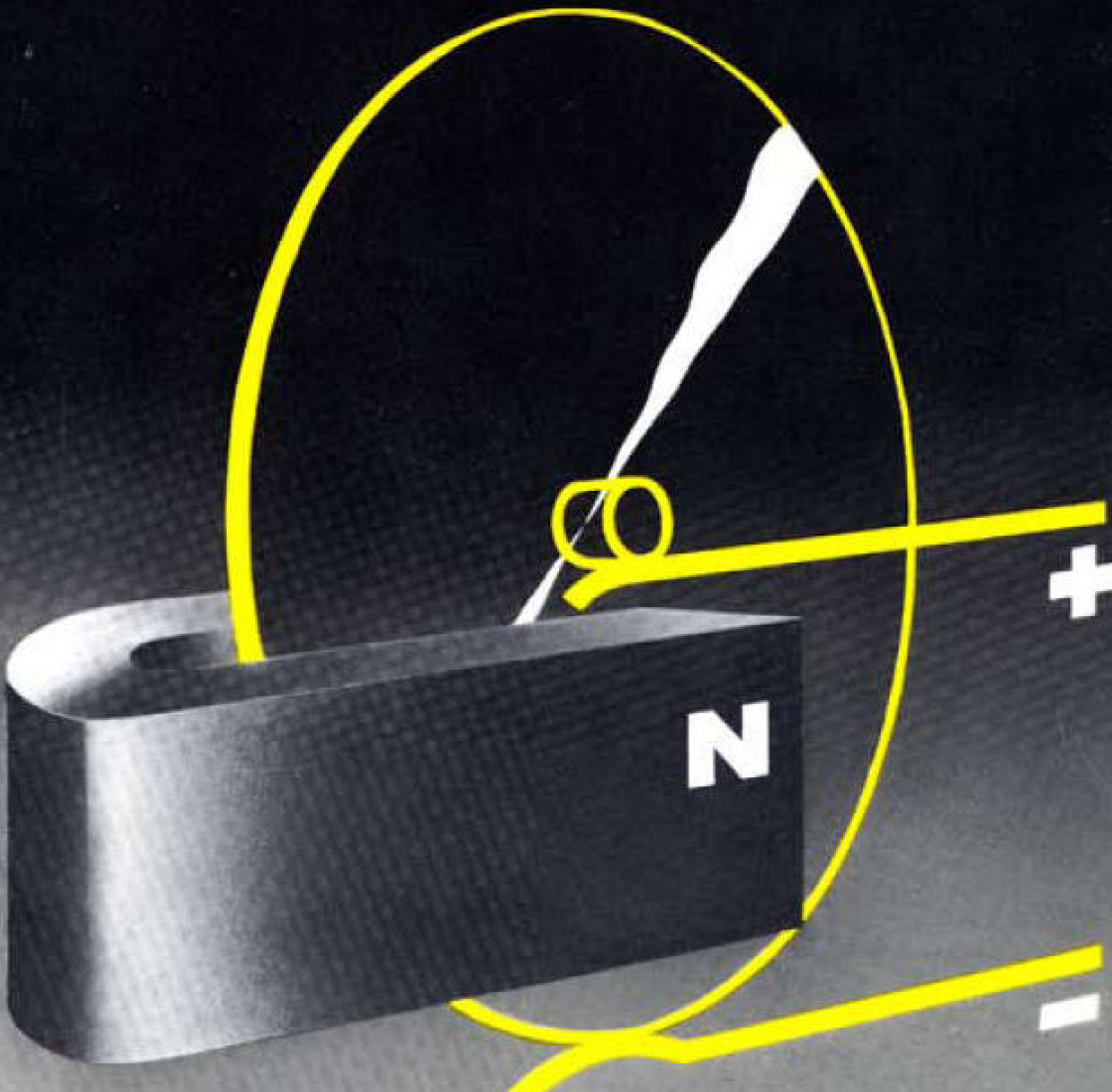
ELECTRICITY

AND WHEELS



HISTORIC DATES IN
"ELECTRICITY AND WHEELS"

2637 B.C.	Hoang-ti uses magnetic chariot.
640-546	Thales mentions attraction of charged amber.
1269 A.D.	Peregrinus discovers like magnetic poles repel and unlike poles attract.
1492	Columbus shows declination of compass varies in different parts of world.
1600	Gilbert writes six volumes on electricity and magnetism.
1660	Von Guericke builds first generator for static electricity.
1729	Grey shows materials are conductors and non-conductors.
1733	duFay proposes two fluid theory of electricity.
1742	Gordon builds first crude motor run by static electricity.
1747	Franklin proposes theory of positive and negative electricity.
1791	Galvani discovers electric current.
1796	Volta makes first battery.
1820	Oersted obtains magnetism from electricity.
1820	Ampere contributes to information on electro-magnetism.
1820	Arago makes electro-magnet.
1831	Faraday and Henry discover electric induction.
1840	Morse invents the telegraph.
1875	Bell invents the telephone.
1879	Edison invents the electric light.
1895	Roentgen discovers X-rays.
1897	J. J. Thomson discovers the electron.

ELECTRICITY AND WHEELS

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The History of Science is

the real History of Mankind.

Du Bois Raymond

ELECTRICITY AND WHEELS

This is the electrical age. Electricity is a cheap, easily transported form of power. It can be used in small amounts to run a razor, light our house, bring us music and world events over the air, or connect us by telephone with our friends. It can be used in large amounts to run the motors in our factories, produce metals from ore, power streamlined trains and for hundreds of other industrial applications.

The steam engine brought large amounts of power to the factory but it was not possible to transport it over any great distance. Belts and shafts were satisfactory for short distances in one or two buildings, but a more flexible means of transmitting power in any quantity to factories, homes, offices, and to isolated locations was needed. Faster means of communication were necessary for business and pleasure. Electric power was the answer. Strands of copper will carry an abundance of power for several hundred miles to the exact spot it is needed. Electricity will carry the written or spoken word over great distances almost instantaneously, either with or without a connecting wire.

The electrical industry has made the automobile possible. No one would have thought when Faraday discovered mutual induction, that he was making possible the ignition coil which fires an average automobile engine over 12,000 times per mile. Or that when he pulled a magnet through a coil of wire and produced an electric current, he was discovering the basic facts underlying the generator and self-starter.

Automobiles are so much an integral part of our mode of living that we seldom think of the mechanism under the hood. The growth of the automobile from an unreliable, expensive horseless carriage to the swift, comfortable, economical motor car is the result of the application of the discoveries of research and engineering. Thousands of individuals and companies have contributed to its development. Thousands of scientists, engineers, chemists, and skilled workmen are working every day to make it a still better means of transportation.

In the automobile we see the best examples of the unforeseen effects of scientific discoveries on practical every-day problems. No one doubts that the automobile has tremendously changed our way of living; has given work to millions of men and has, in a large way, helped increase our standard of living.

By 1910, the automobile industry was in a period of rapid, healthy growth. Each year the number of cars sold was increased. Each year thousands of new jobs were opened up. Demands were growing for new things to make the automobile more reliable, easier to operate, more comfortable, and lower in price. As engines were run faster, ignition had to be improved. When women began to drive in large numbers, a simple method of starting was necessary. It is said that the invention of the self-starter alone made it possible at least to double the number of cars manufactured in the next few years. Now anyone can start an automobile without the danger of breaking his bones and without wading through mud and water to do it. No other single invention has done so much to make the motor car the universal means of individual transportation. It was in 1911 that an electric self-starter was first installed on a production car. From that time on it has been no more difficult to crank an engine than it is to turn on an electric light.

Electrical devices are used for many things on the car. The electric self-starter starts the engine. The ignition system keeps the engine firing. At night the headlamps light our way while the tail lamp and stop lamp tell following drivers where we are and when we intend to stop. An electric gasoline gauge is the common means of recording the amount of our fuel supply. The speedometer works on an electrical principle. Electricity lights our cigarettes, runs the fan in the car heater and defroster, and powers the radio. The generator produces the electric power to run the electrical equipment and to charge the storage battery. The electrical system is truly the heart of the modern motor car. When it fails, the car stops. When it is functioning the car comes to life.

The discoveries which led to our present knowledge of electricity had their beginning almost five thousand years ago. Facts were discovered only to be forgotten or overlooked for centuries and then to be rediscovered. Many fundamental truths were hidden in a great mass of superstitions. Slowly, over the centuries, the truths were sifted from the fancies and man learned how to make them useful in many of the arts, crafts and sciences. We can trace

ELECTRICITY AND WHEELS

this development in our knowledge of electricity as man learned it himself. Three subjects, at first thought to be entirely separate and distinct from one another, but now known to be entirely interdependent, are involved. Since taking them up separately makes the whole subject easier to explain and understand, we shall divide the first part of our discussion into these three subjects, Magnetism, Static Electricity, and Electric Charges in Motion. We shall have time to pick out only a relatively few of the interesting facts which are recorded on each subject, choosing those of the most general nature and those which will aid most in understanding the present day electric system in your automobile.

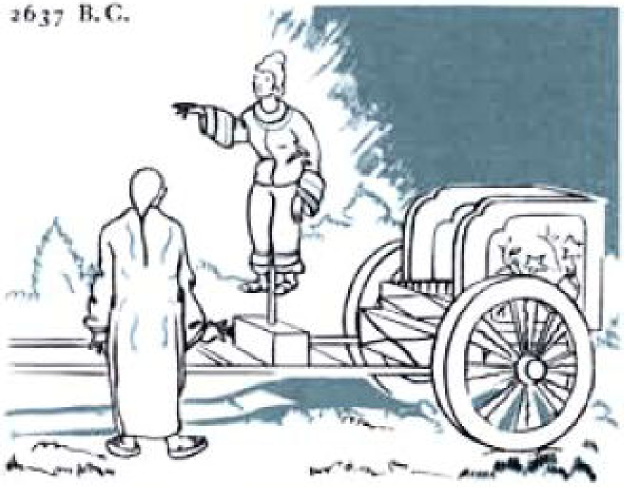
MAGNETISM

The power of a magnet to attract iron was the first electrical phenomenon which our ancestors observed. Undoubtedly, this was because the natural magnet or lodestone occurs widely in nature. We now know that these magnets were the iron ore, magnetite. The magnet is said to have taken its name from the city of Magnesia in Asia Minor, near where some of the best stones were found. According to legend, the magnet was discovered by a Cretan shepherd, Magnes. While tending his flocks, the iron nails in his sandals and the iron tip of his staff were attracted to the earth. Digging down in the ground, he discovered a rock which stuck to his sandals. This was the natural magnet.

The earliest practical use of the magnet was as a compass to point out the directions. It is fortunate that magnets do point north for it was this property which made them of great practical interest to early investigators who learned many important facts which we still use.

The first legendary account of the use of the magnet for directional purposes dates from 2637 B. C., nearly 5000 years ago. Hoang-ti, founder of the Chinese Empire, reigned for 100 years and reached the age of 121 in 2598 B. C. His empire was torn with uprisings. In the sixty-first year of his reign, his troops were pursuing the rebellious prince, Tchiyeou, and got lost in a dense fog that rolled in on them from the broad plains which they were crossing. In danger of losing sight of the prince, Hoang-ti constructed a chariot upon which he mounted a female figure that always turned to the south, no matter which way the chariot was driven. (The Chinese considered that the compass pointed south instead of to the north, as did the Europeans, and as we still do today.) With the aid of this primitive compass he was enabled to follow the rebellious prince, whom he captured.

2637 B.C.

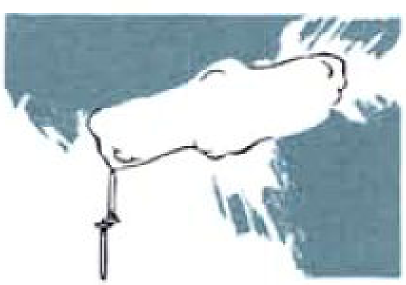


Whether this story is true or not, we do know that the compass probably came from China. By the time Columbus set sail in 1492, the magnetic compass was used all over the civilized world. It was even generally known that the needle did not point to the true north and Columbus found that this declination varied in different parts of the world.

For thousands of years, people believed that magnets had magic power to cure almost every disease—gout, toothache, dropsy, burns and hemorrhages. They were supposed to reconcile husbands to their wives. It was thought that rubbing a magnet with garlic or placing a diamond near one made it lose its properties, and that bathing it in goat's blood brought them back.

The magnet has a number of real and demonstrable properties which will have an important bearing on our conception of the electrical system of an automobile. Let us observe a few of them.

First, magnets attract iron. This was the first property discovered in the natural lodestones. They also attract nickel and cobalt. Most other substances are faintly magnetic. Some substances act in the opposite way and are repelled by a magnet. These are called diamagnetic. The metal, bismuth, shows this effect. Even gases are magnetic. When liquid oxygen is placed near the poles of a powerful magnet it is attracted much the same as if it were iron.

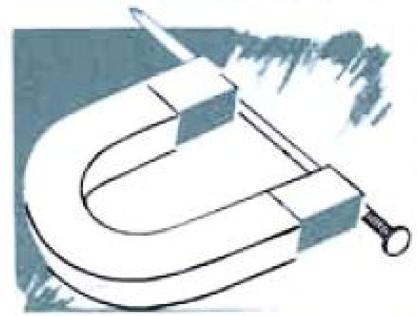


Second, a magnet has two poles, a north seeking pole, or N-pole, and a south seeking pole, or S-pole. This fact makes the compass possible and is easy to demonstrate with a magnetic needle. Take a common needle which has been magnetized by rubbing it on a magnet and float it on a piece of straw in a dish of water. One end of the needle will turn to the north.

Third, unlike poles attract and like poles repel. If we take two bar magnets and place them end to end with N-poles touching, they will immediately jump apart. If we place an N-pole next to an S-pole, they will hold fast together. This fact was discovered in 1269 by Peregrinus, a Crusader, who wrote of his works during the seige of Lucera, an Italian city. The translation of part of his work says, "Know that, as a rule, the northern part of one stone attracts the southern part of another stone and the southern, the northern."

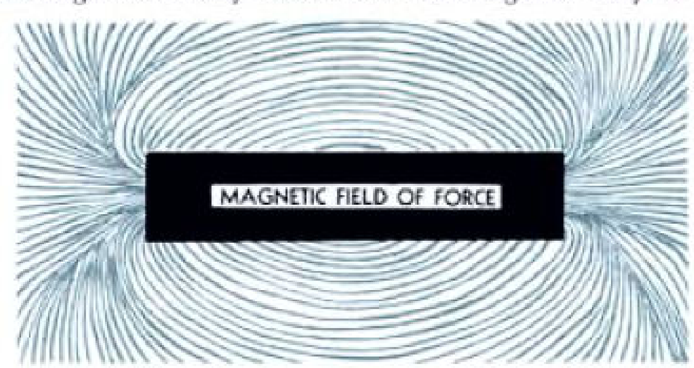
1269 A. D.

Fourth, iron or steel can be magnetized by exposing it to a magnet. Soft iron does not retain the magnetism well, while hard steel does. We now have special alloys which make very strong magnets—several times as powerful as ordinary iron or steel. Another type of magnetic alloy makes possible long distance and transatlantic telephones.



Fifth, there is a magnetic field of force around a magnet. This can be easily demonstrated with a magnet and fine iron filings. In the illustration the lines of force are shown by the position of the iron particles.

There are many more interesting facts about magnets and magnetism, but we shall leave them for the future. We shall soon see that magnetism is not a separate subject but only part of the great study of electricity. We shall see how things we usually think of as non-magnetic may be made to do almost everything a magnet does—attract iron and steel, produce fields of force, point out the north and produce magnetism in iron and steel.



STATIC ELECTRICITY

The ancient Greek philosopher, Thales of Miletus, who lived between 640 and

546 B.C., is said to have been the first to have observed that amber, when rubbed, attracts straws, dried leaves and other light objects. We now know that

the amber was charged with static electricity and it was an electrical force which attracted the straws. Thales was chief of the seven "wise men" of Greece and was both a statesman and a great scientist. He predicted the eclipse of the sun of May 28, 585 B.C., which occurred during the battle between the Medes and the Lydians. The eclipse so frightened the soldiers that they stopped the battle and brought peace to Greece.

Not much was known about magnetism and electricity until Sir William Gilbert, who was physician to Queen Elizabeth, wrote a series of six books in 1600 A. D. which summarized all that was then known on both subjects and added much from his own experimentation. He showed that many other materials besides amber would attract light objects, and listed diamond, opal, glass, sulphur, resin, and mica. It was Gilbert who adopted the word *electric* from the Greek word for amber.

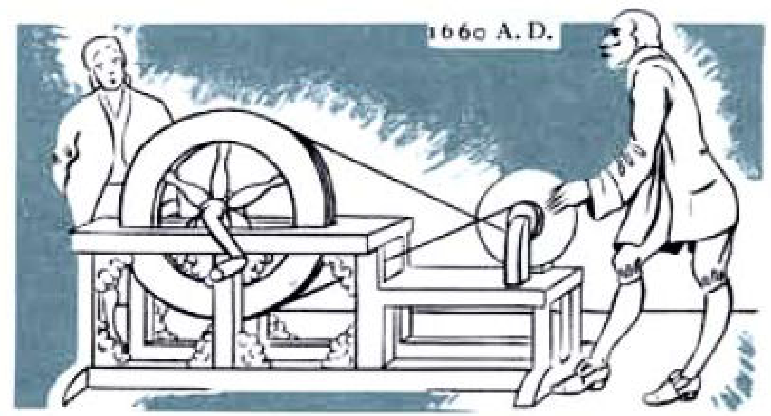
The ancients had many theories as to how amber attracts objects. They said the attraction was caused by "steams which issue out of such bodies and expel the neighboring air making small whirlwinds." The Englishman, Sir Kenelm Digby (A.D. 1644) believed that, "chafed amber is made to emit certain rays of unctuous steams; which, when they come to be a little cooled by the external air, are somewhat condensed, carrying back with them those light bodies to which they happen to adhere at the time of their attraction."

Pierre Gassendi in 1632 said, "These electrical rays get into the pores of a straw and by means of their decussation take the better hold of it and then shrink back to the amber whence they are emitted."

We can try some of these early experiments ourselves. Take a glass rod and rub it with silk. It will attract a pith ball made from a dried potato. A stick of sealing wax rubbed with fur will likewise attract the pith ball.

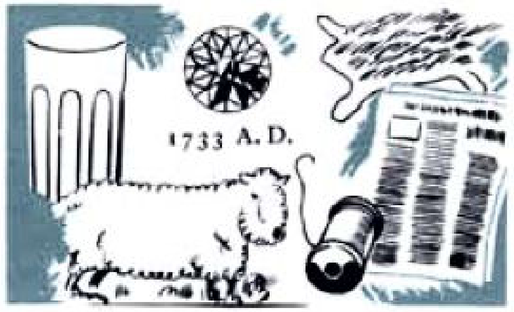
In 1660 Otto von Guericke of Magdeburg built the first static electric generator and proved that electricity could be machine generated. His generator was a globe of sulphur about the size of a man's head which was mounted on an axle. By rotating the sphere and rubbing

the dry hand on the surface, the sulphur ball was charged enough to attract paper, feathers and other light objects. He was the first to notice that bodies were repelled, as well as attracted, and also that the electric charge could travel to the end of a linen thread.

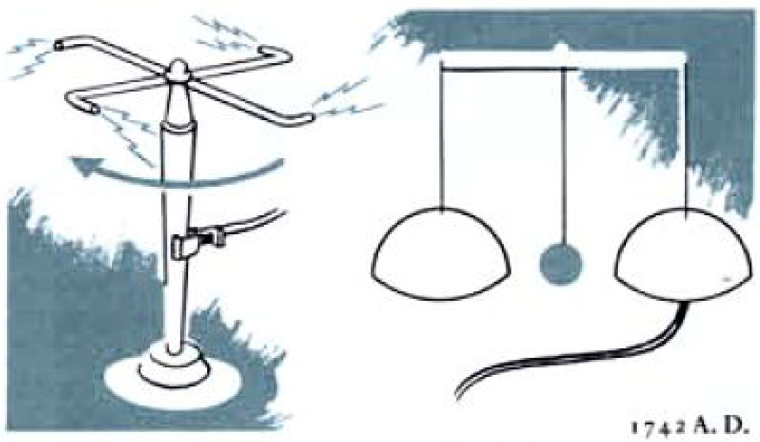


To Stephen Grey is due the credit for discovering that materials were either conductors or non-conductors. He found that when he tried to transmit electricity by a hempen line suspended by pack threads, the system didn't work. At the suggestion of a friend, Granville Wheeler, he suspended the line by silk and transmitted the electricity 765 feet. Silk was a non-conductor while the pack thread was a conductor. When he used wire instead of the hemp line the distance was increased to 886 feet. He also discovered other insulating materials such as hair and resin. It was in 1729 and 1730 that much of his long distance transmission was done. We now know that metals are good conductors. Copper is both a good conductor and can be obtained in abundance; hence, its general use on electrical machinery. Glass,

porcelain, rubber and oil are such poor conductors that they are used as insulators.



Several years later, 1733, Charles Francais de Cisternay du Fay, a French scientist, determined that there were two kinds of electricity. He reports, "there are two kinds of electricity—, one of which I call vitreous and the other resinous electricity. The first is that of glass, rock crystal, precious stones, hairs of animals, wool and many other bodies. The second is that of amber, copal, gum-lac, silk, thread, paper, and a vast number of other substances. The characteristics of these two electricities are that they repel themselves and attract each other."



1742 A.D.

In 1742, Andreas Gordon, a Scotch Benedictine monk, employed a glass cylinder to generate static electricity, using a bow to turn it at a speed of 680 revolutions a minute. He used electric charges to ring a bell and to run an electric whirl. Charges, concentrated on the points of the whirl, leak off and by reaction propel the wheel. The whirl acts like a rotary lawn sprinkler. In one case water reacts to propel the wheel, in the other case, electricity. This is the original crude electric motor.

Benjamin Franklin was not only one of our greatest statesman, but a scientist of the first order as well. It is to him that we owe the one-fluid theory of electricity. Instead of two types of electricity, as du Fay suggested, Franklin believed electricity could exist in two states which he called positive and negative. This is the foundation of our present theories of electricity. In 1747, he mentioned in a letter his experiments that demonstrate this theory. Five years later he made his famous kite experiment, in which he proved that lightning and electricity were the same thing.

By 1775 we had a firm foundation of fundamental facts on magnetism and static electricity. Men knew most of the properties of the magnet, although we still do not know what magnetism is. It attracts iron and steel, has two poles, and tends to point to the north. Of static electricity, they knew how to make a mechanical generator, that many bodies could be charged by friction. They knew that there were conductors and insulators and that there were two kinds of electricity. They also had adopted the names, *electricity*, and *positive* and *negative*.

We have omitted some discoveries which were very important but which space does not allow us to mention. The stage was now set for the final step, the discovery of the electric current, or charges in motion. When this work was done, it paved the way for all modern electrical developments.

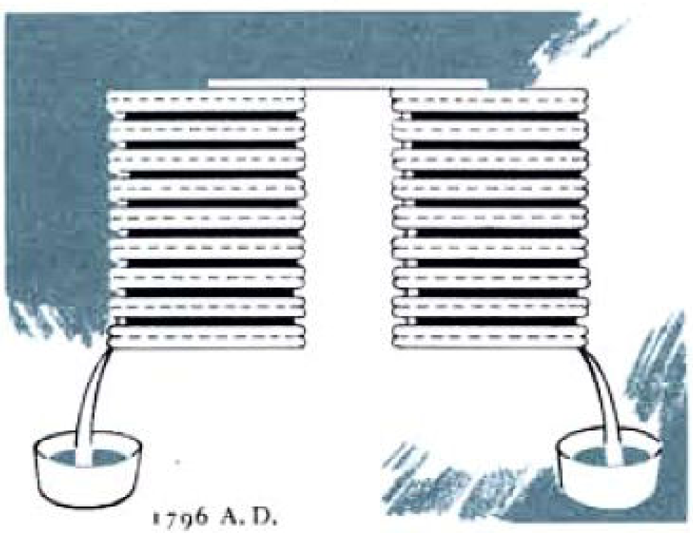
Electric power generation, telegraph, telephones, radio, automobile electrical systems, electric lights, X-rays and even our modern theories of the constitution of matter and the universe are based on electrical phenomena. The fundamentals were well known more than fifty years ago. From these facts scientists and engineers have built up many of our present industries which provided millions of new opportunities for employment.

ELECTRIC CHARGES IN MOTION

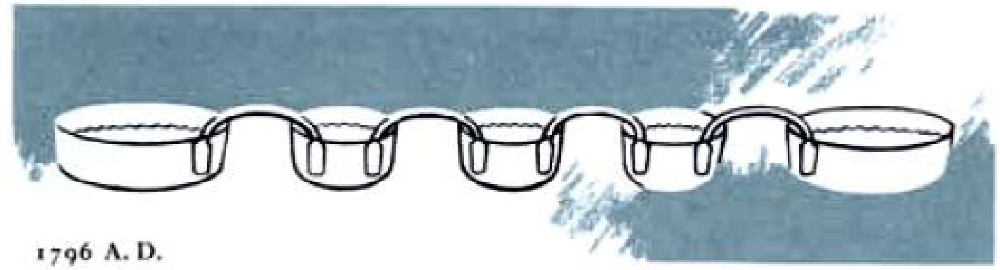
To an Italian physician, Luigi Galvani, is due the credit for the discovery of the electric current although he did not recognize the true explanation of his work. It was while dissecting a frog's leg, that his wife noticed the contraction of the muscles, whenever she held a scalpel against the frog leg. The scalpel lay close to the conductor of a static electric generator which had recently been charged by one of his pupils. He immediately started a long series of experiments on frog legs. He showed that two metals, as iron and copper, when in contact would produce the contraction in the legs, and thus he discovered the action of the battery. Galvani wrongly concluded that the action was produced by the muscles and nerves of the animal itself. He would not believe that the reaction in the muscles of the frog legs was produced by feeble electric currents in the metals with which he touched them. In 1791, he published the great work on his observations of the action of animal electricity.


1791 A. D.

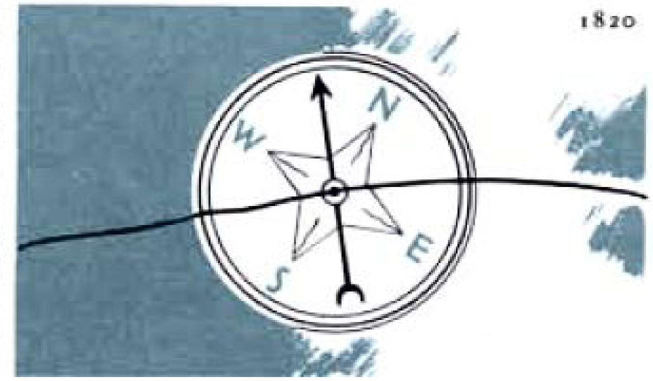
Alessandro Volta, professor of physics at the Italian University of Padua, did not agree with Galvani as to the source of the electricity. He believed that an electrical charge from the metals affected the muscles in the frog. In this he was right. Volta decided that electricity could be produced by the metals alone. His greatest achievement was the voltaic pile, which consisted of an equal number of zinc and copper discs separated by circular plates of cardboard or leather soaked in salt water or lye. With this battery he could make the frog legs jump at will. He used a number of different metals and separators and found that silver coins and zinc discs gave the best results. Later he made batteries using drinking glasses full of lye and water in which he immersed the metals. Thus, he produced the first battery and gave man a strong source of electric power which could be maintained and managed much more easily than static electricity. His discovery was made in 1796 and was announced in a letter written in March, 1800.


1796 A. D.

In 1820, Hans Christian Oersted, the Danish physicist, published a pamphlet in which he showed that electricity and magnetism were intimately related.

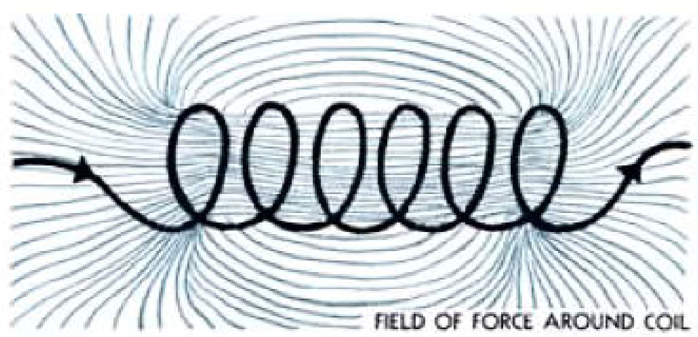

1796 A. D.

In lecturing before a class of pupils, he had a voltaic battery before him. He accidentally pushed a compass under a wire connected to the battery and noticed that, instead of pointing north, it swung at right angles to the wire. He had proven that a wire carrying a current of electricity had a field of force around it which was similar to the field of force around a magnet. Electricity could produce magnetism. This discovery was the wonder of the scientific world and he received honors from many scientific societies of Europe.



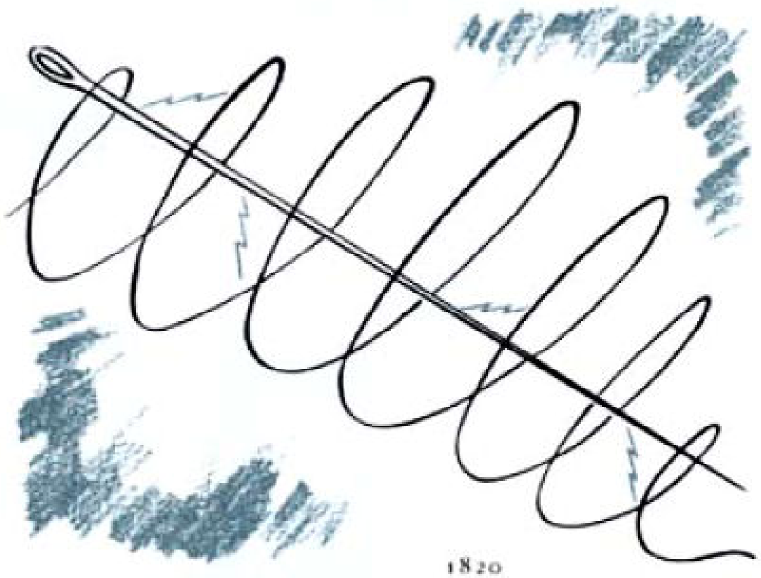
1820

Only a few months after Oersted's pamphlet was published, the Frenchman, Andre Marie Ampere, took up his discovery and found that when current flowed in two parallel wires, they attracted each other when the current was in the same direction, and repelled when in the opposite direction. He also showed that coils of wire acted in all respects like natural magnets when a current was sent through them. Coils of wire which act like magnets are used in many electrical devices on the automobile.


FIELD OF FORCE AROUND COIL

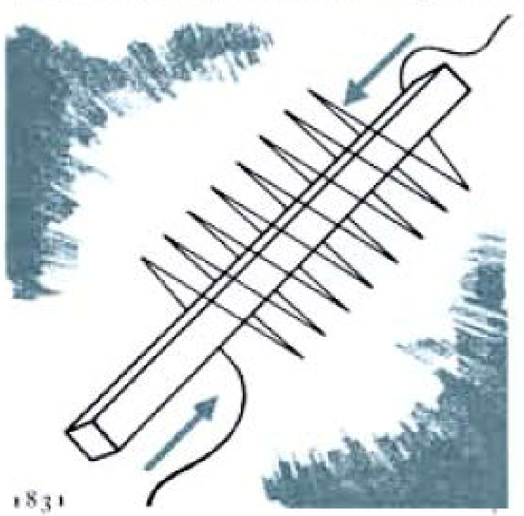
In the same year, another Frenchman, Dominique Francois Jean Arago, discovered that if he placed a needle inside a coil of wire carrying a current, the needle became magnetized. This is the electro-magnet used in many electric machines. He also found that soft iron gave up its magnetism easily but a steel needle could be apparently permanently magnetized.

The next great discoveries were made by Michael Faraday, the great English physicist who lived between 1791 and 1867. Faraday, the son of a poor blacksmith, was apprenticed to a bookbinder in London when he was only thirteen years old. During the business depression of 1801 in England the family received public relief. His formal education consisted only of the rudiments of reading, writing, and arithmetic. While learning the bookbinding business he read many of the books which passed through his hands and thus obtained a firm foundation in the knowledge of electricity and chemistry as it then existed. He likewise attended a series of scientific lectures which confirmed his desire to do scientific work.

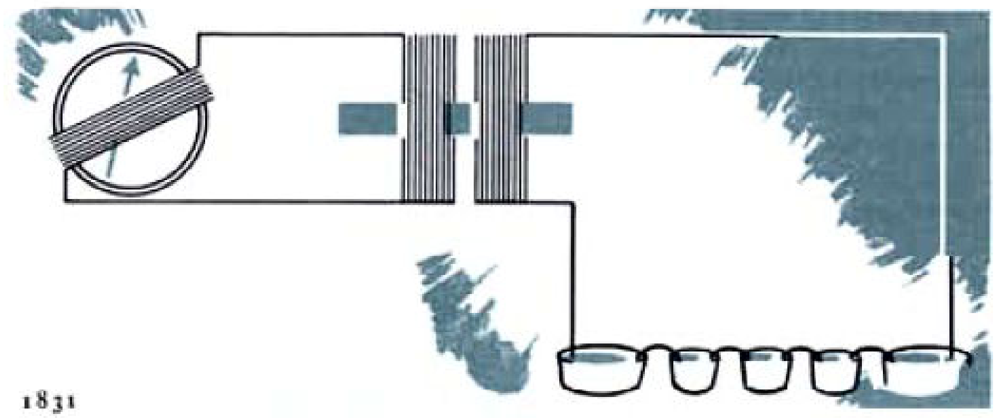


1820

While attending a series of lectures by the great physicist, Davy, he made a complete set of notes which he sent to Davy with a letter asking for work. These so impressed him that Faraday was given a position as laboratory assistant at the Royal Institution. It was here that Faraday made all of his important discoveries. It was Faraday who laid the whole foundation for our present methods of electric power generation. Oersted had obtained magnetism by electricity. Was it not possible to obtain electricity by magnetism? For years he pondered over this question and performed many experiments. His first indication came with a simple experiment. Two coils of wire were wound alongside each other on a cylinder of wood. One set of coils was connected to a galvanometer, the other to a battery. Nothing happened even though he connected almost one hundred batteries to the coil. However, he noticed that when he touched the wire from the battery to the coil the galvanometer needle, which was connected to the second coil, gave a slight jump and a second jump when the wire was removed. Here was the answer. The battery current induced a current in the second coil when the circuit was opened or closed. When the electric field builds up and again when it collapses it cuts the windings of the second coil. Next he wound the two coils on an iron ring, This increased the effect on the galvanometer many times. Then he proved that a magnet could produce a current by pulling a bar magnet in and out of a coil of wire. He made many other experiments,



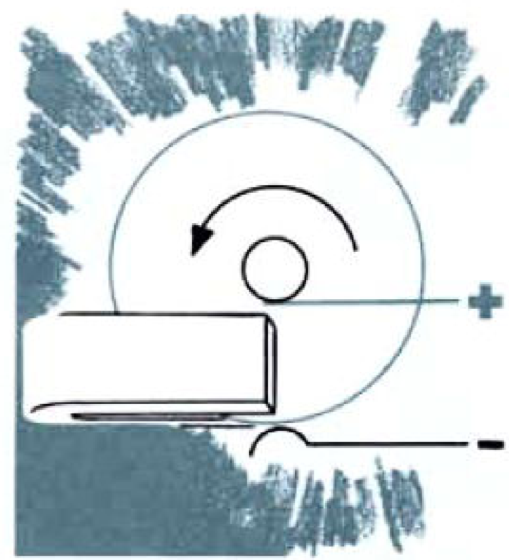
1831



1831

proving that when a conductor cuts a magnetic or electric field of force, a current is induced. It makes no difference whether the magnetic or electric field is moved through the conductor or the conductor through the field. Neither does it make a difference whether the field is moved mechanically or electrically.

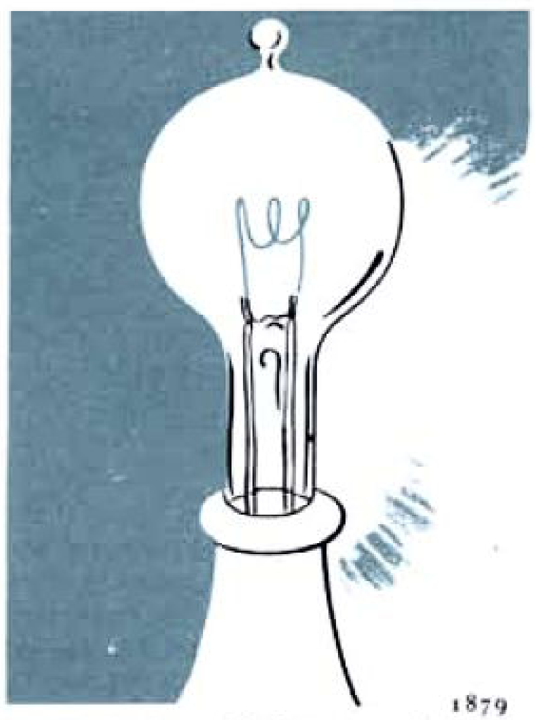
To obtain a continuous current, Faraday took a twelve-inch copper disk and mounted it so it could rotate on a shaft between the poles of a horseshoe magnet. A wire led to the shaft and another to a brush rubbing on the edge of the disk. When the disk was rotated a constant current was generated. Here was a conductor continuously cutting the lines of force, the principle of the generator. Here was an entirely new method of producing electricity. When asked what use his experiments were, he answered, "What is the use of a new-born child?" It took others forty years to make his new found child, the generator, a practical device. Although he might have made a large fortune by accepting the offers made to him, he preferred to continue at the Royal Institution.



In the United States, Joseph Henry independently discovered many of the same things as did Faraday in England. He discovered electric induction and made many experiments with large electro-magnets. He likewise made a demonstration of a telegraph instrument over a mile of wire in 1831, and mentioned that everything necessary to make a commercial telegraph was known. He constructed an electric motor which was the forerunner of present day motors. To Henry and Faraday is due the credit for the fundamentals upon which our present electrical developments are based. Their simple experiment made with only a few cents worth of material laid the foundation for industries creating new jobs and making life more pleasant and complete for each of us.

But it remained for more practical inventors really to utilize the discoveries in electricity and create new industries. The Americans, Samuel F. B. Morse and Alexander Graham Bell, applied electrical fundamentals to the problem of communications and invented the telegraph and telephone. The electric power industry awaited the development of the electric light and the necessity of having large sources of electric power distributed over wide areas. To Thomas Edison is due the credit for creating this, one of our largest and most important industries.

Thomas Edison was born in Milan, Ohio, in 1847. When he was seven years old his parents moved to Port Huron, Michigan. His first job was selling candy on a train running between Port Huron and Detroit. It was in this train that he set up a printing press and published a newspaper. He would have got along all right if he had stuck to the paper but he added a chemical laboratory in the baggage car. One day a bottle of phosphorus dropped to the floor and set fire to the car. The conductor dumped Edison, printing press and laboratory off at the next station, and so ended this part of his career.

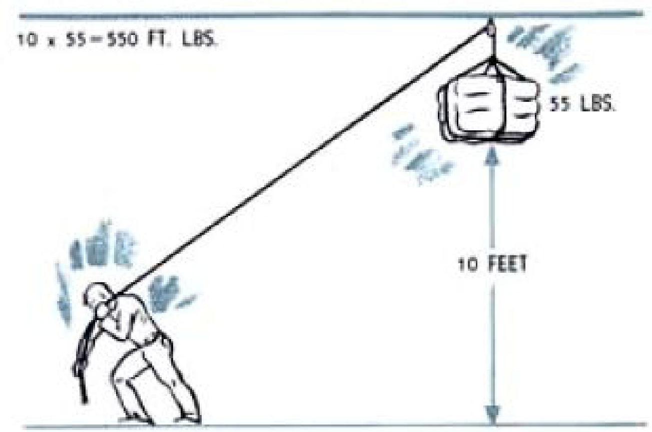


1879

After Edison had made numerous discoveries and had organized a research laboratory to work on the problems in which he was interested, he attacked the problem of electric lights. Arc lamps were in use for street lighting but Edison thought a smaller light was needed for homes, offices, and factories. After several years of patient investigation, he developed the first successful electric light bulb. Realizing that it was necessary to prove that his light was more than a curiosity, he set to work to manufacture light bulbs and build a central power plant to supply electricity. To Edison as an individual is due the credit for starting the electric light and power industry. His Pearl Street station in lower New York was the first central station with lines covering a square mile. All the steam and water electric power plants in the world have grown from this first small unit built by Thomas Edison.

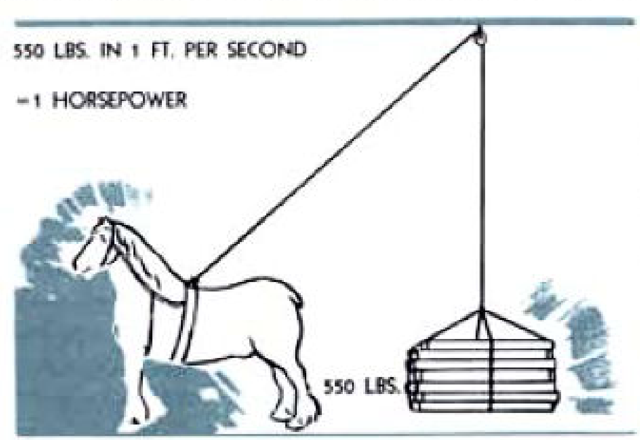
POWER, VOLTS, AMPERES, WATTS

One of the fundamental units which applies to electricity as well as other things is the unit of work. In engineering, work is defined as the product of force times distance. It is measured in foot pounds. If you lift a weight of 55 pounds up ten feet, you have done 10 times 55, or 550 foot pounds of work. Likewise, if you push a box across the floor with a steady force of 55 pounds against friction, when you have moved it 10 feet you have again exerted 550 foot pounds of work.



Power and work are terms which are often confused. Power is the rate of doing work. In our foregoing examples the time it took to lift or move the object was not considered. Whether it took one second or one minute had no bearing on the work done. Power takes into consideration the time it takes to do the work. If you lift the 55 pound weight 10 feet in one second it will take 550 foot pounds per second of power. If it is raised in 10 seconds it will take 550 divided by 10, or 55 foot pounds per second of power.

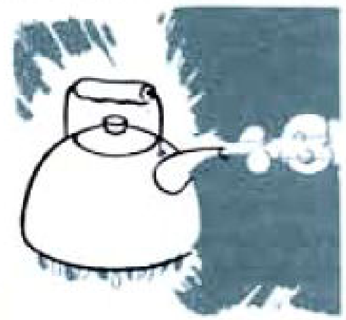
Our common measure of power in engineering is the horsepower. James Watt, who developed the steam engine, wanted a unit to compare the work done by his engines in pumping water out of mines with that done by horse-operated pumps. After a series of careful measurements he established that a horse could lift 550 pounds at the rate of one foot per second. This rate of doing work, 550 foot pounds per second, he termed a horsepower. This figure is somewhat more than a horse can exert over a full day's work, but much less than the rate for short sprints. It has been determined that a horse develops 10 horsepower when running and pulling a light buggy.



A man can exert about one horsepower in certain forms of athletics but in sustained effort 1/10 to 1/15 horsepower is his limit. In the preceding paragraph, it would take one horsepower to raise the weight 10 feet in one second and one-tenth of a horsepower in 10 seconds.

It is not hard to visualize many ways of developing power. When we look at Niagara Falls we get a feeling of tremendous power and we are right. This huge volume of water dropping a great distance and reaching a high velocity gives great power.

Suppose we perform Watt's experiment with a boiling teakettle. If we leave the lid off, steam escapes in a great cloud but with very little pressure. If we put the lid back on, allowing the steam to escape through a small hole, the pressure will be increased but less steam will escape. Steam can escape in large quantities at low pressure or in small quantities at high pressure. An electric current can be likened to the steam. Pressure represents voltage. Quantity represents amperage. These are two fundamental electrical units of measurement. A current can have a high or low voltage (electrical pressure) or a high or low amperage (quantity of electricity). You will recognize that these electrical units are named in honor of the two scientists, Volta and Ampere.



The unit of electrical power is likewise named in honor of a scientist, James Watt, who himself devised the mechanical unit of power, the horsepower. Power in watts is the product of the volts times the amperes in a circuit. Since a watt is a rather small unit, the kilowatt, or 1000 watts, is the usual unit in engineering. A horsepower is about three-fourths of a kilowatt and is therefore smaller. A hundred watt electric lamp uses about an eighth of a horsepower, or a little more than a man can exert in steady work.

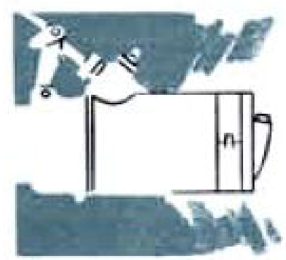
At this point, another factor is of interest. Energy is practically synonymous with work. Energy is the capacity for doing work. It is measured in the same units as work. Energy exists in many familiar forms.

A suspended weight has potential energy by virtue of its position. It takes work to lift the weight against gravity but it will give up its work if released. We have chemical energy in gasoline. When the fuel burns in the cylinder work is done in moving the piston downward. Then we have electrical energy. A storage battery stores up chemical energy which is later reconverted into electrical energy. Leaves convert the energy of radiations from the sun into plant stalks, stems, flowers and seeds. So we see that energy can exist in various states and can be readily converted from one to another.

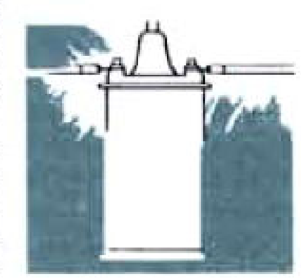
The automobile generator, storage battery, starter and spark coil are such converters. First the chemical energy of gasoline is converted into mechanical energy by the engine. This is converted into electrical energy by the generator. The storage battery stores electrical energy in the form of chemical energy. This chemical energy is reconverted into electrical energy when we push the starter pedal, and the starter converts the electrical energy into mechanical energy to start the engine. The ignition coil is a device that converts electrical energy at one voltage and amperage to a different voltage and amperage. Light bulbs convert electrical energy into light and in so doing convert some of the energy into heat.

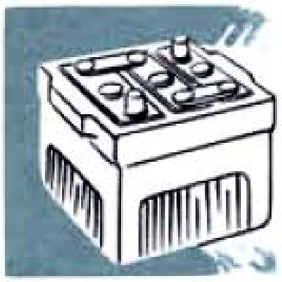
TRANSFORMING ENERGY

The electrical system of an automobile is made up of a means of generating electrical energy and a number of devices for changing the electrical energy into mechanical energy to start the car, into a hot spark to ignite the charge in the cylinder, into light for signals and road illumination and into other forms to operate the accessories. It may be thought of as a miniature electric power system with a power plant (generator), distributing system (wires), and electrical power users (starter, ignition, lights, accessories). The fundamentals of the system are quite simple, if the facts presented in the first part of the booklet are remembered.



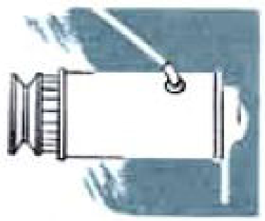
We have already mentioned that energy can exist in many forms and can be readily converted to other forms. The various parts of the electrical system of the automobile will be taken up from this standpoint. Many of the parts are good examples of methods of converting energy from one form to another. The generator changes work from the engine into electrical energy. This electrical energy is changed to chemical energy in the battery. Electrical energy is changed from one voltage and amperage (pressure and quantity) to another voltage and amperage by the ignition coil. In other words, most of the parts of the electrical system are devices for changing a small amount of the energy from the engine into other forms. Since the quantity is small compared to the amount necessary to drive



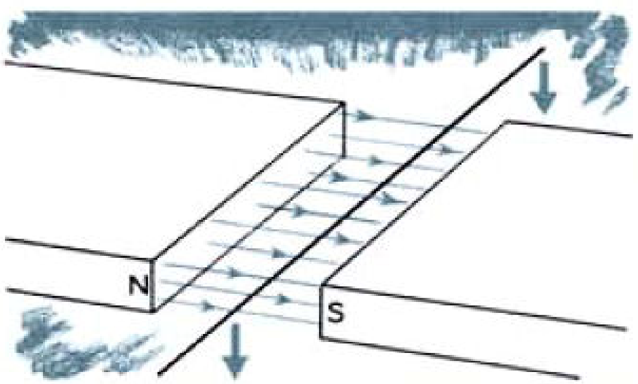


the car it is not noticeable in the mileage we get from a gallon of gasoline. It takes about the same energy to operate the lights, ignition, radio and car heater as it does to operate a 150 watt lamp. Other units take less than a quarter of a horsepower. This is only a small fraction of the power necessary to drive the car. In day driving, radio and heater both only take about a tenth of a horsepower. The ignition alone takes less energy than a small 10 watt light bulb.

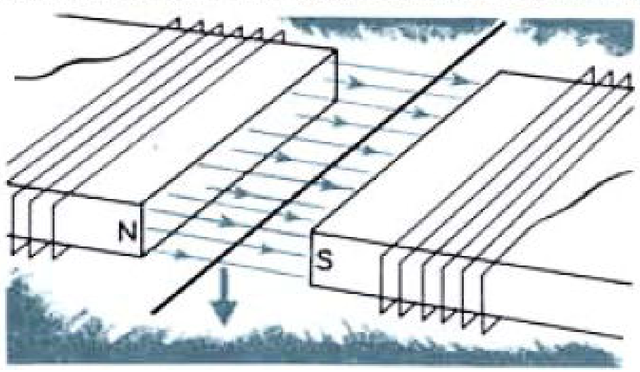
FROM WORK TO ELECTRICITY

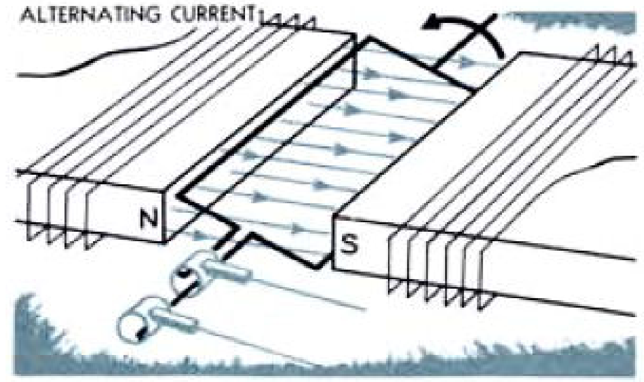


Faraday's discovery of electric induction made it possible to convert work directly into electricity. When a conductor is moved through a magnetic field a voltage is induced in the conductor. It requires work to push the conductor through the magnetic field. The magnetic field is a force which resists the movement of the conductor. The work which is used in pushing the conductor through the field is equal to the electrical energy induced in the conductor. The generator on an automobile is a mechanical device for continuously moving conductors through a magnetic field to produce a steady current. It is exactly the same in principle as the generators in an electric power house.

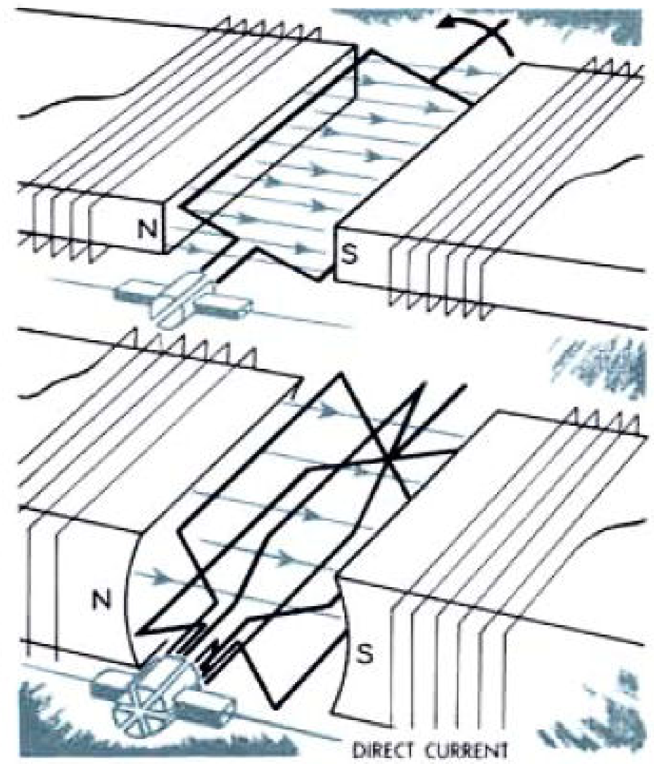


We can trace the operation of an automobile generator from the simple fundamental of a single wire moved through a magnetic field to the complete mechanism for producing a continuous current. A simple generator could be made with two bar magnets and a wire. If the wire is moved downward between the two magnets, as in the illustration, a voltage would be built up in the wire which would cause a current to flow. This could be measured with a sensitive electrical instrument called an *ammeter*. The current would flow only when the wire moved through the magnetic field. The movement of the wire would be resisted by the magnetic field just as though the two magnets were connected by many rubber bands.



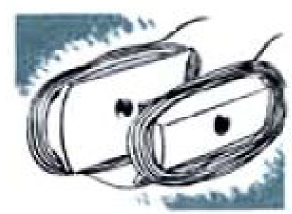


We could go a step further and substitute an electro-magnet instead of the permanent bar magnets. We have seen that when a coil of wire carrying a current is wound around an iron bar, a magnet is produced as long as the current is on. Since the electro-magnet is usually stronger than the bar magnets, we get a stronger current when the wire is moved through the magnetic field. We have thus found how to make a stronger current.

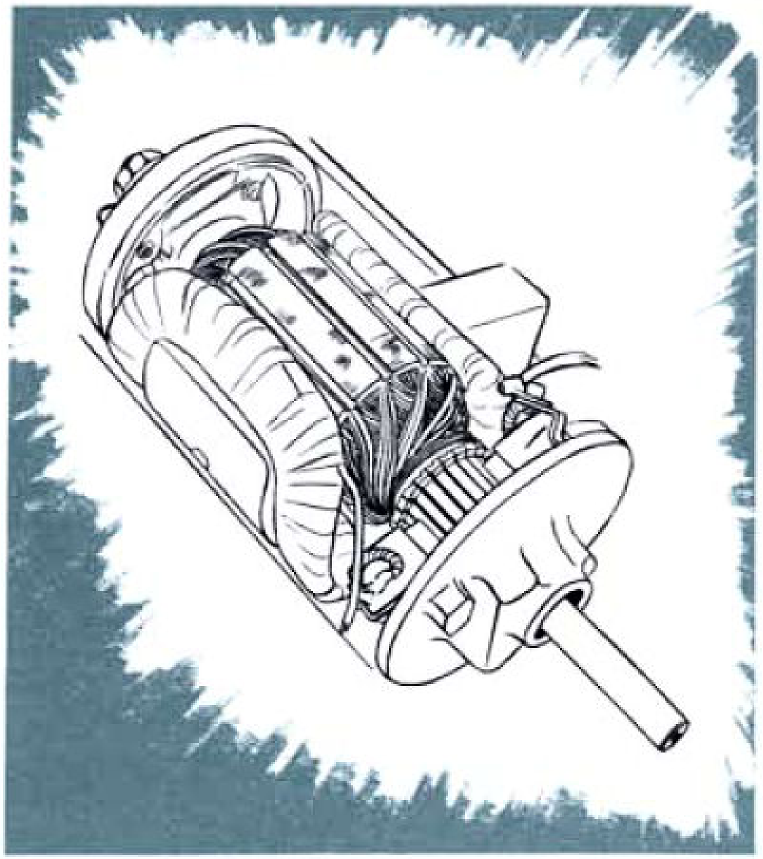


The next step would be a method of producing a continuous current. To do this, we would need to have a device which would continuously cut the magnetic field. If we used the electro-magnets and substituted a loop of wire which could be rotated between them, the voltage induced would send a current around the loop. We would then need a method of collecting this current from the ends of the rotating coil. If the two ends of the loop are connected to two segments upon which two brushes rest, a direct current will flow from the generator. If they are connected to two circular rings, an alternating current will flow. The illustrations show the two methods of collecting the current.

Even a loop does not give a continuous current although it is much better than a single wire moved past the magnets. In an automobile generator, many loops are used, each one contributing its share of the current. A direct current generator is used because a direct current alone can be used to charge a battery. The commutator, as the collector on the end of the loops is called, has many segments. The rotating loops of wire are called the armature. The outside electro-magnets are called the field.



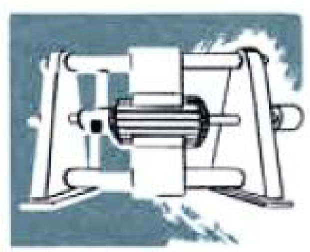
The generator is driven by the engine and current is generated only when the engine is running. Several devices such as the cut out, current regulator and voltage regulator are used to control the generator in charging the battery. The power required to drive the generator, which is another way of saying the work required to move the loops of wire through the magnetic field, is supplied by the engine. Even at high speeds only about a quarter horsepower is used. The generator is the sole source of the electrical energy in the electrical system of the car.



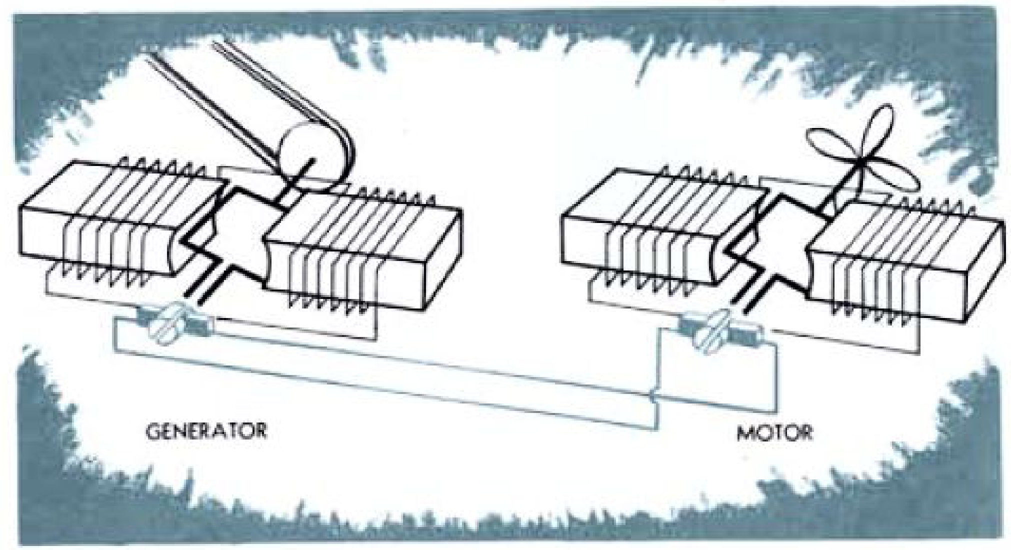
FROM ELECTRICITY TO WORK

We have seen how work can be converted into electricity in the generator. We have also seen how Oersted discovered the action of an electrical field upon a compass needle. When a conductor cuts magnetic lines of force a current is induced. Conversely, when a current is made to flow through the conductor, the conductor is acted upon by a force.

In 1873, a Belgian electrical engineer, Z. T. Gramme, was preparing several of his newly developed direct current generators for the Vienna Industrial Exposition. Two generators were installed side by side and were to be driven by steam engines. The first generator installation was complete and running, the second standing idle waiting to be connected to its engine. With Mr. Gramme near by, a workman accidentally connected the wires from the moving generator to those of the stationary one. At once it began to rotate. Gramme looked at it for a moment. Here was something unexpected. His generator was a motor when a current was sent through its windings. Motors and generators were the same.



Suppose we take the direct current generator just described and connect it to a second similar machine made in the same way. When the generator loop of wire is rotated a current will flow in the circuit, as we have seen. When the current flows through the wire loop of the second machine, it will be acted upon by a magnetic force and will tend to rotate. The field of force around the loop of wire produced by the current will cause a repelling or attracting force on the wire by its reaction with the outside magnetic coils. The loop is the armature. The outside coils, the field. If we have a sufficient number of loops in the armature, there will be a constant force tending to rotate the armature. This is a direct current electric motor. An alternating current motor is based on the same principle but is constructed differently.

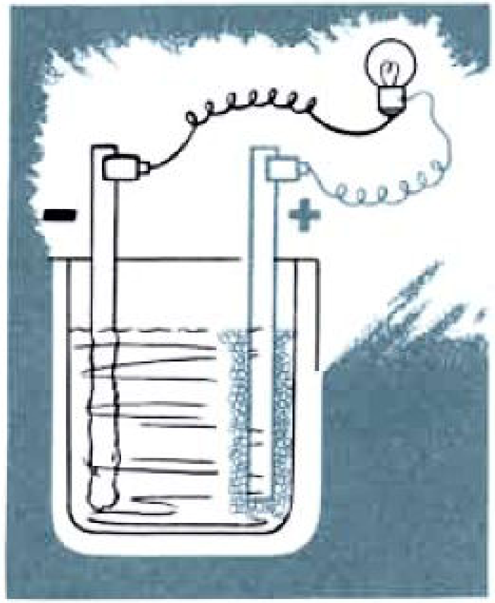


The direct current generator is a motor when connected to a storage battery. The parts are the same. This is the principle of the electric self-starter used on all automobiles. The starter motor is usually mounted on the side of the engine and has a means of connecting and disconnecting it to the flywheel of the engine. When you press the starter switch you both connect the battery to the starter electrically and connect the starter to the flywheel mechanically.

There are many ways of operating the starter to give easy positive starts. Some automobiles have automatic devices interconnected with the spark and throttle. It is necessary to have only a single button, the automatic features taking care of the spark advance and keeping the engine running after it first fires. These have been developed by engineers to make driving an automobile simpler and safer.

FROM ELECTRICAL TO CHEMICAL ENERGY

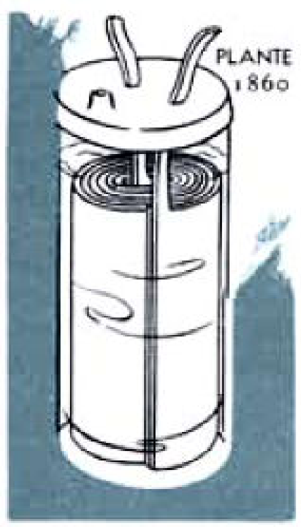
One of the most important developments in electricity was Volta's discovery that a continuous current could be obtained from the action of a chemical solution on two unlike metals. Volta found that many combinations of metals and chemicals could be used. In a battery the electricity comes from the chemical action between the solution and the metals.



If we make a battery, using two plates, one of zinc and one of copper, in a dilute solution of sulphuric acid, a current will flow when the battery plates are connected by a wire. You will notice that the copper plate collects bubbles of gas over its surface and that the zinc plate is eaten away. This action within the battery cell is an indication of the conversion of chemical energy into electrical energy. The gas formed is hydrogen, which comes from the water and acid solution. The zinc plate which is eaten away is changed to zinc sulphate. We pay for the electricity by the loss of the zinc plate and the hydrogen gas, for in science we never get something for nothing. The battery is merely the device for transforming chemical energy into electrical energy.

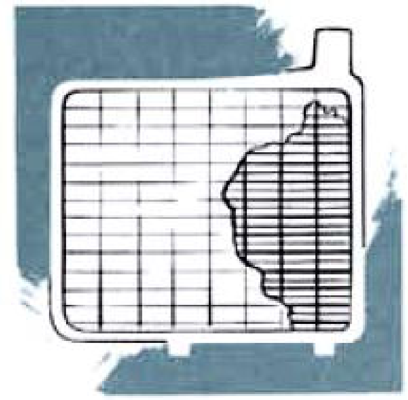
It is often desirable to reverse the process and change electrical energy into chemical energy. All the silver, chromium, and nickel plating on an automobile is dependent upon this principle. The storage battery also operates upon this principle.

In 1860, seventy years after Volta discovered the simple battery, a French physicist, Gaston Plante, was engaged in a study of the gas bubbles which form on the plates. This gas forms an insulating layer over the plates and stops the action of the battery. Plante was trying to prevent or eliminate the gas bubbles so the battery could be used continuously. His plates consisted of sheets of lead immersed in dilute sulphuric acid. This lead cell was connected to a battery made of plates of zinc and copper.

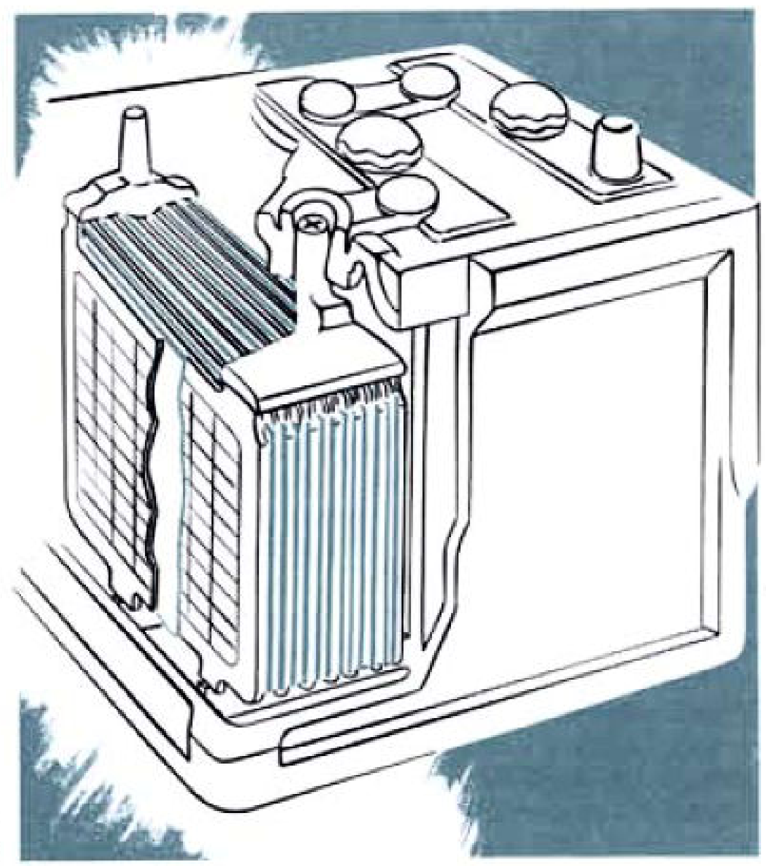


As in many cases when an alert investigator has been working with unknown things, a lucky accident showed him the principle of the storage battery. While he was changing connections on this apparatus he accidentally attached the wires from the lead cell to a galvanometer. The lead cell had been connected to the simple battery for some time before. Much to his surprise, the galvanometer needle jumped. Plante was quick to realize that here was a new type of battery that could work both ways. When the current went into the battery it was changed to chemical energy or *charged* as we now say. After the battery was charged it could be drawn upon as a source of current. The chemical energy could be changed back into electrical energy. This is the principle of the storage battery in our cars. Many men have since contributed improvements to make the storage battery a dependable source of starting power for the automobile.

While a storage battery may be made by placing two sheets of lead in a dilute solution of sulphuric acid and then charging the cell, this process is too slow because there is not enough metal surface. Plates for automobile batteries are made of a lead grid in which a paste of lead oxide is placed. When charged, the oxide is changed to brown peroxide of lead on the positive plates and into gray spongy metallic lead on the negative plates.



The storage battery in your automobile is made up of a number of alternate positive and negative plates separated by wood or rubber sheets. These plates are totally immersed in a dilute solution of sulphuric acid, contained in a hard rubber or plastic cell. Each cell has thirteen plates or more, the number depending upon the capacity of the battery. The more plates there are, the more current can be put in or taken out of the battery. Each cell gives about two volts, no matter what the number of plates. Three such cells are used for a six volt battery and six cells for a twelve volt battery. These are the two types of batteries commonly used in automobiles.



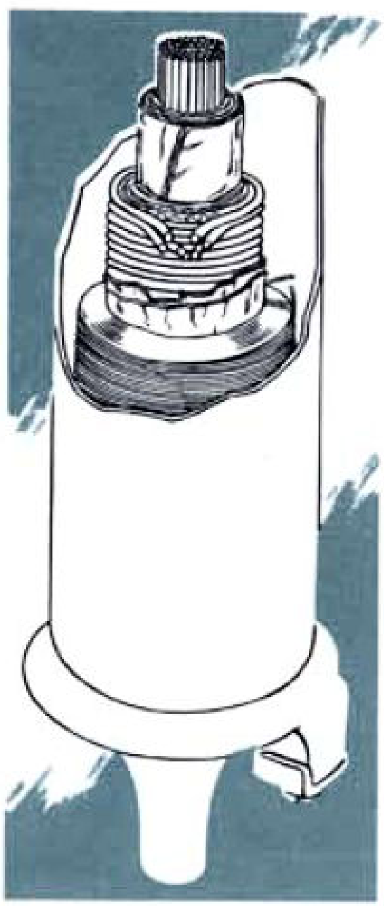
The chemical action within the cell during discharge changes the composition of the plates. When current is being drawn from the battery as in starting, the lead peroxide and spongy lead change to lead sulphate. The acid is said to go into the plates, leaving a less concentrated solution.

During charge, the action is reversed. The acid comes out of the plates and the lead oxide again becomes lead peroxide and spongy lead. The concentration of the acid solution increases.

DRIVING HINT—*The generator charges the battery whenever the automobile engine is running at a sufficient speed. Thus electricity is stored, for use when the engine is not running. The battery is of great importance because we depend upon it to supply the starting current for the electric self-starter. It might be well to mention a few simple things to be remembered in caring for the battery. In cold weather the battery should be kept fully charged. A discharged battery will freeze at a little below the freezing point of water while a fully charged battery will stand temperatures up to 90° F. below zero. Always keep the level of the liquid above the plates by supplying distilled water about once a week in summer and once in two weeks in winter. Use only distilled water, or if this is unobtainable, clean rain water. If the automobile is to be stored for months, remove the battery and store it at your service garage where it will be kept charged. Other than these simple things, the battery needs little attention.*

FROM ELECTRICITY TO ELECTRICITY

The ignition system of an automobile has an arduous duty to perform. The ignition coil on an eight cylinder engine must supply more than 12,000 sparks for every mile the car travels. This is at the rate of 200 per second at 60 miles an hour. Each spark must be positive and occur at exactly the right time with never a miss. We may think of the automobile as travelling by means of a series of small fires in the cylinders of the engine. For each fire in one cylinder the car moves ahead about five inches. In an average year's driving 150 million fires are built. A trip across the continent takes about 36 million fires.

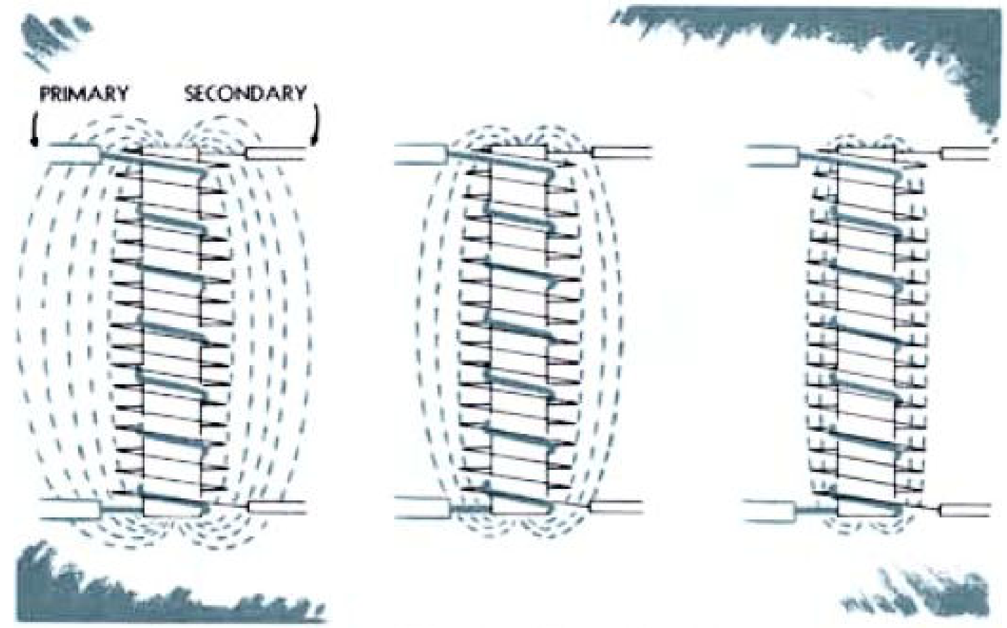


The ignition system consists of an induction coil, condenser, breaker, distributor, spark plugs and wires. Each of these components has an important part to play in supplying the spark which ignites the charge. The operation of each will be taken up so that it may be seen how it employs the fundamental principles.

You will remember that Faraday and Henry discovered that when two coils are placed close together and the first one is connected and disconnected to a battery, a voltage will be built up in the second coil. There is another important factor upon which the ignition coil depends. If the first coil has only a few turns and the second coil many turns, the voltage induced in the second coil will be greater than that in the first coil. Electricity is converted to electricity.

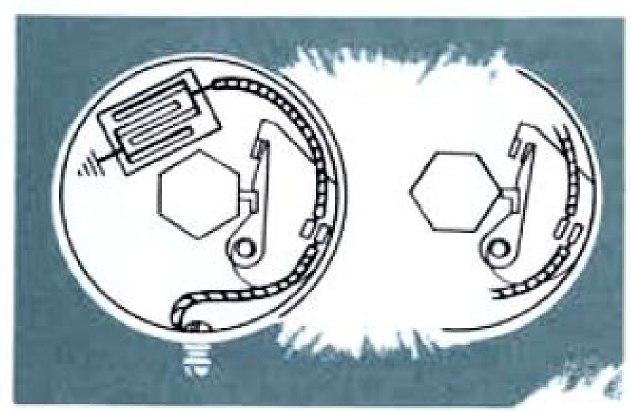
The ignition coil is made up of a first coil, called the primary, wound on an iron core. It consists of 150 to 250 turns of a comparatively large copper wire.

The second coil, or secondary, is wound over the primary and consists of 10,000 to 20,000 turns of fine copper wire. It takes over a mile of wire to wind the secondary. The six or twelve volts which flow from the battery through the



primary windings become 3500 to 15,000 volts in the secondary windings. This high voltage is necessary to jump the gap in the spark plug and provide a hot spark in the cylinder.

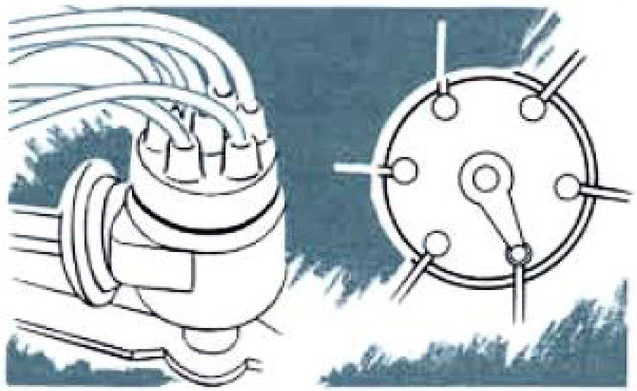
When the primary coil is connected to the battery a magnetic field surrounds the coil. When the connection between the battery and primary is suddenly broken, the magnetic field quickly collapses. The secondary windings are cut by the collapsing field. This is the condition for an induced voltage as discovered by Faraday. As a result of the great number of windings in the secondary, a high voltage is induced. In the coil the magnetic field is moved electrically while in the generator it is moved mechanically.



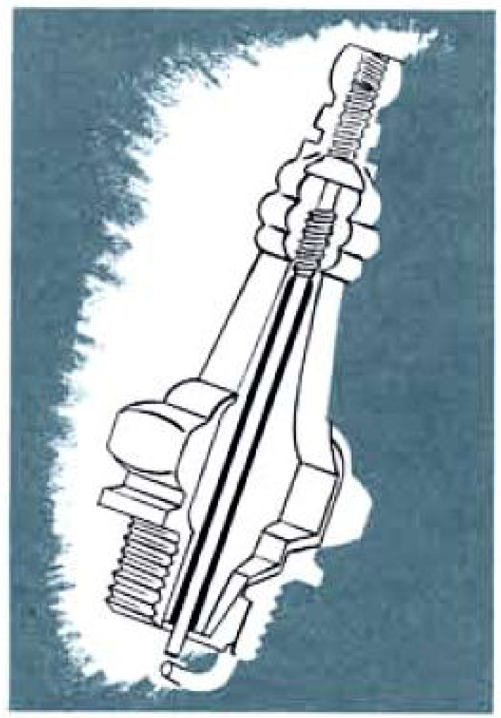
To interrupt the connection between the primary and battery, a breaker is used. This consists of a pair of contact points which are opened and closed rapidly by a cam driven from the engine. The opening is timed to occur sometime near the top of the piston stroke. The cam of a six cylinder engine has six lobes. An eight cylinder engine has either an eight lobe cam or two four lobed cams. Twelve and sixteen cylinder engines have two cams.

The contact points are made of tungsten, tungsten molybdenum, or platinum-iridium to prevent burning and pitting from the small spark which occurs when they are opened. To further cut down sparking and reduce lost energy, a condenser is connected across the breaker points.

In addition to the breaker, a distributor is necessary to connect the coil with the right spark plug when the spark occurs from the opening of the breaker. The breaker and distributor are usually made in one mechanism. The distributor consists of a rotating arm which passes stationary points connected to the spark plugs by insulated wires. There is one stationary contact for each cylinder. The high voltage current from the secondary windings of the ignition coil is fed to the spark plugs at the proper time.



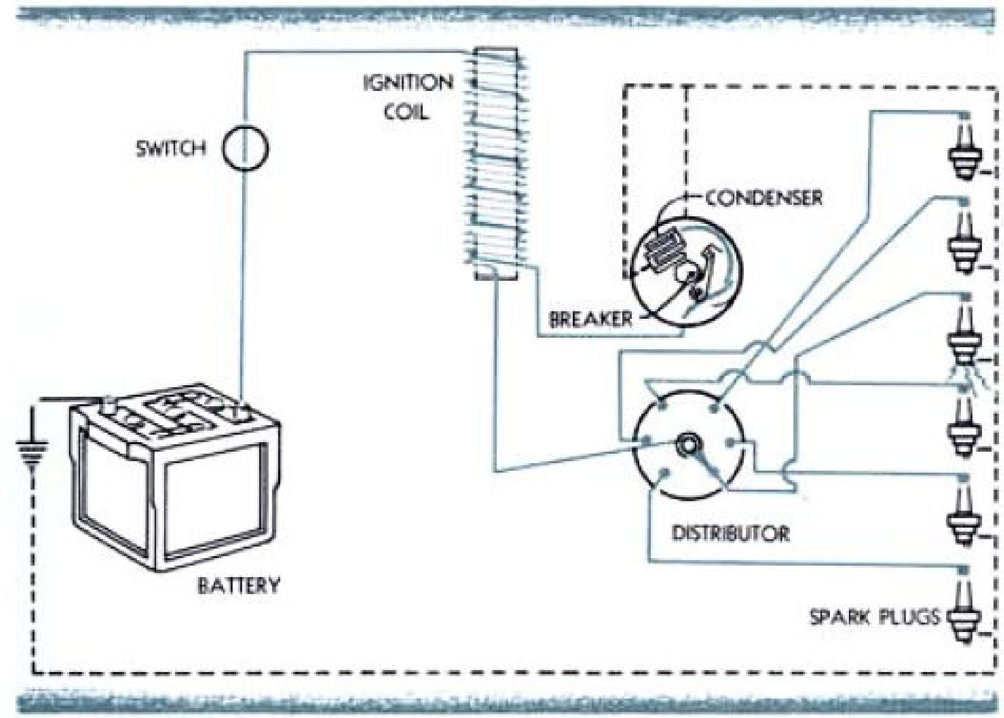
In an automobile engine it is necessary to change the time of occurrence of the spark with changes in engine speed and load. This is done by automatic devices built into the distributor. These devices control the time of opening of the breaker points and therefore the time of occurrence of the spark. It's just like setting the alarm on your clock. Sometimes you want to get up early so you advance the alarm. On Sunday morning you may want to sleep late so you retard the alarm. It's the same in your engine. In starting the engine, driving away from a stop light or pulling up a steep grade at low engine speeds, the spark is retarded. In driving on a smooth, level road at high and intermediate speeds the spark is advanced. The automatic spark advance and vacuum spark advance are twin devices which adjust the breaker to make the spark occur at the proper time, giving better car performance and better fuel economy.



The last important parts of the ignition system are the spark plugs. A spark plug consists of a steel shell which surrounds a porcelain insulator. An electrode extends down the center of the insulator. The spark plug is screwed into the engine cylinder head so that the

points extend into the combustion chamber. A gap is left between the center electrode and an electrode welded to the side of the outside shell. The high voltage from the ignition coil jumps across the gap making a hot spark to ignite the mixture of gasoline and air.

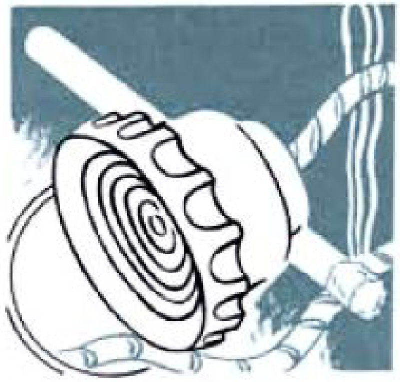
DRIVING HINT—*Spark plugs should be given attention periodically. If the spark does not jump the gap, the fuel is not burned and the engine "misses." This is wasteful and lowers the fuel economy. It is reasonable to expect 10,000 miles of operation from one set of plugs before replacement is necessary. They should be examined, cleaned and the gap set correctly every 3,000 or 4,000 miles.*



The illustration shows a simple ignition system with all the important parts named. When the ignition switch is turned on the current from the battery flows through the breaker and primary windings of the coil. With the engine running, the cam revolves and opens and closes the breaker points at the proper time. Current flowing through the primary windings of the ignition coil builds up a strong magnetic field. When the cam opens the breaker points suddenly, the magnetic field collapses, cutting the many fine turns of the secondary windings of the coil. As much as 15,000 volts is induced in the secondary. The current from the secondary goes to the distributor where it is delivered to the spark plug of the proper cylinder at the right time. The high voltage causes the current to jump the gap of the spark plug, producing a hot spark to ignite the gasoline-air mixture in the cylinder.

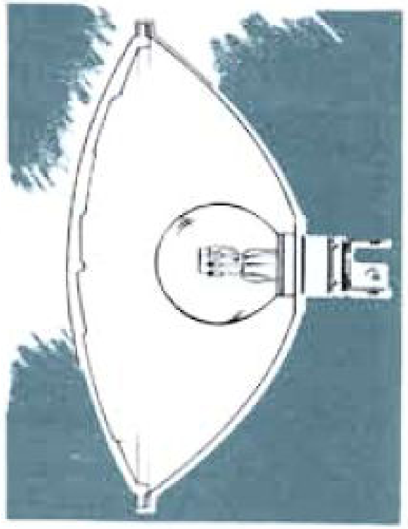
ELECTRICITY TO LIGHT AND HEAT

When electricity flows through a conductor heat is produced. If the material and size of the wire are properly chosen, the wire will get hot enough to give off light. The cigar lighter uses a wire which will become red hot in a short time when electricity flows through it. Electric stoves and heaters operate on the same principle. By this method, electricity is converted directly into heat.



If a small wire is placed within a glass bulb either in a vacuum or filled with a neutral gas, the wire can be made much hotter without burning out. The hotter it gets the more light is given off. The lights in an automobile, as well as those in your home, operate on this principle. Over fifty years ago, Edison developed the first successful electric light of this type.

The automobile headlight bulbs are usually made with two filaments each accurately placed in the bulb. A high accuracy is necessary to obtain a driving beam which is in focus. One filament gives the upper or country driving beam. The other lowers the beam for city driving and passing. The lights are connected to the battery through a conveniently located switch and operate on the regular battery current. They are usually protected by a fuse. This is a small piece of wire which heats up and melts if the current accidentally becomes too high. This disconnects the battery from the lights and protects the ammeter and light bulbs from damage. When a fuse burns out, it must be replaced by a new one.



ELECTRICITY AND THE FUTURE

It was mentioned earlier in the book that many of the discoveries in electricity could not be mentioned because of the lack of space. Only those which directly apply to the automobile were taken up. Some of the more recent discoveries have been of equal importance, both from the standpoint of contributing to our knowledge and of furnishing the fundamental information upon which new industries are built. In 1895, Roentgen discovered X-rays by accident. In 1897, J. J. Thomson discovered the small electrically charged particle, the electron. These fundamental discoveries have been applied to industry and have resulted in the long distance telephone, radio, sound movies, and the photo-electric cell. They have given scientists new tools with which to further explore the unknown. X-rays have been of great help in our progress toward the curing of human ills. These new discoveries have again shown us the way to still further advancement in the future.

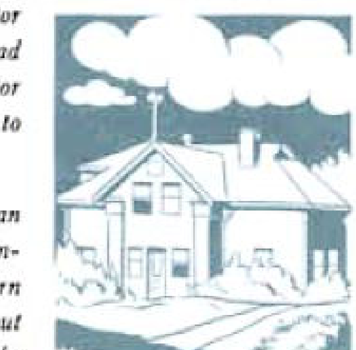
THE STORY OF THE SELF-STARTER

The story of electricity and wheels will be concluded with the story of one of the most important applications of electricity to the automobile—the self-starter. It is an example of the application of scientific information to the solution of practical problems. The self-starter is one of the milestones in the development of the present day motor car.

In the summer of 1910 an accident occurred in Detroit which was destined to doom the old hand crank on automobiles and result in the development of a successful electric self-starter. Mr. Carter, head of a motor car company, was out for a ride in his automobile. Heading for the coolness of Belle Isle in the Detroit River, Mr. Carter was stopped on the bridge behind a lady who had stalled her car. Mr. Carter got out and cranked the car. But the spark had not been retarded and the engine kicked back and broke his jaw. This later caused his death. "Uncle Henry" Leland, head of Cadillac, was a close personal friend of Mr. Carter's and his sudden death weighed heavily upon his mind.

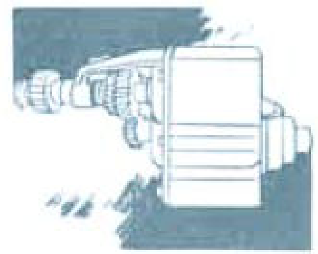
One day soon after the accident, Mr. Kettering was in Mr. Leland's office. With a feeling of confidence after having succcessfully developed a battery ignition system which Cadillac was using, he mentioned that he thought he could build an electric starter. Mr. Leland then told Mr. Kettering of the accident on the Belle Isle bridge and that he was tremendously interested in anything that he could develop which would prevent its recurrence. Mr. Kettering had already gained the reputation for doing the impossible. When he was hired by the National Cash Register Company to develop an electrically operated cash register, the experts had said that it couldn't be done. It would take an electric motor as large as the cash register itself. Despite this opposition, an electric cash register was developed and thousands were then in use.

Remembering the objections to the cash register development, Mr. Kettering went back to Dayton where he had a small shop set up in the loft of Col. Deeds' barn. Mr. Kettering had agreed to the size of the cash register motor if the motor had to drive the register continually, but the service only had to continue for an instant. You could overload a small motor if it only ran for an instant and had rather long periods to cool down between times.



Experts also said it was impossible to build a starter for an automobile. They could prove mathematically it was impossible to build a small enough motor which would turn the engine over and impossible to obtain enough power out of a storage battery. Their calculations proved that the system would weigh as much as the car itself. But "Boss" Kettering did not believe this. Thinking of the experience with the cash register, he thought the problem was the same.

Working day and night with parts of electric motors then available it was tried on an engine on Christmas Eve of 1910. But the starter was still too large, so it was redesigned. In the middle of February 1911, it was finally installed on the engine of a Cadillac and, as "Boss Ket" had thought, it worked satisfactorily. This car and starter were shown to Mr. Leland in Detroit, who kept it in his garage. Another car was kept in Dayton. Mr. Leland was very anxious to install the starter on the 1912 models. Only a short time remained to do the final development and testing before the final design had to be decided upon. Then disaster almost stopped the work.

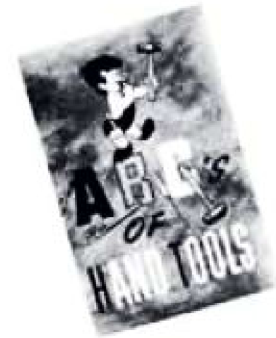


Mr. Kettering drove off the road near Dayton with one car and broke his leg. The next day Mr. Leland's garage burned and with it the self-starter car. Even though the doctor insisted that Kettering should stay in bed for two weeks, he took the next train to Detroit. A new body was obtained for the burned car and "Boss Ket," his leg in a cast, climbed under and over the wrecked car and soon had the starter working again.

Finally "Uncle Henry" decided, after thorough tests, to put the self-starter on all the 1912 Cadillacs. For this improvement, Cadillac won the Dewar trophy for the greatest contribution in automobile progress for the year.

It is said that the self-starter allowed production to be doubled in the following few years. Now it was possible for anyone to start a car without danger of broken bones. For the first time women could feel sure that they could drive without a man along to crank the engine. In a short time all automobiles were equipped with electric self-starters. Later trucks and buses adopted them and any motor vehicle could be started from the driver's seat.

OTHER BOOKLETS OF A SIMILAR NATURE

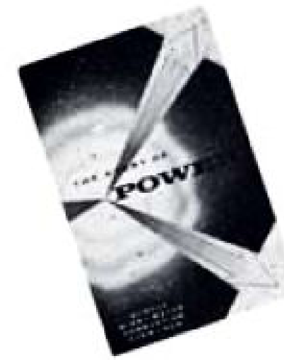


"ABC's OF HAND TOOLS"

A simple and informal text, together with cartoons and drawings, tells the right and wrong ways of handling and using the more common hand tools.

"DIESEL—THE MODERN POWER"

Issued by the General Motors Research Laboratories, this profusely illustrated booklet discusses the past, present and future of the Diesel engine.



"THE STORY OF POWER"

Brief historical descriptions and simple non-technical explanations of the various types of prime movers—wind and water power, combustion engines, the atom and solar energy.

"A POWER PRIMER"

"A Power Primer" strips the internal combustion engine of its technical mysteries by presenting the simple elementary facts about engines in general use today—automobile, aircraft, and Diesel.

"OPTICS AND WHEELS"

A survey of the outstanding historical events in the development of artificial light, as well as the basic principles of optics as applied to automotive lighting problems.

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