MOTOR-CYCLE PRINCIPLES AND THE LIGHT CAR

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WITH EXPLANATIONS OF THE CONSTRUCTION AND OPERATION OF THOSE PARTS OF MOTOR CYCLES, CYCLE CARS AND THE FORD CAR THAT DIFFER FROM AUTOMOBILE PRACTICE, AND CHAPTERS ON CARE AND MAINTENANCE, AND ON THE LOCATION AND REMEDY OF TROUBLE

BY

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FULLY ILLUSTRATED WITH DRAWINGS BY THE AUTHOR

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PREFACE

The small space available on a motor cycle, and the necessity for keeping the weight low, has forced the production of devices quite different from the corresponding parts of an automobile, and the purpose of this book is to make clear their principles and operation.

Distinctive parts of the cycle car, as well as those mechanisms of the Ford car that differ from standard automobile practice, are also described, and text and drawings have been produced with the object of making the subject easily understandable.

The chapters on the care of the machine and on the causes of trouble should make it possible for the novice to handle his mount or car with efficiency and some degree of skill.

As the sole aim has been an explanation of principles, no attempt has been made to go into the details of construction of the different machines. It is believed that when a principle is understood, its application as embodied in a specific mechanism will be readily comprehended.

R. B. W.

Flushing, N. Y.

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CHAPTER I

GAS-ENGINE PRINCIPLES

IF one is asked the question, "What makes a motor cycle go?" the natural answer is "The engine," and if the questioner is anxious for more information he will examine an engine to see what it is like and how it works. He finds that it has a shaft that may revolve, and that this is so connected with the driving wheel that when it turns it makes the wheel turn. Then he goes further to see what makes the shaft turn, and finds the shaft provided with a crank to which is connected a rod, the upper end of which is attached to a plunger that slides in a cylinder.

The arrangement is exactly like a pump. He recalls that in a pump the shaft must be driven in order to make the plunger slide in the cylinder, however; he sees that while the engine may look like a pump it is in reality exactly the opposite, for the pump requires power to drive it while the engine is a power producer. He realizes that something must happen inside of the cylinder to make the plunger or **piston** turn the crank shaft, and asks for information. It is quite evident that pressure must be applied to the piston, but how is that pressure produced?

In the answer to this is the true answer to his first question. It is *heat* that produces pressure against the piston, and thus it is heat that makes the engine go and that drives the motor cycle and the automobile.

When anything is heated, it becomes larger, the most familiar example of this being the mercury in a thermometer. On a cold day, the mercury occupies only a small space, filling the bulb and a little of the tube. As the temperature goes up, the mercury becomes larger in volume, and in expanding to occupy more space it rises in the tube. When air is heated, it also expands, and as is the case with any gas, its expansion is far greater than the expansion of metal or of any other material.

Going back to our engine, let us suppose the cylinder to be filled with cold air, and imagine that air to become heated. It immediately endeavors to expand, but in order to do so it must make more room for itself. Its only way to do this is to displace the piston a sufficient amount to give the additional space required; it follows that in moving the piston the crank shaft must turn. At first glance it would hardly seem possible for heat to make a crank shaft turn, but the matter becomes clear when we see that the heat makes the air expand, and that the air thus becomes the go-between, so to speak.

Having determined the principle under which the engine operates, we may get down to the practical side of it and learn how the principle is applied. The usual way to heat a thing is to build a fire under it, but this could hardly be done in the case of an engine. Another way is to set fire to the thing itself. Here we meet the objection that air will not burn, but we can get around this by mixing the air with a gas that can be burned, and setting fire to the mixture. By its own burning the mixture becomes intensely heated, the air expands, and the engine runs.

There are a number of gases that might be used to make a combustible mixture; illuminating gas, for instance, or acetylene gas, but these would not be convenient because of the difficulty of carrying a sufficient supply on a motor cycle or automobile. It is far simpler to use gasoline, for this may be carried as a liquid and turned into gas only when gas is required.

To make our engine run we must form a mixture of gasoline gas and air, put it into the cylinder, and set fire to it. When it has burned, and has done its work in making the crank shaft turn, the used-up gases must be cleared out of the cylinder to make room for a new charge. In this the engine is much like a muzzle-loading gun, which must have the powder, wadding and bullet put into the barrel and rammed down before the gun can be fired; after firing the barrel must be cleaned out in preparation for the next charge.

The firing of the gun drives the bullet the length of the barrel, just as the burning of the charge in the engine moves the piston the length of the cylinder. In the gun a new bullet is used for each shot, while the piston, having been moved to the outer end of the cylinder, is moved back again by the crank shaft to receive the next charge.

In order that the engine may run, this series of things must take place in regular order; for if there is any interference, the action will stop. The charge of mixture must be taken in and rammed down, so to speak, in order to make it burn quickly and properly; then it must be set on fire, and finally the burned and useless gases must be cleared out of the cylinder to make room for a fresh charge.

This series of events is called the **gas-engine cycle**, the word cycle meaning a number of happenings, each one depending on the others and taking place in regular rotation.

No matter how many cylinders an engine may have, each cylinder may be taken as a separate and independent engine, the cycle being performed in each one regardless of the others, and each one producing its proportion of the power.

We are already familiar with the principal parts of an engine; that is, the crank shaft, the piston, the connecting rod that connects the two, and the cylinder in which the piston moves. When the gas mixture is burning, the piston moves from the inner end of the cylinder toward the outer end, and then produces power and makes the crank shaft turn. Having reached the outer end of the cylinder, or, as it is called, the end of the **stroke,** it ceases to deliver power; some means must then be found to move it back to the inner end of the cylinder. This is done by a fly wheel that is attached to the crank shaft. When a wheel is started turning it tends to continue to turn; thus the fly wheel, having been started turning by the movement of the piston, will keep on turning, taking the crank shaft with it. The piston, being connected to the crank shaft by the connecting rod, will thus be moved, and will slide back and forth in the cylinder until the fly wheel stops turning.

This back and forth movement of the piston is depended on to clear the burned and useless gases out of the cylinder, to draw in a fresh charge, and to prepare the charge for burning. Each of these three acts takes place during a single stroke of the piston, a stroke being the movement of the piston from one end of the cylinder to the other; on an inward stroke the piston moves away from the crank shaft, while on an outward stroke the piston moves toward the crank shaft.

In going through the cycle the piston makes four strokes, and the crank shaft makes two revolutions. During one of these four strokes the engine is developing power and the piston is driving the crank shaft; during the remaining strokes, which are called the **dead strokes**, the crank shaft is moving the piston.

Our engine thus develops power for only one-quarter of the time that it runs. In running for an hour, for instance, it actually develops power for only fifteen minutes; during the remaining forty-five minutes it is performing the dead strokes, and the piston is kept in motion by the spin of the fly wheel.

There must be exact control over the admission of mixture to the cylinder, as well as over the exit of the burned gas, and this is obtained by valves, of which each cylinder has two. One valve admits fresh mixture and is called the **inlet valve**; the other permits the burned and useless gas to escape and is called the **exhaust valve.** The valves are opened by the engine, and are closed through the action of springs.

In order to handle and operate an engine with any kind of skill, the cycle should be well understood, and we will therefore take it up stroke by stroke.

INLET STROKE

During the inlet stroke the piston is moved from the **cylinder head,** which is the closed end of the cylinder, to the outer end, and in making this outward stroke it acts as a suction pump. The inlet valve is open, and air is sucked into the cylinder to fill the space left as the piston moves away from the cylinder head. A device called the **carburetor** feeds gasoline to the air, so that the cylinder is charged with a proper mixture.

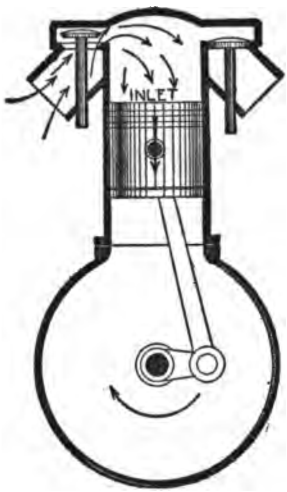


FIG. 1 (No. 1).
INLET STROKE

It goes without saying that the greatest possible charge of mixture should be taken into the cylinder, for the greater the charge, the greater will be the heat that can be produced, and the greater will be the pressure against the piston. The inlet valve should therefore stay open as long as the mixture keeps flowing in.

Before the inlet valve opens, the air in the inlet pipe is at rest; when the valve opens, this stationary body of air is suddenly subjected to the very great suction set up by the movement of the piston. It takes a brief space of time for the air to get into motion, so that by the time it begins to flow freely into the cylinder, the piston is part-way through its stroke. If the piston moved slowly, the flow of air could keep up with the piston, and the cylinder would be completely filled when the end of the stroke was reached. The speed of the piston is so extreme, however, that the air cannot keep up with it, so that at the end of the stroke, the cylinder is only partially filled. Furthermore, the air, having been started in motion, tries to keep on flowing, and it will continue to flow even after the piston has reached its bottom dead point and has begun to move upward.

If the inlet valve were closed when the piston reached the end of its stroke, a full charge would be prevented from entering the cylinder. It is therefore held open for as long as the mixture continues to enter; but, on the other hand, if it is held open too long, some of the mixture that has entered will be pushed out by the next inward stroke of the piston. The correct point at which the valve should close will vary with different engines, but in any case it will be just after the piston has passed its bottom dead point.

COMPRESSION STROKE

During the compression stroke, the piston moves toward the cylinder head, and both valves are closed. Of the reasons for this stroke, the most important is the necessity for getting the piston into a position in which it can be acted on by the pressure that is to be produced in the cylinder. It would be quite useless to set fire to the mixture when the piston is at the outer end of its stroke, for it is then as close to the crank shaft as the connecting rod will let it go; no amount of pressure could move the piston further out unless something broke. By moving the piston to the cylinder head, or, in other words, to its inner dead point, it will be in position to be moved outward by the pressure that is produced above it.

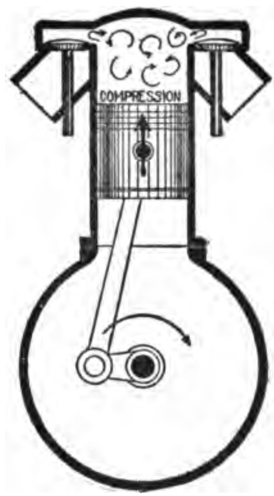


FIG. 1 (No. 2).
COMPRESSION STROKE

Another reason for this stroke is the necessity for preparing the mixture so that when it is set on fire it will produce the greatest possible heat. The preparation consists of squeezing, or compressing, the mixture to about one-quarter of its volume. Let us suppose that the cylinder holds a quart of mixture, and that when heated by its burning, this quart will expand to a gallon. In thus expanding it will, of course, create a certain pressure.

Before setting fire to it, let us compress the quart until it is only a half-pint in volume; this will not alter the ability of the mixture to expand to as great a volume as before, and in expanding from a half-pint to a gallon it will naturally create far more pressure than would be created in expanding from a quart to a gallon.

By the compression stroke, therefore, the charge of mixture is caused to produce greater pressure against the piston than could be produced without it.

A third reason for the compression stroke is in its rendering of the mixture more uniform, thus enabling it to burn quickly and evenly.

Everything in the gas-engine cycle takes place at such high speed that it is difficult to do some of them properly, and this is especially true of the formation of the mixture. The suction of the inlet stroke starts a current of air in the inlet pipe, and this current of air in turn sucks the necessary gasoline from the carburetor. The gasoline comes out in fine drops, and to make a proper mixture, these drops should be turned into gas and thoroughly mixed with the air. The inlet stroke takes place so quickly that it does not allow time for this evaporation; when the inlet valve closes, the cylinder therefore contains some drops of liquid gasoline, a portion of pure air, and a more or less perfect mixture of air and gasoline gas.

During the compression stroke the liquid gasoline is turned into gas, which is thoroughly mixed with it.

At the end of the compression stroke the piston is thus in position to be acted on by pressure, and the space between the piston and the cylinder head is packed with a mixture that is in condition to burn rapidly and thus to produce heat and pressure.

IGNITION

The setting-on-fire of the mixture, or its **ignition**, must take place at such a time that the mixture charge will be intensely hot and producing its greatest pressure when the piston is at its upper dead point. If the piston is partly down in its stroke when the greatest heat is produced, the space between the piston and the cylinder head will be large enough to permit the mixture to expand to some extent without exerting great pressure. This will mean a loss of power, and as we are striving to produce the greatest possible pressure against the piston, it is a thing that must be avoided.

The mixture is ignited by an electric spark, which sets fire to the particles of mixture that it touches, and the flame spreads from these particles throughout the entire charge. To our senses, the charge seems to ignite instantaneously, but as a matter of fact, a little interval of time elapses between the passing of the spark and the instant when the entire charge is in flame. We know that the piston must be at the upper dead point when the whole charge is on fire, and it follows that the igniting spark must pass while the piston is still moving upward on the compression stroke.

When a small engine is running at full speed, the spark will pass when the piston is about seven-eighths of an inch from top dead center, and during its movement over this distance the flame will be spreading through the charge. The point in the stroke at which the spark passes depends chiefly on the speed at which the engine runs. The time necessary for the spreading of the flame through the mixture does not change with the speed of the engine; that is, it remains the same whether the engine runs fast or slow. This time must be allowed for, so that the piston is at top dead center at the instant when ignition is complete.

Let us suppose that the engine is running at 2,000 revolutions per minute **(R. P. M.)** and that the spark passes when the piston still has one inch to travel before reaching top dead center; this we know to be correct, because the time that the piston takes to travel that final inch is the same as the time necessary for the spread of the flame through the mixture.

Now our engine slows down to 1,000 R. P. M. because we strike a hill or a sandy road, and as the piston moves at half its former speed, it takes twice as long to cover the final inch of its stroke. There is no change in the time that the mixture takes to burn, however, and consequently ignition is complete before the piston reaches the end of its stroke. Here we have the piston trying to move upward to finish the compression stroke, while the great pressure of the burning charge is acting against it; as a result, the engine slows down and may stop. This condition is called a **back-fire.** As it is due to the production of full pressure before the piston reaches the end of its stroke, which in turn is caused by passing the spark too early, the natural way to prevent it is to make the spark occur later; when the piston is only one-half inch from the end of its stroke, for instance. This can be done, for the passing of the spark is under our control.

When the engine runs slowly, the spark is **retarded**; that is, it is made to occur toward or at the end of the stroke.

If the engine speeds up to 2,000 R. P. M. with the spark in the retarded position, we will find that it will not deliver its full power, for the reason that the piston has reached the end of its stroke and has started outward on the succeeding stroke by the time that ignition is complete. This we know to be wrong, and to correct it we **advance** the spark; that is, the spark control is moved to make the spark occur earlier in the stroke.

Whenever the speed of the engine changes, there should be a corresponding change in the point at which the spark occurs. For high speeds, the spark is advanced; when the speed is reduced the spark is retarded. When the spark is incorrectly set, the engine will lose power, and in addition the cylinder and piston will become overheated and the bearings will be abnormally worn.

POWER STROKE

During the power stroke the piston moves toward the crank shaft, and both valves are closed. The mixture has been prepared and burned, and the pressure that has been developed is forcing the piston outward. It is now that the engine produces power, for the movement of the piston acts on the connecting rod and crank, and causes the crank shaft to revolve.

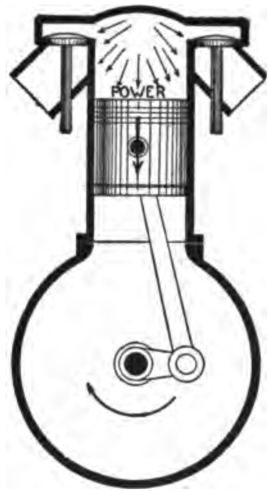


FIG. 1 (No. 3).
POWER STROKE

At the beginning of the stroke the pressure is very great, for the heated gas is trying to make room in which to expand. It secures the room that it needs by pushing the piston out of the way, and expands to fill this larger space. As it expands its pressure becomes less and less, and by the time the piston is three-quarters through its stroke, the pressure against it is so small as to be of little use. It is true that the gas is still hot, and is still exerting some pressure, but the piston is moving so fast from the effects of the high original pressure that the later low pressure can hardly make itself felt.

The low pressure can be made useful, however, by letting it help to drive the burned gases out of the cylinder. The exhaust valve is opened just before the piston reaches the end of the power stroke, and gives the gas a chance to escape; the gas finds an opportunity to expand still more, and starts to flow out of the valve.

EXHAUST STROKE

During the exhaust stroke the piston moves from the crank shaft toward the cylinder head, the exhaust valve being open and the inlet valve being closed. Again the engine acts as a pump, for the piston in moving inward pushes the burned gases out of the cylinder.

On small engines the exhaust valve usually closes at top dead center, and the inlet valve opens immediately afterward to permit the following inlet stroke to start the cycle anew.

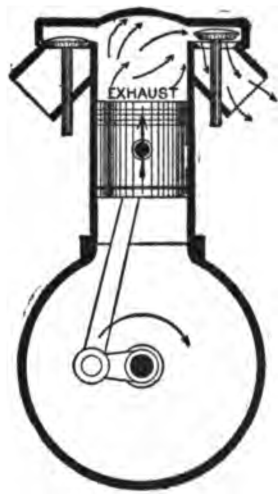


FIG. 1 (No. 4).
EXHAUST STROKE

It will be realized that every part of the cycle will be affected if any one part is not properly performed. An inlet valve that does not open enough, or that is sluggish, will prevent the taking of a full charge; if the valves do not close tightly, part of the charge will leak away during the compression stroke. A failure of the ignition spark will stop the cycle entirely, while an incomplete clearing of the cylinder during the exhaust stroke will not leave room for a full charge to enter.

When the cycle is understood, it becomes an easy matter to determine and to correct a fault that is responsible for a loss of power.

CHAPTER II

ENGINE POWER

IN the great majority of gas engines that are used for motor cycles and automobiles, the piston must make four strokes in order to perform the cycle, and power is produced during but one of these strokes. The effect is exactly the same as riding a bicycle with only one pedal, and pushing on that pedal every second time that it goes down. Thus after being pushed down, the pedal would come up, go down and come up again before receiving the next push. The push would have to be powerful enough to keep the bicycle going while the pedal went through its three dead strokes, and progress would be jerky because the speed of the machine would die down between power strokes. Similarly, the power stroke of a gas engine must drive its motor cycle or automobile, and also provide for carrying itself over its three dead strokes. Its ability to do this is due to the fly wheel, the weight of which is proportioned to the engine.

As the size of the engine increases, there is an increase in the weight of the piston, connecting rod, crank shaft, and the other parts that must be kept moving; the fly wheel must be correspondingly heavy in order to do its work. The moving parts of a small engine are light, and a light fly wheel will keep them in motion; and as small engines run fast, the speed of the fly wheel further makes up for its lack of weight.

The force with which a body moves depends on its weight as well as on its speed, and a light fly wheel at high speed may have force equal to that of a heavy fly wheel turning slowly. For an example of this, take the case of a heavy ball that will roll slowly down a bowling alley and knock down all of the pins. A light ball at the same speed would hardly have force enough to knock down one pin; it would have to be rolled at very high speed in order to make a "strike" with it.

When the small engine is run slowly, the power strokes are distinctly noticeable, and there will be a slowing-down between them. The greater the load the engine is driving, the more will be the slowing-down, and the more the engine will labor. To give it the ability to do its work, it must be speeded up.

Running an engine at high speed is likely to bring trouble, for the bearings wear rapidly and vibration is greater. To obtain power at lower speeds, the engine is built with two or more cylinders, the power stroke of one taking place while another cylinder is on one of the dead strokes. The Ford engine is an example of this. It has four cylinders which are so arranged that the crank shaft is always being turned by a power stroke. The four cylinders are in reality four independent engines, each performing the cycle without regard to the others.

The crank shaft has a crank for each cylinder, and these are so placed on the shaft that when two pistons are at top dead center the other two are at bottom dead center.

The action of the engine is indicated in Figure 2, which shows what is going on in each cylinder at the beginnings of the four strokes. It is seen that pistons 1 and 4 move in the opposite direction to pistons 2 and 3. One may well ask why the engine is not made so that pistons 1 and 3 work together with 2 and 4 moving in the opposite direction; the manufacturers long ago learned that with such a construction the vibration is much greater than is the case with the arrangement shown in Figure 2.

The engine designer lays out his engine in such fashion that the power strokes in the four cylinders come in rotation, and in doing this he bears it in mind that two of the four strokes of the cycle are inward and two are outward; the inward strokes are compression

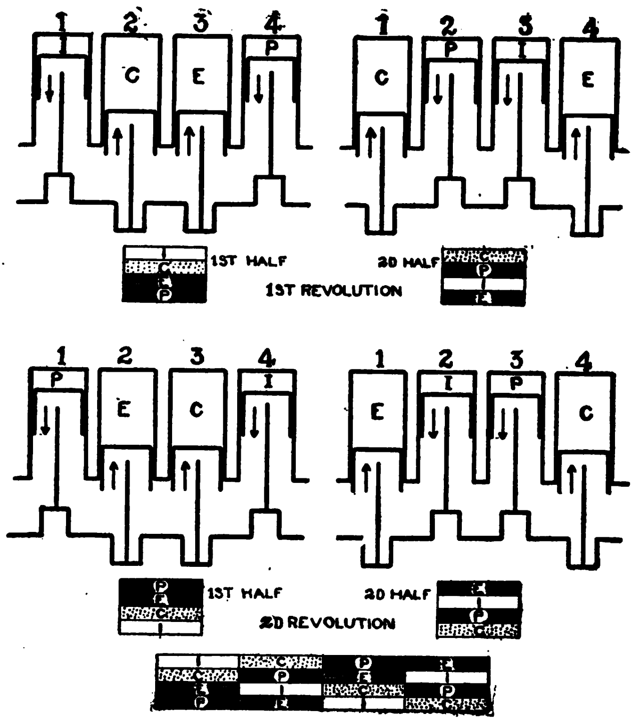


FIG. 2.—ACTION OF FOUR-CYLINDER ENGINE

and exhaust, while the outward strokes are inlet and power.

Starting with the first half of the first revolution (Fig. 2), pistons 1 and 4 are moving outward, and can therefore be performing inlet and power; pistons 2 and 3, moving inward, can be performing compression and exhaust. For the first part of the first revolution we will consider that power is being produced in cylinder 4, which leaves it to piston 1 to perform the inlet stroke.

During the second half of the first revolution, the charge that was drawn into cylinder 1 is compressed, while in cylinder 2, the charge that was compressed in the preceding stroke is producing power. Cylinder 3 is taking in a charge, and cylinder 4 is getting rid of the burned gas left from its power stroke.

With the beginning of the second revolution, cylinder 1 develops power, cylinder 2 is on the exhaust, cylinder 3 is compressing, and cylinder 4 is on inlet. During the second half of the second revolution it is cylinder 3 that delivers power, while cylinder 1 is completing its cycle with the exhaust stroke, cylinder 2 is on inlet and cylinder 4 is on compression.

The power strokes thus follow one another, not in regular order, as 1, 2, 3, 4, but cylinder 1, cylinder 2, then cylinder 4 and finally cylinder 3. This is called the **firing order**. Cylinder 3 could not follow cylinder 2, for when cylinder 2 has finished its power stroke, the piston of cylinder 3 is at the bottom of its stroke and about to move upward, which is opposite to the direction in which it must move for a power stroke. Pistons 1 and 4 are moving in the right direction, and as cylinder 1 has fired, cylinder 4 is the only one in which a power stroke can occur. As pistons 2 and 3 move in the opposite direction to piston 1, either of these cylinders could follow cylinder 1, and some engines are so built that the power strokes occur first in cylinder 1, then in cylinder 3, and then cylinders 4 and 2; or, in other words, the firing is 1, 3, 4, 2. The Ford engine, however, and the great majority of automobile engines, have 1, 2, 4, 3, as the firing order.

One great advantage of a four-cylinder engine is its excellent balance. In a one-cylinder engine, the weight of the piston and connecting rod, moving first one way and then the other, causes the whole engine to vibrate up and down, and this will make vibration in the machine that supports the engine. Engine vibration of this sort can be prevented to some extent by putting balance weights on the crank shaft in such position that they move in the opposite direction to the piston. This is not entirely satisfactory, however, for the balance will be good at only one speed of the engine. At other engine speeds, the vibration will still exist, although it will be reduced.

In a four-cylinder engine, two pistons move up while the other two are moving down, so that one pair balances the other. The engine consequently runs very steadily and with little vibration.

As the crank shaft of a four-cylinder engine is always under the effect of a power stroke from one or the other of the cylinders, the fly wheel need not be heavy, and its weight is little more than what is necessary to carry the pistons over the dead points of their strokes.

The four-cylinder engine is in use on the majority of light cars, and is also widely used on cycle cars. Some makes of motor cycles employ it, but the limited space available, and the desire of the manufacturers to keep the weight low, have thus far prevented its general adoption, in spite of its advantages.

The original motor-cycle engine was one cylinder, and as long as the riders did not demand excessive speed, and were content to help the machine up hill by using the pedals, it was satisfactory. The demand that arose for more power was met in some degree by making the engine larger, but any great increase in size was found to be impracticable because of limited space. The makers have therefore adopted a two-cylinder or **twin** engine, in which the cylinders are at an angle and the two connecting rods work on a single crank. The arrangement of the engine is indicated in Figure 3.

Because of the angle between the cylinders, the two pistons do not start and finish their strokes together; when piston 1 is at top center, piston 2 has made about two-thirds of its upward stroke. For the remaining one-third of its upward stroke, piston 1 will be moving down. When piston 2 has passed its top center it will be moving in the same direction as piston 1, but as before, it will have covered only about two-thirds

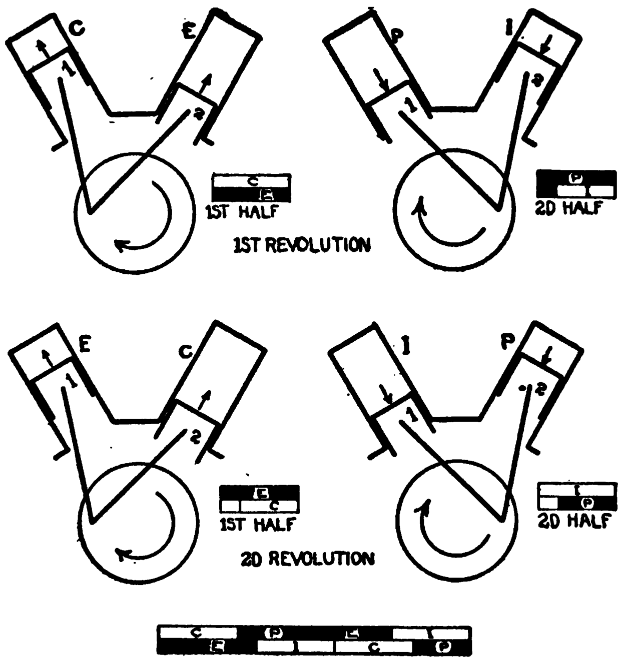


FIG. 3.—ACTION OF TWO-CYLINDER OR TWIN ENGINE

of its stroke when piston 1 reaches the bottom.

As the strokes thus overlap, the cycle overlaps also, as may be seen from the diagrams in Figure 3. In the first half of the first revolution, piston 1 moves upward on compression. while piston 2 moves up on exhaust. Piston 1 then moves down under power, and is about one-third through its stroke by the time that piston 2 completes the exhaust and begins on inlet. As shown by the bottom diagram, there is an interval of about two-thirds of a stroke between the end of power in cylinder 2 and the beginning of power in cylinder 1, and an interval of about one and one-third strokes between the end of power in cylinder 1 and the beginning of power in cylinder 2.

The power strokes of a four-cylinder engine occur at equal intervals, while in a twin engine the power strokes are thus seen to occur at unequal intervals. This would apparently give rise to vibration and unsteady running, but the design of these engines has been carried to so fine a point that these defects are not noticeable.

The power that an engine will develop depends on the capacity of its cylinder and on the speed at which it runs. The pressure against the piston at the beginning of the power stroke depends on the volume of the charge of mixture, while the rapidity with which the power strokes follow one another also has its effect.

The term "horse power" is somewhat confusing, for it would make it appear that a seven-horse-power engine is capable of doing as much work as seven horses. As a matter of fact, the engine will develop as much power as seven horses, but applies its power so differently from the way in which horses apply their power that it is hard to make a comparison.

The term **horse power** has come into use as a measure of the work that an engine can do, just as a second is a measure of time, or as a foot is a measure of distance. When an engine is tested to determine how much power it can produce, it is made to drive an electric generator, or a water pump of special construction. The factory people know how much power it takes to drive the generator or the pump at a certain speed, and if the engine drives it faster or slower, they can figure out just how much power it delivers.

The power claimed for an engine is not always measured in this manner, however, for knowing the size and number of its cylinders and its speed, the power that it should deliver can be figured out. Automobile engines are classified by a simple formula, which takes for granted that all of these engines run at about the same speed.

According to this formula, the diameter or **bore** of the cylinder is multiplied by itself, and then by the number of cylinders; the number thus obtained is divided by 2½. As an example of how the formula works out, the Ford engine, having four cylinders with a bore of 3¾ inches, is shown to have 22½ horse-power.

It is quite necessary to have some standard by which different engines can be measured and compared, and this formula does very well, although an engine on test will show more power than the formula indicates.

It is quite usual to classify motor cycles by the capacity of their cylinders. To figure cylinder capacity, the bore is multiplied by itself and by .7854, which gives the area of the piston head; this number is multiplied by the stroke. Taking a twin engine of 3½ inch bore and 4 inch stroke, for example; 3½ multiplied by itself is 12.25, which multiplied by .7854 gives 9.62 square inches as the area of the piston head. Multiplying this by 4 for the stroke shows a cylinder to have a capacity of 38.48 cubic inches. As the engine has two cylinders, the total capacity is twice this, or 76.96 cubic inches.

CHAPTER III

ENGINE PARTS

IN explaining a gas engine it is convenient to think of it as a combination of four groups, one consisting of the cylinder, piston and connecting rod, crank shaft, valves, and similar parts. A second group includes the parts that supply the mixture to the cylinder; the parts of a third group supply the spark that ignites the mixture; and a fourth group comprises the lubricating mechanism. We may begin with the first group, leaving the others for later chapters.

The crank shaft revolves in **bearings** that are built into the **crank case,** this being a housing that forms the foundation of the engine, and that serves also to protect the moving parts. The cylinder is bolted to the crank case, and cylinder and crank shaft are thus maintained in a fixed relation to one another.

It is of the utmost importance to prevent the leakage of the mixture around the piston and to this end the cylinder walls are made true and given the smoothest possible surface. The piston is slightly smaller than the cylinder, its fit in the cylinder being maintained by **piston rings** that are set in grooves around its upper end. These rings are split, and being elastic they press against the cylinder and prevent the mixture from passing. Piston rings are shown in sketch E, Figure 4.

The piston is subjected to the great heat of the burning mixture, and expands from the effect of it. If the piston were made an exact fit in the cylinder, it would stick fast when expanded by the heat; if it were made of such size that it would have a leak-proof fit when hot, it would be much too small when cold. By the use of piston rings, the piston may expand without sticking, or contract without causing a leakage.

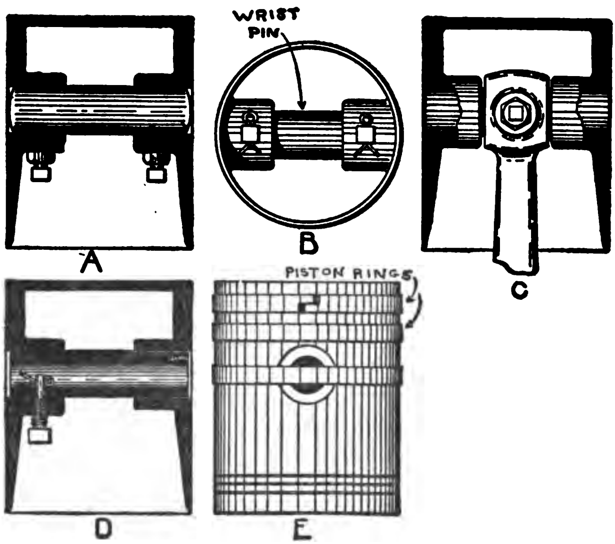


FIG. 4.—WRIST PIN FASTENINGS

Piston rings are made of cast iron, highly polished on the surface that touches the cylinder wall, and also on the side that bears against the upper side of the groove in the piston; it thus becomes impossible for the mixture to leak between the ring and the wall, or between the ring and the piston. While the ring makes a tight joint, its pressure against the cylinder wall is very light and causes little friction.

As is the case with all of the moving parts, the piston is made as light as possible, in order to reduce vibration and wear. It is attached to the connecting rod by a **wrist pin**; Figure 4 shows five methods of attaching the wrist pin to the piston. It is necessary to prevent the wrist pin from moving end ways, for if it were to move in that way its end would cause excessive friction against the cylinder wall, and would wear a groove through which the mixture could escape.

In A and B (Fig. 4), the pin is held by set screws, which in turn are secured by lock nuts or cotter pins; in C the pin is secured to the connecting rod by a set screw, and moves in bearings in the piston. The pin shown in D is hollow, and held by a bolt that passes through it, while in E the pin is kept in position by an extra piston ring that covers its ends. Still another method of securing the wrist pin is shown in Figure 11, the pin in this case being attached to the connecting rod and moving in bearings set into the piston.

The movement of the connecting rod on the wrist pin, or of the wrist pin in the piston, is very slight, for that end of the connecting rod has only a small swinging motion.

The other end of the connecting rod is attached to the crank; its bearing is large, for otherwise the wear would be rapid. The force of the piston is transmitted to the connecting rod, and by the connecting rod bearing to the crank shaft; the bearing must stand this strain, and must also take the wear due to the continual turning of the crank pin in it.

The connecting rod is often fitted with a ball bearing, which is not adjustable; when a plain bearing is used it is always adjustable, and a snug fit must be maintained.

The two connecting rods of a twin engine are attached to a single crank pin, and the two methods of attachment are shown in

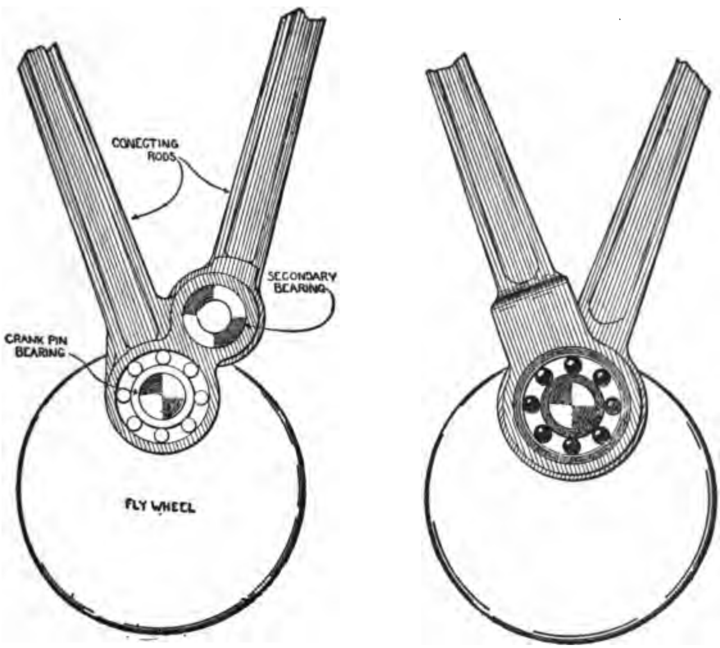


FIG. 5.—CONNECTING RODS OF TWIN ENGINES

Figure 5. In the first method, one connecting rod has a bearing that fits the crank pin in the usual way, and is made with a projection to which is fitted a pin that passes through a bearing in the second rod. When the crank shaft turns the first rod travels around with it, and by the secondary bearing the second rod is carried along. The crank pin turns inside of its bearing, but the second connecting rod has only a swinging motion on the secondary bearing; the secondary bearing in consequence is not subjected to the same wear, and may be of smaller size than the crank pin bearing. In the illustration a roller bearing is shown on the crank pin, while the other bearing is plain.

In the second method of attachment the end of one of the connecting rods is forked, and this forked end straddles the end of the other rod. There are three ball bearings; one for each of the forks of the forked rod, and the third for the second connecting rod.

These bearings are side by side on the crank pin.

A gas-engine valve is a disk of steel or of cast iron with beveled edges, set on the end of a rod called the **valve stem.** The disk fits a funnel-shaped opening or **seat,** and is drawn against it by a spring that surrounds the valve stem. This is shown in Figure 6.

The inlet and exhaust valves are usually of the same size, and are frequently identical in every way so that a valve may be used in either opening.

The power that an engine will produce is very largely due to the exactness with which the valves open and close. When an engine makes sixty strokes a second, as is the case with a motor-cycle engine, it can be seen that a variation of a tiny fraction of a second in the opening or closing of a valve will interfere with the smooth performance of the cycle. The valve mechanism is therefore of very great importance.

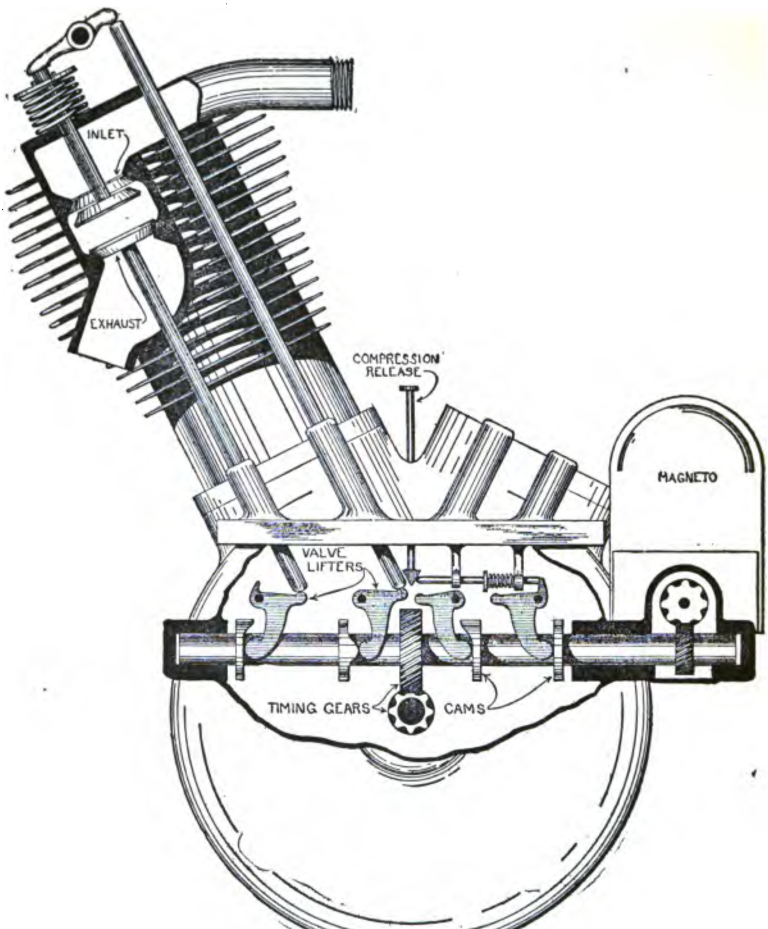


Fig. 6.—Valve Mechanism with Face Cams

Each valve operates once during the cycle; or in other words once during every two revolutions of the crank shaft. The crank shaft cannot operate them directly, for it would open them too often, so a shaft is provided running at one-half of the speed of the crank shaft. This is called the **cam shaft,** or the **half-time shaft.**

The cam shaft carries a gear that is driven by a gear on the crank shaft, the cam-shaft gear having twice as many teeth as the gear on the crank shaft. If, for example, the crank-shaft gear has fifteen teeth, the cam-shaft gear will have thirty teeth, and the crank-shaft gear will make two revolutions in turning the cam-shaft gear once.

The cam shaft operates the valves by means of **cams,** which are irregularly shaped blocks of metal secured to the shaft. A cam shaft with cams is shown in Figure 6. This cam shaft is driven by **skew gears,** in which the teeth are not parallel with the shaft, as is usual, but are at an angle with it, so that the gears will run together even though the shafts are at a right angle.

The sketch shows **face cams**, which are steel disks, each having a projection on one side. As the shaft revolves, a projection will come into contact with an end of a **valve lifter**, which is pivoted so that it may be swung to one side. In thus moving, another portion of the valve lifter raises a rod that in turn lifts the valve from its seat.

In the twin engine shown in Figure 6 there are four valves to be operated. The exhaust valves are directly operated; that is, the push of the valve lifter is in line with the valve stem. The exhaust valves move upward to open, but the inlet valves must move downward to open, for they are over the exhaust valves. The mechanism of the inlet valve therefore includes a **rocker arm**, which is pivoted on top of the cylinder; the rocker arm is moved by the valve lifter and push rod, and in so moving it opens the inlet valve.

Figure 7 shows an **end cam,** which operates with its outer edge instead of with one of its side faces. The cam shaft is driven by straight tooth gears, and the crank shaft and cam shaft are parallel. The shape of the cam is shown; the valve lifters bear against its outer edge, and are moved when the cam projections come into contact with them.

The cam shaft has two cams, one for the exhaust valves and one for the inlet; the exhaust cam is shown, while the inlet cam is behind the cam gear. It is frequently the case that the two cams and the gear are made in one piece, which revolves on a short stationary pin.

The cams of a four-cylinder engine usually act directly against the push rods, without the use of valve lifters, this construction being possible because more space is available. The cam shaft runs the length of the engine,

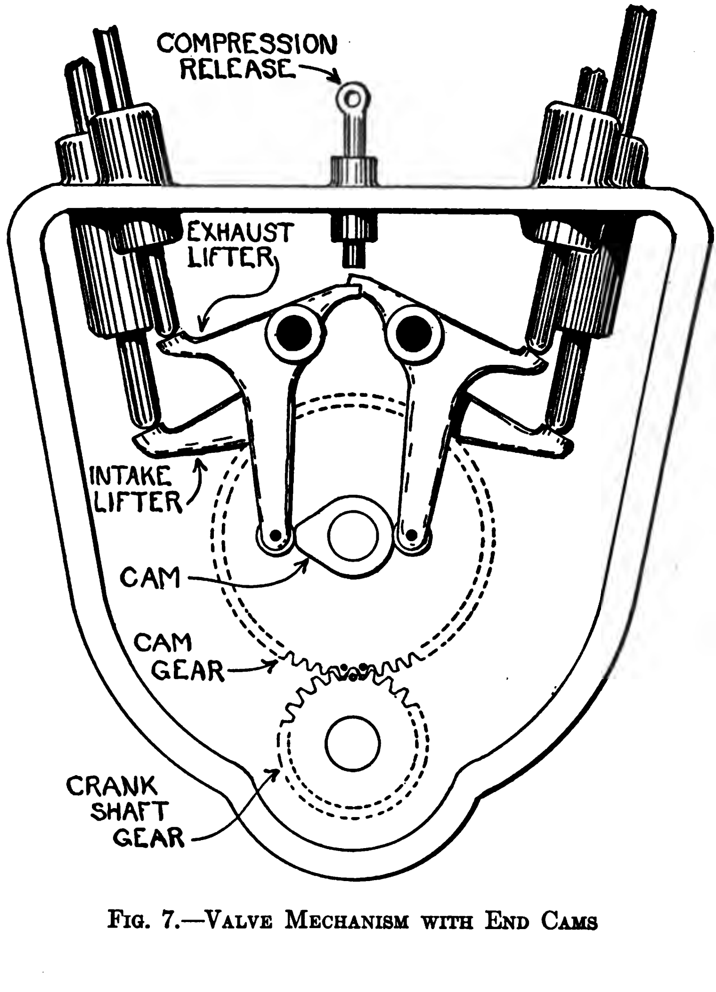


FIG. 7.—VALVE MECHANISM WITH END CAMS

as shown in Figure 8. In some engines there is a cam shaft on each side, this being necessary when the inlet and exhaust valves are on opposite sides of the cylinder.

The valves of the Ford engine are all on one side, and the cam shaft is of the kind shown in Figure 8. The Ford valve arrangement is different, however, for instead of being located one over the other, and moving in opposite directions to open, as shown in the illustration, the valves are side by side and both move upward to open.

As an exhaust valve must open against the pressure that exists in the cylinder toward the end of the power stroke, it must be forced open, and is always operated by the engine in the manner that has been described. At the time when the inlet valve opens, there is no pressure in the cylinder; furthermore, the valve opens in the same direction as the flow of mixture that will enter through it. In some engines the valve is

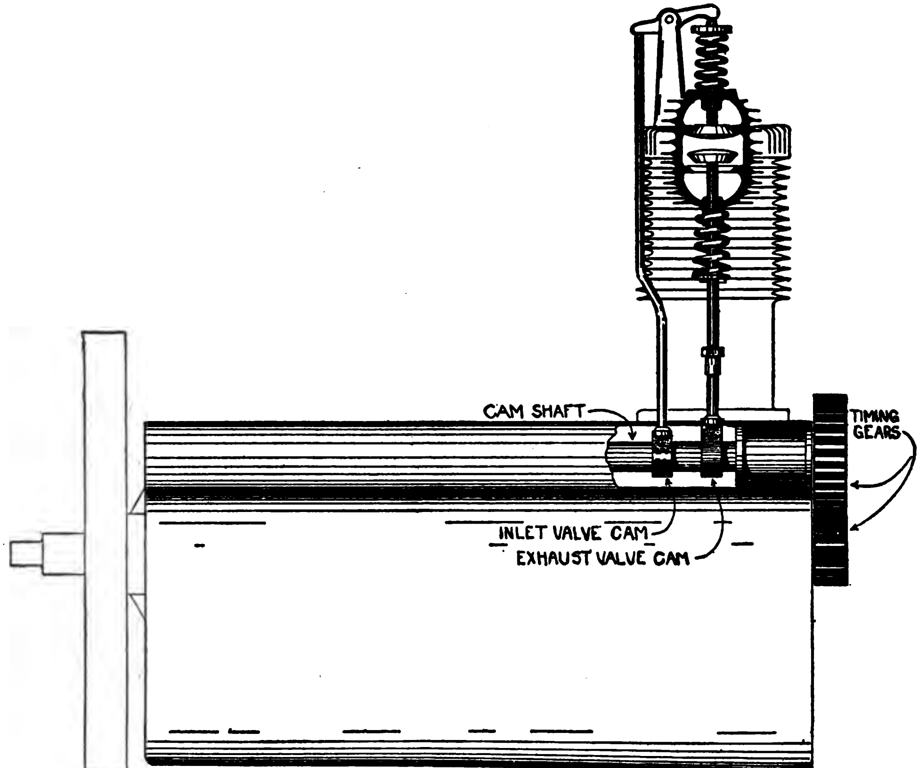


FIG. 8.—VALVE MECHANISM OF FOUR-CYLINDER ENGINE

opened by the suction created during the inlet stroke, an **automatic valve** of this kind being shown in Figure 9.

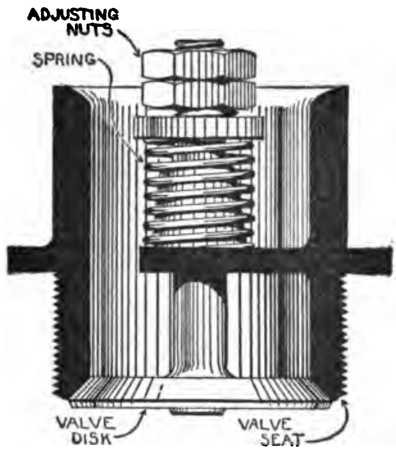


Fig. 9.—Automatic Valve

The valve disk with its seat and spring is contained in a cage that is screwed into the cylinder, while to the upper end of the cage is attached the inlet pipe through which the mixture flows. A proper adjustment of the spring will permit the valve to be sucked open at the beginning of the stroke, and it will be closed by the spring at the end of the stroke when suction ceases.

Automatic valves are not as satisfactory as mechanically operated valves, for the reason that the springs do not stay in adjustment. Thus a valve that works perfectly one day may be sluggish the next day, and by not opening and closing correctly, will prevent the proper charging of the cylinder.

If all of the heat that is produced in the cylinder could be applied to the expansion of the mixture, the engine would run with greater efficiency; that is, a far greater number of miles could be traveled on one gallon of gasoline. Much of the heat is wasted in heating the cylinder, however, and unless something is done to prevent it, the cylinder will get so hot that it will warp out of shape; furthermore, the oil will burn before it has time to lubricate the bearing surfaces. Either of these conditions would jam the piston and cause destruction.

The cylinder cannot be prevented from absorbing heat, and means are therefore provided for getting rid of the heat and keeping the cylinder cool.

When a man wants to cool a hot iron bar he will swing it around his head; the rush of air against the bar will cool it. If he lets the bar stand it will cool off, but much more gradually. By swinging the bar it is continually coming into contact with cool air, the particles of which absorb some of the heat and pass off to make way for other cool particles.

When the hot bar is at rest, the air around it becomes heated, and this heat slowly passes to the surrounding air. Thus the rapidity with which the bar cools depends on whether fresh, cool air can come into contact with it.

The engine of a motor cycle is exposed to the air, and as the machine moves, fresh particles of cool air are continually coming into contact with its cylinders; it is this rush of air that is depended on to carry off the excess heat. In order to make the system effective, however, it is necessary to give a large surface to the outside of the cylinder, the greatest possible quantity of air thus being brought into contact with the heated iron. The cylinder is therefore made with a number of thin flanges projecting from it, as shown in Figures 6, 8 and 10.

Air cooling is by far the simplest method of getting rid of the excess heat, but it requires the engine to be in such a position that it is fully exposed on all sides to the rush of air. This is the situation with motor-cycle engines, but when an air-cooled engine is used on an automobile, where it is inclosed in a bonnet or protected by other parts of the car, it must be provided with some method of supplying a plentiful flow of air.

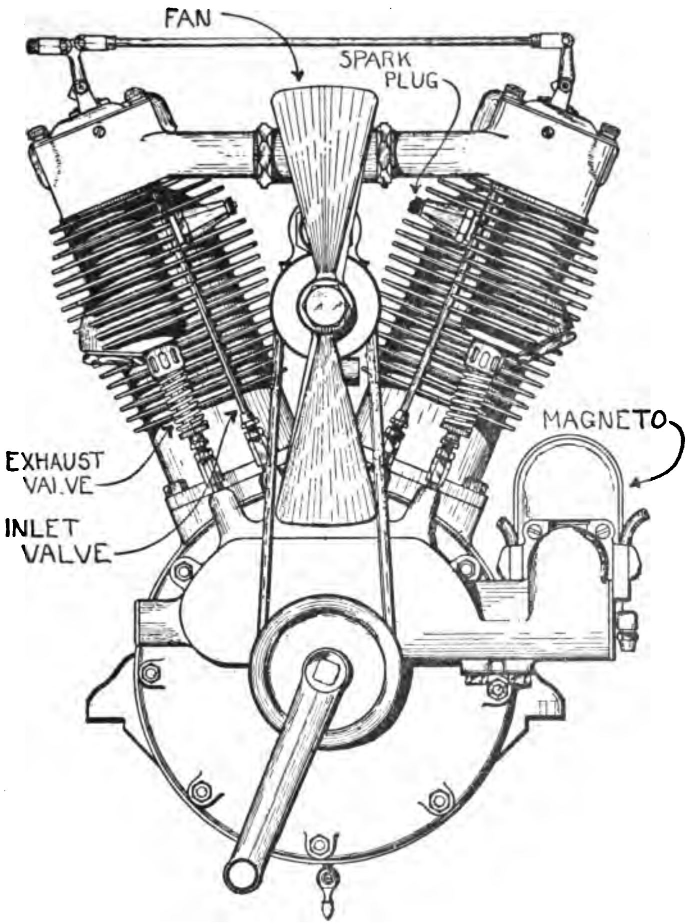


Fig. 10.—Twin Cylinder Engine

Thus the cycle-car engine shown in Figure 10 is fitted with a fan driven by a belt from the crank shaft. The fan runs at high speed and adds its blast of air to the air current that is set up by the movement of the car.

The engines that are used on the more powerful cycle cars and by automobiles in general are cooled by the flow of water through channels, or **water jackets**, cast around the upper part of the cylinder. Water jackets are shown in Figure 11. The water is kept in circulation sometimes by a pump, and sometimes by following the principle that hot water is lighter than cold water and will therefore float on it.

This latter is called the **gravity**, or **thermo-syphon**, system, and it is this that is used on Ford engines. The water spaces are large, and communicate at the top with a pipe that slopes upward to the top of the **water-cooler**, or **radiator**, that is located at the front of the car. This sloping pipe may be seen on top of the engine shown in Figure 14.

The radiator consists of a great number of small pipes through which the water flows from the top to the bottom; air is drawn between the pipes and takes up the heat that the water has absorbed from the cylinders. It is thus seen that even with water-cooling systems the heat finally passes to the air.

From the bottom of the radiator the cooled water passes upward to the bottom of the water spaces. As the water in the water spaces becomes heated, it rises, and its place is taken by the cool water, which becomes heated in its turn. The circulation is slow, but as the quantity of water is quite large, the cooling is effective.

The great advantage of an air-cooled engine is shown in winter, for it is quite unaffected by cold. With a water-cooled engine there is always the danger of having the water freeze; if ice forms in the water spaces it is very likely to crack the thin iron of the water jacket, while the formation of ice in the radiator is sure to burst the pipes. The water in the radiator is in such thin sheets, owing to the small size of the pipes, that it will freeze when the thermometer is barely at the freezing point, and when water standing in the gutters shows no sign of frosting.

In cold weather it is necessary to drain the water from a water-cooled engine if the car is to be left standing, or to mix alcohol, glycerine, or some other material with the water to keep it liquid.

Before an engine can run, a charge of mixture must be taken into the cylinder and compressed; thus it is necessary to revolve the crank shaft in order to take the piston through the inlet and compression strokes. It is easy enough to move the piston through the inlet stroke, but it takes considerable effort to turn the crank shaft while the piston is performing compression. The charge in the cylinder resists compression, but if the engine is to be started, the crank shaft must be turned in spite of the resistance; furthermore, it must be turned at some speed. If the speed is too low, the suction during the inlet stroke will not be sufficient to draw gasoline from the carburetor, and no mixture will form.

In order to make it easy to crank a motorcycle engine at good speed, it is fitted with a device that permits some of the charge to escape during the compression stroke, this device being called the **compression release** or **decompressor.** It usually consists of some method of raising the exhaust valve slightly during the compression stroke, as would be done by an extra cam that could be brought into contact with the exhaust-valve lifter when desired.

More frequently it is a separate attachment that moves the valve lifters independently of the cams, and a device of this sort is shown in Figure 6. By pressing on the compression release rod, the wedge on its lower end presses the sliding rod end-ways, thus moving the valve lifter and opening the valve. In a twin engine, the compression release would operate both valve lifters; for the sake of clearness only one sliding rod is shown in Figure 6.

A similar device is shown in Figure 7.

A compression release can be made to operate either by pushing or by pulling, but, however this may be, the final action is to lift the exhaust valve.

CHAPTER IV

LUBRICATION

IF two ordinary bricks are pressed together it will be found quite difficult to slide one on the other, for the roughness of their surfaces will make them cling, and will tend to prevent motion. If a little sand is placed between the bricks they will be found to slide quite easily, for the rough places will be filled up, and the bricks will be sliding on the sand instead of on each other.

A similar condition exists when one piece of metal is made to slide on another, for even though the surfaces of the two may be smooth and polished they will still tend to cling together and to resist being moved.

If we look at the polished surface of a piece of steel through a microscope, it will be seen to be quite rough, and it is this roughness, slight though it is, that makes it difficult to slide the pieces one on the other. They can be forced to slide, of course, but then the rough spots will chafe each other, and the metal surfaces will finally show signs of wear.

By putting oil between the surfaces, the roughness will be filled up, and the blocks will slide with great ease; but they will be sliding, not against each other, but against the oil that is between them. The oil will form a layer, or film, and will keep them apart.

If the sliding movement of the blocks is continued, the oil will squeeze out at the edges, and it will consequently be necessary to keep feeding fresh oil.

With light blocks, and when the pressure between them is small, a very thin oil, such as typewriter oil, can be used. Such oil is almost as liquid as water, and will not have much ability to cling to the surfaces, but even so, it will be able to stay in place against the light pressure.

If the blocks are heavy, and there is great pressure between them, the thin oil would be squeezed out very quickly, thus permitting the blocks to touch; in such a case it would be necessary to use a thick oil, which has great clinging ability.

The kind of oil to be used is of importance, for it must be adapted to the pressure between the parts that are to be lubricated.

Every part of a machine that moves against some other part must be oiled, the effect of the oiling being to keep the parts from touching. The distance that separates them is extremely small, of course, but it will be sufficient to prevent one from rubbing against the other.

When the movement is small, and when it is slow, no great attention need be paid to the oiling, but when the motion is continuous, as is the case with a revolving shaft, and especially when it is at high speed, the oiling must be looked to with great care. If the oil supply stops, the parts come together; the friction of one against the other produces heat, which expands the parts and makes them bind, with the result that they grind into each other and are eventually destroyed.

The oiling of the moving parts of a gas engine is of far more importance than the oiling of a lawn mower or of a grindstone, for in the first place they are in motion for a far longer time at a stretch, and move at high speed. What is more vital is the heat of the parts due to the burning of the mixture.

When oil is heated it becomes thinner, and is then less able to cling to the surfaces and to lubricate them; if the heating is continued, the oil will burn and thus be rendered entirely useless. If the wrong kind of oil is used between the piston and the cylinder walls it will burn and pass away before it can lubricate, and the parts will then wear rapidly because they are permitted to come into contact. These are the vital parts to oil and to keep oiled, for in addition to the destructive effect of the heat that would be caused by the excessive friction resulting from a lack of oil, the wear of the piston and cylinder walls will permit the mixture to leak between them.

Taking for granted that the proper kind of oil is used, the engine must have a system for distributing the oil in sufficient quantity to all of the moving parts. The crank shaft and connecting rod bearings, the valve mechanism and similar parts either run in oil, or are continually splashed with it.

There is a limit to the amount of oil that can be supplied to the piston and cylinder walls, however, for if too much is used it will work its way up to the combustion space and give rise to various troubles. Being inflammable, the oil will burn with the mixture, but in so doing, it will form a deposit similar to coke on the cylinder and piston heads, the valve pockets, and the rest of the inner surface of the combustion space.

Particles of this **carbon** will collect under the valves and prevent them from closing tightly; they will clog the piston rings and stick them in their grooves; they will interfere with the production of the ignition spark; and by becoming heated, they will glow and ignite the incoming fresh charge before the proper time. The feed of oil is therefore so adjusted that the supply is just sufficient to keep the cylinder walls lubricated, and no more.

When the piston is at the bottom of its stroke the thin film of oil on the upper part of the cylinder walls will be burned, but this quantity is so small that it will not give trouble. As oil is continually being lost in this way, it is necessary to keep feeding fresh oil, which is done by a **lubricator** supplied from the oil tank.

The simplest lubrication method is to keep oil standing in the crank case, to be splashed to all parts of the mechanism as the crank shaft revolves; the oil feed will supply the number of drops per minute that are necessary to compensate for the oil that is used up.

If an engine runs at a constant speed this is satisfactory, for fresh oil will be required in a fixed quantity. When an engine runs at high speed it uses up far more oil than is the case at low speed, so when the engine speed varies, as is the case with motor cycle and light-car engines, the oil feed must vary to correspond.

Figure 11 illustrates an oiling system in which oil is supplied as required by the engine, regardless of the speed at which the engine runs. The oil tank is air-tight, its only opening being a pipe that leads to the crank case, where its end is below the level of the oil standing there. It would seem at first glance that all of the oil could run out of the tank; this is not the case, however, for no

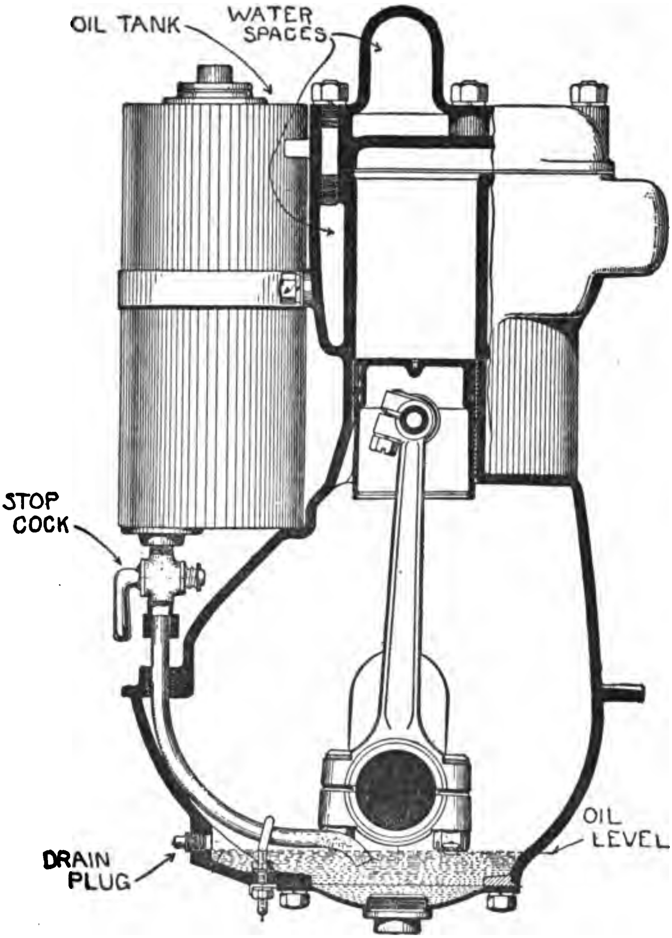


FIG. 11.—VACUUM OILING SYSTEM

oil can run out of the tank unless air can enter to take its place. As the end of the tube is under the surface of the oil, no air can enter, and the tank thus retains its oil.

As the engine uses up the oil in the crank case, the level drops, until finally the end of the pipe is exposed; a portion of air immediately enters, and an equal quantity of oil flows out of the tank. The flow from the tank is controlled by the stopcock. The action of this system is automatic, and any desired depth of oil in the crank case will be maintained.

In other systems the fresh oil is fed by a pump that is driven by the engine; when the engine speed increases the pump runs faster and delivers the greater quantity of oil that is then necessary.

An oil pump is shown in Figure 12. It consists of a round hole in a metal housing, in which is a snugly fitting plunger rod, carrying at its upper end a block of metal in which is cut a crosswise slot. This slot receives a pin that projects from the end of the drive shaft; as the pin is on one side of

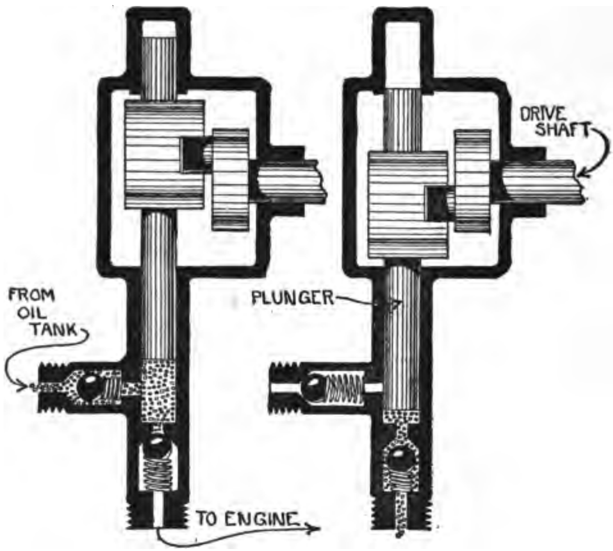


FIG. 12.—OIL PUMP

the center of the shaft, the turning of the shaft makes the plunger rod move up and down.

Below the plunger is a space having two

openings, one connected to the oil tank and the other to the engine. Each opening has a ball check valve, one arranged to permit the oil to enter but preventing it from leaving, while the other permits oil to leave but prevents it from entering.

When the plunger makes an upward stroke, the ball check valve on the tank opening is sucked from its seat and oil is drawn into the oil space; at the same time the ball check valve on the engine opening is sucked against its seat and thus prevents the oil in the crank case from being drawn in. On an outward stroke, the tank valve is held against its seat, and the oil in the oil space is forced out to the engine, the valve opening to let it pass.

The amount of oil forced to the engine depends on the stroke of the pump; or in other words, on the distance that the plunger moves. The pump stroke is adjustable, so that any desired quantity may be delivered.

In a great number of engines the oil is

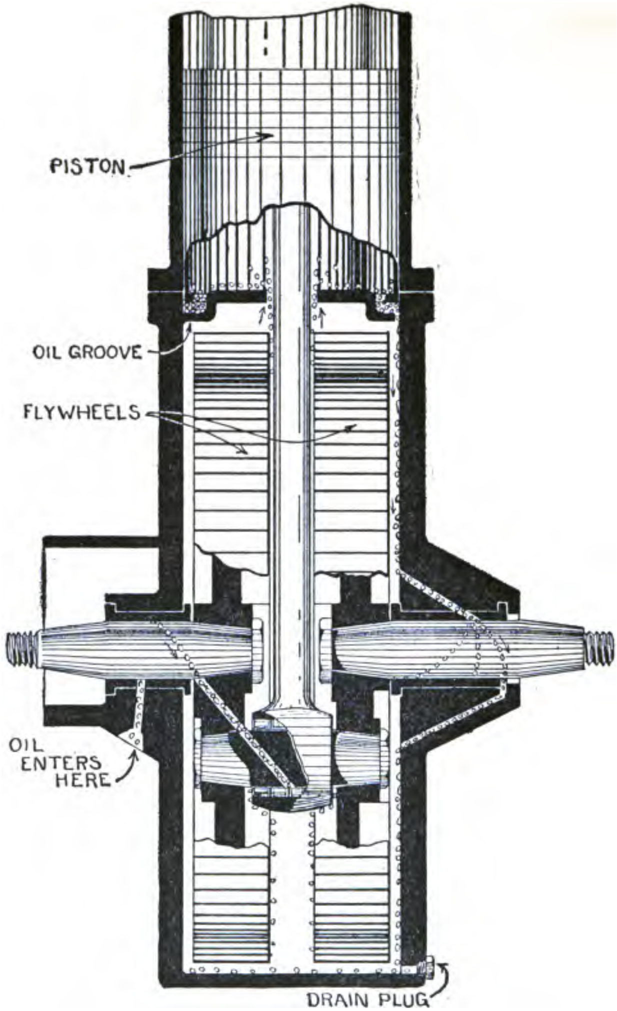


Fig. 13.—Forced Circulation Oiling System

forced to the bearing surfaces, so that if there is oil in the tank and the pump is operating, the bearings will infallibly receive the necessary oil.

A system of this sort is shown in Figure 14. The oil enters at the left crank shaft bearing, and passing around the shaft it flows to the lower connecting rod bearing by channels cut through the fly wheel and the crank pin. Flowing from the connecting rod bearing, it drips on the fly wheel, which throws it to all parts of the crank case.

The lower end of the cylinder is covered with a plate in which is cut a slot for the connecting rod to pass through; some of the oil is thrown through this slot, and collects in a groove into which the lower edge of the piston dips at the end of the stroke. The oil thus picked up by the piston lubricates the piston and cylinder walls.

The excess oil overflows from the groove, and finding its way into the crank case, en-

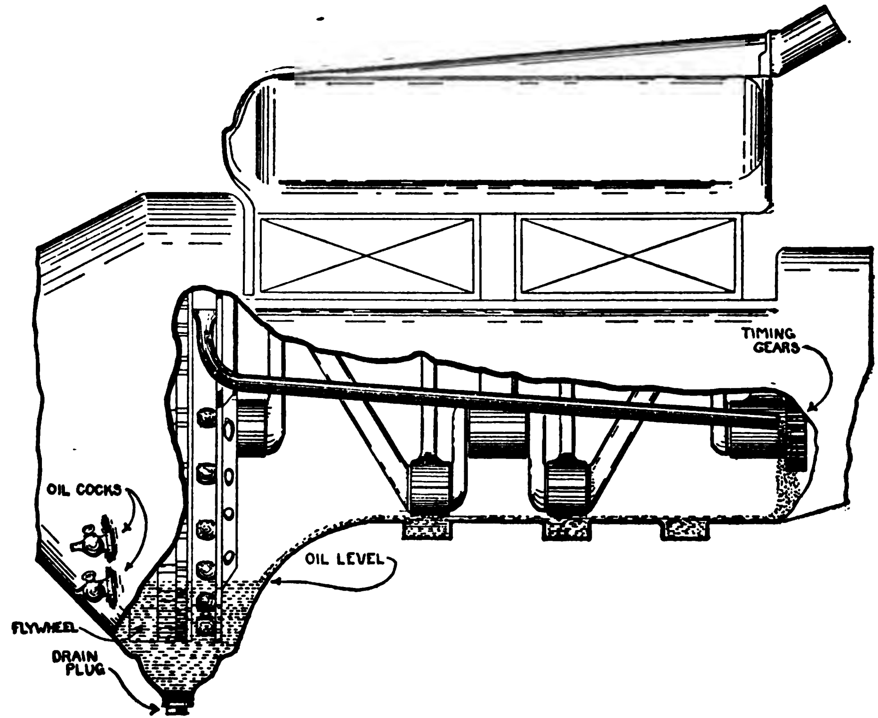


FIG. 14.—OILING SYSTEM OF FORD ENGINE

ters a channel that conducts it to the right crank-shaft bearing. A system of this sort is called a **forced circulation** system.

In the Ford engine the crank case is extended to inclose the fly wheel and other part of the mechanism, the housing around the fly wheel forming a pocket that contains the oil supply. This is shown in Figure 14. As the fly wheel revolves, it churns up the oil and throws it to all parts of the crank case. Some of the oil is caught in the oil tube that is shown, and is thus conducted to the front of the engine, where it lubricates the timing gears and other parts of the mechanism located there.

In draining back to the fly-wheel housing it fills pockets under the cylinders, and the connecting rod ends, dipping into these pockets, splash the oil to the pistons which distribute it to the cylinder walls.

Two oil cocks are set in the fly-wheel housing, by which it can be told whether there is a sufficient quantity of oil. If the oil does not flow when the lower cock is opened, the oil level is too low, and if it flows from the upper cock the level is too high.

If an engine is run with insufficient oil the results may be serious, and the oiling system should therefore be watched with the greatest care. A failure of the oil supply will cause the piston to stick or "seize" in the cylinder, the first signs of this being a loss of power and the abnormal heating of the cylinder. If the engine is kept running it will begin to make a groaning noise, which will quickly be followed by seizing.

The effects of a seize are likely to be warped and cut piston and cylinder, cut ball and roller bearings and melted plain bearings. Aside from a wreck, the injury caused by running without oil gives rise to the most expensive repairs that an owner is called on to face. There is truth in the saying that oil costs less than repair bills.

CHAPTER V

CARBURETION

WHILE gasoline is the fuel used for motor-cycle and automobile engines, these engines will not run on gasoline alone, for by itself gasoline will not burn. In order that there may be fire there must be air, for air provides the oxygen without which fire cannot exist. A lighted candle dropped into a bottle will flicker and go out, for it quickly uses up the oxygen in the bottle; as no more is able to enter, the flame dies for lack of support.

Gasoline must thus be mixed with air in order that it may burn, and as a liquid cannot mix with a gas, the first step is to turn the gasoline into gas by vaporizing it; the ease with which gasoline may be vaporized is the reason why this particular liquid is used as fuel.

Gasoline is supplied to the engine by a device called a **carburetor.** The carburetor is first of all a proportioner, for it must deliver gasoline in the exact proportion to form a proper mixture with the air drawn into the cylinder.

In order that the engine may deliver its full power, the mixture must burn with the utmost rapidity; furthermore, it should be uniform, so that it will burn evenly and completely. If there is too much gasoline in the mixture for the air, the mixture, which is then said to be **rich,** will burn slowly, and, like a lamp that is turned up too high, its flame will be smoky. The smoke arising from it contains lamp black, which will collect on the walls of the combustion space and will eventually be the cause of trouble.

If there is not enough gasoline for the air, the mixture is said to be **poor**, and will produce but little heat.

The volume of air that may be drawn into the cylinder depends on the bore and stroke of the engine. To produce a proper mixture from this volume of air the carburetor is so made that the quantity of gasoline that flows from it may be adjusted to suit.

A carburetor much used for motor-cycle engines is shown in Figure 15. The opening marked **mixture outlet** is connected to the inlet-valve chamber, so that all of the air that passes into the cylinder through the inlet valve must first pass through the carburetor. The suction that is created in the cylinder during an inlet stroke extends to the carburetor and starts a current of air through it, most of the air entering through the main inlet.

The passage through which the air flows passes through a bowl containing gasoline; a small pipe called the **spray nozzle** permits gasoline to flow from the bowl to the air passage. When the engine is at rest, the gasoline stands just below the tip of the nozzle. When suction is created in the air passage, gasoline is drawn out, and is picked up and carried along by the air that is flowing to the cylinder.

As shown in the second sketch, Figure 15, a **needle valve** fits into the tip of the spray nozzle; by adjusting this needle valve any desired amount of gasoline can be permitted to flow out.

If the flow of air through the air passage were constant and uniform, a carburetor would be a simple thing to build and to adjust. This, however, is not the case. The air flows only when the piston is making an inlet stroke; the flow starts abruptly and is very intense while it lasts. As air is light in weight, it starts to move as soon as the inlet valve opens, and quickly reaches full speed. Gasoline being heavier, it gets into motion more slowly, and by the time it has started to flow the air is moving at some speed. The first part of the charge that enters the cylinder therefore contains very little gasoline.

When the inlet valve closes, the flow of air ceases instantly, but the heavier gasoline, which by that time is flowing strongly, cannot stop so abruptly, and continues to flow for a brief period. This extra gasoline is not sufficient to make much difference when the engine is running slowly, for then the suction is not great. With the intense suction that is created at high speed, however, the extra gasoline will be sufficient to make the mixture entirely too rich. It would be possible to prevent this by closing down on the gasoline adjustment, of course, but that would make the mixture too poor at low speed.

The difficulty is overcome by providing the carburetor with a second opening to admit an extra quantity of air at those times when the mixture tends to become too rich.

This opening takes the form of an **extra air valve,** which is a seat with a light disk held against it by a spring. The suction works in the opposite direction to the spring; at high speeds it is able to draw the valve open, thus allowing the admission of extra air.

At low speeds a proper proportion is maintained between the air entering the main air inlet and the gasoline that is drawn out of the spray nozzle, by the spray nozzle adjustment. The surplus gasoline that is forced out of the spray nozzle at high speed by inertia is taken care of by the adjustment of the extra air valve.

At extreme high speed, too much air is likely to enter through the extra air valve, the mixture thus being rendered too poor; in the carburetor shown in Figure 15, this is taken care of by opening the gasoline adjustment, a little more gasoline then being admitted. This is done by placing a cam on the throttle in such a manner that when the

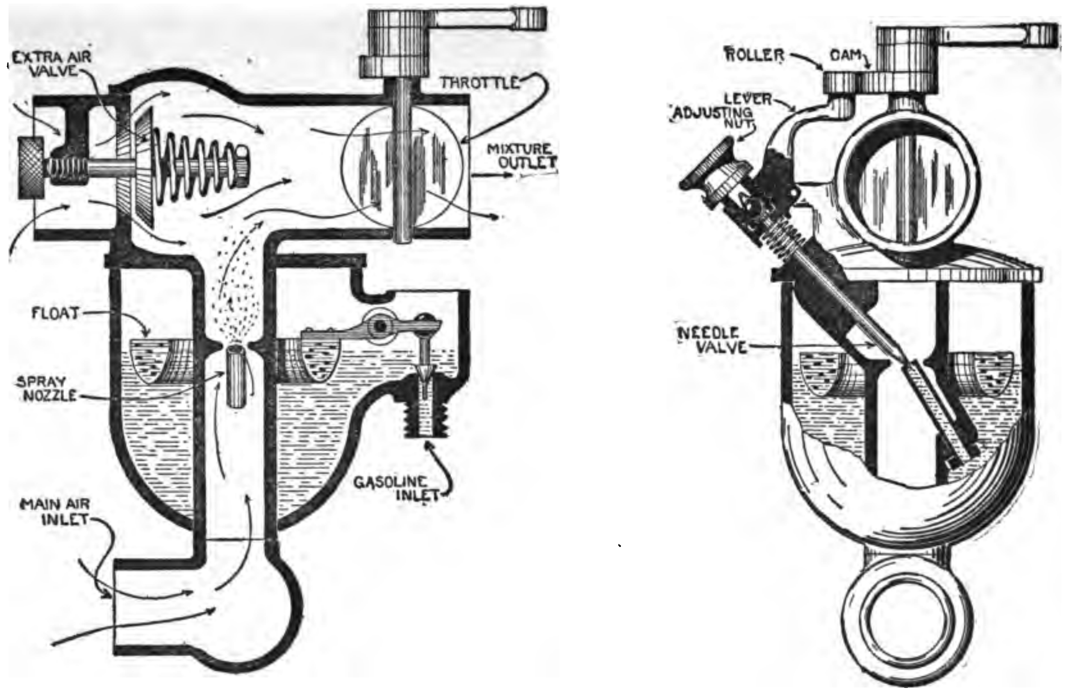


FIG. 15.—COMPENSATING CARBURETOR

throttle is opened the cam moves a lever that in turn lifts the needle valve from the tip of the spray nozzle.

This carburetor thus has three adjustments: the gasoline needle valve, the extra air valve, and the lift of the lever that is operated by the throttle cam. When making the adjustment for low speed, the extra air valve should be closed, all of the air thus being forced to enter through the main air inlet; the needle valve is then adjusted to admit the correct amount of gasoline.

On speeding up the engine by opening the throttle and advancing the spark, the mixture will become too rich, and the quantity of extra air that is then necessary is regulated by adjusting the tension of the air-valve spring. Further regulation of the mixture for high speed is made by an adjusting device on the lever that raises the needle valve.

It is important to maintain a fixed level of gasoline in the spray nozzle, and this is done by means of a **float** and **float valve.** From the gasoline tank the gasoline enters the bowl through an opening that is controlled by a needle valve attached to one end of a pivoted lever; on the other end of the lever is a piece of cork. As gasoline enters the bowl the cork floats on it, and when it has risen to the proper point, its movement of the lever closes the float valve. When gasoline is drawn from the bowl by suction on the spray nozzle, the float drops, and as this moves the lever and opens the float valve, fresh gasoline enters from the tank and brings the level to the proper point.

The carburetors that are used on Ford cars are somewhat different in details from the one described, but the principle is much the same. In the one shown in Figure 16, the gasoline does not flow into the air current from the spray nozzle, but from a puddle, over the surface of which the air passes on its way to the cylinder. In flowing over the surface of the gasoline, the air picks up enough to form a mixture, and the gasoline thus carried off is replaced by a flow through the opening that serves as a spray nozzle.

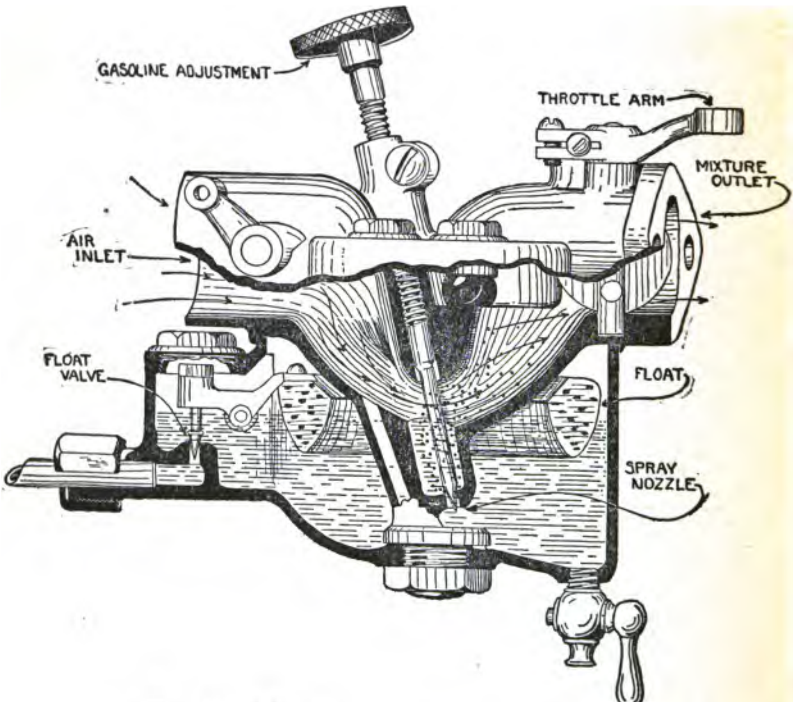


Fig. 16.—One Type of Ford Carburetor

When the engine is running at speed the gasoline is picked up as fast as it flows through the nozzle, and the puddle consequently forms only when the speed is low or when the engine is at rest. The flow of gasoline is controlled by the needle valve, which may be turned by a knob on the dash.

At higher speeds, extra air is admitted through holes which are covered by balls of various sizes and weights. At medium speed the suction will lift the lighter balls from the holes, thus permitting the entrance of a little extra air, while at high speed the suction will be sufficient to lift all of the balls from their seats.

Figure 17 shows another type of Ford carburetor, which is similar in action.

The gasoline that was on the market some years ago was quite different in quality from what is being supplied to-day, and it was a much simpler matter to form a mixture with

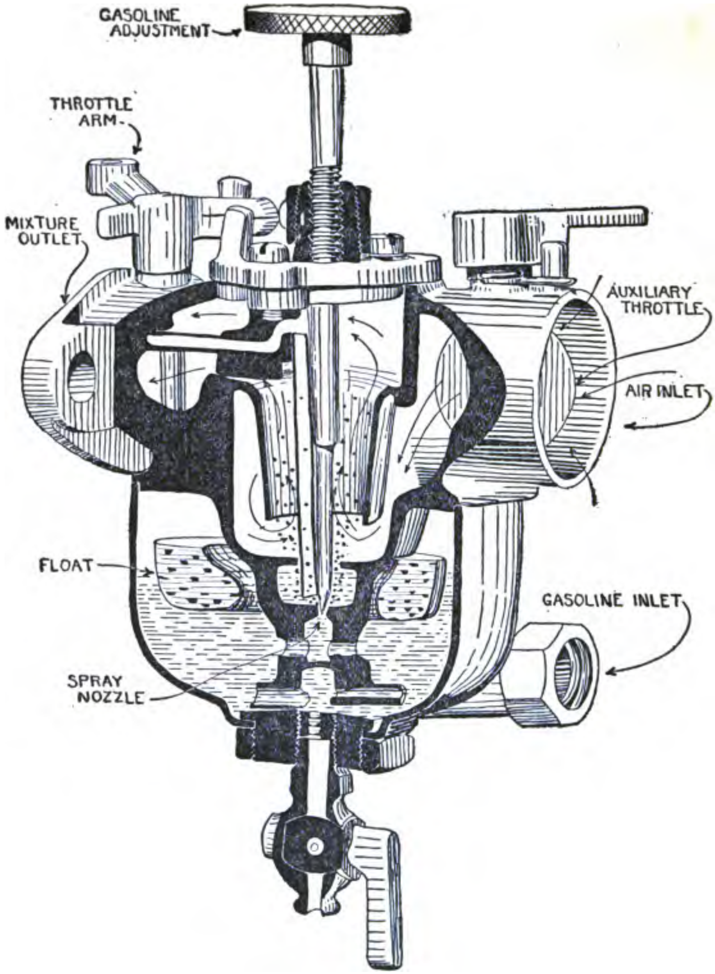


Fig. 17.—Another Type of Ford Carburetor

it. It evaporated so readily that a saucerful would quickly pass away, leaving the saucer bone dry; the gasoline of to-day evaporates slowly, and when it passes off it leaves an oily deposit.

The former kind of gasoline would evaporate as soon as it left the spray nozzle; the kind that we have to-day evaporates so slowly that much of it is carried into the cylinder in drops, not having time to turn to gas while passing through the inlet pipe. These drops turn to gas during the compression stroke, which makes difficult the formation of a uniform mixture.

By heating the gasoline it can be made to evaporate more quickly, and it is for this purpose that a carburetor should be supplied with warm air. The attachment that provides for this consists of a sleeve that surrounds the exhaust pipe or some other hot part of the engine, with a tube leading to the main air inlet. The air entering the carburetor is thus heated, and causes the rapid evaporation of the gasoline.

Gasoline will evaporate much more quickly when it is in the form of fine spray than when it is in large drops, and the carburetor makers therefore design their carburetors so that the gasoline will be broken up into fine drops as it leaves the spray nozzle. Sometimes this is done by the form of the spray-nozzle tip, but it is more usual to reduce the size of the air passage at the point where the gasoline leaves the nozzle. This is indicated in Figure 15.

In order to flow through this small opening, the air must greatly increase its speed, and the rush of air at this point tears the gasoline into very fine drops. This is satisfactory when the engine is running fast, but when it is running slowly, the air is not moving fast enough to have this effect; in consequence, a portion of the gasoline will leave the nozzle in comparatively large drops.

These drops will be too heavy for the air current to carry to the cylinder, and they will lodge on the intake pipe walls. This is illustrated in Figure 18. Sketch A shows an inlet pipe when the engine is running at speed; the throttle is open, and the finely divided gasoline is carried to the cylinder.

In sketch B the engine is supposed to be running more slowly, but with the throttle wide open, as is the case when climbing a hill. As the air current has a lower speed, it is not able to carry all the gasoline to the cylinder, and a portion collects on the walls of the inlet pipe, as indicated.

When the top of the hill is reached and the engine resumes its speed, the first effect of the increase in the speed of the air current is to draw from the spray nozzle the quantity of gasoline necessary to form a proper mixture. Another effect of the increased suction, however, is to strip from the walls of the inlet pipe the gasoline that has lodged on

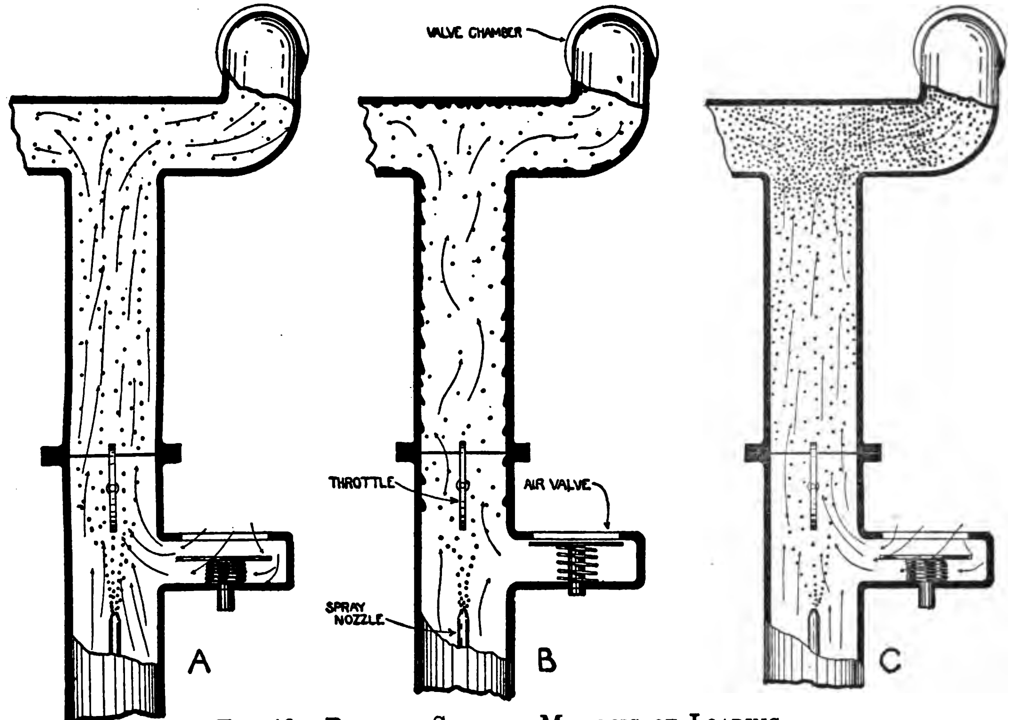


Fig. 18.—Diagram Showing Meaning of Loading

them, and this gasoline, added to what is being supplied by the spray nozzle, will make the mixture entirely too rich. This is indicated in sketch C.

The mixture will be so rich that it will be unable to ignite, and the engine will go through two or three revolutions without producing power strokes. When these charges of over-rich mixture have passed through the cylinders, and a proper mixture is again established, the engine will take up its cycle once more. This condition is known as **loading**, and it is caused primarily by the low grade of the gasoline and its consequent inability to evaporate readily.

Loading may be reduced or prevented by the use of a high-grade carburetor properly adjusted to the engine, and by the application of heat, which may be supplied by a warm air intake such has been described, or by so arranging the carburetor and intake pipe that a circulation of hot water from the engine may be maintained around them.

CHAPTER VI

IGNITION

WHEN the charge of mixture has been taken into the cylinder and compressed, it is ignited, or set on fire, by passing an electric spark through it. Every gas engine must therefore be equipped with apparatus for producing this spark. This apparatus is called the ignition system, and it includes the parts that are necessary for making an electric current, and for controlling the current so that the spark will occur at the exact instant when the cycle requires it.

An engine can be made to run after a fashion with an imperfect mixture, but when anything goes wrong with the ignition it will not run at all. It is therefore necessary to know how the ignition system works in order to handle it properly, and the first step in learning this is to learn something of electricity.

The force that we call electricity is considered to exist in everything, but as long as it is at rest we do not notice it. To make electricity useful it must be started in motion, or, in other words, converted into an **electric current**; an electric current is electricity that is moving, just as wind is moving air, and as a river is moving water. A **generator** starts electricity into motion and thus produces an electric current; the battery that rings the front door-bell is a generator, and so is the dynamo that lights the electric lamp.

Figure 19 shows a pump drawing water out of a tank and forcing it through a pipe; in flowing out of the pipe the water drives a water wheel. Thus the pump generates a current of water, and as long as it continues to run, the water will flow and the wheel will turn.

In order to keep on delivering its current, the pump must be continually supplied with water; in the system shown in the sketch, the water returns to the tank after driving the wheel. Thus the water can be said to be flow-

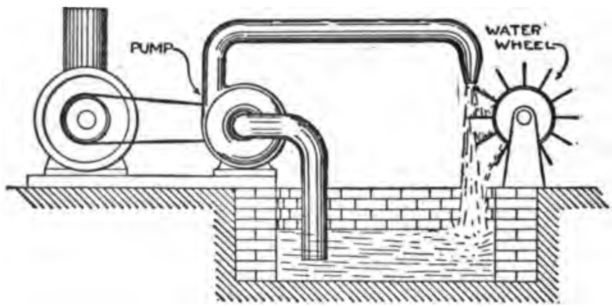


Fig. 19.—Principle of Current Flow

ing over a **circuit**, the circuit consisting of the pump, the pipe, the wheel and the tank.

When an electric generator starts working, its electricity will flow and become an electric current, if it has a circuit to flow over, and the circuit, of course, must permit the electricity to return to the generator. Then if we want to ring a bell or to light a lamp, the bell or the lamp is put into the circuit so that the current must go through it in order to flow.

The circuit is made of material that will permit the current to flow, such as metal or carbon; these are called **conductors** of electricity. As electricity cannot flow through rubber, or wood, or cloth, or china, these substances cannot be used in an electric circuit. There is a necessity for these things, however, for they are used to keep the current on its proper circuit, thus preventing it from leaking back to the generator without doing its work. Such substances as these are called **nonconductors** or **insulators.**

The circuit provided for the current may be of wire, or it may be made up of different pieces of metal. The pieces of metal must touch, however, or be in **contact**; if they do not touch, so that there is an air space between them, the current cannot flow, for air is one of the best insulators. When the circuit is interrupted by an air space it is said to be an **open circuit**; when the metal path is complete, and the current can flow, it is said to be a **closed circuit.**

In an ignition system the current flows part of the way by wire and the rest of the way by the metal of the engine; a circuit of this sort is called a **grounded circuit.**

If a pump is pumping hot water the pipe will become heated, and so will the air surrounding the pipe. The flow of water thus has a direct effect on the air around the pipe. In a similar way, the flow of electric current over a wire has a direct effect on the air surrounding the wire; the space around the wire becomes charged with magnetism. This force appears the instant that the current begins to flow, and dies away when the current stops flowing.

At first thought magnetism would not seem to have anything to do with an ignition spark, but as a matter of fact it has everything to do with it, for the electric current that forms the ignition spark is always produced by magnetism. The battery that rings the front door bell, for instance, would not give a proper spark, but the battery current can be used to produce magnetism, which in turn can be made to generate an electric current that will give a good ignition spark. In order to understand an ignition system we must therefore understand something about magnetism, and how it is produced and used.

Everyone has played with a magnet, and knows that it will pick up pieces of iron and steel, but that it has no effect on wood, copper, rubber, or any other substances. When iron filings are stirred with a copper wire they will not be attracted to it, but if an electric current is made to flow through the wire, the filings will cling to it as if it were a true steel magnet (Fig. 20). The filings will jump to the wire and cling to it the instant that the current begins to flow, but will fall away then the flow of current stops.

Iron filings will not be attracted to a piece of iron, but if a magnet is brought near the

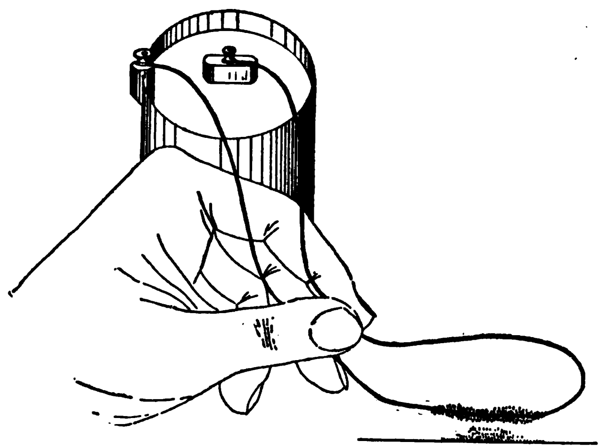


FIG. 20.—MAGNETISM FROM ELECTRICITY

piece of iron, the filings will be attracted, and will thus show that under that condition the iron is a magnet, with magnetism of its own (Fig. 21). When a piece of iron is near magnetism it becomes a magnet, and it remains a magnet until the magnetism is removed.

FIG. 21.—MAGNETIZING A PIECE OF IRON

We thus learn two things of importance; first, that the flow of an electric current over a wire produces magnetism, and second, that iron will itself be a magnet as long as it is near magnetism. Bearing these facts in mind, let us wind a piece of wire around a bar of iron, and pass a current through it, as shown in Figure 22; the bar of iron will

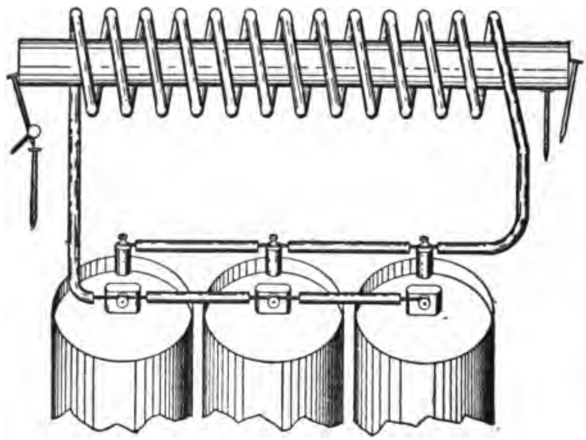


FIG. 22.—MAGNETIZING AN IRON BAR BY ELECTRICITY

become a magnet and will remain so as long as the current continues to flow.

Magnetism can thus be produced from electricity, and, conversely, electricity can be produced from magnetism. Figure 23 shows an iron bar with a wire wound around one end, this wire being connected with a generator so that an electric current can flow through it; around the other end of the bar is wound a second wire in no way connected with the first.

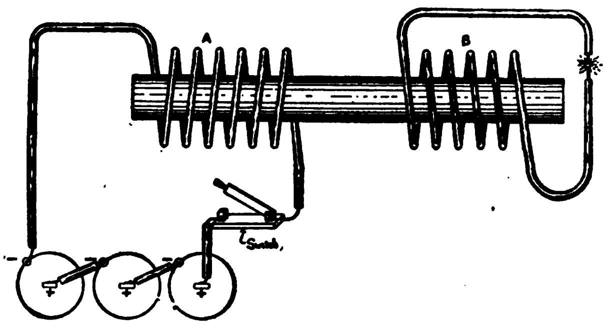


FIG. 23.—ELECTRICITY FROM MAGNETISM

When the current is not flowing, there will be no magnetism in the bar; it will be no more than a plain piece of iron. When the circuit is closed and the current flows, the bar will become magnetized by the magnetism set up by the current in the wire. The bar will begin to become magnetized the instant that the current starts to flow, and its magnetism will get stronger and stronger until it reaches the greatest strength that can be produced by that current. The bar will remain magnetized as long as the current continues to flow, and its magnetism will die away very abruptly the instant that the flow of current stops.

If the current weakens, the strength of the magnetism will weaken also; any change in the strength of the current will be accompanied by a corresponding change in the strength of the magnetism of the bar.

Whenever the magnetism of the bar changes strength, an electric current will appear in the second wire, and the strength of this new current will correspond to the change in the strength of the magnetism. Every slightest change in the strength of the magnetism produces a current, and the current will be strongest when the change from weak to strong, or from strong to weak, is most abrupt.

When the circuit of the first wire is closed and the generator current starts flowing, the bar rapidly becomes magnetized to full strength, and the magnetism remains at full strength while the current continues to flow. The new current will flow in the second wire *only while the change is going on,* the flow stopping the instant that the strength of the magnetism of the bar stops changing.

On the breaking of the generator circuit the magnetism of the bar will die away very abruptly, and while it is dying the new current will again flow in the second wire.

Thus it is seen that the new current is produced, or **induced**, only while the magnetism is changing strength. It makes no difference how the bar is magnetized; it may be magnetized by an electric current, as described, or by bringing a steel magnet near it, or in any other way.

In the generators used on ignition systems, we have to do chiefly with permanent magnets, which are bars of hard steel, usually bent in the form of the letter U; they are highly magnetized, and retain their magnetism indefinitely. Magnetism flows from one end of the bar through the metal to the other end, and, because it must have a complete circuit, it passes across the space between the ends.

Magnetism can flow through air, and will do so if it must, but it is easier for it to flow through iron. In consequence, when a piece of iron is near the ends of the magnet, the magnetism will flow through it if by so doing its path will be made easier. This flow of magnetism will make the iron a magnet, and it is the magnetizing of such a piece of iron that makes an ignition generator give a current.

An arrangement of this sort is shown in Figure 24, which illustrates the principle of the generator on a Ford car. The magnets

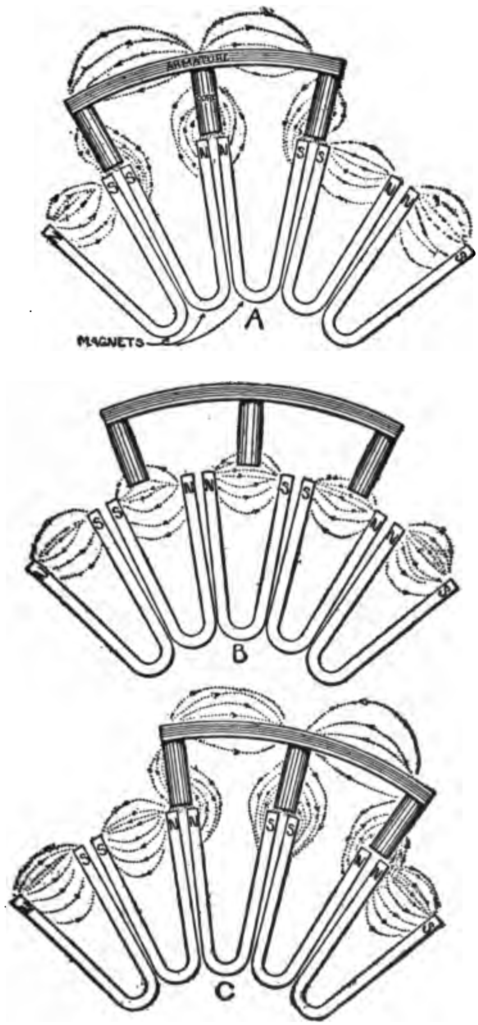


Fig. 24.—Principle of Ford Magneto

are arranged around a circle, and a piece of iron is moved past their ends. This piece of iron, called an **armature**, has **iron cores** projecting from it, the ends of the cores passing the ends of the magnets as the armature moves. When the cores are opposite the ends of the magnets, as in sketch A, the armature forms a sort of bridge by which the magnetism can flow; it is easier for the magnetism to take this bridge than to flow through the shorter air space between the magnet ends.

When the armature has moved to the position shown in sketch B, it no longer forms a bridge for the magnetism; the paths offered by the tips of the cores are of little help, and practically all of the magnetism flows through the air. While the cores are magnets when in position A, they lose their magnetism when in position B, but again become magnetized when the further movement of the armature takes them to position C.

As the armature moves, there is thus a

constant change of magnetism in its cores. Their magnetism dies away to nothing and then reappears, and this complete change occurs while the cores move across from one end of a magnet to its other end.

In the Ford magneto, sixteen magnets are secured, like spokes, to the side of the fly wheel, with their ends at the fly wheel edge. The cores project from the side of the armature ring, which is held stationary facing the side of the fly wheel. In Figure 24 the core ends are shown opposite the tips of the magnet ends, but this is for the sake of clearness; in the actual magneto the core ends face the sides of the magneto ends.

When the fly wheel turns through one revolution, each core is magnetized and demagnetized sixteen times; the faster the wheel turns, the more abruptly do these changes in magnetism occur. By winding a coil of wire on each core, the arrangement becomes a generator, for a current is produced in each coil with every change in the magnetism of its core. The current produced in any one coil is very small, but as the coils are connected into one circuit the total current produced is quite sufficient for ignition purposes.

The current produced by this generator will not produce an ignition spark, however, for it is not under sufficient pressure. In this it is similar to water flowing from the ordinary fire hydrant at so low a pressure that it does little more than run out of the spout. A fire engine takes that water, and by its pump applies so great a pressure to it that the stream will carry over the roof of a three-story building.

The pressure of the electric current is increased by the use of an **induction coil**, the principle of which is shown in Figure 23. A low pressure current will produce intense magnetism in the core of an induction coil; by special means this magnetism is caused to die away with great abruptness, and a current of very high pressure will then appear in a second coil of wire that is wound on the core. The arrangement is shown in Figure 25, the generator being three dry cells.

The low pressure current flows to the primary winding, which consists of a layer of heavy wire, by way of the **vibrator,** the purpose of the vibrator being to break the circuit with great abruptness. The **vibrator blade** is a flat spring secured at one end, the free end being opposite the end of the core; an adjusting screw touches the vibrator blade near the middle. The current flows from the generator to the blade, and as the blade touches the screw, it can pass to the screw and thence to the primary winding and to the generator.

The magnetism of the core produced by this flow of current will attract to the core any iron or steel near it, and the blade is consequently drawn in. This movement of the blade breaks its contact with the screw, and the flow of current is thus cut off; as a result the magentism dies out of the core, and the blade, thus being released, springs back to its former position. On touching the screw it re-establishes the circuit; the core is magnet-

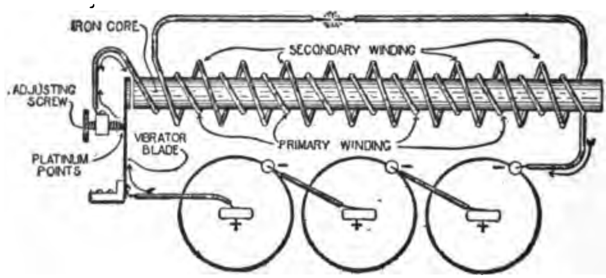


FIG. 25.—PRINCIPLE OF INDUCTION COIL

ized, the blade again drawn away from the screw, and the series of operations is repeated. This takes place some hundreds of times every second, each movement of the blade indicating a change in the magnetism of the core.

To take advantage of these changes in

magnetism, and to cause them to produce currents, a second or **secondary winding** is placed on top of the primary winding, as indicated in Figure 25. Each turn of wire is affected by the changes in magnetism, and the current produced in the secondary winding will be under such high pressure that it will be able to jump across a small air space, thus forming a spark.

In making a coil, two or three layers of heavy wire will be used for the primary winding. For the secondary winding a very great number of layers is necessary, for the greater the number of turns of wire that are affected by the magnetism, the greater will be the pressure of the current. In order to get many turns of wire close to the magnetism, the wire used is very fine, and resembles a horse hair in size.

In Ford cars, there is a coil for each cylinder, each coil being in a box; the four boxes are set in a case on the dash. The system thus has a generator to produce a current and coils to give this current the necessary pressure; in addition, there must be a device for making each coil produce its sparking current at the instant when it is required in the cylinder.

This device is called a **timer or a commutator**, and it is nothing more than a revolving switch. A timer is shown in Figure 26. It consists of an outer case containing a ring of insulating material, such as wood fiber or hard rubber. This is held over the end of the cam shaft, so that a roller attached to the cam shaft rolls around the inside of the ring. Four pieces of metal are equally spaced around the ring, so that as the cam shaft turns, the roller will come into contact with them, one after the other.

As shown in Figure 26, the magneto current flows to a switch, and then to a wire connecting one end of the primary windings of the four coils. The other ends of the prim-

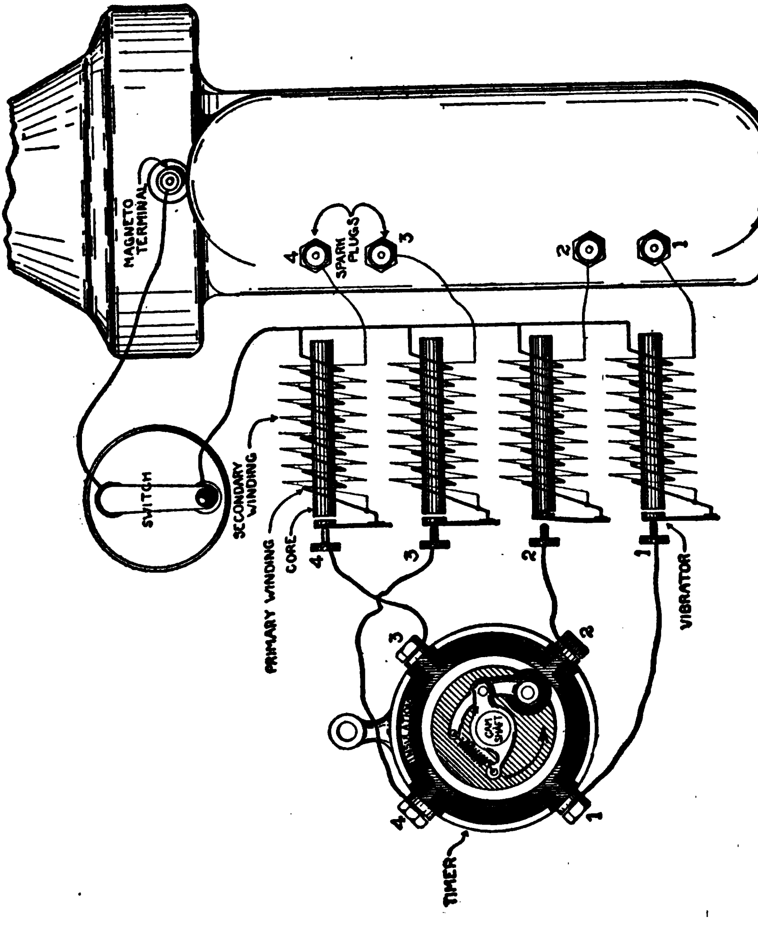


FIG. 26.—FORD IGNITION SYSTEM

ary windings are each connected to one of the timer contacts; when the timer roller touches one of the contacts, the current can flow to it and thus to the metal of the engine. As the inner end of the magneto winding is also attached to the metal of the engine, the circuit is thus complete.

The timer roller is shown touching the contact of coil 2, and as long as it continues to touch, the vibrator blade will be in action. Every movement of the blade will be accompanied by a high-pressure, or **high-tension,** current in the secondary winding, and by a spark in the spark plug.

It will be noticed in Figure 26 that while one end of the secondary winding leads to the spark plug, the other end is attached to the primary winding; it is by this connection that the high tension current returns to the secondary winding after passing through the spark plug. In the early ignition systems using such coils as these, one end of the secondary winding led to the spark plug, while the other end was secured to the metal of the engine. A complete circuit was thus provided, for after forming the spark in the spark plug, the high tension current could flow to the metal of the engine, to this **ground connection,** and so to the secondary winding.

It was then realized that as the primary winding was grounded, it was not necessary to provide another ground connection for the secondary winding; both currents could make use of the single ground connection. Thus in the Ford system, the high tension current flows to the metal of the engine after forming the spark in the spark plug, and can thus reach the grounded end of the magneto winding; by flowing through the magneto winding, the switch, and the primary winding of the coil, it thus returns to the secondary winding. As the magneto and primary windings are of good size, the secondary current can easily flow over them.

Thus it is that while there are two windings on each coil, the coil box has but three terminals where apparently it should have four.

In order to be able to advance and retard the spark, the timer ring with its contacts may be turned around the shaft for part of a revolution. With the timer in the position shown in the sketch, let us suppose that the spark is to be retarded, which requires the timer roller to touch a contact later in the revolution of the cam shaft. To get this effect, the timer ring is turned in the direction in which the shaft is revolving and, as will be seen, this will move the timer contact ahead of the roller. The roller, therefore, will not reach the contact until later in the revolution of the cam shaft, which means later in the revolution of the crank shaft and later in the stroke of the piston.

When the spark is to be advanced, the

timer ring is turned in the opposite direction to the way the shaft is turning, in which case the roller will reach the contact earlier in the revolution of the cam shaft.

The timer ring is attached to a rod that may be moved by a finger lever under the steering wheel; the position of the spark is thus under the control of the driver.

Ignition by vibrator coils is very general, and may be found on various makes of cycle cars and automobiles. Except in the Ford car, however, the generator is a battery.

In order that the sparks may be uniform in each cylinder, and may occur at precisely the same point in the stroke, the vibrators must be adjusted with great exactness. If one blade is stiffer than the others, the core of its coil must be more strongly magnetized in order to draw the blade away from the adjusting screw; as the current must flow through the primary winding for a longer time in order to produce this more intense magnetism, the spark from that coil will be delayed.

There is no great difficulty in making the adjustment, but as the slight sparking at the vibrator contacts will eventually wear them down and corrode them, it is necessary to repeat the process with some frequency. To avoid this the **master vibrator** system has been introduced.

In applying a master vibrator, the vibrators of the coils are put out of action by screwing down on the adjusting screws, and thus making a permanent connection. A special coil with a vibrator is then connected into the circuit so that the generator must flow through it in order to reach the induction coils.

This is illustrated in Figure 27, which shows four sparking coils. The vibrators are not shown, their places being taken by permanent connections. The master vibrator is

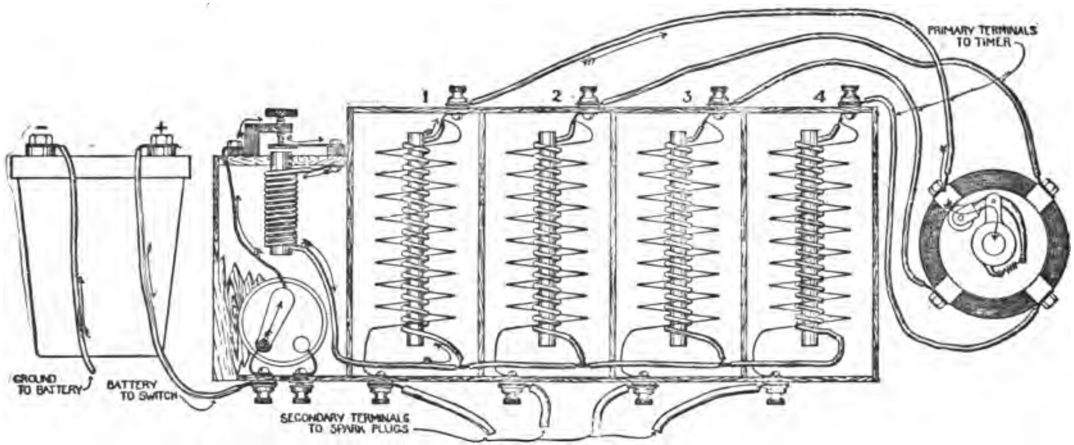


Fig. 27.—Master Vibrator Battery System

a core with a primary winding only, the vibrator blade being opposite its end.

The battery current flows through this coil on its way to the primary windings of the sparking coils, and the vibrator operates whenever the timer makes a contact. Whatever may be the adjustment of the master vibrator, its action is the same for the four coils, and the sparks are therefore uniform in intensity and in appearance.

In a coil ignition system such as this, the flow of current through the primary winding continues for a sufficient time to magnetize the core very intensely, and it is the great change from intense magnetism to no magnetism that produces the high tension current. A spark can be obtained from weaker magnetism if the magnetism is made to die out with extreme abruptness, and this is taken advantage of in the Atwater-Kent ignition system.

This system uses a coil without a vibrator, its primary winding being supplied with current from a battery; the circuit is made and

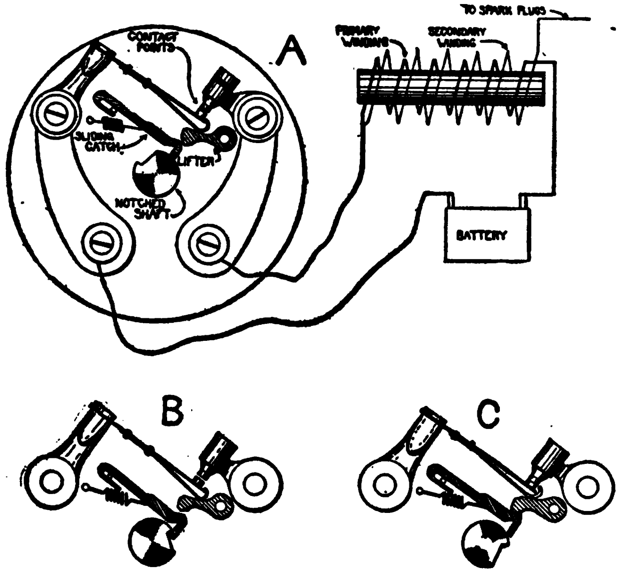


FIG. 28.—ACTION OF ATWATER-KENT SPARK GENERATOR

broken by the device shown in Figure 28. The parts of the device are carried on a plate, in the center of which revolves a notched shaft driven by the engine. As shown in diagram A, the end of a sliding catch rests on the side of the notched shaft. When the shaft revolves, the end of the catch drops into the notch, and the catch is drawn forward, as shown in diagram B. By dropping into the notch, the catch passes below the lifter, and can thus be drawn beyond it without touching it.

As the shaft continues to revolve, the notch passes from under the catch, which is then free to be snapped back to its original position by the spring. While thus moving, its upper angle strikes the lifter, which is thrown upward to make room for the catch to pass. This movement of the lifter closes the circuit through the primary winding of the coil, for, as shown in diagram C, it moves the contact spring upward and thus brings the contact points together. When the catch has passed, the lifter drops back to its original position, and the contact points spring apart.

The closing and opening of the contact points occurs with such extreme rapidity that the movement cannot be observed; when watching the operation of the device, the movements of the sliding catch may be seen, but the contact spring appears to be stationary.

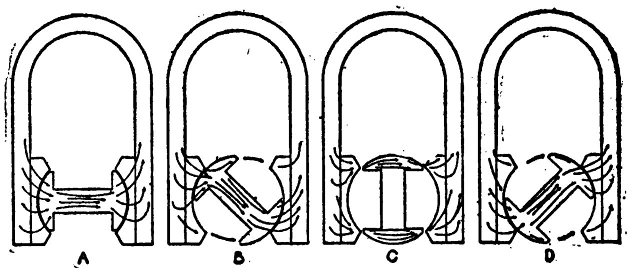


FIG. 29.—ACTION OF A MAGNETO

So brief a closing of the circuit does not allow time for the core to become thoroughly magnetized, but the dying out of such magnetism as is produced is so abrupt that a satisfactory sparking current appears in the secondary winding of the coil.

A further part of the apparatus is a high-

tension distributor, which is a revolving switch that passes the high tension current to the spark plugs in proper rotation. This system has been adopted by many makers of cycle cars and automobiles.

On motor cycles the ignition spark is universally produced by a **high-tension magneto,** and this system is also found on many cycle cars and on all classes of automobiles. This magneto is an independent machine, containing within itself everything that is necessary for the production and control of the spark.

The motor-cycle and light-car magneto has two U-shaped magnets; between their ends revolves an iron core on which is wound a great length of wire. As the core revolves, its center part is continually being magnetized and demagnetized, and these changes produce sparking currents in the wire winding.

Figure 29 shows an end view of the magnets of a magneto and the shape of the core;

it also illustrates the different paths taken by the magnetism as the core revolves.

When the core is in position A, its center bar forms a bridge that permits the easy flow of magnetism from one end of the magnet to the other. When the core is in position B it still forms a bridge, but the magnetism must flow for a greater distance in order to pass over it; in consequence, some of the magnetism is finding it easier to flow part of the way by the heads of the core and to jump through the air for the rest of the way. As less magnetism thus passes through the center bar of the core, this part is not so strongly magnetized.

When the core is in position C the center bar loses all of its magnetism, for then the flow is by the heads of the core. In position D the flow is again through the center bar, and this part retains its magnetism until the core makes half a turn and comes into the position corresponding to position C.

In one revolution of the core there are thus two positions in which its center bar is demagnetized, and the sudden loss and then renewal of the magnetism as the core passes over each of these positions produces an ignition spark. The magneto is therefore capable of producing two sparks during each revolution.

Figure 30 shows the arrangement of the windings and other parts of a high tension magneto. The core, which, with its windings, is called the **armature**, has a few layers of heavy wire forming the primary winding, on top of which is a great number of layers of very fine wire forming the secondary winding. In the diagram the windings are shown side by side for the sake of clearness. The secondary winding is connected to the primary winding, and forms a continuation of it.

The magneto is fitted with a **circuit breaker**, one part of which is a pivoted lever in contact with the metal of the magneto,

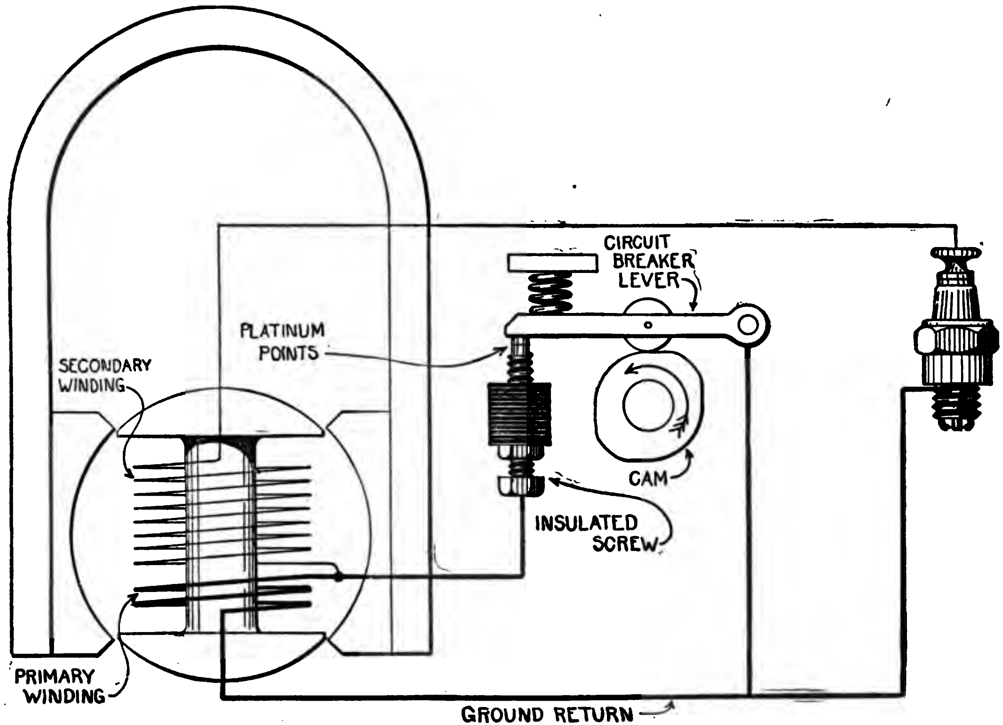


FIG. 30.—ACTION OF HIGH-TENSION MAGNETO

while the other part is a stationary insulated screw. These two parts form a circuit with the primary winding, and when the lever is touching the screw the primary current has a complete path over which it can flow.

During the time when the armature is approaching position C, the circuit breaker contacts are closed, and current flows in the circuit, being produced by the weakening of the magnetism of the core. When the armature passes to position C the very great change in magnetism that then occurs causes an intense flow of current in the primary winding, and while that intense current is flowing the circuit breaker opens and breaks the primary circuit.

In the meantime, the same change of magnetism that causes the flow of primary current tends also to produce a current in the secondary winding. The electricity in the secondary winding struggles to flow and to become a current, but cannot do so because its only path, which is across the spark plug, is broken by the space between the spark-plug points.

When the primary current is prevented from using its circuit by the opening of the circuit breaker, it seeks a new path in which it may continue its flow, and finds that its only outlet is through the secondary winding. The sudden rush of primary current into the secondary winding, added to the endeavor of the electricity in the secondary winding to form a current, gives a combination that is sufficiently intense to force a path across the space between the spark-plug points, and a spark is produced there as it passes.

In a magneto, one end of the primary winding is grounded by being secured to the metal of the core, while the other end leads to the insulated screw of the circuit breaker. The circuit-breaker lever is grounded by being pivoted on a metal part of the magneto, the circuit being closed when the lever touches the screw.

In a Bosch magneto the circuit breaker is mounted on the armature and revolves with it, as shown in Figure 31, which illustrates the magneto used on single-cylinder engines. The free end of the secondary winding is connected to the **slip ring,** which is a ring of brass supported on a hard rubber wheel; the slip ring is also mounted on the armature. A stationary carbon brush presses against the slip ring; any secondary current flowing to the slip ring is picked off by the brush, from which a wire leads it to the spark plug.

The principal parts of the circuit breaker are the insulated screw and the pivoted lever, and they are mounted on a disk which is attached to the armature. This is illustrated in Figure 32. Around the disk is a ring containing a curved piece of steel called the cam. As the disk revolves, the end of the pivoted lever strikes one end of the cam, and is forced

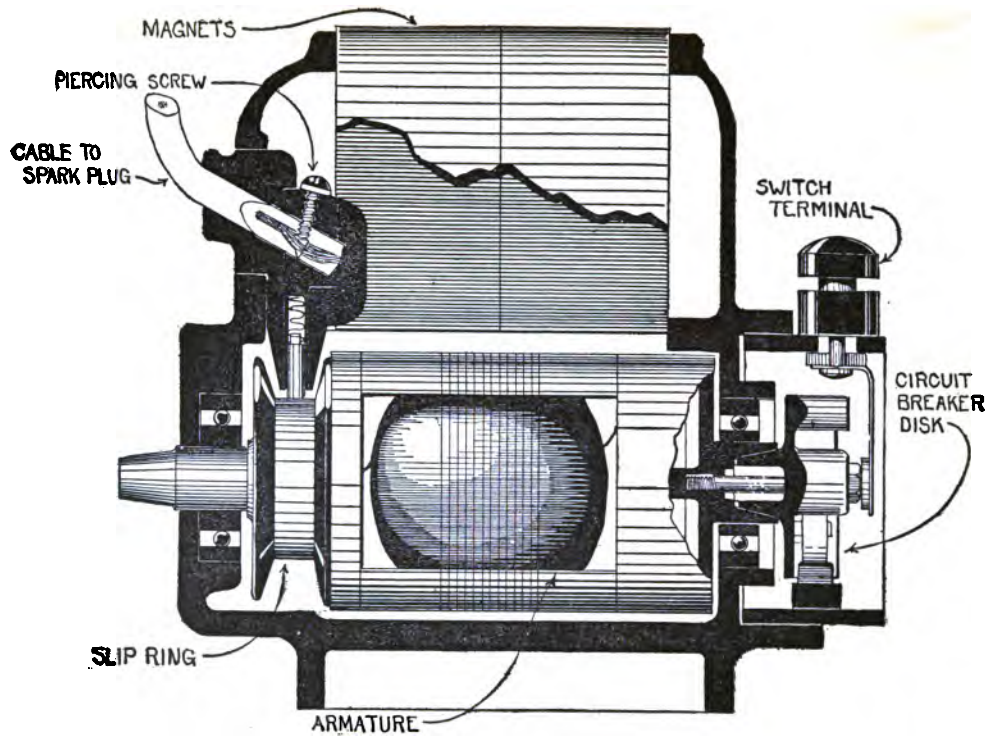


FIG. 31.—BOSCH SINGLE-CYLINDER MAGNETO

to move on its pivot; this moves the lever away from the insulated screw and breaks the circuit. Later in the revolution of the

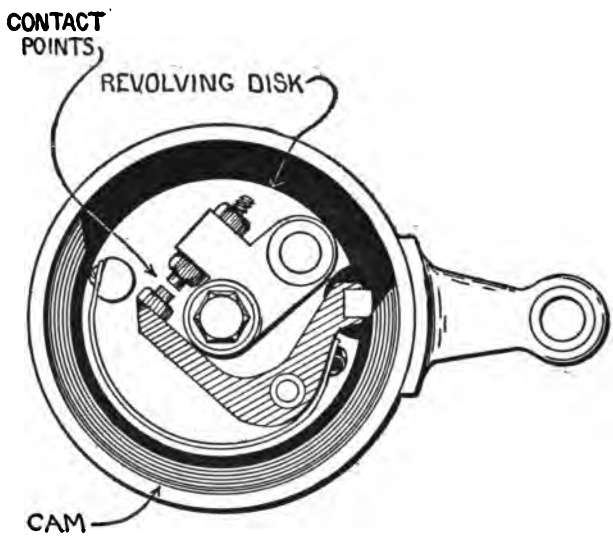


FIG. 32.—BOSCH CIRCUIT BREAKER ON SINGLE CYLINDER MAGNETO

armature the end of the lever passes beyond the cam, and a spring returns it to position, the contact points then closing.

By moving the ring, and with it the cam, the contact points may be made to open early or late in the revolution of the armature, thus giving the advance and retard of the spark.

As a magneto is capable of giving a spark every half-revolution of the armature, and as a single-cylinder engine requires a spark once in every two revolutions of the crank shaft, it would appear that the magneto should be driven so that its armature makes half a revolution while the crank shaft makes two; or in other words, at quarter-speed. This would give good results when the engine ran at full speed, but ignition would cease when engine speed was reduced, for then the armature would be turning so slowly that the changes in the magnetism of its core would not occur abruptly enough to give a good sparking current.

Magnetos for single-cylinder engines are therefore so made that they produce only one spark during each revolution of the armature, and are driven at half the speed of the crank shaft. A magneto will give a spark only on the opening of the contact points; if these are not permitted to close there can be no flow of primary current and therefore no production of a sparking current.

It will be seen in Figure 32 that the cam will hold the contact points open for more than half of the revolution of the armature, which covers one of the two times during each revolution when the armature is in position C, Figure 29. If both sparks are to be utilized there will be two cams, the circuit breaker then closing and opening each time that the armature goes over position C. This is the case with magnetos built for engines with more than one cylinder.

For two-cylinder engines the slip ring band extends only half-way around the rubber wheel, as shown in Figure 33, and two carbon brushes are provided. During one break of the contact points the slip ring will be touching the right-hand brush, and the sparking current will flow to the spark plug with which that brush is connected. At the next break of the contact points, the slip ring will be

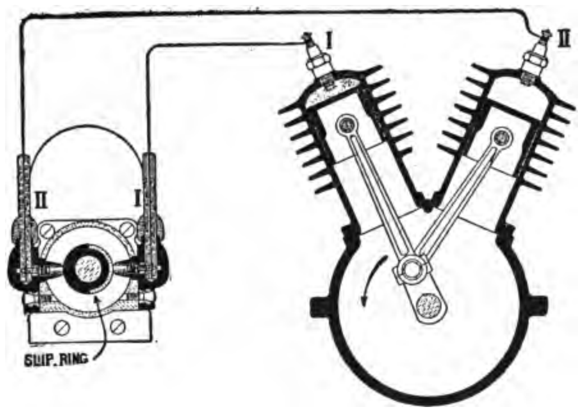


FIG. 33.—MAGNETO FOR TWIN-CYLINDER ENGINE

touching the other brush, so that the sparking current then produced will pass to the remaining spark plug. A two-cylinder magneto is driven at one-half of the speed of the crank shaft, because the two sparks that will be required by the engine during two revolutions of the crank shaft will be supplied by one revolution of the armature.

A four-cylinder magneto has a complete slip ring, and the single brush will pass the sparking current to a distributor that is built into the magneto. The distributor has as many contacts as the engine has cylinders, and the revolving distributor brush is so driven that it moves from one contact to the next while the armature makes one-half revolution. The distributor of a four-cylinder magneto will thus have four contacts.

During each revolution of the crank shaft, a four-cylinder engine will require two sparks; the armature is therefore driven at the speed of the crank shaft. The distributor must send a sparking current to each cylinder once during every two revolutions of the crank shaft, and it is therefore driven at one-half of the speed of the armature. The four sparks that are produced by the armature during two revolutions are thus passed to the cylinders during one revolution of the distributor.

In a four-cylinder engine, two pistons will be at top dead center when the other two are at bottom dead center, and some two-cylinder engines also are so made that their pistons are half a revolution apart. With the twin engines used on motor cycles, the situation is quite different, for when one of the pistons is at top dead center the other will be part of the way up the stroke. This was explained in the description of Figure 3.

The first diagram in Figure 3 shows that after piston 1 reaches top dead center, the crank shaft must make about one-third of a revolution before piston 2 reaches the same point; to make the magneto deliver sparks in these two cylinders, the armature would be required to make one-half of a revolution in this short period. This would require the armature to turn through one-half of a revolution during about one-third of a revolution of the crank shaft.

After producing its spark in cylinder 2, the armature, being driven by the engine, would make a number of revolutions before cylinder 1 was again ready for a spark. During these revolutions the magneto would be producing sparks, which would, of course, be passed to the cylinders; by occurring at the wrong points in the stroke they would prevent the proper operation of the engine. Furthermore, the high speed at which the magneto would be turning might be injurious to it.

Thus it becomes necessary to arrange the magneto so that it gives two sparks, not at intervals of exactly half a revolution, but at unequal intervals to match the unequal interval at which sparks are required by the engine. This is done by the construction of the heads of the armature core and of the iron blocks, or **pole shoes**, on the magnet ends.

The armature core is shown in Figure 34, and it will be seen that the overhanging edge of the upper head is cut away at the back, while the corresponding part of the lower head is cut away in front. The armature core in position in the pole shoes is shown in

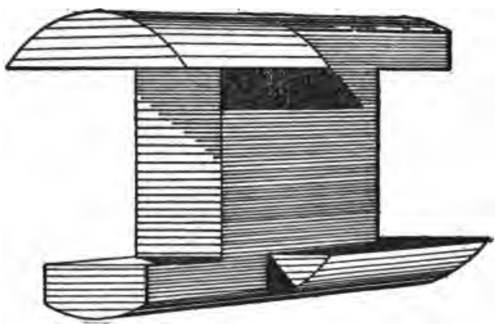


FIG. 34.—ARMATURE CORE FOR V-ENGINE

Figure 35. This shows that although the narrow ends of the core have left the short edges of the pole shoes, the wide ends of the core are still under the long edges; the magnetism is therefore still flowing through the center bar of the core. The center bar will not lose its magnetism, and the sparking current will

not be produced, until the wide heads pass from the long edges.

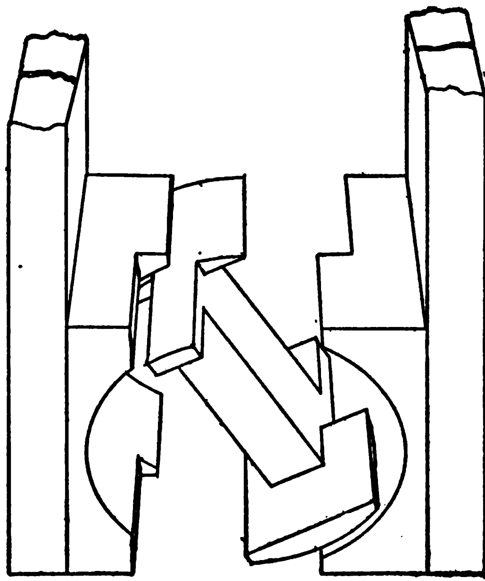


FIG. 35.—ARMATURE CORE AND MAGNET ENDS FOR V-ENGINES

When the core makes a half-revolution from the position shown in Figure 35, the narrow heads will be under the long pole-shoe edges, and the wide heads under the short edges. As the core continues to revolve, its wide and narrow ends will pass from under their pole-shoe edges at the same instant. A sparking current will then be produced, but it will be seen that the core has made considerably less than half a revolution from the point at which the previous sparking current was produced. Following on, it will then be cônsiderably more than half a revolution before the next spark it produced.

As all twin-cylinder engines do not have the same intervals between their firing points, the magneto must be made to suit any particular by a variation in the construction.

The circuit-breaker cams are so set that the contact points break at intervals corresponding with the production of sparking currents. This is shown in Figure 36, which illustrates the circuit breaker of the Splitdorf twin-cylinder magneto. The levers carrying the contact points are pivoted on a plate supported by the magneto frame, and it is the cam that moves; its action is along different lines from the Bosch circuit breaker illustrated in Figure 32.

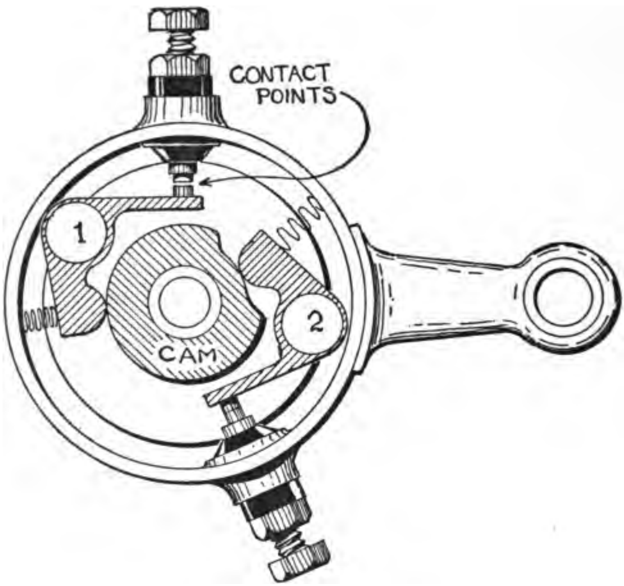


FIG. 36.—SPLITDORF CIRCUIT BREAKER ON TWIN-CYLINDER MAGNETO

The position of the two levers is such that after moving lever 2, the cam must turn further before moving lever 1 than will be necessary in turning from lever 1 to lever 2.

In any magneto, the most complete change in magnetism occurs as the armature passes over position C, Figure 29, for then the center bar of the core loses its magnetism, but after having lost it, it is immediately regained as the core moves toward position D. The gain in magnetism does not occur with the rapidity with which magnetism is lost, and consequently the sparking current produced by the dying away of the magnetism will be more intense than the current produced by the gain in magnetism.

When the magneto circuit breaker is in the advance position, the contact points separate at the instant when the rear edge of the armature is just leaving the pole shoes, as shown in the first sketch, Figure 37. When in the retard position, the circuit breaker does not open until later in the revolution of the armature, or until the armature is in the position shown in the second sketch. By the time the armature has reached this position, the change in its magnetism is not very great,

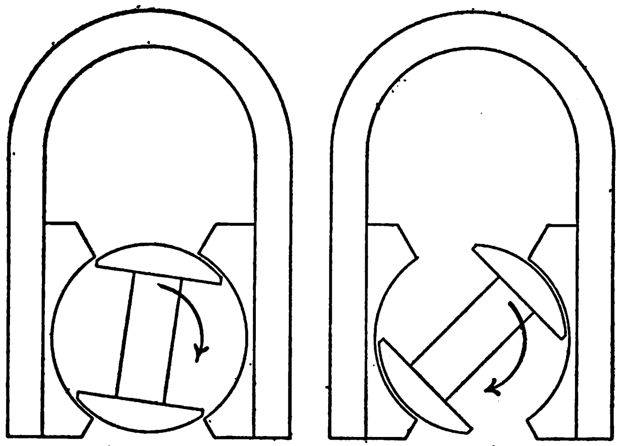


FIG. 37.—ARMATURE POSITIONS FOR ADVANCE AND RETARD

and if a spark is to be produced at that instant the armature must be turning at such high speed that the change in magnetism, while small, occurs with great rapidity.

When in the advance position the change

is great, and it will produce a spark although the change may be occurring slowly. From this it will be seen that a magneto will give a spark at low speed when the spark control is advanced, but that when it is retarded the armature speed must be increased in order to produce a spark.

When cranking an engine the spark should be retarded, for otherwise pressure will be produced before the piston reaches its upper dead point, and there will be a kick-back. When starting on the magneto, the engine must be cranked at some speed in order to get a spark in the retarded position, and thus it is usual to advance the spark slightly, to a point at which a kick-back will not occur, but that at the same time will produce a spark at moderate speed.

In order to stop a running engine it is usual to cut off the ignition spark. On systems using coils, a switch is opened to break the primary circuit, but on high tension magneto systems the switch short-circuits the primary current, allowing it to flow even when the circuit breaker is open.

The arrangement of a magneto cut-out switch as used on motor cycles is shown in

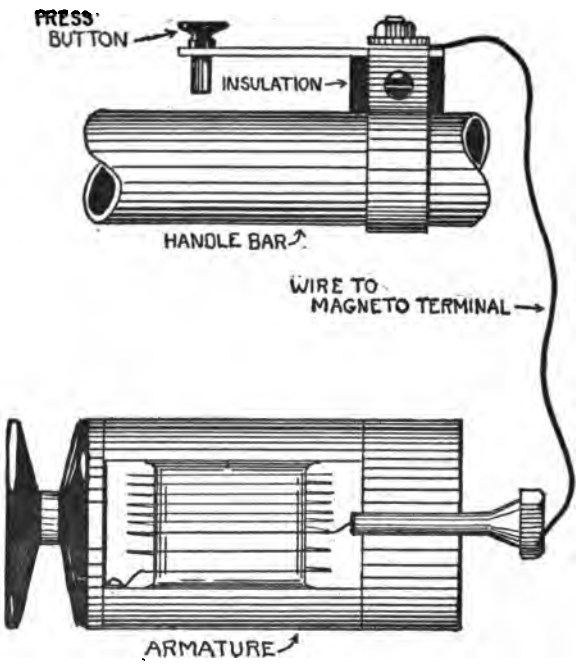


FIG. 38.—WIRING OF MAGNETO CUT-OUT SWITCH

Figure 38. By reference to Figure 31 it will be seen that a flat spring extends downward from the switch terminal, with its end resting

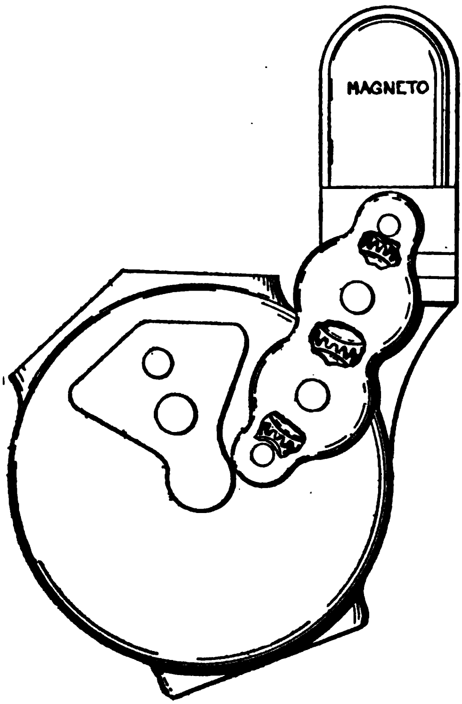


FIG. 39.—MAGNETO DRIVEN BY TRAIN OF GEARS

on the head of the long bolt by which the circuit-breaker disk is secured to the armature.

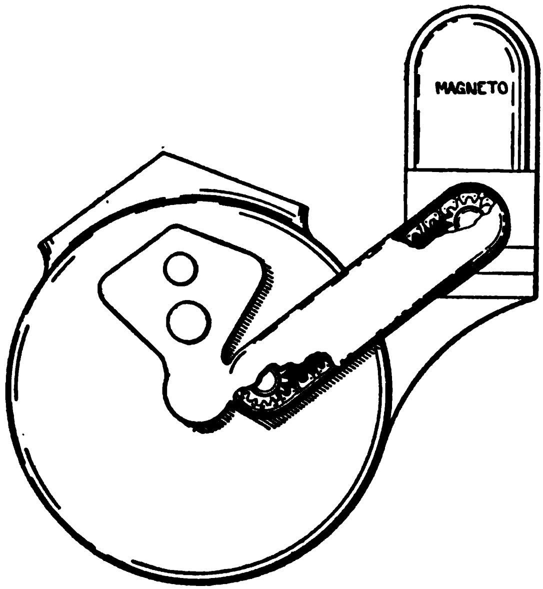


FIG. 40.—MAGNETO DRIVEN BY CHAIN

This bolt also conducts the current from the primary winding to the insulated screw of the circuit breaker; if, therefore, it is connected to the metal of the magneto, the primary current will have a complete circuit even when the circuit breaker is open.

The switch terminal of the magneto is connected to a flat spring that is attached at one end to the handle bar, Figure 38, but insulated from it. When the free end of the spring is pressed down it touches the metal of the handle bar, and thus forms a path by which the current can flow. The primary circuit is then complete, and there is no production of sparking current.

In some magnetos the circuit-breaker ring is so made that when it is in the extreme retard position, the switch-terminal spring touches a metal pin, thus grounding the circuit. This acts as a cut-out switch, and ignition is cut off by simply retarding the spark.

On four-cylinder engines, the position of the cam shaft is such that the magneto may be driven by it, either directly or through gears. On a motor-cycle engine the magneto cannot be mounted next to the cam shaft, and a special drive must be arranged. Figure 39 shows a magneto driven by a train of gears, while the drive shown in Figure 40 is by chain and sprockets.

CHAPTER VII

TRANSMISSION

HAVING an engine that will develop the power that we want, we must apply this power to the wheels of our car or motor cycle so that we may climb a steep hill, go fast on a level road, or work our way through traffic. Before we finish,we will find that many conditions must be considered, and many parts added, in order to make the machine complete.

It is not practicable to connect the engine direct to the driving wheels, for then it could not be started without starting the car also; furthermore, whenever the car was stopped by a halt in the traffic or some similar hold-up, the engine would also stop. Then, too, the slowing of the car by a steep hill or heavy road would slow the engine, and as the power developed by the engine depends on keeping up its speed, there would be a loss of power at the time when the greatest power was needed.

The parts that are provided to put the motor cycle or car under the necessary control are called the **transmission**, and consist of the **clutch**, by which the engine may be run independently of the machine; the **change-speed gear**, which gives speed on level roads or ability to climb hills, and the **final drive**, through which power is applied to the driving wheels.

The transmission permits the engine to make several revolutions to one of the rear wheels, the necessity for this being especially noticeable with the motor cycle. If the engine made but one power stroke to each revolution of the wheel, the speed of the machine would die down in the interval between power strokes, and it would go forward in a series of jerks. Furthermore, if the engine could get up to its speed of 2,000 revolutions a minute, it would drive the motor cycle over 150 miles an hour.

With the transmission arranged to let the engine make several power strokes to one

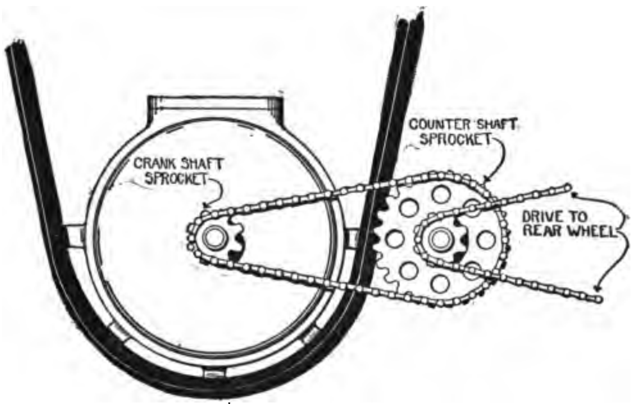


FIG. 41.—FIRST GEAR REDUCTION

revolution of the wheel, the intervals between power strokes will not be noticeable, and the engine can attain its full speed without driving the machine unduly fast. This is accomplished by the **first gear reduction,** which is shown in Figure 41.

A sprocket on the crank shaft is connected by a chain to a sprocket on the **countershaft**; the sketch shows the crankshaft sprocket to have eight teeth and the countershaft sprocket twenty-four teeth, so that the crank shaft will make three revolutions in turning the countershaft once.

A second sprocket on the countershaft drives a sprocket on the rear wheel; sometimes these two final drive sprockets have the same number of teeth, in which case the rear wheel turns at the same speed as the countershaft, or the rear wheel sprocket may have a greater number of teeth, when the wheel will turn more slowly than the countershaft.

The number of revolutions of the crankshaft to one of the rear wheel is called the **gear ratio**. With a gear ratio of 3 to 1, and the engine running at 2,100 revolutions a minute, a motor cycle with a 28-inch wheel will go about 60 miles an hour; if the gear ratio is

6 to 1 the speed will be about thirty miles an hour, and the machine will have twice the ability to traverse heavy roads and to climb steep hills.

The motor cycle makers offer a choice of gear ratios; the selection will depend on whether the rider wants speed, or whether he is in a hilly country where climbing ability is the first requisite. The standard gear ratios vary from 3½ to 1, to 5 to 1.

The motor cycles that were built a few years ago had the engine directly connected to the transmission, so that in order to start the engine it was necessary to push or pedal the machine. This was inconvenient, and the fitting of a clutch was a great advance.

A clutch is in two parts, one attached to the part of the transmission that is driven by the engine, and the other to the part that drives the wheel. When these two parts are separated the engine may run independently; when the parts are brought together the wheel turns and the machine moves.

With the engine running and the wheel stationary, the wheel would start with a jerk if the two parts of the clutch were suddenly gripped together; unless the engine was running fast this abrupt demand for power would stop it. In any case, all parts of the mechanism would be strained. The clutch is therefore made so that it takes hold gradually, for thus the wheel begins to turn slowly and increases its speed as the clutch slips less and less.

The parts of the clutch are controlled by the rider, who can bring them together or separate them as he desires. To close or throw in the clutch, he moves a lever that permits a spring to bring one part into contact with the other, and the friction between them causes the driving part to start the driven part into motion.

There are many different kinds of clutches, but the one that is coming into very general use in the **disk clutch**, or **plate clutch.** This consists of a number of flat steel rings, some attached to the driven part and some to the driving part, the driving and driven rings being placed alternately. When the clutch is open, or **thrown out**, the rings are not in contact, and one set may revolve independently of the others. When the clutch is thrown in, the two sets are pressed together by the spring, and the friction between them binds them.

A disk clutch is shown in Figure 42. The two driving plates are attached to the sprocket that is driven by the engine, and are placed alternately with the back plate, the central driven plate, and the front plate; these three plates are attached to the main shaft that drives the rear wheel. The plates are faced with asbestos cloth, which increases the friction.

When the plates are separated, as shown

in the drawing, the sprocket and its plates may revolve without moving the driven plates. When the springs are released, the spring

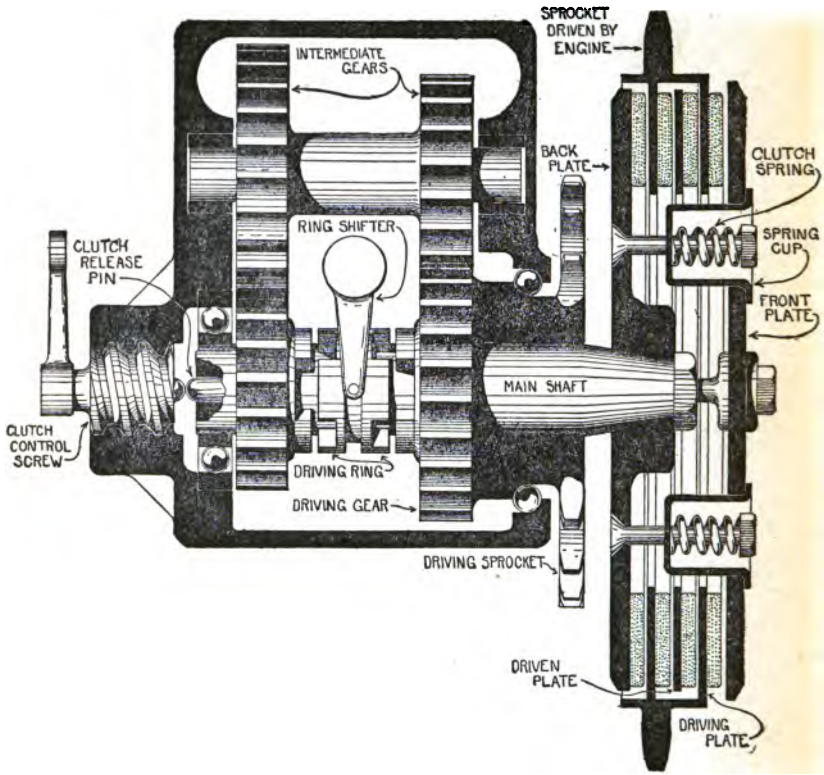


FIG. 42.—DISK CLUTCH AND SLIDING CHANGE-SPEED GEAR

cups are forced inward, and in moving toward the back plate, the front plate binds all of the plates together.

The clutch is controlled by the screw on the opposite end of the mechanism. The clutch pin, which passes through a hole in the center of the main shaft, is secured at one end to the front plate, while the other end bears against the clutch release screw. By moving the arm to unscrew the screw, the clutch release pin is given room to move endways, the springs thus being permitted to expand and to tighten the clutch.

To make the action clear, it should be understood that while the driving plates must revolve with the sprocket they may slide sideways on it, and may be pushed toward the back plate when the front plate is moved by the springs.

The Ford car also employs a disk clutch, which is shown in Figure 45. The engine crank shaft extends through the mechanism shown, and carries on its end the clutch drum that supports one set of the disks. The driven disks are carried inside of the brake drum, which is so connected to the driving shaft that when the brake drum revolves, the wheels turn and the car moves.

The clutch shift has a square hole through it, by which it fits on the squared part of the driving shaft; the clutch shift may thus slide along the driving shaft but must revolve with it. A spring, which is not shown in the drawing, can move the clutch shift toward the brake drum; the clutch fingers will then move on their pivots, and pressing in on their pins they force the clutch plate and the driving and driven disks into contact.

To release the clutch, the clutch shift is moved away from the brake drum by means of a pedal or the hand lever.

Many automobiles and some motor cycles use a cone clutch, the action of which may be compared to putting a cork in a bottle. The driving part of the clutch is in the form of a funnel-shaped ring that on automobile engines is built into the fly wheel. The driven part is a cone-shaped disk that may slide along its shaft but must revolve with it. A spring forces the disk into the ring, and a leather lining gives it a firm grip. To release the clutch the disk is slid away from the ring by pressing on a pedal.

In the early motor cycles the drive was by a flat leather belt from a pulley on the crank shaft or countershaft to a pulley on the rear wheel; a third pulley on a lever could be made to bear down on the belt and thus tighten it on the driving and driven pulleys. This gave the effect of a clutch, for by raising the third pulley the belt would be slackened, and would slip so that the drive of the engine would not be transmitted to the wheel.

An attachment that has been generally adopted for motor cycles in recent years is the change speed gear, which makes it possible to change the number of revolutions of the engine to one of the wheel according to road conditions. This has been part of the mechanism of an automobile from the first, but the light weight of a motor cycle, together with the willingness of the early riders to help the engine on heavy grades, made a change speed gear appear to be something of a luxury. The rider of to-day, however, considers a change speed gear a necessity, and practically all makers of motor cycles supply them.

The use of a change speed gear on a motor cycle or an automobile is similar to the use of a block and tackle in lifting a heavy weight. By using a block and tackle, a man who could not lift one hundred pounds unaided can easily lift a far greater weight. It is the same with a motor cycle or a car; if an engine is geared 4 to 1, so that two power stroke will occur during one revolution of the wheel, the power developed might not be sufficient to drive the weight of the machine up a steep hill. By gearing the engine 8 to 1, which gives four power strokes to one revolution of the wheel, the grade can easily be surmounted, for the effect is the same as doubling the power of the engine.

In climbing hills it is an advantage to have many power strokes occur during one revolution of the wheel. With such gearing the machine could not travel very fast, however; in order to run fast, only a few power strokes should occur while the wheel turns once. By the use of a change speed gear the rider can give his machine a hill-climbing gear ratio, or a gear ratio that will enable him to run at high speed.

One type of change speed gear, as used on motor cycles, is shown in Figure 42. The main shaft is driven by the engine through the clutch; on the shaft are two gears, which, however, are loose, and can revolve independently of it. One of these is the driving gear, which is one piece with the driving sprocket that drives the rear wheel; when the driving gear revolves the wheel turns.

Next to the driving gear is the driving ring, which revolves with the main shaft but may slide along it. This driving ring has broad teeth on each of its faces; by sliding it one way or the other these teeth will lock with corresponding teeth on the driving gear or the smaller gear that rides on the other end of the driving shaft. When the driving ring is thus locked to one of the gears, that gear must revolve with it and thus with the driving shaft.

If the driving ring is locked to the driving gear, the gear and the driving sprocket revolve with the main shaft; the machine is then said to be on high gear, for the effect is exactly the same as if the driving sprocket were solid with the main shaft. This is indicated in Figure 43.

To obtain the low speed gear ratio the

driving ring is shifted to lock the small gear to the main shaft, the driving gear and main shaft then being disconnected and free to turn independently. The small gear is in mesh with one of the intermediate gears, so that when it revolves the intermediate gears must revolve also. The two intermediate

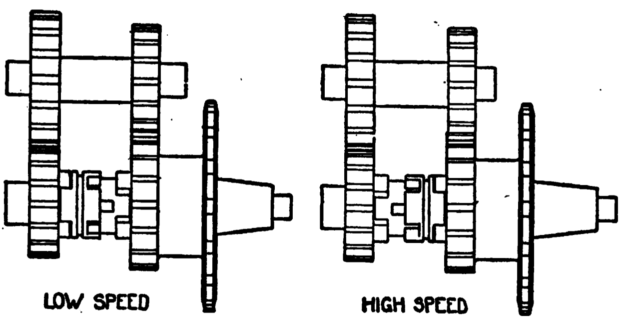


FIG. 43.—DIAGRAM SHOWING ACTION OF SLIDING CHANGE SPEED GEAR

gears being in one piece, and the smaller being in mesh with the driving gear, that gear and the driving sprocket will thus be revolved when the main shaft revolves, but at a different speed.

The small gear on the main shaft has twenty teeth, while the intermediate gear with which it meshes has thirty teeth; the intermediate gears will thus make only two revolutions while the main shaft makes three. The driving gear has more teeth than the small intermediate gear meshing with it, and will consequently revolve more slowly, so that the final effect of the train of gears is to make the driving gear and its sprocket revolve at about half the speed of the main shaft.

The position of the driving ring controls the gear ratio between the engine and the rear wheel, and the ring is moved by the gear shifter located inside of the gear box; a lever attached to its shaft permits the rider to move it at will.

In the sliding change-speed gears used on automobiles the driving ring and the main-shaft gears are replaced by a block formed of two gears, which correspond in size to the driving gear and the small main-shaft gear. This block may slide along the shaft as the shaft revolves, and either gear may be brought into mesh or out of mesh with its corresponding intermediate gear. For the high speed, broad teeth in the end of the block may grip the teeth of a block that is solid on the main shaft.

A change-speed gear of this kind usually has three forward speeds, as well as a reverse.

Another type of change-speed gear is the **planetary**, illustrated in Figure 44. Gear *B* is solid on the shaft driven by the engine and gear *C* is solid on the shaft driving the rear wheel. These gears are inclosed in a gear box, the walls of which support shafts on which the intermediate gears *A1* and *A2* may revolve. These intermediate gears are permanently in mesh with gears *B* and *C*.

To obtain high gear, the intermediate gears are locked so that they cannot turn

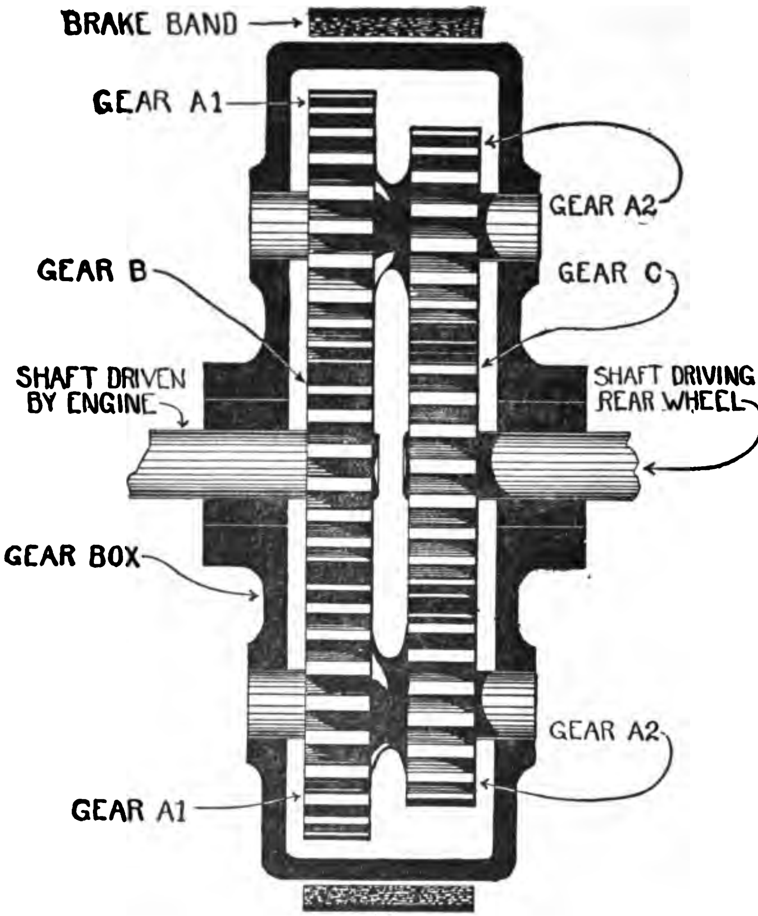


Fig. 44.—Planetary Change-Speed Gear

on their shafts; if gear *B* is then revolved, the intermediate gears, being fixed on their shafts, are carried around with it, and the entire gear box revolves as one piece with the shaft driven by the engine. Gear *C* is carried along, and is forced to revolve at the same speed as the engine shaft.

For low gear, gears *A1* and *A2* are released, and are thus free to revolve on their shafts; the brake band is then tightened to hold the gear box stationary. The revolving of gear B will then cause the intermediate gears to revolve on their shafts, and they in turn will make gear *C* revolve. Gear *A1* being larger than gear *B* will revolve more slowly; gear *C* being larger than gear *A2* will revolve more slowly still, so that the shaft driving the rear wheel will turn at a much lower speed than the shaft driven by the engine.

The change-speed gears used on automobiles are more comprehensive than those that have been described, for they must provide a reverse as well as the gear changes. The planetary change-speed gear used on Ford cars is illustrated in Figure 45. The engine shaft, to which the fly wheel is secured, extends through the gear box, and on its end

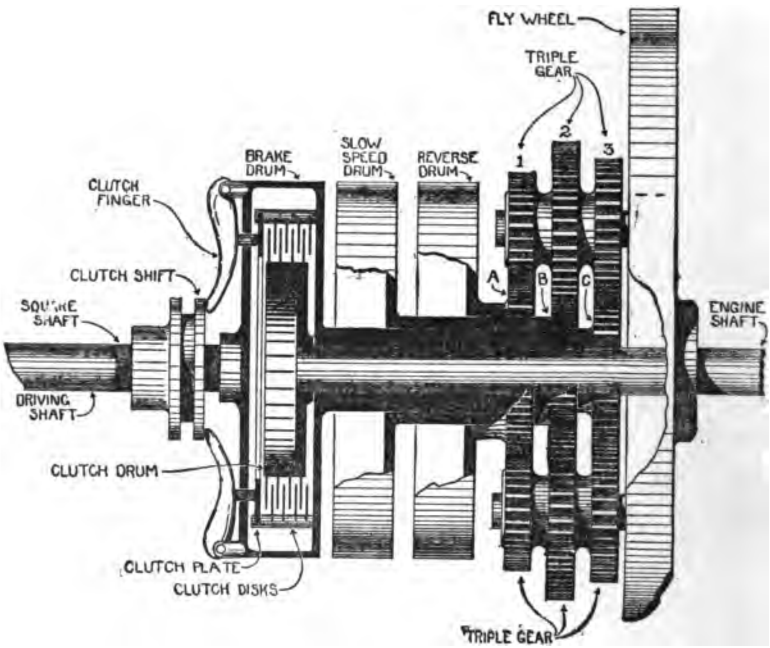


FIG. 45.—FORD CLUTCH AND CHANGE-SPEED GEAR

is the clutch drum. On the shaft are three sleeves, one inside of the other, each sleeve being independent of the others and of the shaft. Each sleeve has a gear on one end and a drum on the other; a brake band surrounds each drum, so that any desired drum may be gripped and held stationary.

The innermost sleeve carries gear *C* on one end, and on the other end is the brake drum, the outside hub of which contains a square hole. Into this hole fits the squared end of the driving shaft, which drives the rear wheels; thus the wheels must turn whenever the brake drum sleeve is revolved.

Three shafts are set solidly in the fly wheel, each shaft supporting a set of three gears; for the sake of clearness only two shafts and sets of gears are shown in the sketch. When the fly wheel revolves these sets of gears, called the triple gears, are carried around with it, and in addition they may revolve on their shafts; it is by making the triple gears revolve on their shafts that the different speed changes are obtained.

If there were no gears in mesh with them, there would be nothing to make the triple gears revolve on their shafts. They can be made to revolve, however, by holding one of the sleeve gears stationary.

To start the car, the brake band around the slow-speed drum is tightened to hold that drum stationary, and consequently to hold stationary its sleeve and gear *B*. Gear *2* being in mesh with stationary gear *B*, the triple gear will be forced to revolve on its shaft in order that gear *2* may roll around on gear *B*. The revolution of the triple gear will be slow, however, for supposing gear *2* to have forty teeth and gear *B* twenty, gear *2* will make only half a revolution in rolling completely around gear *B*. In carrying the triple gear around gear *B*, the fly wheel will make one revolution; thus the triple gear makes half a revolution while the fly wheel revolves once.

By revolving, the triple gear will make gears *A* and *C* revolve also, for they are in mesh with it. Gear *A* and its reverse drum revolve without doing anything, for these parts are not connected to the drive of the car.

With gear *C* the situation is different, for when that revolves the brake drum and driving shaft revolve also, and the car moves. Gears *C* and *3* we can assume to be of the same size; they will therefore turn at equal speed. Gear *3*, as part of the triple gear, makes half a revolution to one revolution of the fly wheel, and gear *C*, its sleeve and the driving shaft will therefore run at half-speed.

For high speed, the brake band on the slow-speed drum is released, and the clutch thrown in. This connects the brake drum directly with the engine shaft, and they revolve as one piece; the driving shaft will then turn at twice the speed that it had when the slow speed was working.

To put the car in reverse, the clutch is thrown out and the brake band tightened on the reverse drum. Gear *A* is then held stationary. The speed with which the triple gear now revolves on its shaft depends on the number of teeth in gear *1* compared with the number of teeth in gear *A*. Let us suppose that gear *1* has twenty teeth and gear *A* forty; then the triple gear will turn twice on its shaft as gear *1* rolls once around gear *A*. Through the triple gear making more than one revolution on its shaft to one revolution of the fly wheel, gear *3* causes gear *C* to revolve in the opposite direction to the way the fly wheel revolves, and the car backs.

In Figure 45 the parts are separated, so that each may be distinctly seen. The actual Ford change speed is more compact, for the gears of the triple gear and of the sleeves are close together, and there is only sufficient space between the drums to prevent them from rubbing. The entire mechanism is enclosed in an extension of the crank case, as indicated in Figure 14, and its parts are oiled by splash, just as the parts of the engine are oiled.

The change speed gear is controlled by two foot pedals and a hand lever; one pedal for reverse, one for slow speed, and the lever for the high-speed clutch. A connection between the slow-speed pedal and the clutch lever prevents the clutch from being thrown in unless the lever is forward and the pedal released.

To start the car, the slow-speed pedal is pressed forward to tighten the brake band on the slow-speed drum. When the car is moving, the hand lever is thrown forward, but this movement does not of itself engage the clutch; the clutch is then held open by the forward position of the slow-speed pedal. To go into high speed the pedal is released; by the back position of the pedal combined with the forward position of the lever the spring forces the clutch disks together.

To change from high speed the slow-speed pedal is pushed forward, the first effect of this movement being to throw out the clutch. At that instant the change-speed gear is in **neutral**, for the clutch has been released, but the pedal has not been moved far enough to tighten the low speed brake band. When in the neutral position there is no connection between the engine shaft and the driving shaft, although the hand lever is in the high speed position, and the car can coast or stand still regardless of whether or not the engine is running.

The neutral position is utilized when the driver makes a slow-down or a brief stop. The arrangement is very convenient, for the car speed is under perfect control with the driver's hands free to operate the steering wheel, the engine controls, the horn, or for any other purpose.

To apply the reverse, the clutch lever is pulled back to the upright position, the car is stopped, and the reverse pedal pushed forward to tighten the brake band on the reverse drum.

A third pedal controls a brake band on the brake drum; checking the rotation of the brake drum also checks the driving shaft and the rear wheels. By pulling back on the hand lever, a second set of brakes is applied to the hubs of the rear wheels.

For cycle cars, the **friction change-speed gear** is in frequent use because of its simplicity of construction and operation; for the light weight of these cars it is entirely satisfactory. A change speed gear of this type is shown in Figure 46. On the end of the engine shaft and revolving with it is a driving disk, which has a flat face usually made of aluminum. The edge of the friction wheel bears against this face, the friction between the two being sufficiently great to cause the wheel to turn when the disk turns.

The disk and wheel are of the same size;

thus when the wheel runs at the edge of the disk, as shown in the diagram marked "High," one revolution of the disk will cause the wheel to make one revolution. If, however, the

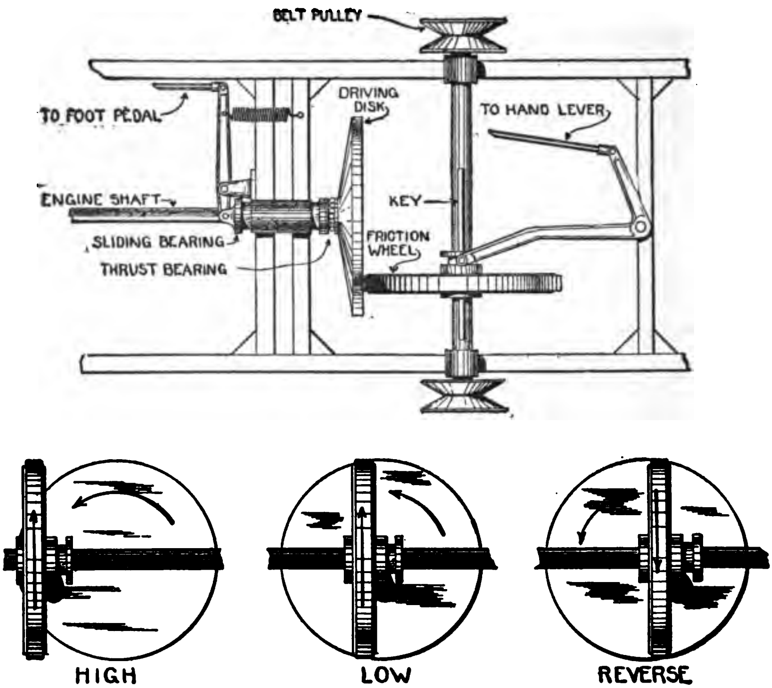


FIG. 46.—FRICTION CHANGE SPEED GEAR

wheel is near the center of the disk, the effect will be the same as if the disk were much smaller than the wheel, and the disk will make several revolutions while the wheel is turning once; this is the low speed. By moving the wheel across the center of the disk it will be made to turn in the opposite direction, thus giving the reverse.

The wheel may be brought against the disk at any point from the center to the edge, and any desired gear ratio may thus be obtained.

In order to slide the wheel across the face of the disk, the two must be separated, and the disk is so made that it can slide along the engine shaft. The disk has a square hole through the center of the hub which fits the squared end of the engine shaft, the disk thus being able to slide endways on the shaft, while turning with it. By pressing on the foot pedal the disk is drawn away from the wheel, and the latter is then free to be moved to the desired position.

The wheel is so attached to its shaft that when it turns, the shaft must turn also; the shaft drives the rear wheels by chain and sprockets or by belt and pulleys.

As the high speed is in use for the greater part of the time, a groove will eventually be worn in the face of the disk near its edge. For this reason the face of the disk is so made that it may be reversed, its life thus being doubled.

CHAPTER VIII

FINAL DRIVE

THE driving of the rear wheel of a motor cycle is the same in principle as the driving of a bicycle; but because of the power delivered by the engine, as well as the high speed at which the machine runs, the parts must be more rigid and of greater strength.

In the early motor cycles a flat belt was used, running from a pulley on the engine shaft to a pulley attached to the rim of the wheel, and this is still employed to some extent. The difficulty encountered with it is the liability of the belt to slip through stretching or moisture, and to obviate this a belt tightener is used. This consists of a third pulley that bears on the top of the belt and is pressed against it by a spring or by a lever that permits the rider to apply the necessary pressure.

In order to obtain the desired gear reduction a small pulley was used on the engine shaft, while the wheel pulley was large. As the pulleys were of necessity close together, the belt touched only a small part of the surface of the engine pulley, which required the belt to be very tight in order to prevent slipping; this tension caused the rapid wear of the bearings.

The flat belt was followed by a belt in the shape of the letter V, its section being shown in Figure 47. The V-shaped pulleys on which it runs tend to make it bind, so that slipping is less likely, even with a loose belt. This drive is in very considerable use.

These belts are made of various materials; leather blocks riveted to leather strips, rubber blocks, rubber and canvas, etc., the object of the manufacturer being to prevent stretching. Stretching is always likely to occur, however, and a machine is provided with some means of tightening the belt.

In many machines, the rear axle can be moved, to bring the proper distance between

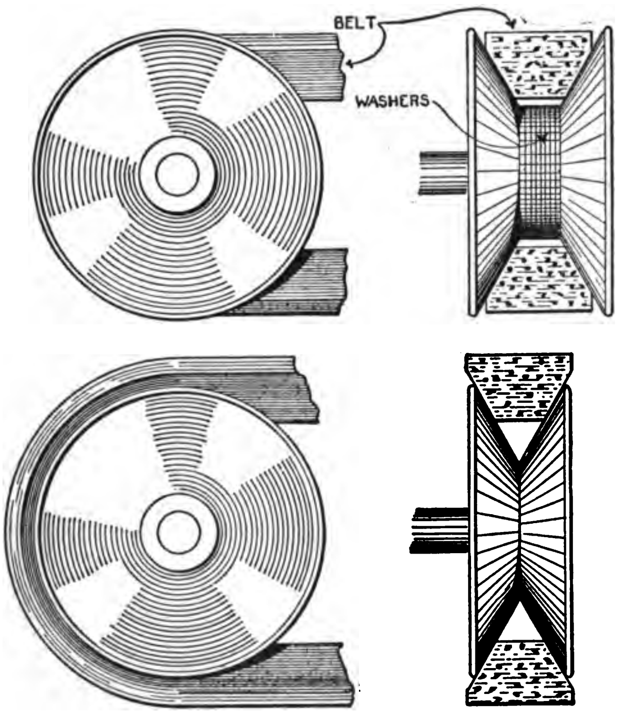


FIG. 47.—TIGHTENING A LOOSE BELT

the pulleys. In other cases, the tightener is on the driving pulley, and follows the principle shown in Figure 47. This driving pulley is in two parts, which may be separated any desired amount by putting washers between them, as shown, or by a screw arrangement.

When the parts are separated, as in the first sketch, the belt will lie near the bottom of the pulley; when close together, the belt will ride farther out, which will have the same effect as using a larger pulley.

In addition to tightening the belt, this makes a change in the gear ratio, and in many English motor cycles this principle is used for the change-speed gear.

The difficulty of preventing a slip of the belt, which means a loss of power, has made the use of chain and sprockets very general.

It is usual to have two sets of chains and sprockets, one between the engine shaft and the countershaft, and the other between the countershaft and the wheel.

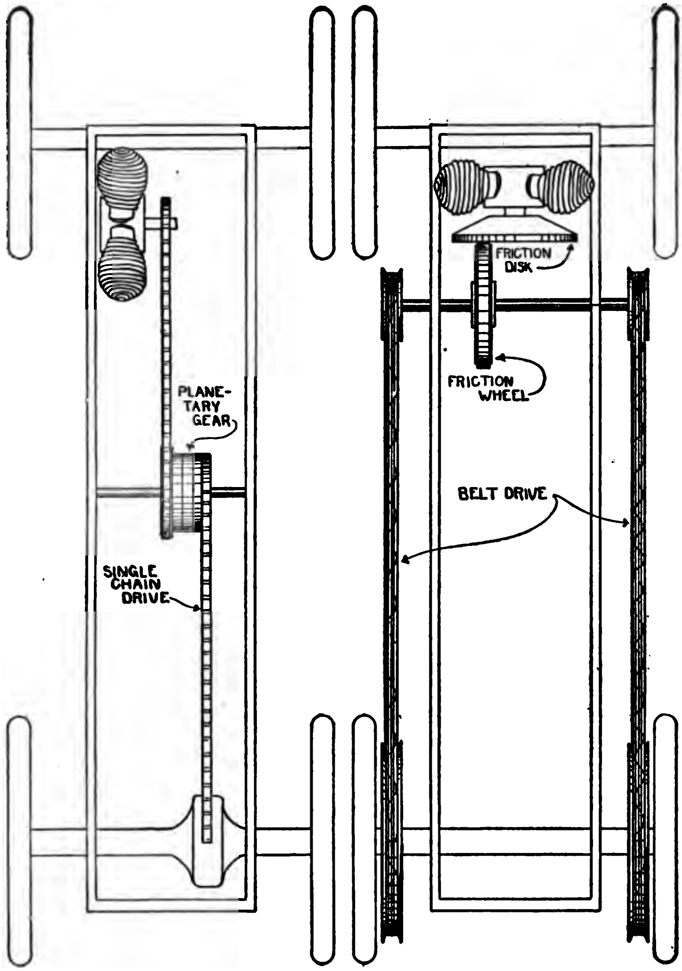


Fig. 48.—Final Drive by Chain and by Belt

There is great variety in the final drives of cycle cars, belts, chains and shafts being used. A belt drive is satisfactory on a cycle car because the distance between the pulleys is great enough to permit the belt to hug the surface of the small pulley for a considerable part of its surface. To get all of the distance possible, the belts run for almost the entire length of the car, as shown in the second sketch, Figure 48.

When chain drive is used, there are usually two sets of chains, as shown in the first sketch, Figure 48. It is also quite frequent to have a separate chain for each rear wheel.

In the shaft drive, the driving shaft runs lengthways with the car, and on its end is a bevel gear in mesh with a bevel gear carried on the axle. The driving gears of a shaft drive are shown in Figure 49. A drive of this sort is used on some makes of motor cycles, and is universal on pleasure automobiles.

On all cars that are driven by both rear

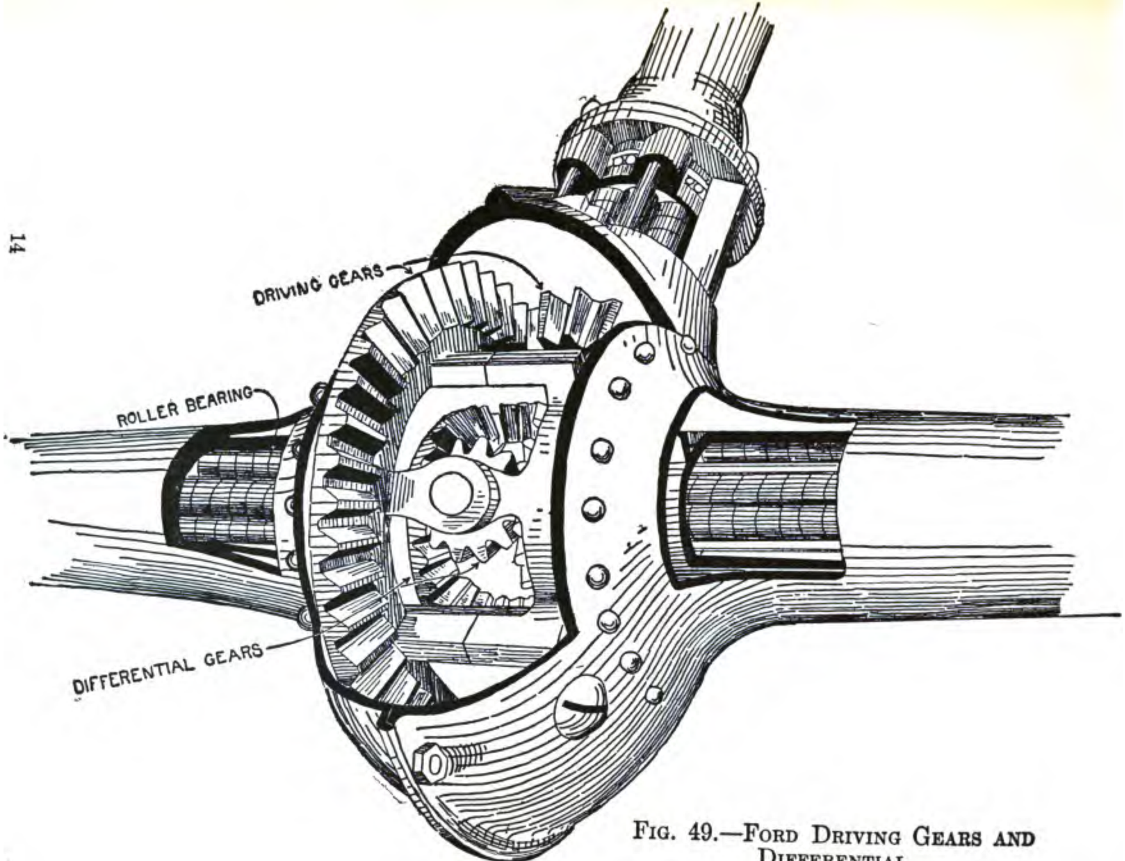


FIG. 49.—FORD DRIVING GEARS AND DIFFERENTIAL

wheels it is necessary to provide some means of permitting the rear wheels to move at different speeds when the car is turning a corner. In making a turn, the outside wheel must travel a longer distance than the inside wheel; if both were driven at the same speed one would be forced to slide.

With a belt-driven cycle car, the belts slip on the pulleys, which takes care of the situation. On all other types of final drive there must be what is called the **differential gear.** This drives both rear wheels all of the time, but when the car makes a turn, the outside wheel automatically speeds up and the inside wheel slows down to correspond.

The differential gear is driven by the engine and in turn drives the rear wheels; it is usually located on the rear axle, but if the final drive is by a separate chain to each rear wheel, it will be located in the position of the planetary gear shown in the first sketch, Figure 48.

As indicated in Figure 49, a small bevel gear on the end of the driving shaft meshes with a large bevel gear; these are the driving gears. The rear axle is in two parts, each part having a rear wheel on one end, while on the other end is a bevel gear smaller in size than the large driving gear. Figure 49 shows one of these axle gears inside of the large driving gear.

The two axle gears are face to face, and separated by a short distance; between them, and meshing with them both, are three small bevel gears, equally spaced. Each of these small bevel gears is on a shaft on which it can revolve, and these shafts project inward from a cage that is mounted on the large driving gear. Thus when the driving gear revolves, the cage and the small bevel gears and their shafts go with it. As these small gears are in mesh with the axle gears, they too must move, the rear wheels turning with them.

Let us suppose one of the axle gears to be taken away; then if the driving gear and its cage are turned, the small bevel gears will revolve on their shafts as the cage carries them around, because they will roll on the remaining axle gear, which is stationary. With the two axle gears in place, the small bevel gears, being in mesh with them both, cannot revolve on their shafts, but in being carried around by the cage will take the axle gears with them.

This is the situation when the car is travelling straight on a smooth road; the grip of the wheels on the ground being equal. The wheels will turn at the same speed.

Now let one of the wheels strike a muddy spot; the grip of that wheel on the ground will be reduced, because the mud is slippery. Because of the differential, that wheel is speeded up and slips. This changes the situation in the differential, for now the axle gears are turning at different speeds; the natural result is to make the small gears revolve on their shafts. There is no change in the speed of the driving gear, and the cage carrying the small gears is turning uniformly, but now, instead of being stationary on their shafts, the small gears are revolving as they are carried around.

When the wheel runs out of the mud and again strikes dry road, it will regain its grip and take up its former speed. The small gears will stop revolving on their shafts, although, of course, they continue to be carried around by the cage.

As long as the wheels meet with the same resistance as they turn, they will revolve at equal speed, and the small gears will be stationary on their shafts. When for any reason one of the wheels encounters something that will make it more difficult or more easy to roll than is the case with the other wheel, the small gears will begin to revolve on their shafts, and the wheels will then be driven at different speeds to equalize the resistance.

When the car turns a corner, the differential gear will begin to work, and will speed up the outside wheel and slow down the inside one. There will be no change in the speed of the car, for the speed of the driving gear does not change, but by the action of the differential, the corner will be taken smoothly and without slipping.

In addition to showing the driving gears and differential of the Ford car, Figure 49 illustrates the use of roller bearings for the driving shaft and the inner ends of the axles.

Figure 50 shows the bearing at the outer end of the Ford rear axle. The rollers that form the bearing are between the axle and the axle housing; the axle projects, and the wheel is secured to its end by a key.

The drawing also shows the arrangement of the emergency brake. The brake drum is bolted to the wheel and revolves with it; the brake shoes are held stationary by their attachment to the axle housing. The action of

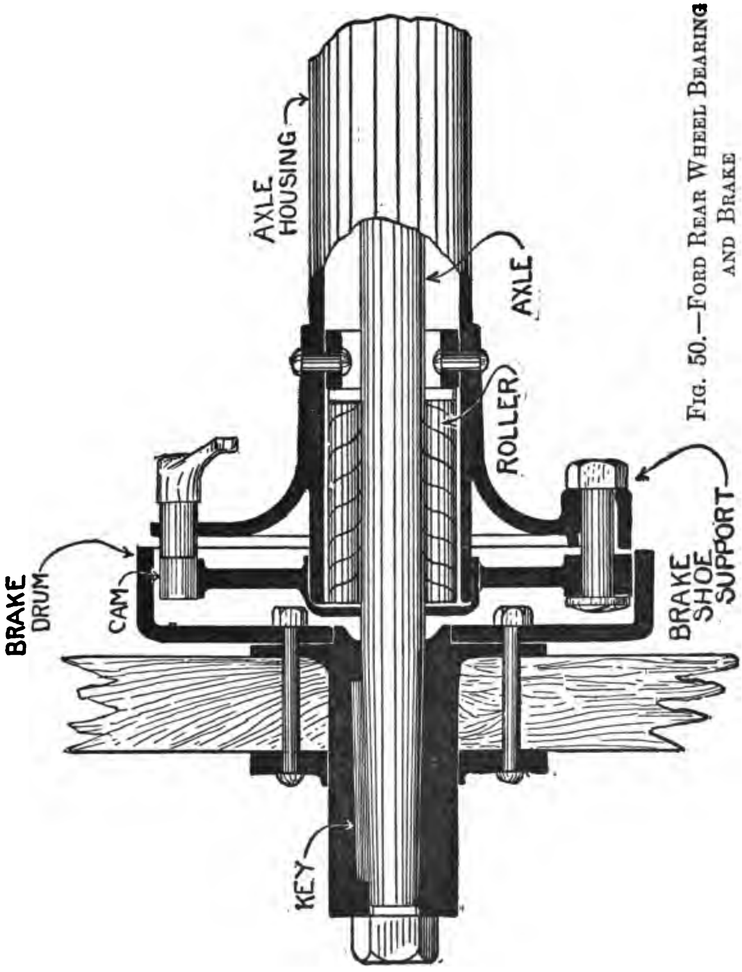


FIG. 50.—FORD REAR WHEEL BEARING AND BRAKE

the brake is illustrated in Figure 51. The two brake shoes are inside of the drum and pivoted at one end to the brake-shoe support. The other ends of the shoes bear against a cam, and two springs hold them away from the drum.

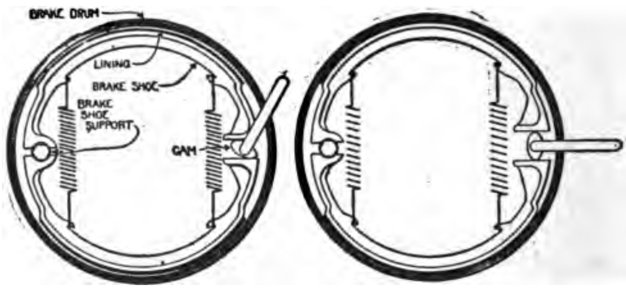


FIG. 51.—ACTION OF FORD EMERGENCY BRAKE

When the cam is turned, as shown in the second sketch, the shoes turn on the pivot and are forced against the drum, the friction between the drum and the shoes being great enough to prevent the drum and the wheel from turning. The shoes are faced with asbestos cloth, which is proof against destruction from heat due to the friction.

The emergency brake is applied by a hand lever at the driver's seat. Moving this lever forward throws in the clutch, while pulling it back puts on the emergency brake.

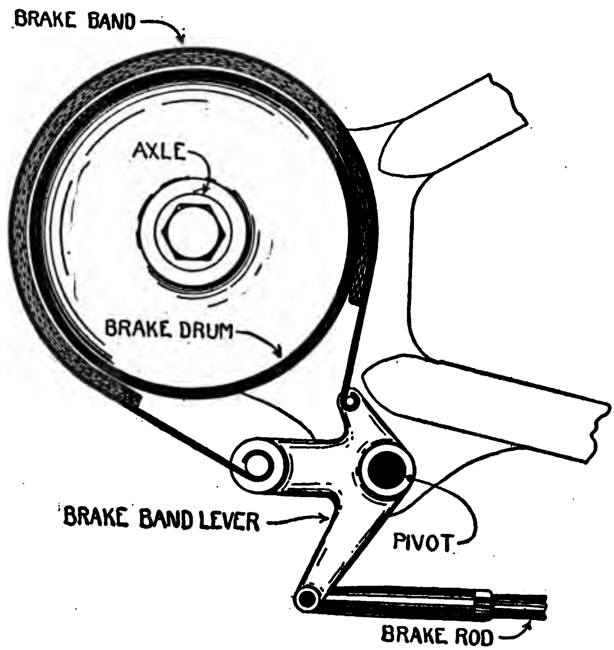


FIG. 52.—BAND BRAKE ON MOTOR-CYCLE WHEEL HUB

Figure 52 shows a band brake used on motor cycles. The brake-band lever has three arms; one for the rod by which the brake is applied, and the other two for the ends of the brake band. When the rod is pulled, the movement of the lever on its pivot tightens the brake band around the drum.

CHAPTER IX

SUSPENSION

THE ordinary bicycle is not an uncomfortable machine to ride, for although it usually has no springs, it does not move at a sufficient speed to be greatly affected by rough places in the road. With a motor cycle the situation is quite different, for with its greater weight and much higher speed it is more severely jolted by stones and uneven road surfaces.

The early motor cycles were notoriously uncomfortable, for the jars received by the machine were communicated to the rider, who suffered accordingly. Beside this, the constant and extreme vibration made it almost impossible to keep nuts and bolts tight, and accidents from this cause were frequent.

Thus there was every necessity for putting springs on the machine, but this proved more difficult than the fitting of springs to an automobile. As the axles of an automobile are entirely separate from the frame, springs can easily be attached; the wheels of a motor cycle are built into the frame, and this complicates matters. The motor cycle makers have nevertheless worked out a number of successful plans, and a rider may now traverse rough roads with a very high degree of comfort.

The first steps were extra springs in the saddle and the fitting of long, soft rubber grips on the handle bar; by this latter attachment, the vibration of the front wheel was prevented from affecting the rider's arms. This arrangement was insufficient, however, and the makers were forced to apply springs in order to satisfy the demand.

A successful suspension must permit a free up-and-down motion, but must be stiff sideways; a side movement of the frame might cause a skid, or might throw the rider when taking a turn at high speed.

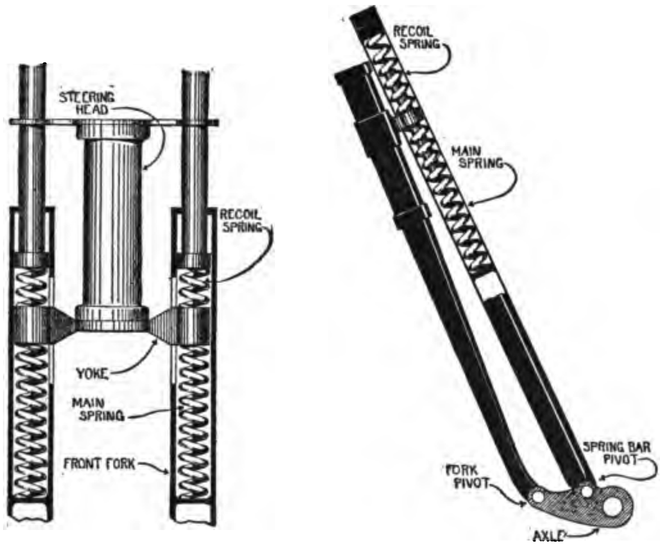


FIG. 53.—FRONT FORK SUSPENSION WITH COIL SPRINGS

Figure 53 shows the application of coil springs to the front forks, the two methods illustrated being in very considerable use. In the first arrangement, the lower end of the steering head carries a yoke with ends fitting inside of the forks, the fork sides being slotted so that the head and its yoke may move up and down. The main springs are below the yoke ends, and are supported at the bottom by plugs set into the forks. Above the yoke ends are recoil springs, their upper ends pressing against guide bars set solidly into the fork ends.

The upper end of the steering head carries a plate containing holes through which the guide bars pass.

When the rider mounts the machine a portion of his weight comes on the steering head, which moves down and compresses the main springs. On striking a stone, the front wheel rises and rides over it; in a rigid machine the rising of the front wheel would lift the rider, but with the suspension shown the effect is to press up on the lower end of the main springs. By compressing, the springs thus absorb the shock.

On striking a hole in the road, the front wheel sinks, the main springs then expanding; this expansion is followed by compression as the rider's weight forces the steering head down, and the shock is absorbed. As the wheel rides out of the hole it carries up the forks, and, as may well be the case, if this occurs at the instant when the springs are expanding after the compression, the two forces would throw the rider up sharply. The recoil springs are provided to prevent this, and the rider is thus protected from upward as well as from downward shocks.

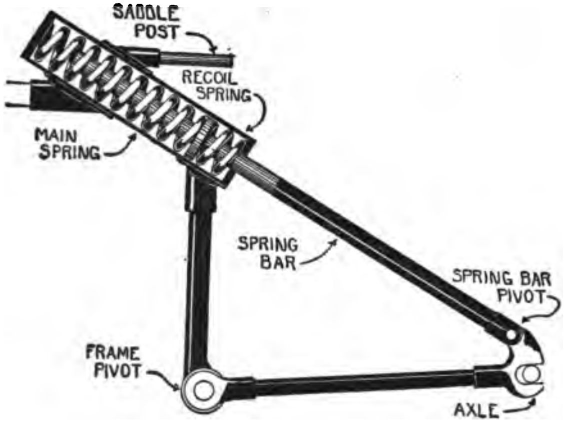
Side sway is prevented by the guide bars, and by the fit of the yoke ends in the forks.

In the second sketch (Fig. 53), the springs are contained in tubes, one on each side of the wheel. The tubes containing the springs are in front of the forks, and lugs on the upper ends of the forks project into the spring tubes, or spring bars, to be acted on by the main and recoil springs.

At their lower ends the forks and spring bars are pivoted to plates that also support the axle. When the wheel moves up and down from the roughness of the road it carries the plates with it and the fork and spring bars move on their pivots. This has the effect of still further reducing movement of the fork.

It is a more difficult matter to put springs on the rear wheel, for in addition to supporting its share of the weight, this is also the driving wheel, and connected to the engine by the transmission. Thus the suspension must be so made, that while the wheel may move up and down, there must be no change in the distance between the front and rear sprockets or pulleys.

The first sketch (Fig. 54), illustrates one method by which this is accomplished. The frame is pivoted at the countershaft, so that there will be no change in the distance between the countershaft sprocket and the wheel sprocket as the frame moves. The springs are contained in a tube built into the frame;



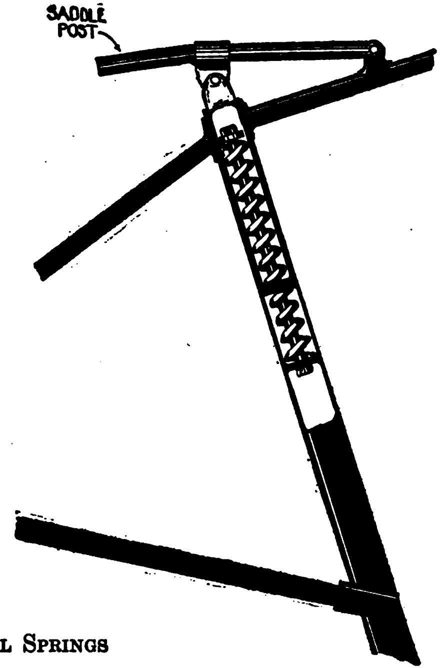


Fig. 54.—Rear Suspensions with Coil Springs

one end of the spring bar projects into the tube and is supported by the springs. The other end of the spring bar is pivoted to the frame.

In the construction shown in the second sketch (Fig. 54), the springs are held between the ends of a rod that at its lower end is bolted to a cross piece of the upright frame tube. A smaller tube telescopes into the frame tube, the bottom of the telescoping tube forming the plate against which the two springs act.

One end of the saddle post is pivoted to the frame, while its other end carries the saddle; its center is pivoted to the telescoping tube. Any movement of the frame must thus pass through the springs before being felt by the rider.

In the suspensions that have been described the weight of the rider compresses the springs; Figure 55 shows an arrangement in which the weight tends to open the spring.

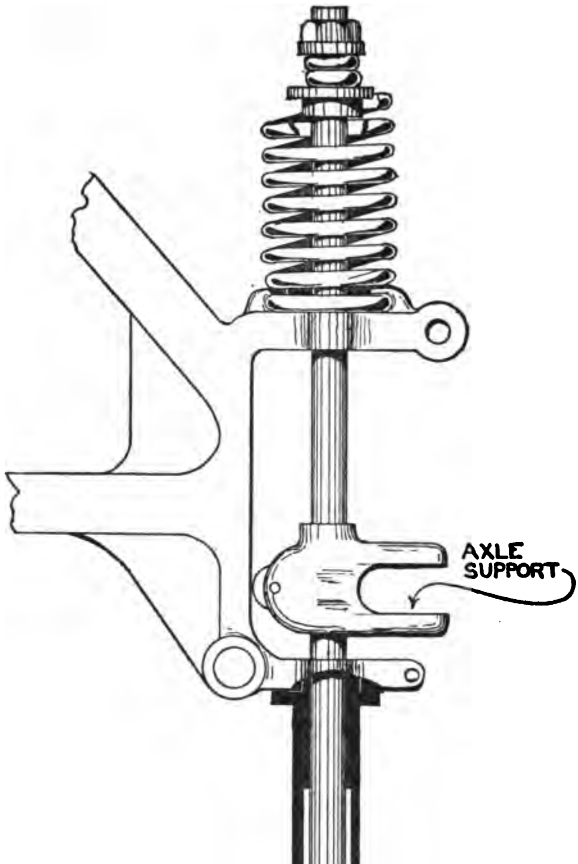


Fig. 55.—Axle Suspended on Coil Spring

In this, the top of the spring is attached to the upper end of a rod that supports the axle. The rear end of the frame forms a yoke through which the rod passes, the top arm of the yoke being attached to the lower end of the spring. The rod, and by it the top of the spring, is supported by the wheel, while the weight of the frame pulls down on the lower end of the spring; thus the frame is suspended.

The axle support carries a roller that runs on the flat inner surface of the yoke; the drive of the wheel is thus applied to the frame without placing any strain on the spring, while at the same time the frame is not prevented from moving up and down.

Side sway is prevented by the fit of the lower end of the rod in the tube on the bottom arm of the yoke.

In some motor cycles flat springs are used, similar to those of an automobile. This is shown in Figure 56. The first sketch shows

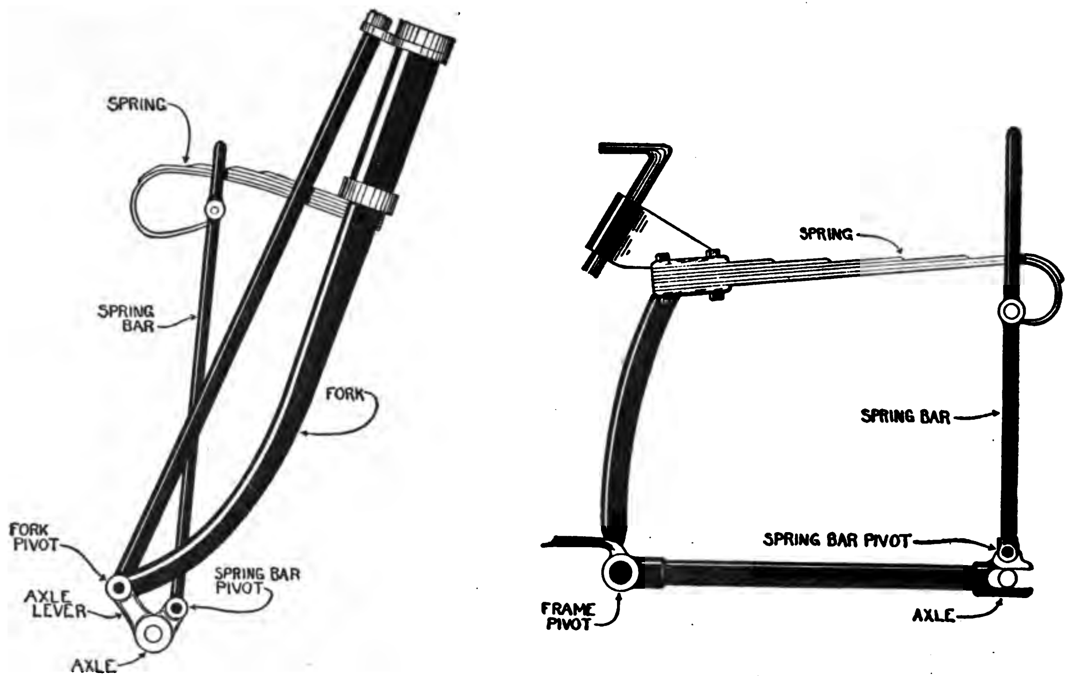


FIG. 56.—MOTOR-CYCLE SUSPENSION, WITH LEAP SPRINGS

the front suspension. One end of the spring is secured to the front fork, while the other end is pivoted to the spring bars. The fork and spring bars are pivoted to a lever that also supports the axle, the necessary movement of the parts thus being provided.

When the wheel strikes an obstruction the tendency is to force the wheel back as well as to lift it. The spring bar is thus raised and the spring is compressed. In order to pass a road shock to the rider the shock must be sufficiently severe to raise the forks as well as the axle. The small bars secured to the fork are rigid, and prevent side sway by their contact with the spring.

The rear suspension is similar in construction. The pivoting of the frame at the countershaft, and also the spring bar pivot, permits the free up-and-down movement of the rear wheel.

CHAPTERS X

CARE OF THE ENGINE

NO piece of machinery can be expected to give good service unless care is taken of it and it is kept in proper condition; even so simple a thing as a pocket knife will not do good work unless the blade is sharpened occasionally, and the pivot oiled. Thus it goes without saying that the parts of a motor cycle and an automobile must be looked after, for the constant vibration to which they are subjected, as well as the dust and grit surrounding them, makes them especially liable to give trouble.

With an understanding of how the parts work, a frequent inspection will keep the owner familiar with their condition, and he will notice immediately the loosening of a nut or an ignition terminal, or his ear will

recognize an unusual sound that will lead him to investigate the cause.

Such matters as the squeak of a spring or the looseness of a fender are not of great importance, and they may be attended to as convenient, but a loss of compression, a badly adjusted carburetor, a dragging brake or something of the kind, requires prompt action, for a loss of power, and possible injury, will otherwise be the result.

COMPRESSION

If compression is weak, there will be a loss of power, and it is quite essential to keep the engine parts in such condition that the necessary compression is maintained. On receiving his machine, the owner should note the effort necessary to crank the engine over the compression stroke, and should be so familiar with it that he will at once notice any weakening.

The most usual cause of a loss of compression is the sticking of the piston rings in their grooves by gummy oil or by carbon particles. To prevent sticking, the cylinder should frequently be dosed with two or three tablespoonfuls of kerosene or of denatured alcohol, which will soften the oil or carbon and free the rings.

Once a week is not too often for this; the kerosene or alcohol should be poured in while the engine is hot from a run, and distributed by cranking the engine two or three times. The gummed oil and carbon will be blown out when the engine is started the next morning.

Other points at which compression may leak are around the spark plug and pet cock, either because they are not screwed in tight or because they do not fit properly. To test these, run a little lubricating oil around the joint; a leak of compression will blow it into bubbles. Gasoline can be used for this test, and a change in the speed of the engine will show that the gasoline is drawn into the cylinder through the leak during the inlet stroke.

Half-inch spark plugs usually have a tapered thread, and are supposed to be screwed in until they bind. If the threads of the plug are not a good fit with those of the cylinder opening, there may be a leak even with the plug screwed in tight; in such a case the threads should be coated with graphite grease, which will usually stop the leak.

Spark plugs of other sizes are made with a shoulder that bears against the flat surface around the cylinder opening. A copper-asbestos gasket will prevent leakage, provided the gasket, spark plug and cylinder surfaces are clean.

The pet cock has a taper thread, which should be given a coat of shellac if the test shows a compresson leak around it. Shellac should not be used for the spark plug because it will make its removal very difficult.

A third cause of compression leakage is

the wear of the valves. A valve will maintain a tight fit for a greater or less period, but eventually its surface and the surface of its seat will become so roughened that it will not hold compression. The roughening of the surfaces is due principally to the formation of carbon in the combustion space. Hard particles of this will lodge on the seat, and the hammering of the valve will drive them into the surfaces. When this condition exists the valve must be reground.

The grinding of a valve consists in rubbing the valve disk against its seat, a little grinding paste being placed between the two. Grinding should be done with light pressure, for heavy pressure will be likely to make the disk and seat slightly oval. It is not necessary to continue grinding until the entire width of the surfaces is true, for compression will be held by a narrow band if it is true.

To test the grinding of a valve, clean the disk and seat surfaces and make a number of marks across them with a soft pencil; replace the valve and give it a quarter-turn on its seat, and if the grinding has been correctly done, each pencil mark will be erased either completely or in part.

If valves require regrinding at frequent intervals, it indicates too rich a mixture, too much oil, or a poor quality of oil, for these are the causes of carbon deposit.

CARBONIZING

The carbonizing of the cylinder not only interferes with compression by sticking the rings in their grooves and pitting the valves, but gives rise to a condition known as **preignition.** The effect of preignition is to ignite the charge too early in the stroke, thus causing a partial or complete kick-back. The deposit of carbon on the walls of the combustion space gives a rough surface, and the little lumps that stick up will become so heated during the ignition of the charge that they will glow; they will continue to glow during the exhaust stroke, and will ignite the fresh charge as it enters on the inlet stroke.

Carbon is formed principally from the use of oil that is not suited to the lubrication of a gas engine. No oil can stand the intense heat, but some oils stand it better than others, and will lubricate the cylinder and piston walls properly before being burned. An unsuitable oil will burn quickly, and must be fed in considerable quantity in order that the walls may be lubricated. It is the burning of excessive quantities of such oil that carbonizes the combustion space.

An overrich mixture will also produce carbonization, but as it will also interfere with the operation of the engine, the driver will be aware of the misadjustment of his carburetor.

When an engine is so carbonized that it causes preignition the carbon must be removed, and this is usually done by taking off

the front suspension. One end of the spring is secured to the front fork, while the other end is pivoted to the spring bars. The fork and spring bars are pivoted to a lever that also supports the axle, the necessary movement of the parts thus being provided.

When the wheel strikes an obstruction the tendency is to force the wheel back as well as to lift it. The spring bar is thus raised and the spring is compressed. In order to pass a road shock to the rider the shock must be sufficiently severe to raise the forks as well as the axle. The small bars secured to the fork are rigid, and prevent side sway by their contact with the spring.

The rear suspension is similar in construction. The pivoting of the frame at the countershaft, and also the spring bar pivot, permits the free up-and-down movement of the rear wheel.

CHAPTERS X

CARE OF THE ENGINE

NO piece of machinery can be expected to give good service unless care is taken of it and it is kept in proper condition; even so simple a thing as a pocket knife will not do good work unless the blade is sharpened occasionally, and the pivot oiled. Thus it goes without saying that the parts of a motor cycle and an automobile must be looked after, for the constant vibration to which they are subjected, as well as the dust and grit surrounding them, makes them especially liable to give trouble.

With an understanding of how the parts work, a frequent inspection will keep the owner familiar with their condition, and he will notice immediately the loosening of a nut or an ignition terminal, or his ear will

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To prevent this a little space is left between the push rod and valve stem, for then the stem has room to expand downward and the valve disk remains on its seat. Too much space cannot be left, for then the push rod will move so far before lifting the valve that the valve will not be lifted far enough from its seat to admit a sufficient charge or to allow a free exhaust.

The adjustment should be such that there is the slightest space, hardly more than the thickness of a cigarette paper, when the engine and valve are thoroughly heated. The push rod usually has a nut on its end by which the adjustment can be made, the nut being secured by a lock nut. It is usual to make the adjustment when the engine is cold, and if the push rod is then adjusted so that there is one-thirty-second inch between it and the end of the valve stem, the space will be about right when the engine is hot.

The timing of the valves, the setting that will cause them to open at the right point in the stroke, is usually indicated on the timing gears. This is illustrated in Figure 7. One of the gears will have a punch-mark on one of its teeth, while the other gear will have punch-marks on two adjoining teeth; by putting the gears together so that the marked tooth comes between the two marked teeth, the cam shaft will be properly set in relation to the crank shaft.

If the gears are not marked, the valves may easily be timed in a manner that will permit the engine to run, and that can be taken as a starting point for experiments that will lead to a more correct setting. Putting the piston on top dead center, the timing gears are so meshed that the exhaust valve is closing and the inlet valve about to open. If the engine does not develop full power, the setting is changed by meshing the gears one tooth away from this position; a gain in power will suggest shifting the gears one more tooth. If there is no improvement, mesh the gears one tooth away from the first setting, in the opposite direction, and continue the trials until the best setting is found. The gears should then be marked as an aid in future settings.

If an engine begins to lose power little by little when it has been running well, it is very likely that its valve springs have become weak, and are no longer able to close the valves promptly. This sluggishness will permit the escape of the fresh charge, and even if they close at the correct point, the weakness of the springs will permit them to rebound slightly from their seats, this brief opening having the same effect.

The remedy is a new set of springs of the proper tension, but if these are not available, the old springs may be stretched. A stretched spring is not as reliable as a new spring, however, and this remedy cannot be considered permanent.

In applying new springs, it is a difficult matter to compress them so that the spring retainer can be attached to the valve stem. The job is much simplified by squeezing the spring in a vise to compress it, then tying in the compressed condition with stout twine or light wire. The twine or wire is cut when the spring is in position and the spring retainer secured.

CARBURETOR

The adjustments of carburetors are provide with locking devices, and when these adjustments are properly made and locked it is not advisable to alter them unless there is certainty that it is required. It seems to be a matter of course for a rider to do something to the carburetor whenever the engine is not acting right, and this is a habit that leads to endless trouble. A carburetor can hardly change its adjustment by itself, and if it has been working well it is rash to blame it for an engine irregularity unless there is absolute proof that it is at fault.

A carburetor will give trouble, of course, but this is far more likely to be due to dirt than to anything else. Gasoline is very likely to contain dirt and water, and every gasoline pipe should have a trap and strainer that will prevent these from reaching the carburetor. If the motor cycle or car is not equipped in this way, the device should be purchased and attached, for it is the surest safeguard against trouble from these sources.

A grain of dirt in the float chamber will be carried into the nozzle, where it will obstruct the flow of gasoline; if it is small enough it will pass through, but otherwise it will stick and must be removed with a slender wire.

It is quite usual for the main air intake of a motor-cycle carburetor to be covered with wire gauze to keep out dust; if the gauze becomes oily it will quickly become covered with dust to such an extent that the free passage of the air will be prevented. This will give the same effect as closing the throttle. To prevent it, keep the gauze free from oil by frequent washings with gasoline.

The most usual trouble with a carburetor is flooding, which is indicated by a drip of gasoline when the machine is standing. This may be due to any one of several causes, but the most frequent is a badly fitting float valve. Gasoline is very likely to contain acids that will corrode brass, and the corrosion will first affect the float valve, which will become roughened and thus will allow gasoline to pass.

A corroded valve can be ground to a seat if the corrosion has not gone too far, and the first step in the process is to dismount the carburetor and remove the float valve. After putting a touch of fine grinding paste on it, the valve is then rotated lightly on its seat to obtain smooth surfaces. If the grinding process is repeated freuently, the level in the float chamber will become too high, and readjustment will be necessary. When the carburetor is level, the float adjustment should be such that the gasoline stands just below the tip of the spray nozzle.

On motor-cycle and light-car carburetors, the float is usually a block of cork, coated with shellac to prevent the gasoline from soaking in. If the coating is too light, or if the impurities in the gasoline dissolve the shellac, the cork will become heavy with gasoline, and by not floating high enough will allow the level in the float chamber to become too high. As a result, gasoline will flow out of the spray nozzle, and give flooding. This may be remedied by baking the cork to drive off the gasoline, and then giving it a proper coat of shellac.

When the float is a light metal box it can give trouble only by puncturing and allowing the gasoline to enter. Shaking it will show whether or not it is empty; if it contains gasoline, this may be driven off by holding the float in hot water. The gasoline will then vaporize, and the bubbles formed by the escape of the gas will show the location of the puncture. The hole may be closed by the least possible quantity of solder.

A grain of sand in the float valve will also cause flooding, but can usually be dislodged by moving the float valve up and down.

When flooding occurs only while the machine is going it is due to the jumping of the needle through vibration; there is usually a light spring to check this motion.

Air leaks will cause a carburetor to act irregularly, and should be eliminated. The intake manifolds of motor-cycle engines are made of thin metal, and are likely to leak where the elbows connect with straight sections. When the ends are threaded for attachment to the valve pockets or at the carburetor end, the threads will be fine, and the parts must be screwed together with great care for assurance that the threads are properly meshed.

On old machines it is very usual to find air leaks around the valve stem guides. The constant movement of the valves enlarges the holes in the guides, and air will enter during the inlet stroke. The remedy is to fit new guides.

CHAPTER XI

CARE OF THE IGNITION SYSTEM

IT is frequently the case that a man who is quite competent to take care of the engine, to time the valves, to adjust the carburetor, to set up on the brakes, and to do similar work, will not feel at all sure of his ability to work on the ignition system, and will take his ignition troubles to a garage. This feeling is due to the greater or less mystery surrounding anything electrical.

As a matter of fact, the action of the ignition apparatus is not difficult of comprehension, and there is no reason to be afraid of it. The spark will be produced if the generator is working, and if the electric currents have proper circuits in which to flow. When the ignition system gives trouble, it is a simple matter to test it to see if the generator is giving current; if it is, the trouble must lie in the circuit, which is broken, or which permits the current to leak back to the generator before passing through the apparatus that produces the sparking current.

It must be remembered that the ignition system has two circuits; a primary circuit and a secondary circuit. The generator current flows through the primary circuit, and it is this circuit that is responsible for most of the ignition trouble. As to the first cause of trouble, this will usually be dirt; by keeping the engine and its external parts clean, and wiping off the oil and grease, dirt cannot collect, and the greatest trouble breeder is thus eliminated at the start.

WIRING

The wiring of an ignition system is exposed to oil and moisture, which will attack and destroy the insulation that keeps the electric current on its appointed circuit. The wire used should be very flexible, for the vibration will break it if it is stiff; twisted cable is always used instead of solid wire.

The insulation should be proof against oil and moisture; soft, black rubber cannot be excelled.

A temporary connection can be made by stripping the insulation and twisting the wire around the binding post, but this is bound to give eventual trouble. A proper terminal should be attached to every cable, for this confines the straying ends of the fine wires, and being supported by the insulation it prevents breaking.

TIMING

It is almost always the case that the primary contact breaker or the timer can be turned slightly to give the advance and retard of the spark, and this part must be adjusted in a certain definite relation to the crank in order that the spark may occur at the proper point in the stroke. The exact setting that will give the greatest power output can only be determined by experiment. To secure an approximate setting, and one that will permit the engine to run, the spark-control lever is placed in the retarded position, and the engine cranked to bring the piston to top dead center of the compression stroke.

If ignition is by magneto, the armature is then turned in the proper direction until the circuit breaker is in the act of separating; that is its sparking position, and the armature shaft is then to be secured to its driving gear or its driving shaft. When the spark control is advanced, the circuit breaker will open before the piston reaches top dead center; if timing is correct, the spark will occur at the proper point in the stroke for high speed. If this timing does not develop full power, the armature is to be shifted very slightly in relation to the shaft that drives it, first one way and then the other, until the correct point is determined.

A magneto produces its spark when the circuit breaker opens, but the timer of a coil-and-battery system closes the circuit to produce sparks. In timing a system of this sort, the timer ring is connected to the control rod, and the control lever is placed in the retard position; the revolving part of the timer is then turned on the end of its driving shaft until its roller begins to touch the contact. It is then secured.

As a coil-and-battery system gives sparks of the same intensity in the retard as in the advance, it is then only a question of whether the spark-control lever has sufficient movement to give the timer enough advance. It will probably be found that there is more than enough movement, and that the spark can be advanced far beyond the proper point. The driver must then remember never to advance the spark too far, or else he may shift the revolving part of the timer on its driving shaft so that the extreme advance position of the control lever will produce the spark at the proper point in the stroke. Then in the retard position the spark will occur while the piston is moving outward on the power stroke, and entirely too late to be of service. In such a case the driver must note the position of the spark-control lever that corresponds to top dead center, for this will be its position when the engine is being started.

CONNECTIONS

Whenever a connection is made, the wire ends should be scraped clean to remove shreds of insulation and dirt, and the metal part to which the wire is to be connected should also be thoroughly cleaned.

In a battery-and-coil system, the connection that is likely to give trouble is the one by which the battery is grounded. This ground connection is usually a bolt or nut on the engine, and is likely to be exposed to oil and dirt. The bolt or nut should be removed and cleaned, and the part of the engine against which it bears should be polished off with emery cloth. The wire should have a solid terminal, against which the nut or bolt can be drawn tight.

Bosch magnetos of the waterproof type require the use of cable with insulation of proper size to go into the holes at which connection is made. The cable is cut off square and pushed to the bottom of the hole, the piercing screw first being withdrawn. By driving the piercing screw back into position it pierces the insulation and passes through the wire center of the cable, thus making the connection. The high-tension cable connection of the single-cylinder motor-cycle magneto is shown in Figure 31.

Figure 57 shows the high-tension connection of the twin-cylinder magneto, in which two connections are made. The magneto terminals are blocks of hard rubber, which are to be removed by withdrawing the screws at-

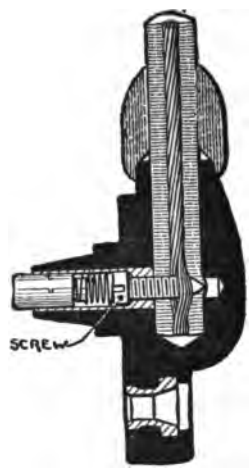

Fig. 57.—Magneto Cable Attachment

taching them to the magneto. The part of the block that projects into the magneto is hollow, and contains a carbon brush that is pressed against the slip ring by a spring. The brush and its spring are to be pulled out, when the head of a screw may be seen at the bottom of the hole. This is to be unscrewed, and the end of the cable pushed to the bottom of the outside cable hole. By returning the screw to position the cable is secured and the connection made; the brush and spring are then replaced and the block screwed on.

MAGNETOS

Beyond keeping it clean, there is little that can be done to a magneto, but on the other hand, that little must be attended to. Dirt and moisture are the enemies of a magneto, and by the water-proof construction of these machines they are prevented from working to the inside parts to any great extent. The water-proof terminal of the high tension wire can hardly be interfered with, but the switch terminal is not so carefully protected. This terminal carries the low-tension current, which is not so likely to leak as the high-tension current, but flooding it with water or mud may cause a short circuit.

CIRCUIT BREAKER

The parts of the circuit breaker must be kept clean, especially the contact points. The circuit-breaker disk and the parts that it supports may be removed by unscrewing the long bolt that passes through its center; this bolt is shown in Figure 31. The disk has a cone-shaped extension that fits a corresponding hole in the armature; if the disk does not come out readily after the bolt is removed, it may be started by careful and light prying with a small screw-driver.

To clean the parts, use a brush dipped in gasoline; if there is a great deal of dirt and gummy oil, soak it in gasoline, first removing the carbon brush set in the rear surface of the disk. After drying, a small drop of very light oil is put on the lever bearing, which is exposed by swinging to one side the flat spring covering it. The bearing is made of red wood-fiber, and at first glance the pivot appears to be rusty, for the color of the fiber is identical with that of rust.

It will occasionally happen that the fiber bearing will swell, thus binding the lever and preventing its operation; this is remedied by the use of a reamer of the proper size, *very lightly applied.*

The points should be adjusted so that when they are open there is a space of slightly less than one-thirty-second inch between them. The exactness of this adjustment is not of vital importance, for there is no difference in the intensity of the spark with the space varying from a bare separation to one-sixteenth inch. With a wide space, there is more of a hammer blow when the contact points come together, and the wear is then more rapid.

Dirt on the contact points will cause sparking, which will burn away the platinum.

When the contact points are badly burned, they will not make a good contact and should be cleaned. A flat file with the finest teeth should be used; this is known as a "dead smooth" file. The operation must be performed carefully, for the points should be so filed that they are flat, and are true to each other when closed.

MAGNETO SPARK PLUGS

The sparking current of a magneto is of such great intensity that it will burn away the points of the spark plug unless these are made of proper resistant material. Iron and soft steel will not give good results, and the best plugs are made with points of nickel.

The adjustment of the spark-plug points for magneto ignition is of importance, for if it is incorrect, ignition will be irregular. The correct distance between the points should be slightly less than one thirty-second of an inch; with a gap slightly greater than one thirty-second of an inch, but less than one-sixteenth of an inch, starting on the magneto and slow running, will be somewhat easier, but ignition will not be good at high engine speeds.

To a man who has been used to battery-and-coil ignition, this gap seems entirely too small, but he must bear it in mind that while the magneto delivers a sparking current of great quantity, it is not under so high a pressure as the current delivered by a coil, and in consequence is not able to jump so wide an air space.

When a magneto or coil is permitted to form a spark in open air, the spark may be as long as one-quarter of an inch; that is, there may be as much as one-quarter of an inch between the ends at the wires carrying the current. This does not mean that the current can form an equally long spark in the cylinder; the air or gas in the cylinder is compressed at the time when the spark passes, and compressed air is a much better insulator than open air.

An ignition system is often tested by unscrewing the spark plug, connecting its cable, and laying it on the cylinder with its threaded end touching the iron. The spark that then passes across its gap is going through open air, and it by no means follows that the spark would pass if the plug were exposed to the compression of the cylinder. This test, therefore, is not definite, and the novice is often deceived by it, for not knowing the conditions he is justified in thinking that if the current forms a spark outside of the cylinder it must form one inside.

A more definite test is to disconnect the cable and hold its end one-quarter of an inch away from the metal of the cylinder; if the spark jumps this distance through open air it will jump the gap of one thirty-second of an inch under compression.

BATTERY AND COIL SYSTEM

In this ignition system, the generator delivers a current that passes through the primary circuit, and causes the production of a sparking current in the coil; the generator is a battery, or in the case of the Ford car, a magneto that produces a low-tension current.

BATTERY

When dry cells are used, it is poor economy to use only four; eight cells connected to give a single current will last three times as long as a single set of four cells.

Dry cells should be as fresh as possible when bought, for they weaken with age, even if they are not in use. In connecting them, the terminals should be scraped clean, and the connecting wires should have solid terminals so that the binding nuts can be screwed down tight with pliers. If the ends of the wires are simply twisted around the binding posts the nut will flatten them out when it is screwed down, and it will not have anything hard to bear against; in consequence it will be likely to loosen from vibration.

STORAGE CELLS

The construction and action of a storage battery are rather complicated, and its care should be in charge of one who is familiar with the subject. It is an excellent plan to have the battery inspected by an expert at frequent intervals; if the car owner is so placed that he must look after his battery himself, he should procure an instruction book from the manufacturer and follow it implicitly.

COILS

The coils, one for each cylinder, are in a case, each coil being in a separate box. A coil has three terminals: one for connection to the battery; a second for the timer connection; and a third for the spark plug. If it is possible for it to do so, the sparking current will jump from its wire to any part of the engine or to one of the primary wires; to prevent this, the wire over which it flows is well insulated, and the coil terminal put on the opposite end of the coil box from the timer and battery terminals. It is also usual to protect the sparking wire terminal with a hard rubber cap.

The high-tension current, or sparking current, can use water as a conductor; consequently there will be a leakage of current if the sparking terminal of the coil box is wet; if the spark-plug wire is wet it should make no difference, for the insulation of the wire should be waterproof; it is the terminals of the wire that must be protected from moisture.

VIBRATORS

The vibrators of the coils must be inspected frequently, and it is this part of the system that requires the most careful attention. Whenever the vibrator blade leaves the adjusting screw and the contact points separate, a spark will form because the current tries to continue to flow. Sparking will wear and corrode the platinum points, and as this will make the sparking worse, the points will fail rapidly.

To prevent this condition the points must be kept clean, and by the adjustment the sparking should be kept as small as possible. It is only by correct adjustment of the vibrator that the engine can be made to deliver full power, so the essential thing in adjusting the vibrator is the running of the engine; the coil is supposed to be so constructed that sparking at the contact points will be as little as possible when the correct adjustment is made. If sparking is excessive, the points should be cleaned with gasoline on a rag or a brush; if they appear rough, they should be smoothed by a dead smooth file or be very fine sand paper; not with emery cloth.

To adjust a vibrator, back off the adjusting screw until the contact points are separated; then turn down the screw until the points make contact. Now start the engine on a partly open throttle, and turn the adjusting screw one way and the other, noting the effect on the running of the engine. The adjustment is correct when the engine speed is greatest.

On a four-cylinder engine it is important to have each cylinder deliver its full proportion of power, and this requires the adjustment of the vibrators to be such that they will act alike.

A four-cylinder engine will run on one cylinder, although it will not drive the car; in adjusting the vibrators the engine is run on one cylinder at a time, which permits the action of the cylinders to be compared.

The engine is run on a half-open throttle, and three of the vibrator blades are held down by the fingers; this prevents ignition in the three cylinders, and the engine will slow down to the speed at which the remaining cylinder will drive it. The active vibrator is then adjusted until its cylinder is doing its best, when it in turn is held down and another vibrator blade is released.

The process is simple, and the novice should familiarize himself with it as soon as he receives his car.

The normal spark at the vibrator is thin; if the spark is heavy and bluish, and does not change much with a change in adjustment, it indicates trouble with the condenser of the coil. This will become worse, until the coil will refuse to deliver a sparking current; it can only be remedied by the maker, and the coil should be returned to him for repair or replacement.

TIMER

When the timer is in poor condition it will not make contact, and the coils cannot operate in consequence. The most usual cause of trouble is dirt or gummy oil, by which a film forms over the contacts and prevents the roller from touching them. By cleaning the timer occasionally, and keeping its cover screwed on tight, this trouble will be avoided.

The weakening or breaking of the roller spring will also interfere with the proper operation of the timer.

The revolving part of the timer should be tightly secured to the shaft that drives it, for if it can work its way around it will throw the engine out of time.

TESTING

In spite of the number of its parts, it is an easy matter to test a coil-and-battery system, if it is remembered that the primary and secondary circuits are distinct and separate. Thus if a vibrator does not operate, the fault cannot be in the secondary circuit, and no time need be lost in looking there for it.

Furthermore, some parts of the primary circuit carry the current for all of the coils, while for the remainder of the circuit each coil has a wire of its own. Thus if one coil will not work, the fault cannot be in the battery, the battery ground wire or the wire from the battery to the switch, for if one of these is defective the current would be cut off from all of the coils, and none of them would work.

The breaking of the wire between a coil and the timer will affect that one coil only, the other coils continuing to operate as usual.

The failure of one coil will be due to a defect in the coil itself or in its vibrator, in the wire to the timer, or in the timer.

The failure of all of the coils will be due to the battery, to the wires from battery to ground or from battery to switch, in the switch, or in something that has put the timer entirely out of commission.

The best test for the secondary circuits is to run the engine in darkness; any leakage of current will then be plainly visible. While doing this, the spark plug wires should be moved about a little, so that any short circuit that may exist will have a chance to show itself.

CHAPTER XII

GENERAL CARE

IT is a measure of precaution to look over the entire machine at frequent intervals for assurance that nuts and bolts are tight, brake parts in proper adjustment, steering gear in good condition, and other parts as they should be. A thorough inspection takes only a few minutes, and the habit of making it should be formed. The loosening of a part is the forerunner of an accident or a repair bill.

BRAKES

The brakes should be so adjusted that the brake shoes or band is entirely out of contact with the drum when in the "off" position, and grips tightly when "on." When the shoes or band drag on the drum, power is lost, for in addition to sending the car ahead, the engine must then overcome the friction of the brakes. If it is suspected that the brakes are dragging, place the hand on the drum after a run during which the brakes have not been applied; if the drum is hot, there is evidence that the shoes or band are dragging on it.

It is practically universal to line brake shoes and bands with a cloth woven of asbestos and fine wire. This offers sufficient friction against the drum, and does not suffer from the heat that is generated when the brakes are applied. Brake lining material of this sort can be purchased, and is attached by means of rivets.

When one lever or pedal applies brakes on both rear wheels, the adjustment must make them go on equally. It is usual to fit an **equalizer** on brakes of this sort; in its simplest form it is a bar lying across the car and pulled forward by the lever or pedal.

The brakes are applied by rods from the end of the bar, and as the bar acts as a lever, it puts on the brakes equally, although one brake band may be looser than the other.

On descending a hill in an automobile, it is a good plan to switch off the ignition; the coasting of the car then drives the dead engine, the resistance of which will check the speed. For very steep hills the low gear may be engaged, which will add greatly to the resistance.

On reaching the bottom of the hill the ignition is switched on. This is likely to cause a muffler explosion, for the muffler contains the unburned gas that has been passing through the cylinders, and this gas is ignited by the hot exhaust gases that pass to the muffler when the engine takes up its cycle. An explosion of this sort will do no harm, however.

One great advantage of this method of braking, in addition to saving the brakes, is in the cooling of the engine by the flow of cool mixture through its cylinders.

TIRES

To keep tire shoes in good condition, they should be kept pumped up hard; if they are at all soft they will be cut by the rims as they flatten under the weight of the car. Many injuries to a shoe can be repaired, but nothing can be done to a rim-cut.

The tires should be examined at very frequent intervals to locate possible tears or cuts, and when these are found they should be immediately repaired to prevent them from getting worse. They should be cleaned of dirt by means of a toothbrush dipped in gasoline, and filled with thick rubber cement well worked in. Bad cuts can be repaired by the use of a small vulcanizer.

The worst enemy of rubber is oil, and the tires should be kept wiped clean; on no account should the machine be left with a tire standing on an oily floor.

When an inner tube is carried, it should be well protected from oil, and from contact

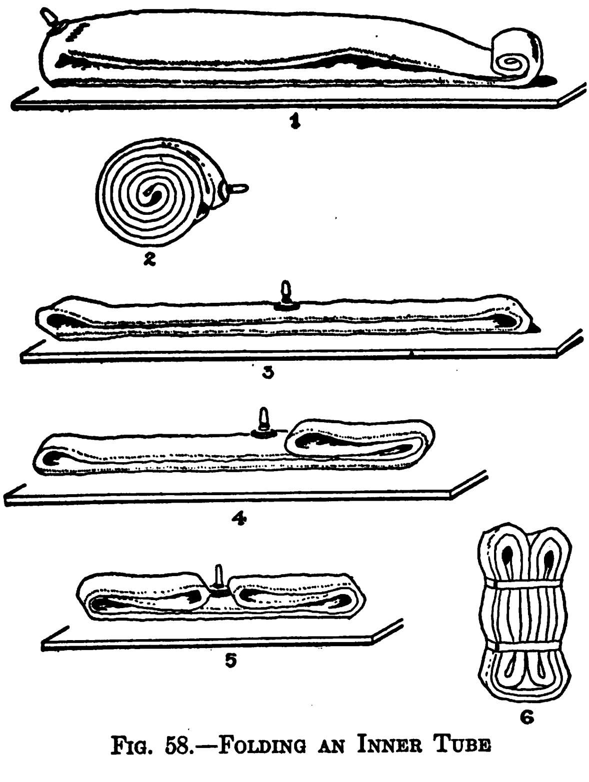

FIG. 58.—FOLDING AN INNER TUBE

with tools or other hard and sharp articles. If a tube is simply laid in the box under the seat or in the tool box it is very likely to be so injured as to be useless. It should be carefully folded in such a manner as to protect the valve stem, and then wrapped in oilcloth.

The method of folding a tube is shown in Figure 58. The first step is to remove the working parts of the valve to permit the air to be driven out; this is done by using the flat tip of the valve cap as a screw-driver, and unscrewing the valve parts. The tube is then laid on a table, folded with the valve at one end, and rolled up, as shown in sketches 1 and 2. The valve parts are then replaced, and the tube folded as in sketch 3, with the valve stem in the center.

As indicated in sketches 4 and 5, the ends of the tube are folded in, and bent up, the tube then being in the position shown in sketch 6. It is tied in position by two bands of broad tape, not too tightly drawn.

A tube folded in this manner and properly wrapped is thoroughly protected against injury.

CHAINS

Taking off a driving chain and cleaning it is an unpleasant and dirty piece of work at best, and is usually put off as long as possible. The cost of repairs due to running with a chain in bad condition is likely to be high, however, and the man who keeps his chains in proper shape is the one whose expense bill is low.

The roller chain that is universally used is made of side links connected at regular intervals by rivets, each rivet forming the shaft on which a hardened steel roller may turn. As the chain goes over a sprocket, the rollers rest between the teeth, and the rivets turn inside of the rollers. Thus there is no sliding or rubbing motion between the chain and the sprocket to wear out the parts; the movement is entirely between the rollers and the rivets supporting them.

When dust and moisture work their way between rollers and rivets, the rollers stick, and then are forced to slide on the sprocket. The natural result is the wearing of the roller as well as of the sprocket; when the sprocket teeth are worn they no longer conform to the chain, and sprockets and chain must be renewed.

There is no permanent way of keeping dust and moisture out of the roller bearings, and the best that can be done is to lubricate the chain in such a manner that a layer of lubricant is formed in them. Squirting oil on the chain has no effect, for the oil cannot work its way to the inside of the rollers; the proper method is to clean the dirt out of these parts and to put in a lubricant that will stay for a reasonable time. The following description of the process is based on instructions issued by the Coventry Chain Company, and applies to all makes of chains.

The rolled-up chain is placed on a piece of coarse wire mesh, supported a little distance above the bottom of a round pan, such as a deep pie plate or a frying pan. It is covered with kerosene and left for twenty-four hours, occasionally being unrolled and rolled up again for assurance that the kerosene is penetrating the rollers. This soaking will cut the gummy oil and extract the dirt. The chain is then soaked in gasoline for a short time, and hung up to dry.

A quantity of graphite grease of the best quality is then melted in the pan and the rolled-up chain immersed in it; the heating should be sufficient to make the grease thoroughly liquid, and should be continued for a sufficient time to allow the grease to penetrate the bearings of the rollers. Stirring the mixture will assist the graphite to work its way in. The chain is left in the pan to cool off, the grease that has penetrated the bearings then solidifying in them. After wiping off the outside grease the chain is ready for use, and it will be found that by the frequent application of this process the chain will last almost indefinitely.

The best course to pursue is to have two sets of chains in use, to be exchanged every thousand miles.

Before applying the chain, the sprocket should be cleaned and examined, and if it shows signs of wear it should be replaced before the shape of the teeth is so altered as to make it likely that the chain will jump off.

Another matter of importance in the care of a chain is to maintain the proper tension. Too great a tension not only increases the wear of the chain itself and of the sprocket, but causes a loss in power transmission and wears the sprocket bearings.

A slack chain, on the other hand, is likely to climb the sprockets and to jump off.

A chain is at the proper tension when only the under side shows a slight sag; just enough to relieve the sprocket bearings of any strain when the machine is not under way.

If a chain shows a tendency to jump off the sprockets although it is apparently adjusted correctly, the sprockets should be inspected to determine whether they are in line, or whether one of them has been bent.

BELTS

The pulley side of a belt should be kept clean, and wiped free from dust. If it is not cleaned it will become glazed and shiny and will then show a tendency to slip. The pulley grooves should also be kept clean. A leather belt should be treated with a good belt dressing, or wiped with castor or neat's-foot oil. Without this treatment it will harden and give poor service.

The belt should fit the pulley; if it does not, it will wear very rapidly and its life will be short.

The slipping of a belt is due either to its poor condition, or to its improper fit on the pulleys. A leather belt should be kept dressed with oil, and a rubber belt free from grease. The top surface of a V-belt should be flush with the pulley rims, and its bottom clear of the bottom of the pulley groove. If the belt fits the pulley its side surfaces will then have full contact with the pulley; if the belt runs on the bottom of the pulley grooves the sides will lose their grip and the belt will slip.

CHAPTER XIII

CAUSES OF TROUBLE

IF the engine gets a proper charge of mixture, ignition is correct and compression good, it will run; unless, of course, something is the matter in the nature of a broken crank shaft or a stuck piston.

When something goes wrong, the source of trouble cannot be determined by guessing at it; as a general thing the engine will tell its own troubles by the way it acts. When the gasoline supply fails, for instance, the engine will die down gradually as the carburetor goes dry; when the battery ground wire breaks or the magento circuit breaker sticks, the engine will quit abruptly.

The commonest causes of engine failure are given below.

ENGINE WILL NOT START

No ignition.

No carburetion.

No compression.

In the last named case, the ease with which the engine can be cranked will show the fault.

ENGINE STARTS, BUT WILL NOT CONTINUE RUNNING

Partial stoppage of gasoline flow to the carburetor.

Dirt in carburetor.

Exhausted battery.

EXPLOSIONS STOP ABRUPTLY

Break in a wire that conducts current for all cylinders.

Loose terminal.

Defective switch.

Magneto circuit breaker stuck.

EXPLOSIONS WEAKEN AND STOP

No gasoline.

Exhausted battery.

STEADY MISS IN ONE CYLINDER

No ignition, due to defective spark plug or spark-plug wire.

No compression, due to stuck or broken valve, or broken valve spring.

OCCASIONAL MISS IN ONE CYLINDER

Defective spark plug or spark-plug wire.

Defective valve or valve spring.

Water in the cylinder.

The engine should be run on one cylinder at a time to locate the one that is giving trouble. This test with battery and coil ignition is described in Chapter XI, under the heading of "Vibrators."

With magneto ignition, the spark-plug wires are disconnected from all plugs but one.

OCCASIONAL MISS IN ALL CYLINDERS

Dirt or water in the gasoline.

Loose battery connection.

Dirt in the timer or weak timer spring.

Magneto contact breaker sticking.

ENGINE OVERHEATS

Too much running on low gear.

Spark retarded too much, another effect of which will be a loss of power.

Insufficient lubrication.

Defective cooling, caused by too little water, a clogged radiator or circulation system, or dirt on the radiator or the flanges of an air-cooled engine, the air thereby being prevented from coming into contact with it.

ENGINE DOES NOT DEVELOP FULL POWER

Weak compression, due to badly-fitting piston rings, worn valve, weak valve springs, leaks around the spark plug or pet cock, or a crack in the piston head.

Piston too tight; this will also overheat the cylinder, the effect being especially noticeable on the part of the cylinder below the water jacket.

Slipping clutch; this will be indicated by the overheating of the clutch parts.

Tight or dragging brakes; in this event the brake parts will be overheated.

Insufficient lubrication or defective cooling. These two causes will overheat the engine.

Engine or transmission bearings too tight; indicated by their overheating.

Ignition out of time; if too late, the engine will overheat, while if too early, the engine will make a pounding or knocking noise.

Poor mixture.

Clogged air-intake gauze.

"POPPING" IN THE CARBURETOR

Mixture too weak.

Inlet valve worn or stuck, the burning mixture then blowing past the valve and igniting the mixture in the inlet pipe.

KNOCKS AND POUNDS

Ignition too early.

Loose bearings, connecting rod or crank shaft.

Loose cylinder.

Loose fly wheel.

Engine base loose on frame.

HISSING

Compression leaks around the spark plug or pet cock; test as explained in Chapter X under the heading "Compression."

Leaky inlet or exhaust pipe.

ENGINE KICKS BACK ON STARTING

Ignition too early.

ENGINE WILL NOT STOP

Defective switch; sparking continues with switch in the "off" position.

Heavy carbon deposit in the cylinder.

MUFFLER EXPLOSIONS

Due to a miss in the cylinder; the unburned charge passes to the muffler, and is exploded there by the hot gases of the previous or subsequent power stroke.

BLACK SMOKE AT EXHAUST

Too rich a mixture.

WHITE OR BLUE SMOKE AT EXHAUST

Too much lubricating oil.

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