about radio. Have you found it so? Up to the present time it has just been a matter of reading and learning, and all the lessons that stand before you are just as easy.

QUESTIONS

LESSON TEXT No. 4

We suggest that you study this lesson over twice before attempting to answer the following questions. Send your answers to the Institute for grading.

61. Explain by aid of a drawing the essential parts of a transformer.

62. What are laminated cores and why are they used?

63. Draw the following types of transformers, open core, closed core, auto and air core.

64. Name a few transformers used for different classes of service in radio.

65. State the difference in ratio values (secondary turns and primary turns) between radio and audio frequency transformers.

66. Describe the transformer as shown in Fig. 30-S, page 7, specifying type, class and service.

67. Name the principal parts of a dynamo.

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

69. Describe the type of brushes used on dynamos.

70. Give diagrams of three types of dynamos.

71. What is the principle of the electric motor?

72. What is the advantage of a compound wound motor or generator?

73. What is the cause of the back or counter e. m. f. of a motor and dynamo?

74. How is the speed of a motor controlled?

75. Explain the use of a starting box. Draw one.

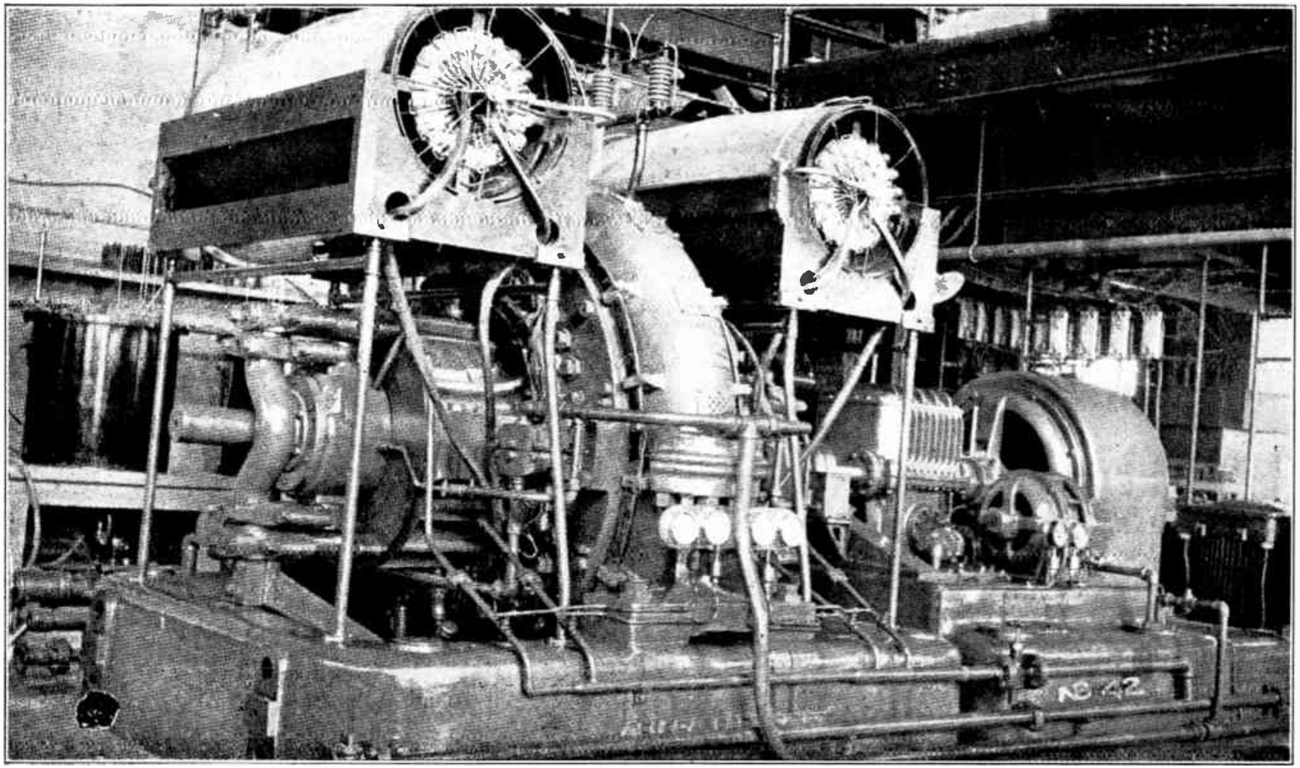
76. Why is the voltmeter connected across the circuit rather than in series?

77. What is a wattmeter?

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

79. Give the operating principles of the thermocouple ammeter.

80. What is a frequency meter?



By Courtesy of Proceedings I. R. E.

200 K. W. Alexanderson High Frequency Generator.

LESON TEXT NO. 5

OF A

Complete Course in Radio Telegraphy and Telephony

The Motor Generator

TENTH EDITION

NATIONAL RADIO INSTITUTE, Inc.

Established 1914
WASHINGTON, D. C.

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THE MOTOR GENERATOR

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

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

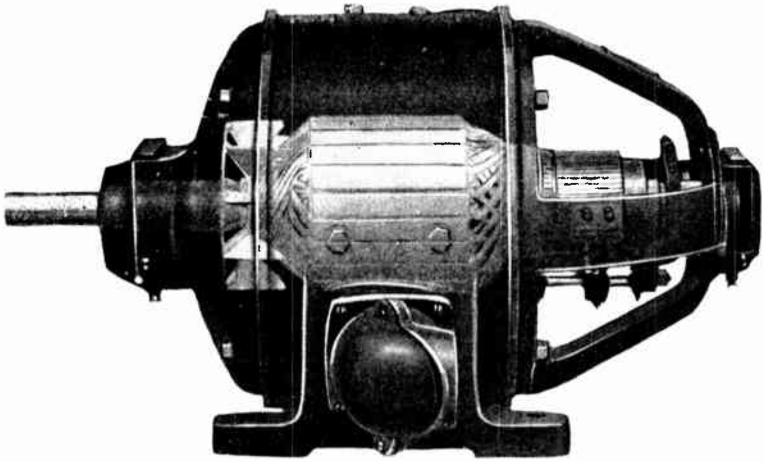


Fig. 40—Mechanical Arrangement and Construction of a Modern D. C. Motor or Generator. (Frame is Shown Transparent)

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

The generator has from four to thirty field poles, depending upon the frequency desired and has an armature speed of 1,800 to 2,400 revolutions per minute.

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

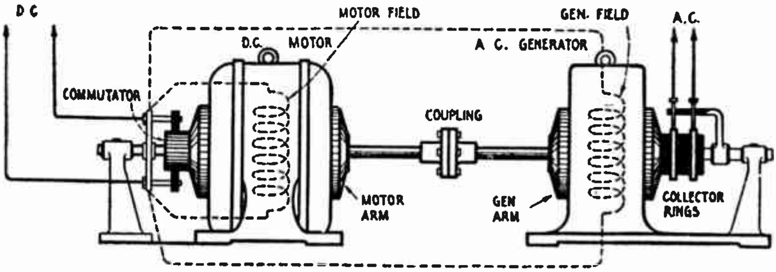


Fig. 41—Showing general construction of a motor generator (with inside bearings removed for clearness). The motor is supplied with direct current and the generator armature delivers alternating current at frequencies varying from 60 to 500 cycles and at voltages varying from 110 to 500 volts according to design. The terminals of the generator field winding are shunted across the D. C. power mains with a field rheostat (not shown) connected in series for regulating the A. C. Voltage. A motor starter and field rheostat is required for the motor.

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

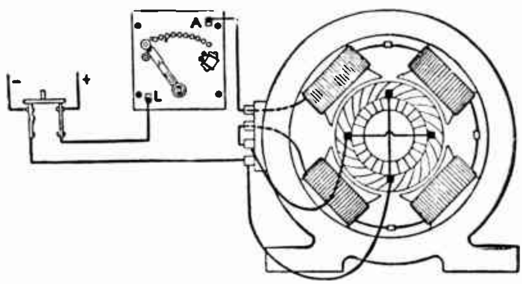


Fig. 41-B—Series Motor

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

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

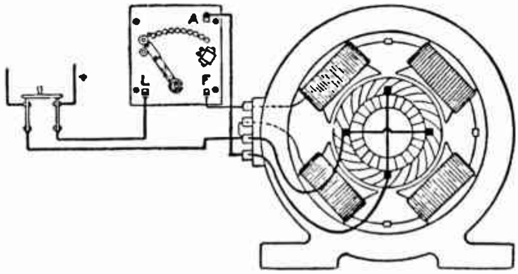


Fig. 41-C—Shunt Motor

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

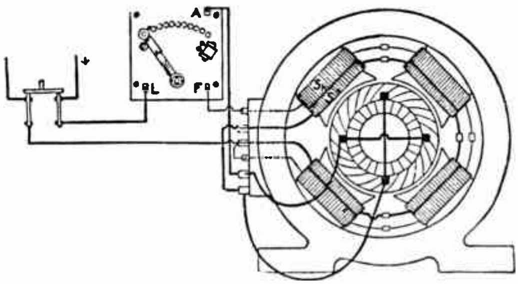


Fig. 41-D—Differential Compound Motor

Type four is known as differential compound motor, and is a combination of the series and shunt wound fields on the pole pieces of the motor, but in this type the series field acts in the opposite direction from that of the shunt and thus has a tendency to weaken the pole pieces as the load increases. This type of motor maintains a constant speed, and is used in all cases where a close regulation of the speed is a necessity for the work of the machinery, as, for example, in driving a weaving machine; or we might better say for a radio generator, where the frequency must be maintained at 500 cycles.

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

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

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

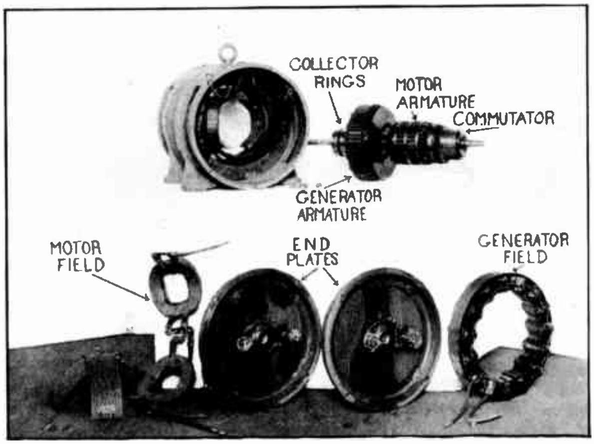


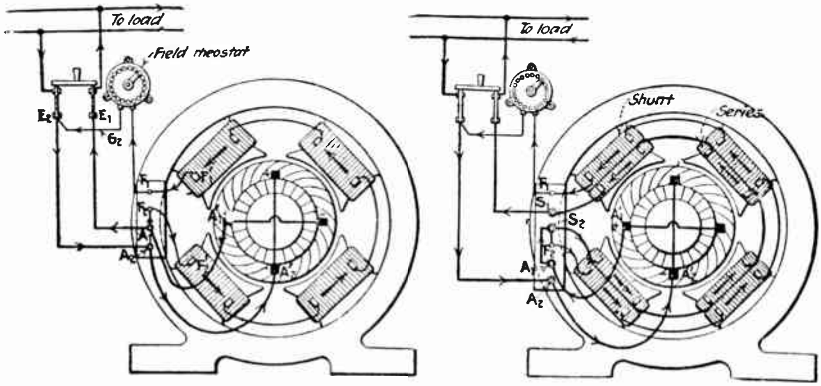
Fig. 41-E—Exploded View of a Two-Kilowatt Five Hundred Cycle Motor Generator, Having Revolving Armature

(Courtesy of Crocker-Wheeler Company, Ampere, New Jersey.)

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

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

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



Shunt Generator Compound Generator

Fig. 41-F

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

The armature is stationary and consists of a number of coils arranged about the inner surface of the frame as shown in Fig. 42. These coils are built on iron cores and are arranged in two circular rows. Between these two rows a circular field coil of the same diameter as the armature coils is placed and has precisely the same action as a solenoid winding, producing a field parallel with the shaft. The number of stationary armature coils depends upon the frequency desired, and are equal in number to the teeth protruding from the revolving core, as shown in Fig. 12.

At one instant, the teeth of the core are opposite the stationary armature poles and the lines of force from the field coil pass through the armature cores on one end of the frame through the rotating core and back into the armature cores at

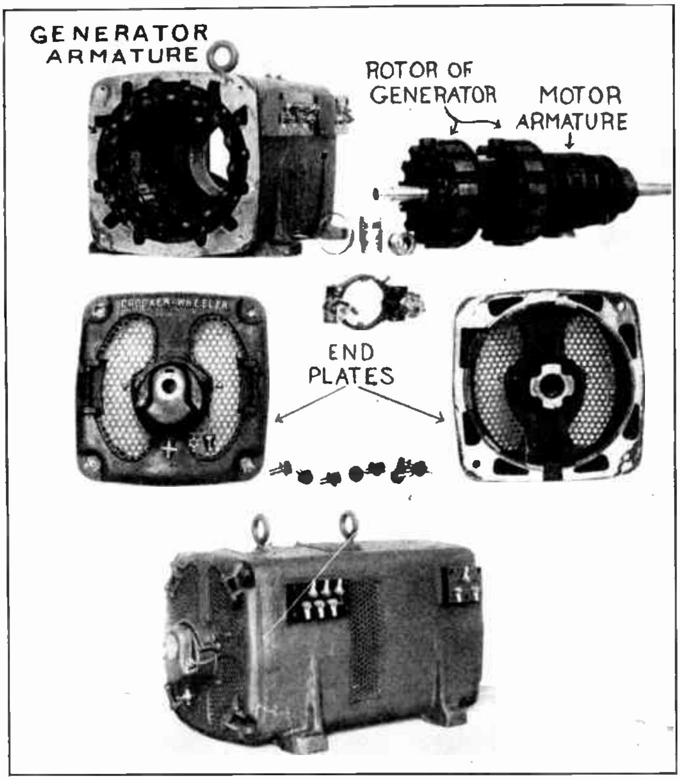


Fig. 42—Exploded and Assembled Views of a Two-Kilowatt Five Hundred Cycle Motor Generator of the Inductor Type
(Courtesy of Crocker-Wheeler Company, Ampere, New Jersey.)

the other end of the frame. An instant later, the core teeth are opposite the open space between the armature coils and therefore the lines of force have a more difficult path from the stationary field coil through the revolving core. In other words, owing to the high permeability of the revolving teeth, the number of lines of forces are increased in number at the time the teeth are opposite the armature coils, and when the teeth are opposite the open spaces between the armature coils, the number of lines of force are greatly reduced, due to the lower permeability of air. This increase and decrease of the strength of the field threading through the armature coils induces an alternating current in them. A machine of the type shown in Fig. 42 produces a 500 cycle current (outside view of Fig. 18-B).

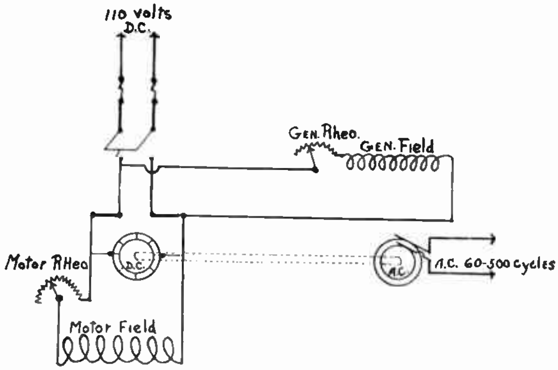


Fig. 43—Simple Shunt Wound Motor Generator

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

(1) Shunt wound motor and simple alternator.

(2) Shunt wound motor and accumulately compounded alternator.

(3) Differentially compounded motor and simple alternator.

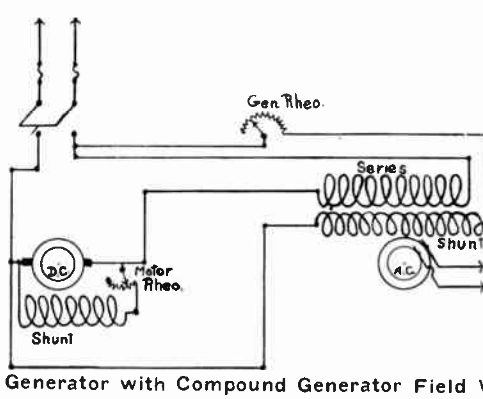


Fig. 44—Motor Generator with Compound Generator Field Windings

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

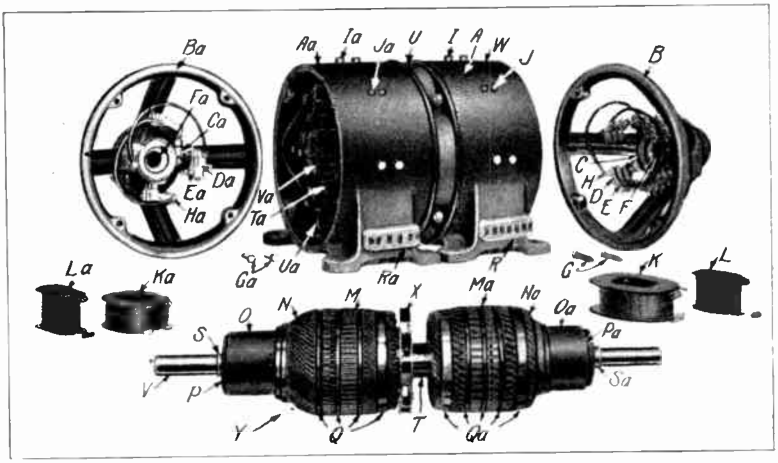


Fig. 45-A—Parts of Motor Generator Set

Generator Parts

A Magnet frame
B End shield
C Brush yoke
D Brush-holder
E Brushes
F Bearing lining
G End shield bolts
H Brush-holder stud
I Main pole bolts
J Commutating pole bolts
K Main field spool
L Commutating field spool
M Armature core
N armature winding
O Commutator
P Commutator segments
Q Armature bands
R Terminal board
S Thrust collar.
T Intermediate sleeve and armature head
U Intermediate ring
V Shaft
W Name plate
X Ventilating fan

Motor Parts

Y Armature complete.
Aa Magnet frame
Ba End shield
Ca Brush yoke
Da Brush-holder
Ea Brushes
Fa Bearing lining
Ga End shield bolts
Ha Brush-holder stud
Ia Main pole bolts
Ja Commutating pole bolts
Ka Main field spool
La Commutatng field spool
Ma Armature core
Na Armature winding
Oa Commutator
Pa Commutator segments
Qa Armature bands
Ra Terminal board
Sa Thrust collar
Ta Commutating pole
Ua Connecting cables
Va Main pole

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

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

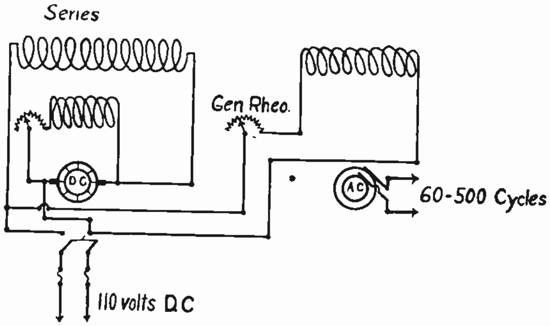


Fig. 45—Circuits of Motor Generator with Differential Field Winding

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

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

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

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

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

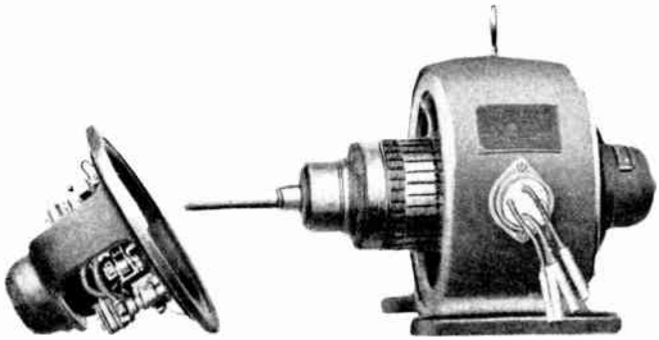


Fig. 46—Showing Method of Removing Armature of D. C. Motor or Generator

The Motor Starter—The function of the motor starter is to prevent a heavy flow of current through the low resistance armature windings of the motor while starting.

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

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

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

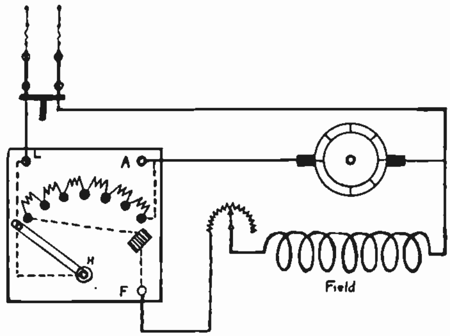


Fig. 47—Cutler Hammer Hand Starter and Connections

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

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

There are various types of motor starters on the market. The two principal divisions are:

(1) The Hand Starter.

(2) The Automatic Starter.

Fig. 47-A—Cutler Hammer Hand Motor Starting Box

The Cutler Hammer hand starter is shown in Figs. 47 and 47-A. It consists of several coils of resistance wire, a handle, contact studs and a small electro magnet. The terminals of the resistance coils are soldered to the studs on the back of the panel. As the handle passes over the contacts on the face of the panel, connection is made to the coils. When the handle is on the first contact, all the resistance wire is in series with the armature and the current flow is a minimum, but as the handle moves over each successive contact, the corresponding resistance coil is removed from the circuit. The small magnet holds the handle in the running position. In case the current in the line fails for any reason, this magnet being in series with the field winding, will lose its power and allow the handle to go back to the off position. This release of the handle, when the current ceases to flow, protects the armature from possible damage in case the current should be again turned on. Usually 15 seconds is sufficient time to start most motors and should not be greater than this because of the danger of burning out the resistance wire.

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

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

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

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

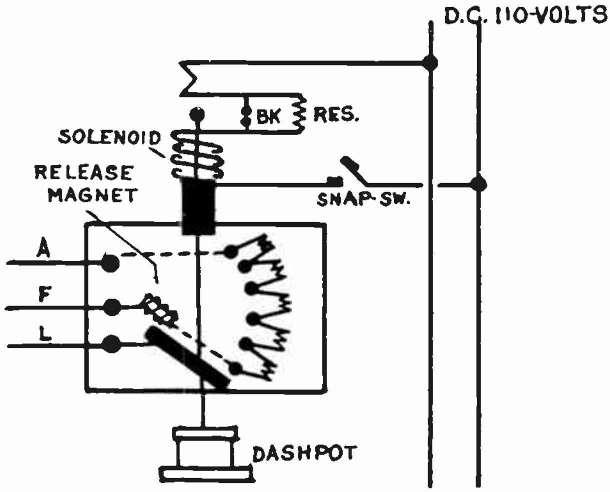


Fig. 48—Cutler Hammer Automatic Motor Starter

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

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

In Fig. 48 is shown a simple type of automatic starter used on spark transmitting sets. A solenoid is arranged so as to cause an arm to move upward and cut out the resistance coils. This motion is gradual and serves the same purpose as pulling the handle of the ordinary starter over by hand. To prevent the solenoid from pulling the arm up too quickly, an oil cup called a dash pot is used. A rod attached to the starter arm is fastened to the piston of a small cylinder. As the starter arm moves up, the piston moves also and tends to force the oil from the top end of the cylinder to the bottom, but due to a small hole in the piston the arm is allowed to move slowly upward. The cylinder is called a dash pot and in some cases is filled with air instead of oil.

Circuits of a Simple Automatic Starter and Motor Generator

The two vertical lines coming down at left side of Fig. 48-A then turning at right angles at the bottom are the main supply leads from the ship generator or emergency battery and supplies current, first to solenoid of the automatic starter through the snap switch, second to the main leads of the motor which extend upward near the center of the base of the diagram, and third they supply D. C. to the field of the A. C. generator through the switch SW.

Operating instructions for starting this set, and the description of the parts will now be given: first the snap SW (upper left-hand corner) is closed allowing current to flow through the solenoid up and across the contacts BK (which are together). The current in the solenoid exerts a upward pull on the rheostat arm which moves it across the contact points cutting out the resistance units gradually until it reaches its top position when full voltage is placed on the motor armature. When the rheo-

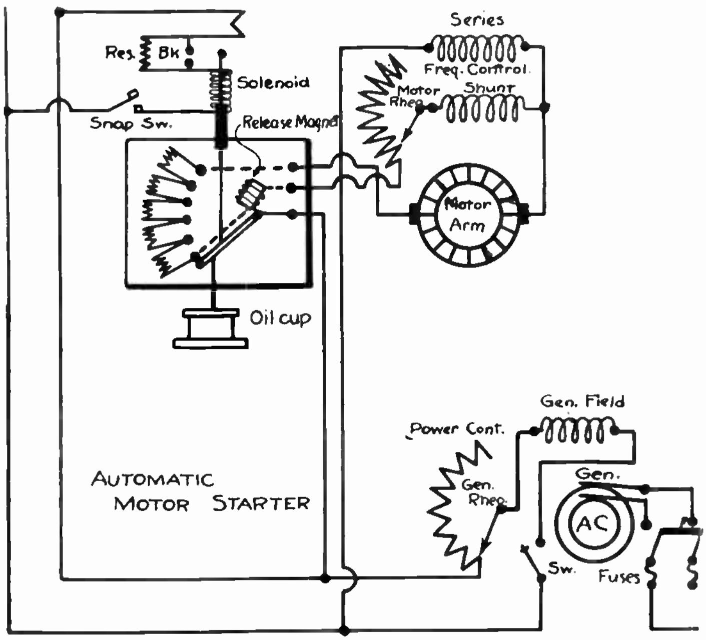


Fig. 48-A—Simple Circuit Diagram of Automatic Starter and Motor Generator

stat arm reaches the top position it opens the contact points BK and introduces the resistance (Res) into the solenoid circuit, thus reducing the current to smaller value which is sufficient to hold the arm in its upper position.

Figure 48 shows a diagram of the automatic starter by itself. A is the wire to the motor armature, F to the shunt field and L to main line or source of supply.

Now we will turn our attention again to Fig. 48-A and consider the operation of the compound wound motor. The motor field rheostat should have all of its field resistance cut out of the circuit on starting. This will allow the shunt field to have maximum strength and, therefore, exert maximum torque on starting the set. The student will notice that when the automatic starter handle moves upward slightly so as to make contact with the first point on the starter, both the shunt field and the armature circuits are closed and, therefore, current will flow through each.

The path of the shunt field is as follows: From the top wire of the main line source (just below the words "automatic motor starter" in the lower left-hand corner) up to the lower connector of the automatic starter through the handle, then on through the release magnet with the metal connector of the starter through the rheostat shunt field winding and then back through the series field to the lower wire of the main line lead.

The armature circuit starts with the same main line wire passing through the armature rheostat and up through the five sections of resistance with the top connector of the automatic starter through the armature and up through the series field and back to the other side of the main line. As the arm moves upward the five sections of resistance are gradually cut out of the armature circuit, increasing the speed of the motor with the smootth acceleration until it has reached the full speed and full line voltage is impressed upon the armature circuit.

Now that the complete operation of starting the motor is over we will turn our attention to the A. C. generator, which is usually 110 or 220 volts and 500 cycles. First, we should see that the volt meter and the frequency meter are attached to the A. C. armature circuit and then the field switch SW should be closed and the reading of the frequency meter noticed. If the frequency is below 500 cycles then it may be increased to the right point by increasing the speed of the motor by adding resistance in the motor rheostat of the shunt field.

When the frequency of the A. C. generator has been adjusted to the proper point, then the voltage of the generator should be brought up to the proper value—110 or 220, according to the type of machine—by means of the rheostat in the generator shunt field. The apparatus is now ready for transmitting and as soon as the generator main switch in the lower right-hand corner is closed the operator may begin transmitting.

A student should study these instructions in order to make sure that he is fully informed of each operation and the order in which each should be made.

In the diagram of Fig. 45 the complete circuit of a differentially wound motor coupled to a simple alternating current generator is shown, including the connection of the field rheostats. The student should give this diagram careful consideration as it serves to show the complete fundamental circuit of various types of motor generators in commercial service. This diagram should be used in answer to the Government examination query regarding the fundamental circuits of the motor generator.

In modern commercial generators the student will have little difficulty in making the necessary reconnections should it become necessary to disassemble the set. All binding posts are stamped with numbers and all connecting leads have a stamp on the terminal lug. If lug No. 8, for instance, is connected to binding post No. 8, and so on, proper wiring is assured.

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

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

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

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

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

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

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

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

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

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

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

The commercial 240 cycle type of motor generator is designed to have an armature speed of 2,400 revolutions per minute or 40 revolutions per second.

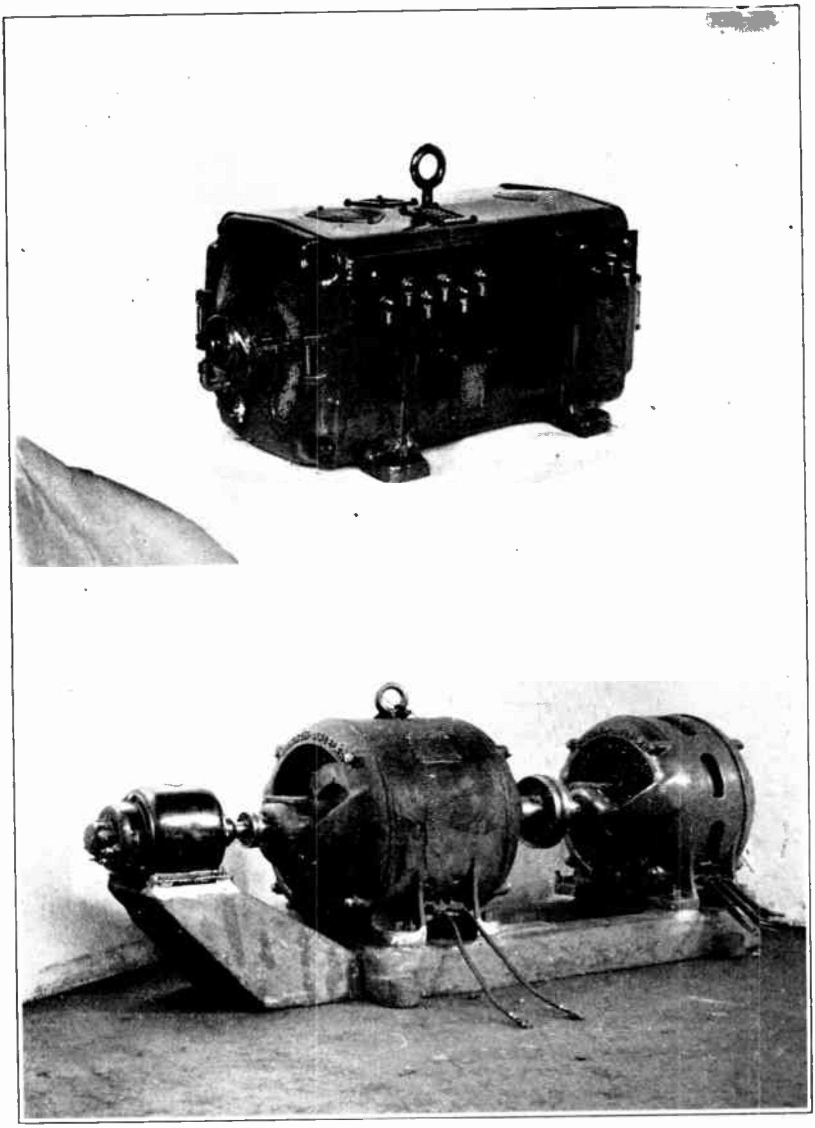


Fig. 48-B—Top outside view of 500-Cycle Inductor Type Alternator.
Bottom—5 K. W., 500 Cycles Motor Generator Set with an Exciter mounted on a pedestal at the left-hand end.
(Courtesy of Crocker-Wheeler Company, Ampere, New Jersey).

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

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

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

$$2 \times 240 = 480 \qquad 40\,n \div 480$$

$$N = 12 \text{ Field Poles.}$$

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

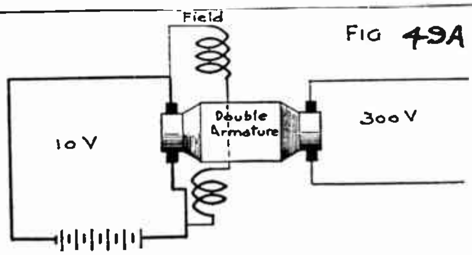
The field rheostat is merely a variable resistance wire wrapped on a rectangular piece of slate and a slider arranged so as to make contact with the different turns. When connected in series with the field windings one terminal of the field coil makes connection with the slider and one end of the coil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

Rotary Converters—If connections are made to a pair of collector rings from opposite sides of a two-pole D. C. armature, it will generate alternating current. At the same time, direct current can be taken from the commutator. In that case the machine is a "double current generator." If not driven by an engine, but connected to a D. C. circuit, it operates as a shunt motor and can be used to generate A. C. Operated on A. C. as a motor, it delivers D. C. When used for such conversion, it is called a rotary converter. When an A. C. generator is used as a motor (not an induction motor) it requires D. C. for field excitation and operates at the exact speed (called "synchonous" speed), corresponding to the frequency of the supply. The D. C. for the rotary converter field comes from the commutator. On the other hand, when such a converter is used to generate A. C., the frequency depends on the speed of rotation of the armature, which can be controlled as previously described for the shunt motor.

The rotary converter has the advantage of accomplishing in a single machine what the motor-generator does in two. Its disadvantage is that the voltage at the generator end depends entirely on the voltage supplied to it as a motor, the A. C. voltage in the case of a single phase converter being about 71 per cent of the D. C. voltage, slightly more or less, depending on the direction of the conversion. Thus, if operated on a 10-volt storage battery, it would give about 7 volt A. C. Also, frequencies anything like 500 cycles, which it is desirable to get in radio communication from D. C. with storage batteries as a source, are impossible; either the speed or the number of commutator segments would have to be increased beyond reason.

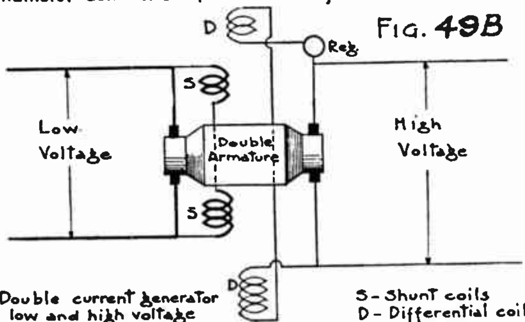
Instead of single phase, rotary converters can be built for two-phase or three-phase currents, the former by four connections equally spaced on the armature and four rings, the latter by three connections and three collector rings. The statements made for bipolar machines are equally true for multipolar rotary converters, if it is understood that each ring has as many connections to the armature as there are pairs of poles.

FIG 49A



Dynamotor connections for conversion from 10 to 300 Volts

FIG. 49B



Double current generator for low and high voltage

S - Shunt coils
D - Differential coils
Reg. - Automatic regulator

Dynamotors—Rotary converters cannot be used for changing direct current at one voltage to D. C. at another voltage. The most compact machine for that purpose is the "dynamotor."

An application which will occur to the radio student is the securing of several hundred volts for the plate potential of vacuum transmitting tubes from batteries giving only 10 or 12 volts. (See Fig. 49-A). In the dynamotor two seperate armature windings are placed on a common core. One acts as a motor, the other as a generator. There is but one frame and one set of field magnets. The two windings are connected to commutators at opposite ends of the shaft. The ratio of voltages is fixed when the machine is built, so the output voltage depends on the voltage applied. The field coils receive current from the same source as the motor armature.

Double Current Generators—A dynamotor can be driven by mechanical power as a generator, and can then deliver D. C. at two different voltages. Such machines have been designed for fan drive on airplanes, the low and high voltages being used for the filament and plate currents, respectively, of vacuum tube transmitters.

To get constant voltages, in spite of the varying speed at which the armature is driven, the field flux must be weakened as the speed rises. Current taken from one commutator is sent around the field coils, supplying the main magnetization. A weaker current from the other commutator is sent around the opposite way, giving a differential effect. (See Fig. 49-B). If the speed rises, and consequently the voltage, the current in the second winding is made to increase considerably by a sensitive automatic regulator. The flux is therefore reduced, counteracting the effect of the rise in speed.

GENERATORS FOR TUBE TRANSMITTERS

The use of tube transmitters into modern radio transmission demands two sources of current, one of low voltage, 8 to 16 either A. C. or D. C. in order to light the filament of the tubes and a high voltage direct current ranging from 350 to 2,000 for supplying the plate voltage from which the tube gets its real power for wave transmission.

A few of these machines for supplying these two different sources of current will be illustrated in this book. A full detailed description of tube transmitters and also the auxiliary apparatus for supplying the power will be taken up in one of the later books.

Protective Devices—Whenever a radio set is in operation, high frequency, high voltage currents, flow in certain circuits.

On account of the high voltage circuits being parallel at certain points to the motor generator circuits, dangerous voltages may be induced in the latter. The insulation of the motor generator windings is not designed to carry currents of high voltage and frequency and thus there is constant danger of breakdown unless protective measures are taken.

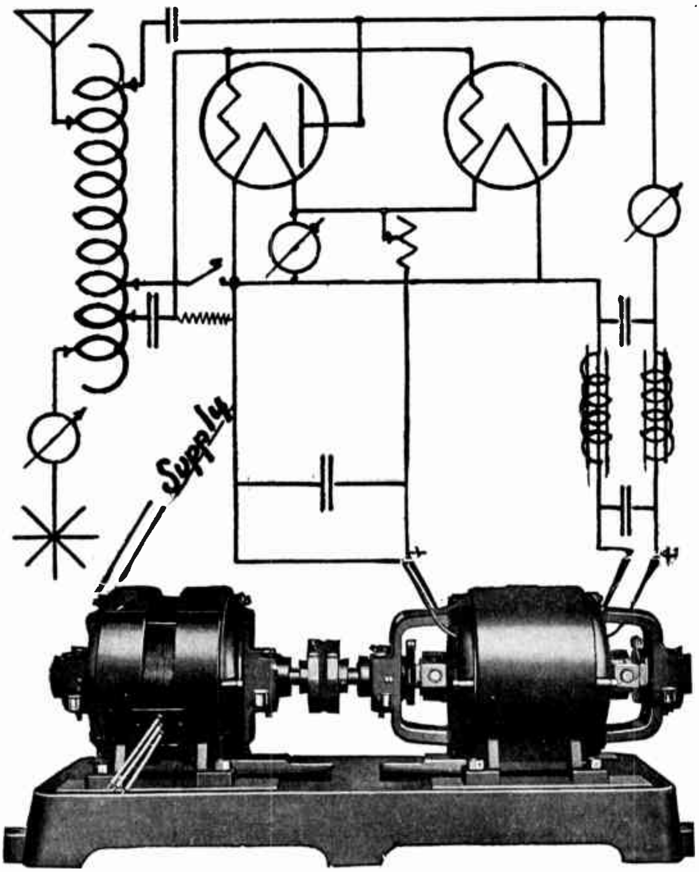


Fig. 50—Motor-Generator Set, built by the Electric Specialty Company, for supplying both filament and plate power for tube transmitters.
Courtesy Electric Specialty Company.

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

An important device for the protection of the set consists of two one-half microfarad condensers connected in series and is called a protective condenser. The middle connection of the two condensers is connected to earth and the two remaining terminals are connected either (1) across the armature of the

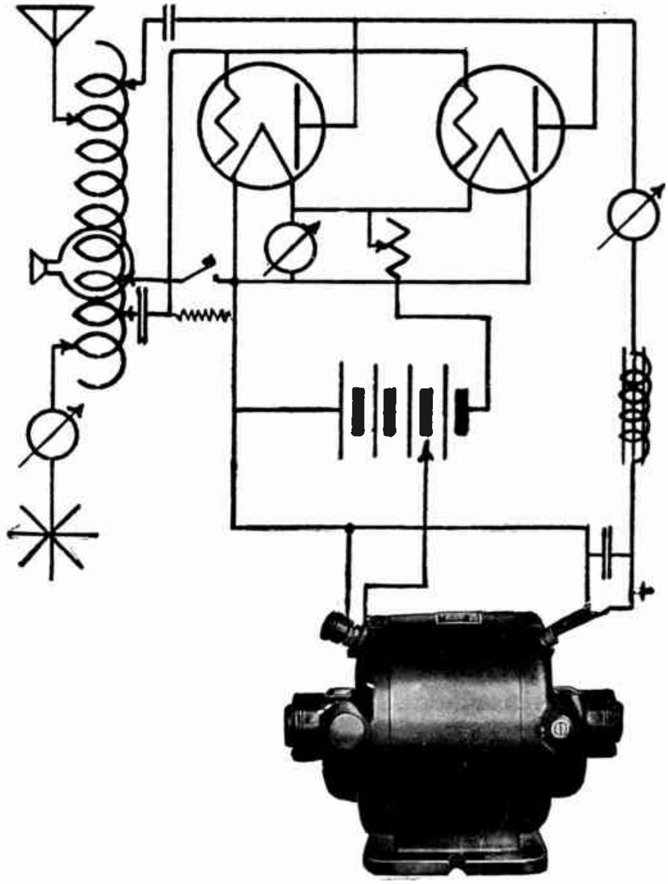


Fig. 50-A—Dynamotor, built by the Electric Specialty Company, for supplying 8 to 10 volts for lighting the filament and 350 volts for main power supply for tube transmitters. This machine operates on 110 or 220 volts direct current.

Courtesy Electric Specialty Company.

motor, (2) across the armature of the generator, (3) across the field and frame of motor, (4) or across the field and frame of generator. This device, shown in Fig. 51, will allow high frequency, high voltage currents to flow through it to the earth, but will not allow the low voltage, low frequency currents to pass. Fuses may be connected in series with the condensers to protect the motor generator in case of a short circuit of a condenser. In case of such short circuit the low voltage current of the motor generator will in passing through the protective condenser, blow the fuse and prevent breakdown of the set.

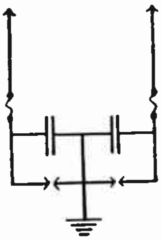


Fig. 51—Protective Condensers

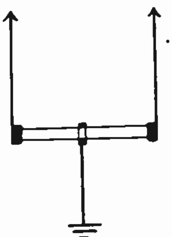


Fig. 51-A—Protective Resistance Rod

Another device shown in Fig. 51-A that serves the same purpose as the protective condenser is the protective resistance rod. It consists of a graphite rod of about 6,000 ohms resistance, having its middle point connected to the ground, and the two end terminals connected to the same points as given above for the protective condenser. The graphite rod will conduct the high voltage, high frequency currents to the ground, but due to its high resistance it will not conduct the low voltage currents flowing in the motor generator.

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

1. Brushes bearing unevenly on the commutator.
2. Grooved commutator.
3. Raised insulating wedges.
4. Brushes not being in neutral field.
5. Open circuit in armature.

6. Dirty brushes or commutator.

7. A partially short circuited field coil.

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

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

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

2. Keep all connections tight.

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

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

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

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

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

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

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

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

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

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

QUESTIONS

LESSON TEXT No. 5

Answer the following questions and submit them to this Institute for grading. A careful comparison of your answers with the model answers we furnish will help you decidedly.

81. What is a motor generator?

82. Why is a motor generator required aboard ship?

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

84. What is an inductor alternator?

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

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

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

88. What is a dynamotor?

89. What is a rotary converter?

90. Explain briefly the action of the hand motor starter.

91. Give a diagram of the Cutler Hammer Automatic Motor Starter.

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

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

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

95. How many poles would be necessary for a generator delivering 120 cycles at 2,400 revolutions per minute?

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

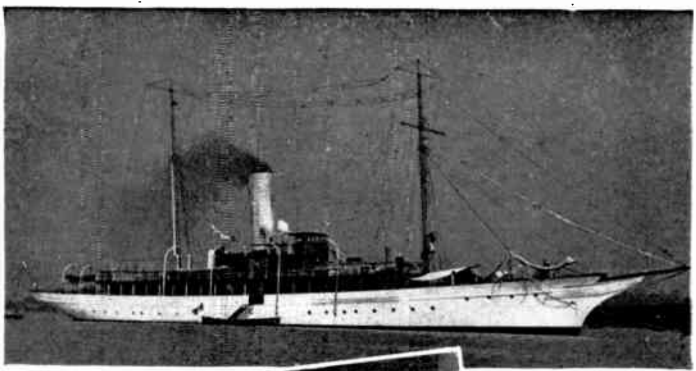
97. Why is it necessary to use protective devices on the motor generator?

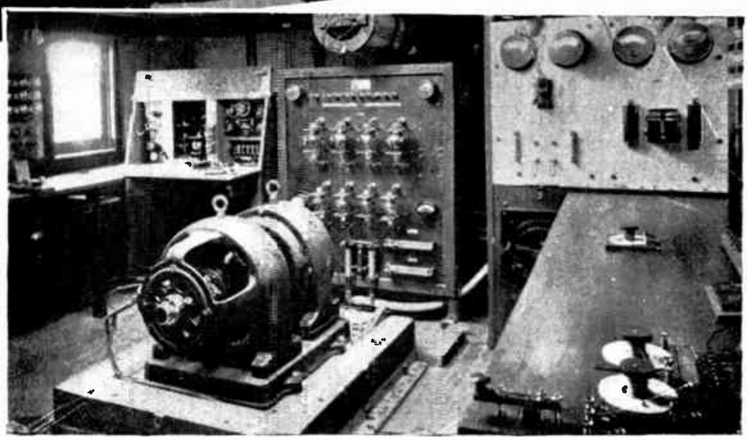
98. Draw a diagram and describe the protective condenser.

99. Name five causes of a sparking commutator.

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

MARCONI'S YACHT "THE ELECTRA"





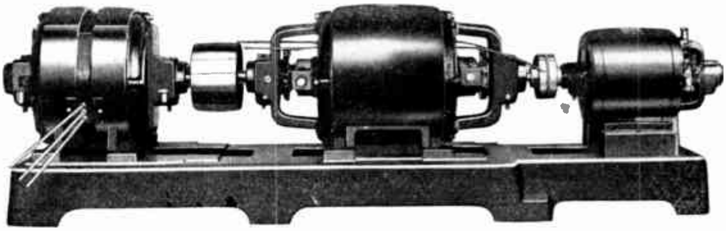
Courtesty of Radio News.

These striking photographs show three views of the "Electra." The upper photograph is that of the yacht, where may be seen the unique Hoop Type Aerials. The photograph in the center shows one of Mr. Marconi's Expert Operators seated at the new Radiophone Instruments, which have a range of 500 miles durng daylight. Bottom—Another section of the Operating Room. Here may be seen the motor generator unit, which is mounted on cork padding in order to eliminate vibration and noise. The eight high-power transmitter vacuum tubes employed in the Duplex Radiophone System are also shown.

HIGH VOLTAGE MACHINES FOR TUBE TRANSMITTERS

DYNAMOTOR

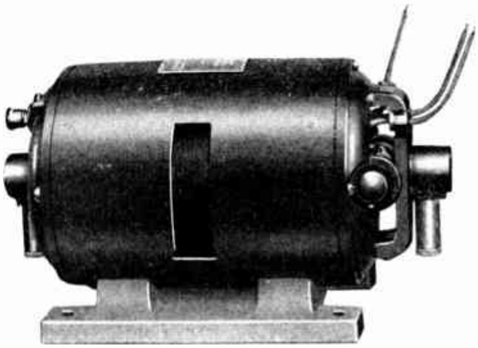
GENERATOR



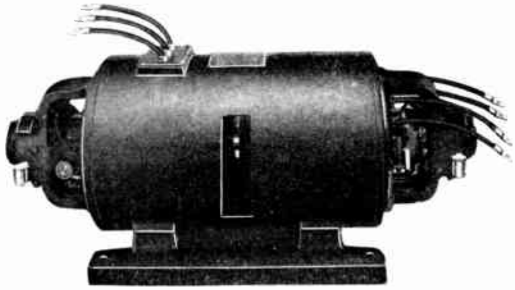
THREE UNIT SET

HIGH VOLTAGE

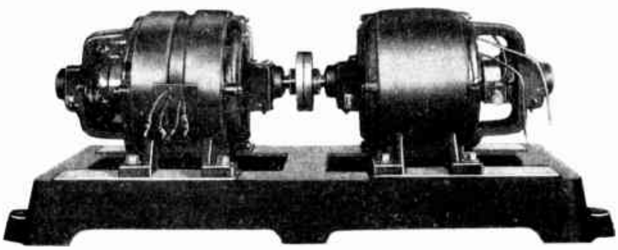
GENERATORS, MOTOR-GENERATORS AND DYNAMOTORS



TWO BEARING WICK-OILED SET



TWO BEARING RING-OILED SET



FOUR BEARING RING-OILED SET