How the WHEELS REVOLVE

How the Wheels Revolve

GENERAL MOTORS

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RESEARCH and the AUTOMOBILE

"GET A HORSE! Get out and get under!"

This was the cry of derision at the turn of the century when a little gasoline buggy faltered down the muddy street. Chances were about fifty-fifty that it would reach its destination under its own power. A rich man's toy it was then, and with less than 5000 cars in the entire country, the only impression it made on the average person was that here was a wonderful opportunity for ridicule and fun-making.

Today there are enough automobiles in the United States to give every man, woman and child a ride at the same time and without crowding. What's more, they are almost sure of getting where they want to go without any "get-out-and-get-under" business or mechanical troubles of any sort. And automobiles are no longer a plaything; they are the basis of our transportation system and a necessary part of our whole way of life.

What has brought about this great change in a comparatively short period of time?

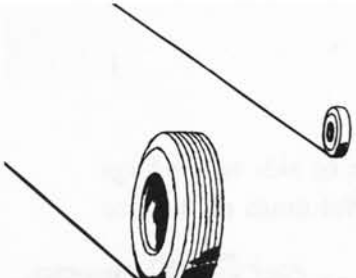
It would be foolish, of course, to credit it all to any one thing, but if we might single out one activity which certainly made large contributions to it, it would be Industrial Research.

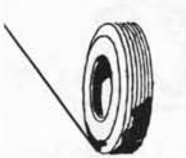
Simply placing the old and new side by side tells a large part of the story. The bright and colorful finish of the new car, the closed body, solid top and glass windows—all this bears little resemblance to the early cars. Getting in and driving the two cars tells even more. Self-starter, automatic drive, soft springs and comfortable seats,

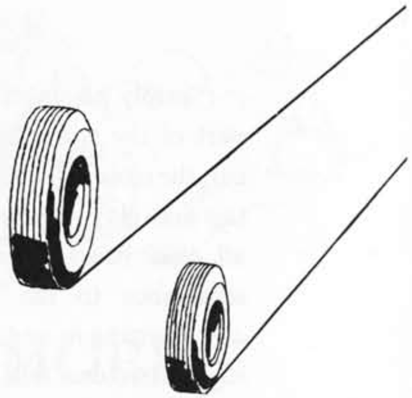
powerful engine—these and many other items of safety and convenience have increased the number of people able and eager to drive. But even this does not tell the whole story. Many things come out only after a period of time. Most of the marvelous metallurgical improvements made through the years, for example, show up only in a negative sense—that is, lack of breakage and mechanical trouble.

And so it goes. Every piece of the chassis and body of an automobile is better today than it used to be. All of these mechanical improvements and safety features, such as the energy absorbing steering column, are the result of industrial research, either directly, or indirectly by furnishing the basic information needed for engineering development.

We do not have the space in this booklet to cover all these changes and new devices on automobiles today. It attempts only to explain simply the fundamentals of what makes a car go and how the basic parts operate. But if it were not for the contributions of engineering and research, there would be no such booklet to publish. The automobile would still be a rich man's plaything, and most of us would not care about the fundamentals of its operation.

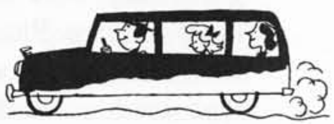


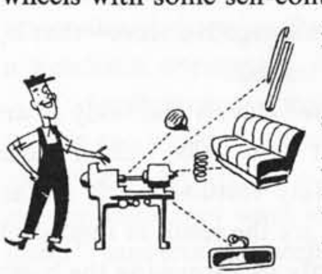




HOW the WHEELS REVOLVE

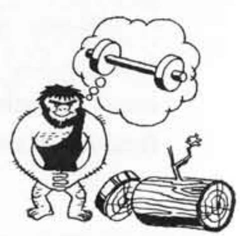
FUNDAMENTALLY the automobile is a compartment mounted on wheels with some self-contained means for propelling it over the ground.





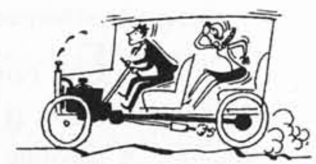
Of course, today's automobiles consist of a great deal more than that. Easy-riding springs, soft comfortable seats, headlights for night-driving, windshield wipers, rear-view mirrors and many other driver conveniences and safety features. If these were lacking, we would feel that the car was quite incomplete. Yet the fundamentals are still there, and there was a time when many of these "extras" were unknown to the builders of automobiles.

One of the fundamentals is without doubt the wheel. When the wheel was first discovered—probably in the form of a log or a section of a log—the world took a long step forward. For thousands of years, the wheel has made transportation easier.

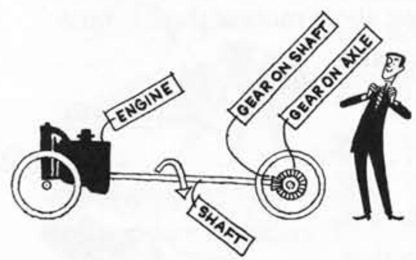


But for most of that time the wheel served only as a support for the vehicle, to make it easier for something to pull it or push it. A separate motive power propelled the vehicle—slaves, animals, or even the wind.

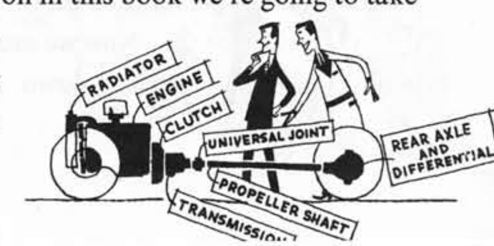
Finally came the time when the motive power was made a part of the vehicle, driving the wheels which in turn propelled the whole thing—engine, carriage, passengers and all. Then the internal combustion engine, with its light weight and comparatively high efficiency, made the automobile a practical mechanism for transporting people from where they were to where they wanted to be. This was the beginning of the automobile we know today.



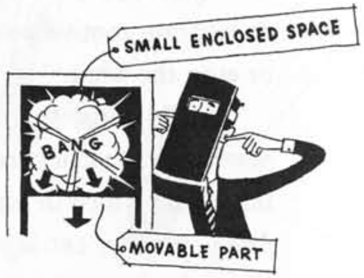
It is easy to see that the very least we need to make an automobile go is an engine and some means of connecting the engine to the wheels. It might look something like the illustration. The engine turns the shaft, which runs back toward the rear wheels. It has a gear on the end which meshes with a gear on the axle connecting the rear wheels together. As the first shaft turns, it rotates the axle and the wheels propel the car.



If there were no hills around, and we didn't want to go very fast and didn't want to turn any corners, this arrangement might work. But in an actual automobile, we have some more parts between the engine and the wheels. All we show now is where they are and their names. From here on in this book we're going to take them up one by one and try to explain what they are and what they do and How the Wheels Revolve.



ENGINE

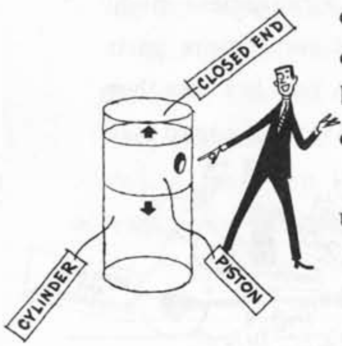


The power of an automobile engine comes from the burning of a mixture of gasoline and air in a small, enclosed space. When this mixture burns it expands greatly, and pushes out in all directions. It happens so quickly that we sometimes call it an explosion. This push or pressure can be used to move a part of the engine, and the movement of this part is eventually transmitted back to the wheels to drive the car.

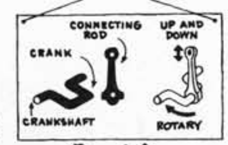
Looking at an engine under the hood of an automobile, it seems to be a complicated sort of thing with hundreds of pieces and attachments and what-nots. But we can forget about most of these for the present, and consider only the basic parts.

First we must have a cylinder. This is something like a tall metal can, or a pipe closed at one end. In fact some of the early automobiles used cast iron pipe for cylinders.

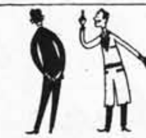
Inside the cylinder we have a piston. This is a plug which is close-fitting but which can slide up and down easily. It is the part of the engine mentioned above which is moved by the expanding gases, being driven down on each power impulse or explosion.



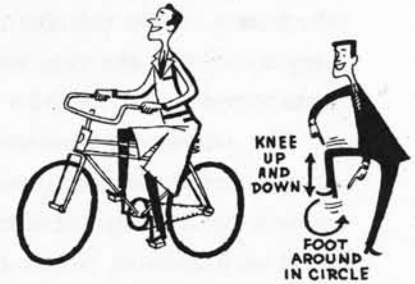
Now we must find some way to change that up-and-down motion to rotary motion to



propel the car. For this we have a connecting rod and crankshaft. The crankshaft is a shaft with an offset portion, the crank, which describes a circle as the shaft rotates. The top end of the connecting rod is fastened to the piston, so it goes up and down in a straight line. The bottom end is fastened to the crank, so that end has to go around in a circle as the piston moves up and down.

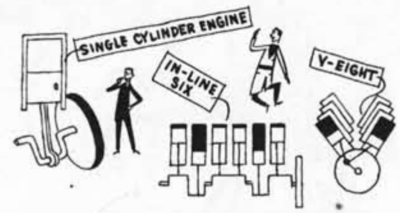


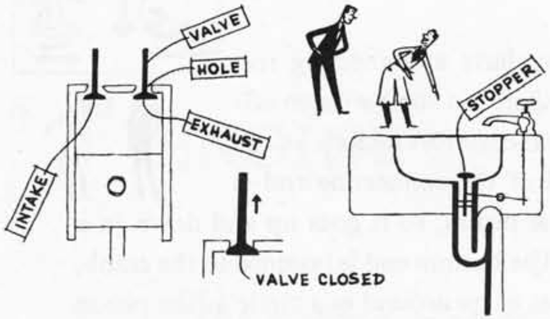
This is the most common way of changing straight line motion to rotary motion. Familiar examples of it are a kitchen meat grinder or a bicycle. In the latter the foot pedal is the crank and our leg the connecting rod. Our knee moves up and down in a straight line while our foot goes round in a circle.



On one end of the crankshaft is a heavy wheel called the flywheel. If we turn a grindstone or emery wheel rapidly by hand, and then let go, the wheel will keep on rotating. This is the same action as the flywheel. It keeps the engine turning between power impulses.

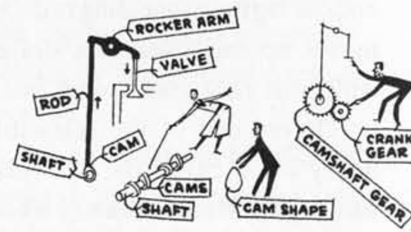
These are the basic parts of an engine; but what we have shown here would make only a single-cylinder engine. All automobile engines today have four or more cylinders. They can be arranged in one straight row, which we call an in-line engine, or in two rows set at an angle, descriptively called a V-type engine. In either case we have only one crankshaft, but it has a number of cranks instead of only one. With a number of cylinders the flywheel does not have such a big job to do because the power impulses occur more often and thus keep the crankshaft turning.



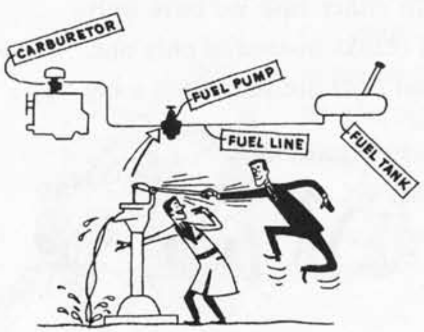


This basic engine we have put together so far has no way of getting the fuel-air mixture into it or burned gases out of it. We need some "doors," which in this case we call valves. Two holes are cut in the top of the cylinder, one for intake and one for exhaust. Metal discs are arranged to fit tightly over the holes to close them, but when pushed down they open the holes to allow passage of the gases through them. They work very much like the familiar stopper in a washbowl, but turned upside down.

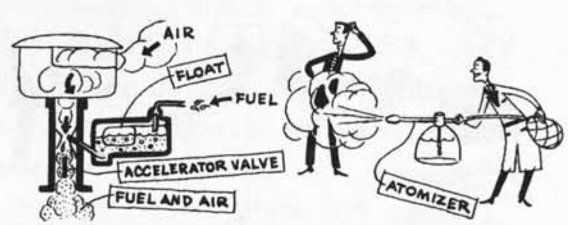
The valves are controlled by rocker arms and rods which are moved by a camshaft. This is a shaft with cams or bumps on it—one bump for each valve—which push up on the rods to open the valves. The camshaft is driven by the crankshaft, at one-half speed. The cams are accurately shaped and located, and the shaft rotates at just the proper speed, as the valves must open and close at exactly the right moment.



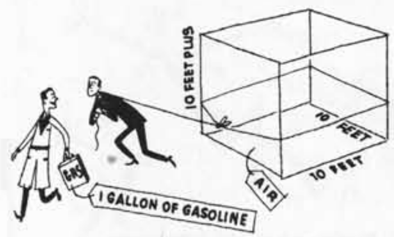
In order to produce power, the engine needs a supply of gasoline and air mixed in the proper proportions. The carburetor does the mixing job. Gasoline is pumped from the tank to the carburetor by the fuel pump. This operates in much the same manner as the old-fashioned water pump, each stroke pushing a little fuel on to the carburetor where it goes first to the float chamber.



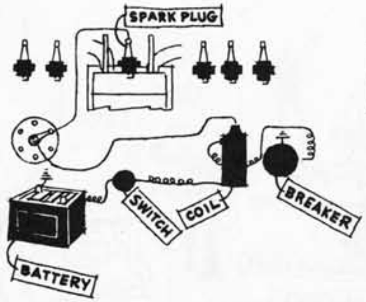
Air enters the carburetor through the air cleaner, being pulled in by the pumping action of the engine pistons working in the cylinders. It flows through the tube at high speed, past the end of a smaller tube extending into the float chamber. This sucks out the fuel into the air stream, breaking the liquid up into a fine mist and mixing it thoroughly with the air. An atomizer or garden sprayer works exactly the same way. Then the explosive mixture goes on into the engine, the amount being controlled by a valve in the tube which is opened or closed by movement of the accelerator pedal.



A good mixture for burning in an engine is about 15 pounds of air to 1 pound of gasoline. Air being so much lighter than gasoline, this means that for every gallon of gasoline we burn, we use enough air to fill a room 10 feet square and more than 10 feet high. We call them gasoline engines, but it is easy to see that in some ways air plays the more important part.



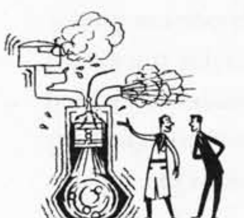
Now we have everything we need to make an engine run except something to start the mixture burning in the cylinder. Any kind of a spark will do it. In a cigarette lighter we make a spark by friction against a special metal. In an engine we do it electrically. A spark plug is inserted in the top of each cylinder, and a spark is created by electricity jumping across the gap between the two electrodes of the plug.



A battery furnishes the electricity, but several additional pieces of equipment are necessary for a complete ignition system. The coil and the breaker cooperate to develop a very high voltage, and the distributor is responsible for getting the high voltage electricity to the right spark plug at the right time. The distributor is like a clock with one hand and with raised numerals. There is a "numeral"—actually a contact point—for each spark plug. As the rotor—our clock "hand"—passes across each contact, it sends electricity to the particular spark plug connected with that contact.

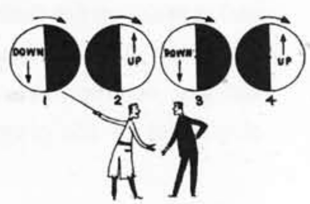
All of this must take place very rapidly. In an eight-cylinder engine driving a car 60 miles per hour, the ignition system would have to furnish about 12,000 sparks per minute, or 200 each second. And it must do this at exactly the right time and without a miss.

8 SPARK PLUGS-60 MILES PER HOUR-200 SPARKS PER SECOND



The reason the valve mechanism and ignition system must perform their duties at just the right time is that an engine operates with a certain definite cycle of events—over and over again, at a high rate of speed. Now that we have all the necessary parts of an engine, we can see how it actually works.

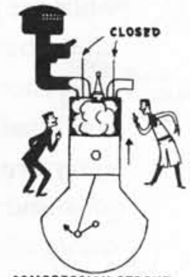
Most automobile engines are four-cycle engines. This means they operate on a four-stroke cycle, taking four strokes of the piston—down, up,



INTAKE STROKE

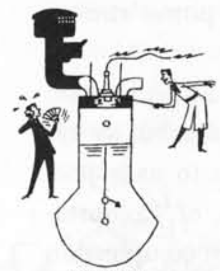
down, up—for one complete cycle of events.

On the first stroke the intake valve is open and the piston moves down, pulling in the fuel-air mixture until the cylinder is full. This is the *intake stroke*.



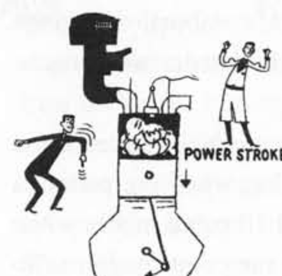
COMPRESSION STROKE

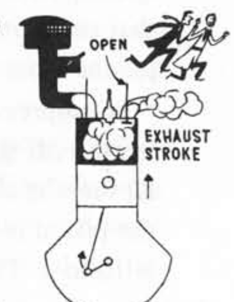
Then the intake valve closes and piston starts up on the *compression stroke*. It squeezes the mixture up into a small space at the top of the cylinder which increases the pressure in the cylinder to almost 200 pounds per square inch.



IGNITION

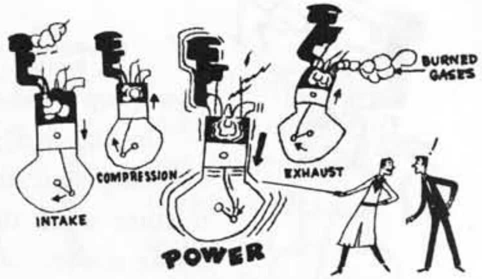
Between the second and third strokes, ignition or firing takes place. The spark, jumping the gap of the spark plug, ignites the mixture of fuel and air squeezed at the top of the cylinder. In burning, the mixture of course gets very hot and tries to expand in all directions. The pressure rises to about 600 or 700 pounds per square inch. The piston is the only thing that can move, so the expanding gases push it down to the bottom of the cylinder. This is the *power stroke*.



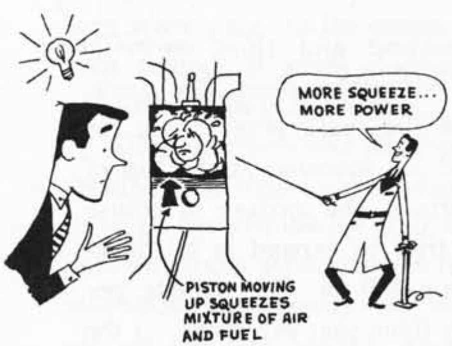


The fuel is now burned and the energy in the gases has been used up in pushing the piston downward. Now it is necessary to clear these burned gases out of the cylinder to make room for a new charge. On the *exhaust stroke*, the exhaust valve opens and the piston pushes the gases out through the opening.

So the cycle is completed and we are ready to start over again with the intake stroke of the next cycle. Intake—Compression—

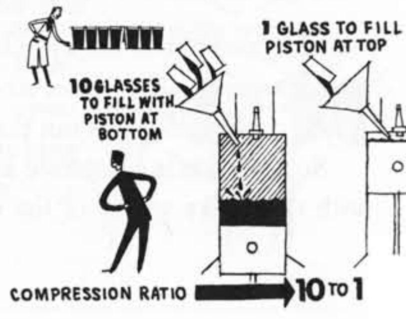


Power—Exhaust. Over and over again through the same series of actions. The crankshaft is going around continuously while the piston is going up and down, but we should note that it is only on the power stroke that the piston is driving it around. On the other three strokes, the crankshaft is driving the piston. There is one power stroke to every two revolutions of the crankshaft. This is for each cylinder, of course; with an eight-cylinder engine there are 4 power strokes for each revolution.

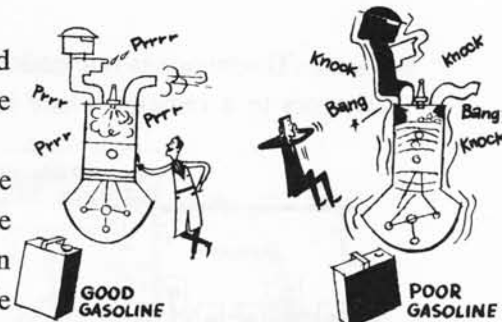


We described what happens on the compression stroke, but we did not go into detail as to its importance. We hear talk of "compression ratio" and "high compression engines," all of which has to do with how much we squeeze the mixture in the cylinder before igniting it. It is a fundamental fact of internal combustion engines that the more we compress the mixture—the harder we squeeze it—the more power we get from it.

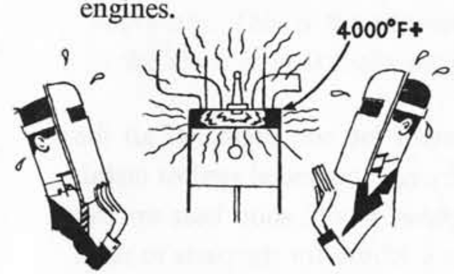
Compression ratio is a measure of how much we squeeze the mixture. If the cylinder holds 100 cubic inches when the piston is all the way down in its lowest position, and 10 cubic inches when the piston is up as far as it can go, we say the compression ratio is 10 to 1. The mixture has been compressed into a space 1/10 as large as it originally occupied. Fifty years ago 4 to 1 was a common figure for the compression ratio of automobile engines.



This has increased steadily, and today compression ratios range from 8 to 1 to 10 to 1 or higher.

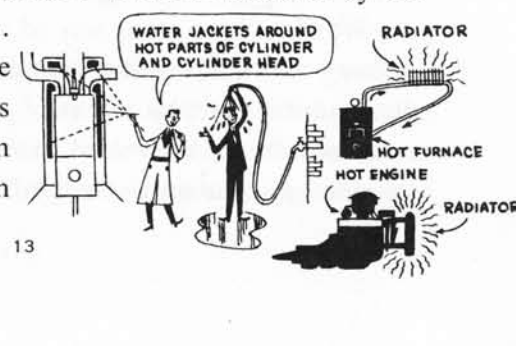


Most of the increase in engine power and economy through the years is due to higher compression ratio. That, in turn, has been made possible largely through the improvements in gasoline. When compression is too high, the engine "knocks." Some years ago it was determined that this knock was dependent on the fuel being used. Intensive research and continual improvements in the molecular structure of gasoline and new refining processes served to reduce the knocking characteristics of fuel used in automobile engines.

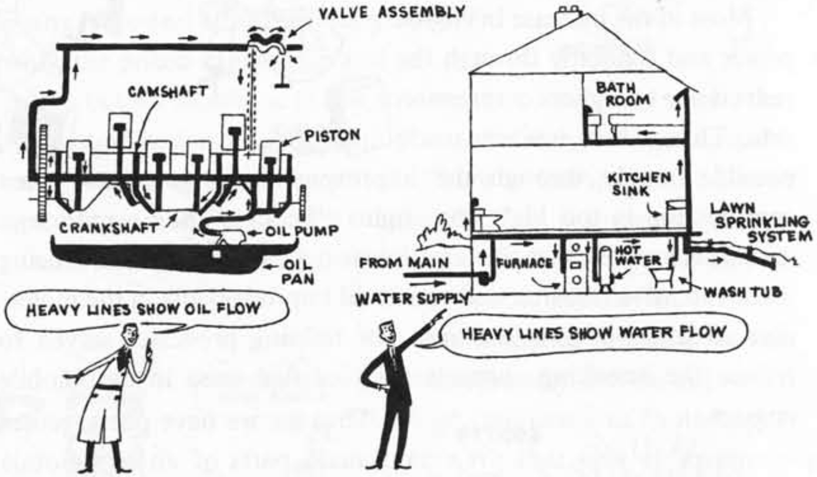


Thus far we have put together the main parts of an automobile engine. Such an engine would run—but it would not run very long. When the mixture of fuel and air burns in the cylinder, it creates a temperature of 4000 to 4500 degrees Fahrenheit. This is almost twice the temperature at which iron melts. So it is easy to see that if we did not have a cooling system our engine would not last very long.

The usual way of cooling the engine is to put water jackets around the hottest parts. Water is constantly circulated through these by a small pump. The heat of the cylinder makes the water hot, and it then goes to the radiator where it is cooled by the outside air passing through. Then it starts back to the engine again to do more cooling. It is actually very much like a steam or hot water heating system in



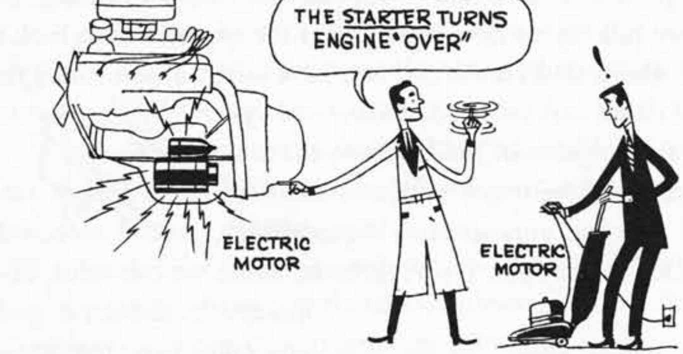
a home. The engine is our boiler which heats up the water which then goes to a radiator where it gives up its heat to the air.



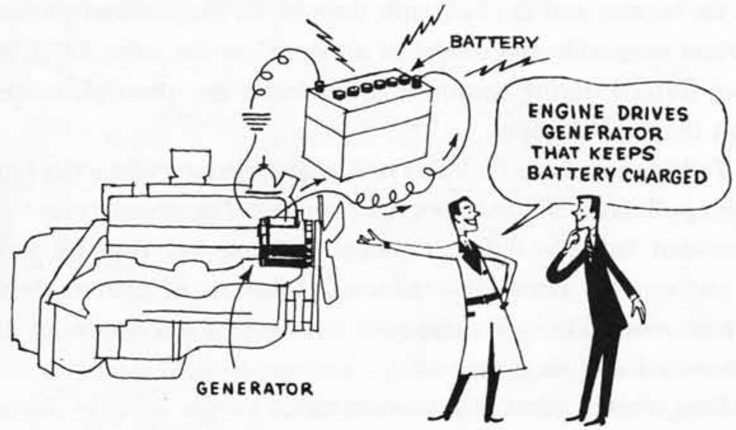
We also need a lubrication system for our engine. If all the rotating and reciprocating parts were running metal against metal, with no film of oil between them, they would soon heat up and stick. The friction would also make it harder for the parts to turn. So we have a reservoir of oil in the crankcase, where a pump forces it to the bearings and more critical points in the engine. Some of it flows through tubes and some through passages drilled in the crankshaft and connecting rods. The lubrication system might be compared to the water system in a house. The liquid is forced from one central place through pipes to many different locations where it is needed.

We must have some way of starting the engine. It has to be turning over before it can run under its own power, and we give it this initial start by means of an electric motor. This is somewhat similar to the motor in our vacuum cleaner or washing machine. It runs on electricity from the battery, and the starter

switch is similar to the electric wall switch which turns on the lights in our home.



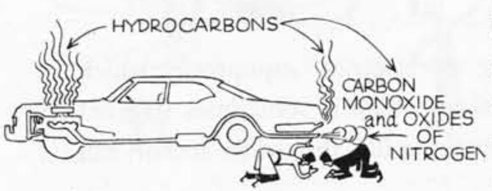
There is one more piece of electrical equipment which is important. This is the generator, which is sometimes referred to as the alternator. It looks something like the starter motor, but its



job is just the opposite. Instead of taking electricity from the battery to start the engine, the generator is driven by the engine and generates electric current which feeds back into the battery to keep it charged for starting. The generator also supplies power for the ignition system, lights, radio, and other electrical units.

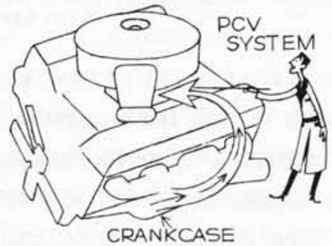
We have put together a complete automobile engine—at least enough parts of one so that it will run and keep on running. But before we talk about how power from the engine is sent back to the rear wheels to drive the car, let's look briefly at something that is found on all cars produced today—the systems that are used to control the emission of pollutants to the atmosphere.

There are three major pollutants that are emitted from automobiles into the atmosphere—hydrocarbons, carbon monoxide, and oxides of nitrogen. Hydrocarbons, which we can think of as essentially unburned gasoline, come from the exhaust pipe and the engine's crankcase as a result of the combustion process. They also enter the atmosphere from the carburetor and the fuel tank through an evaporation process. Carbon monoxide and oxides of nitrogen, on the other hand, are gases formed during combustion and enter the atmosphere only from the exhaust pipe.

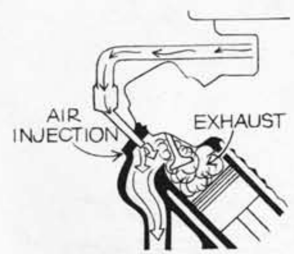


Today's cars have built-in systems designed to reduce the three major pollutants emitted from these sources. The systems may vary somewhat between different makes of cars, but they all work to perform the same job—reducing emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen. Let's see what the systems are and what they do.

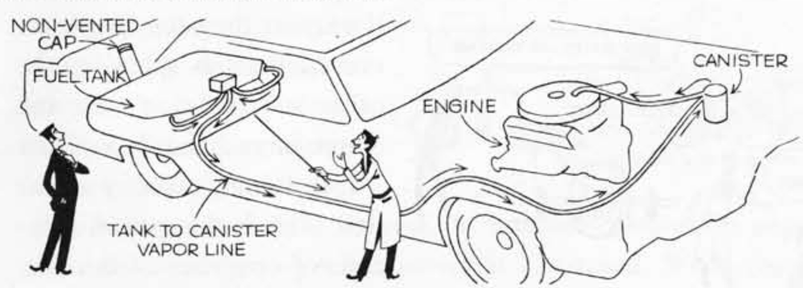
First, there's what is known as the positive crankcase ventilation system. This system helps control hydrocarbon emissions by making sure that any unburned gasoline vapors that might leak out between the pistons and cylinder walls and go into the engine crankcase are sent back to the combustion chambers to be burned.



To control the emission of hydrocarbons and carbon monoxide from the exhaust pipe, there's another system that injects air into the engine's exhaust ports to cause further burning of the hot gasoline vapors before they pass out the exhaust pipe.



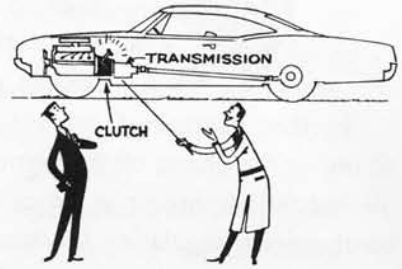
Further control of exhaust emissions is brought about by changing the shape of the combustion chambers, using a leaner air-fuel ratio (more air in the mixture that goes to the cylinders for combustion), regulating the temperature of the air entering the carburetor, increasing the speed at which the engine idles, and modifying spark timing for stop and go driving. These changes to the engine all combine to help achieve more complete combustion and decrease exhaust emissions.



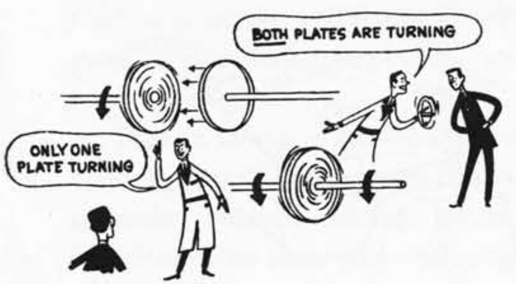
To reduce hydrocarbons that evaporate from the carburetor and the fuel tank when the engine is not running, there's a system that vents gasoline vapors into a canister filled with carbon granules. These granules act like a sponge and soak up the fumes and store them while the car is parked and the engine cools down. When the engine starts up, the fumes are fed back to the engine and burned.

DRIVE SYSTEM

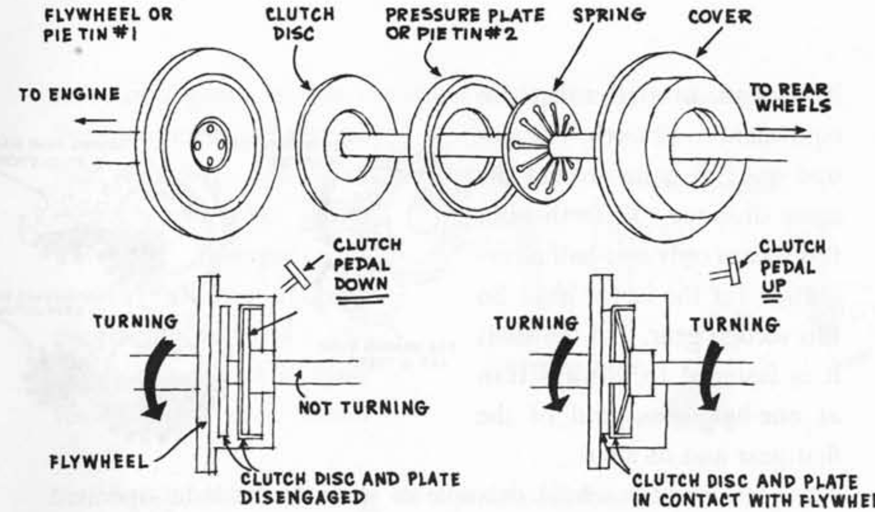
THE FIRST THING needed in the drive system is a device that will completely disconnect the engine from the rear wheels and the rest of the power transmission system. This will allow the engine to run when the car is standing still.



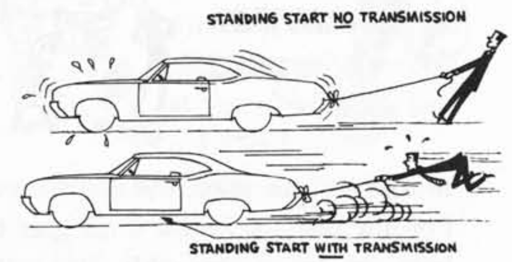
Suppose we mount two ordinary pie tins, each on a shaft, as shown. As long as they are not touching each other, we can spin one as fast as we want to without affecting the other at all. But if we move them together when one of them is spinning, the other will begin to turn and almost immediately both shafts will be turning together as one unit. This is the general principle of operation of the disc, or friction, clutch used in automobiles having manual shift transmissions. The discs are forced together by strong springs, and are separated by pushing down on the clutch pedal in the driver's compartment.



Cars equipped with automatic transmissions do not have a friction clutch or clutch pedal. We will discuss those shortly, but first we will cover the manual shift type transmission and drive system.

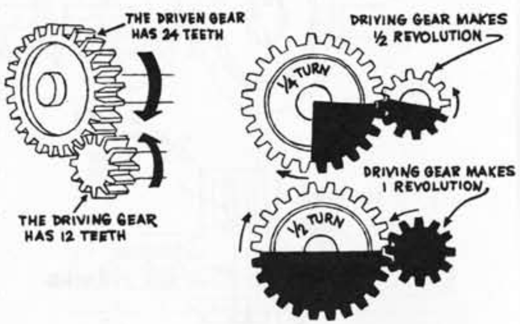


A transmission is used in automobiles to enable us to change the speed of the engine in relation to the speed of the rear wheels. When a car is starting up or in heavy going at low speed, we need more twisting force on the rear wheels to make it go than we need cruising along a good highway at constant speed. The transmission gives us this increased twisting force, and also allows the engine to run faster.

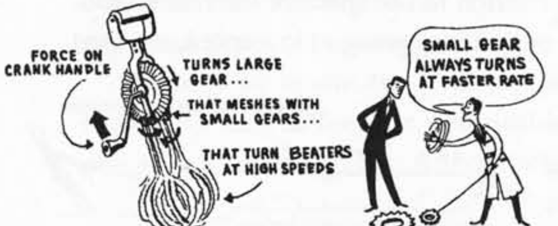


The latter is important because an internal combustion engine does not develop very much power at low speed. When the car has picked up speed, the transmission is shifted to change the speed ratio between the engine and the wheels, and eventually is shifted into direct drive. Direct drive actually means that the effect of the transmission is eliminated completely; it might just as well not be there.

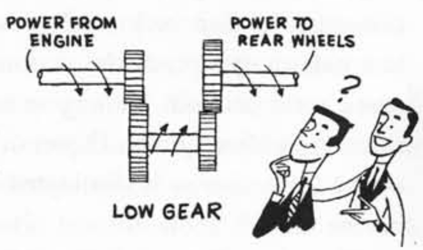
The transmission is a system of gears. Suppose we have a small gear with 12 teeth driving a larger gear with 24 teeth. When the first gear has made one complete revolution, we might say that it has gone around a distance equivalent to 12 teeth. The second one has gone around the same distance—12 teeth—but this means only one-half a revolution for the larger gear. So this second gear, and the shaft it is fastened to, always turn at one-half the speed of the first gear and its shaft.



A familiar household example of gears is the hand-operated egg beater. We can turn the large gear fairly slowly and the small gears meshing with it turn rapidly to drive the beaters at high speed.

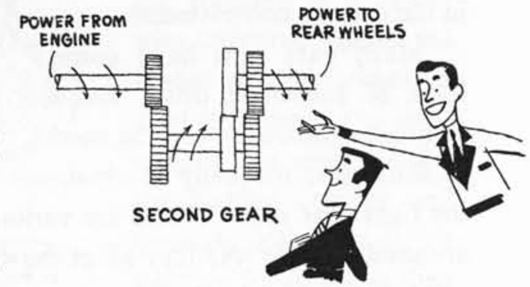


In a manual shift automobile transmission we have several combinations of gears arranged so that we can select the one we want to use at any moment. For low gear, or first, a small gear on the engine shaft drives a large gear on another shaft. This reduces the speed and increases the twisting force. Then a small gear on the second shaft drives a large gear on the drive shaft which goes to the rear axle. This reduces the speed and increases the twist still more, giving a ratio of about 3 to 1 for starting up or heavy pulling.

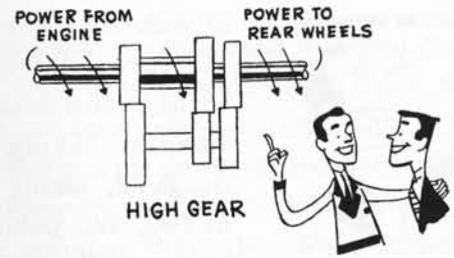


When the car has started we need less twisting force to turn the rear wheels and we would like more speed. For intermediate

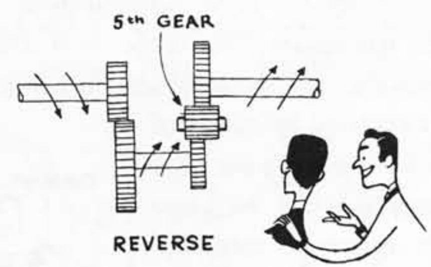
or second gear, we use the same first pair of gears as in low. We disconnect the second pair, however, and drive through two other gears. These are arranged with the larger one driving the smaller, so there is less overall speed reduction than in first gear, about 1⅔ to 1.



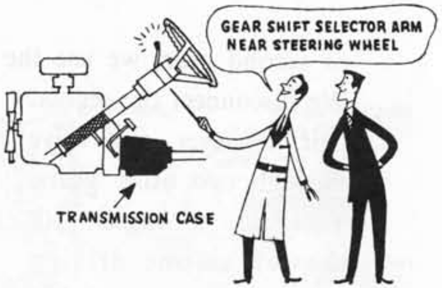
Most of the time while we are driving we need no reduction at all in the transmission. This is third, or high gear, and the engine shaft is connected directly to the drive shaft. They both revolve at the same speed, that is a 1 to 1 ratio.



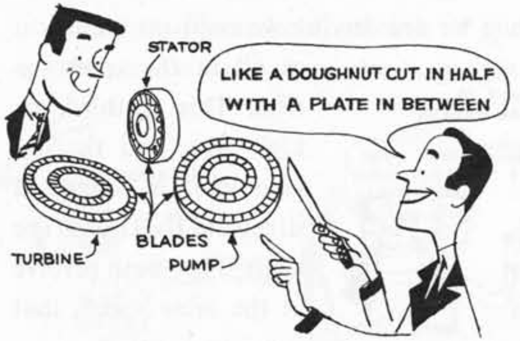
One very important requirement of a transmission is to provide means to make a car back up. Reverse gear is very much like first, giving about the same ratio and using the same four gears. It also uses a fifth gear, however, which causes the drive-shaft to turn in the opposite direction.



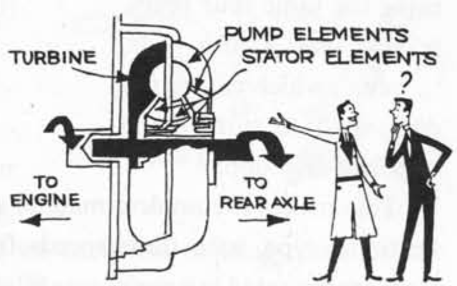
This makes a complete manual shift transmission of the conventional type, with three speeds forward and one reverse. The gears are mounted in a metal case filled with oil to lubricate the gears and bearings. The various speeds are selected by moving a gearshift in the driver's compartment.



Many cars now have some form of automatic drive, which eliminates the clutch and the need to shift gears manually to obtain the right gear ratios. There are various types, but most of them are similar in the way they affect the driving of the car.

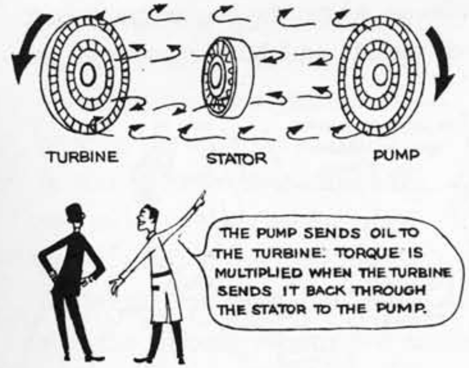


They usually have a hydraulic drive of some sort. One type in wide use today is the three-element torque converter. Imagine taking a doughnut, slicing it in two, and putting blades on the inside of each half. Both halves represent two elements of the torque converter—the pump, or driving element, and the turbine, or driven element. Now, between these two halves place a plate that also has blades. This is the third element of the converter called the stator. All three elements are in a casing filled with oil, which is circulated by means of the blades. Let's see what happens when we place the automatic transmission selector in the Drive position.

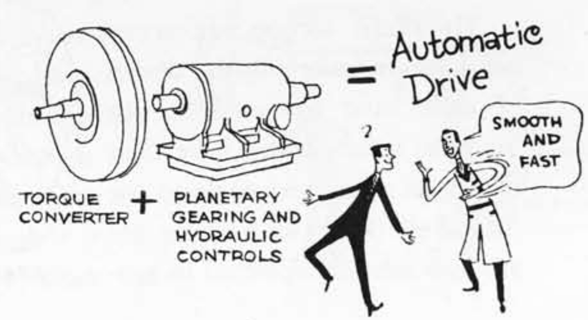


The pump is mechanically connected to the

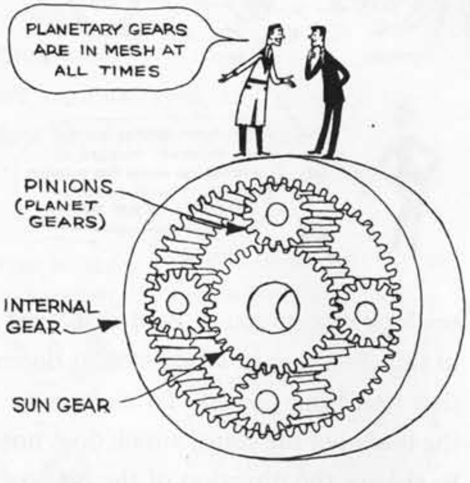
engine's crankshaft, so it always rotates when the engine runs. When the engine is started, the pump begins rotating and sends oil, spinning in a clockwise direction, against the blades of the turbine to start it turning. The spinning oil has energy which the turbine absorbs and converts into torque, or twisting force, which then is sent to the rear wheels. When the oil leaves the turbine it spins in a counterclockwise direction, and if it went back to the pump spinning in this direction it would slow it down. We would lose any torque that had been gained. To make sure this doesn't happen, we use the blades of the stator which does not rotate (not just yet, anyway) to change the direction of the oil flow so it spins again in a clockwise direction. When the oil now enters the pump it adds to the torque the pump receives from the engine, the pump starts to turn faster, and we start to obtain torque multiplication. The cycle of oil going from the pump to the turbine, then through the stator, and back to the pump is repeated over and over until the car reaches a speed where torque multiplication is no longer needed.



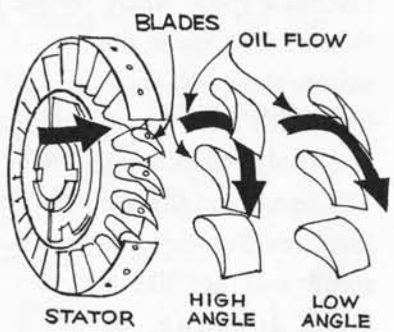
When this happens, the stator starts to turn freely (it's fixed to rotate only clockwise). The pump and turbine then rotate at the same speed and act like a fluid coupling, or



clutch. (The fluid coupling, another form of hydraulic drive seldom used today in automatic transmissions, has a pump and turbine, but no stator.) We now have a situation similar to high gear in a manual shift transmission where the engine crankshaft is connected directly to the driveshaft and both revolve at the same speed, or a 1 to 1 ratio. The stator stops rotating when torque multiplication is needed again.



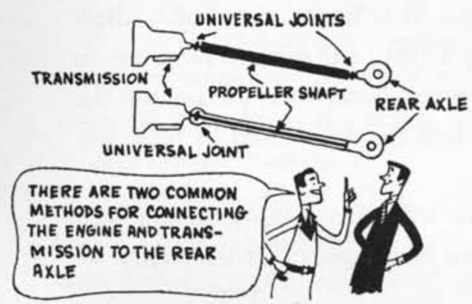
The turbine is connected by a shaft to a gear transmission located behind the converter. The transmission usually used is a planetary gear set and provides the proper forward speed gear ratios automatically plus a special low gear for greater engine braking or exceptionally hard pulling, a reverse gear, and neutral. The planetary type of gear transmission has its gears in mesh at all times. Gear ratios for different driving conditions are obtained using hydraulic controls that cause friction bands and clutches to grab and hold certain gears of the set stationary while the others rotate.



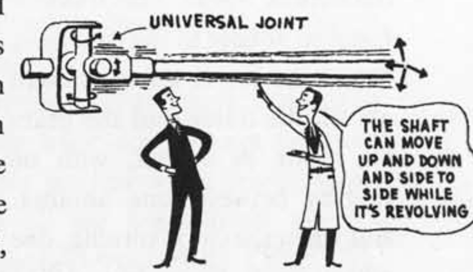
Hydraulic torque converters can have variations in the design of their basic components. For example, some stators have their blades set at a fixed angle to the flow of oil. Others have blades that are hydraulically operated to pro-

vide two blade angles automatically—a low angle for maximum efficiency during the average operating range of the transmission and a high angle for increased acceleration and performance (when more torque is needed at the rear wheels). There also are variations in the way the components are arranged in hydraulic torque converters. Some have two stators, others have multiple sets of pump and turbine blades. Differences can exist, too, in the way the planetary gears are combined with the pump, turbine, and stator elements.

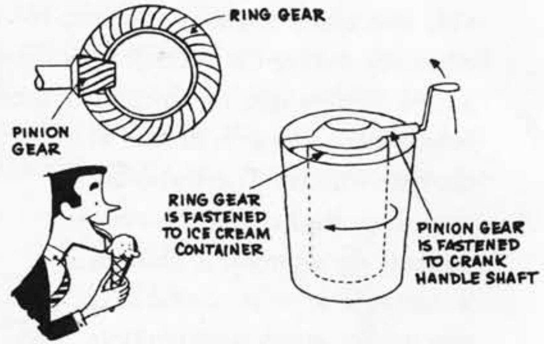
Under ordinary circumstances, however, these variations will not make a great deal of difference to the driver of the car. He still will find no clutch pedal and will have no shifting to do, except when he wants to back up. And for forward driving, all he has to do is step on the accelerator to go and the brake pedal to stop.



From the transmission the propeller shaft, or drive shaft, goes back to the rear axle. This is simply a solid or tubular steel shaft. The universal joint allows the rear axle to move up or down in relation to the transmission without bending or breaking the shaft. It is something like the gimbals of a compass on a boat, which allows the compass to



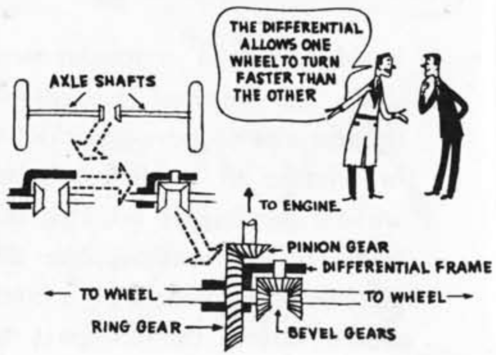
remain level at all times no matter how the boat rolls or pitches.



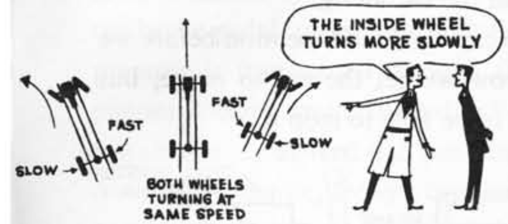
In the rear axle we have two sets of gears. The first —ring gear and pinion— is simply to transmit the power around a corner. It enables the propeller shaft to drive the axle shafts which are at right angles to it. The old-fashioned ice cream freezer has a set of gears to do the same thing.

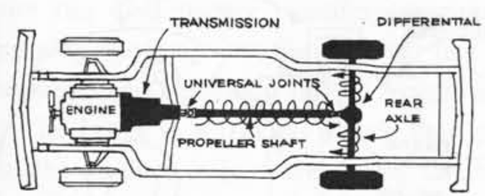
If we didn't ever have to turn a corner that is all the gearing we would need at the rear axle. But when we turn a corner the outside wheel has to travel farther than the inside wheel, and so it has to go faster during that time. It is like a squad of soldiers making a turn; the outside man has to march much faster than the one on the inside. We have a set of gears called the differential to take care of this.

The differential consists of two small bevel gears on the ends of the axle shafts meshed with two bevel gears (for simplicity we show only one) mounted in the differential frame. This frame is fastened solidly to the ring gear. When the car is going straight ahead, the frame and the gears all rotate as a unit, with no motion between one another. But when the car is turning, one wheel wants to go faster than



the other, so the gears on the axle shafts rotate relative to the other small gear. If the ring gear were stationary, one axle would turn frontward and the other one backward. But inasmuch as the ring gear is turning the whole unit, it means that one axle is turning faster than the ring gear and the other is turning slower by the same amount. This can be carried to the point where one wheel is stationary and the other one is turning at twice ring gear speed, which is the situation we sometimes get when one wheel is on a slippery spot and the other isn't. Some cars, however, can be equipped with a limited slip differential, a type of differential that allows the major driving force to go to the wheel having greater traction.





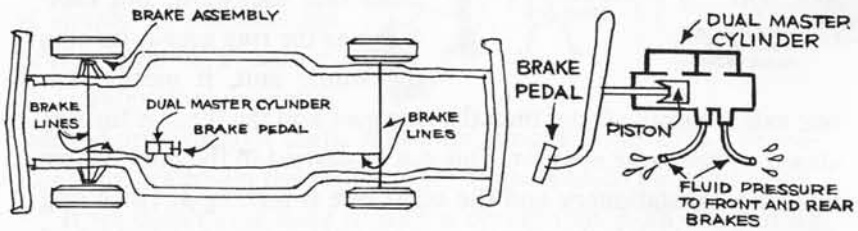
COMPLETE POWER PATH - ENGINE TO REAR WHEELS

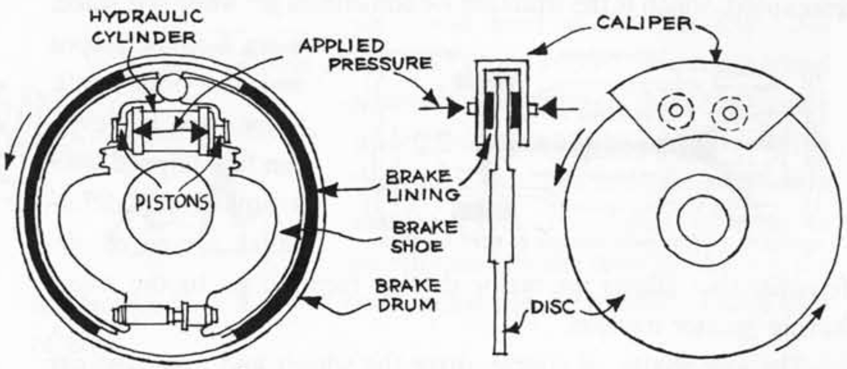
The axle shafts, of course, drive the wheels and make the car move, which is the point we have been getting to all this time. We now have a complete rear wheel drive system, just as outlined at the beginning. Power starts at the engine and eventually gets to the rear wheels, after passing through various mechanisms so that it will arrive there in the proper form.

There also are cars today that have front wheel drive. The same basic components are used as for the rear wheel drive system, but all the components are arranged up front of the driver. The power flow from the engine is to

the front wheel axle shafts. Instead of the rear wheels pushing the car forward, the front wheels pull the car along.

There is one more part of the car we should mention before we are through. We have shown how we get the car to move, but another very important point is to be able to stop it.





DRUM BRAKE

PISTONS PUSH BRAKE SHOE AND BRAKE LINING AGAINST ROTATING DRUM

DISC BRAKE

OPPOSING PADS WITH BRAKE LINING PRESSED AGAINST ROTATING DISC

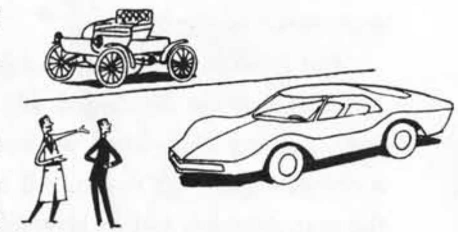
Brakes are provided for this purpose. There is one in each of the four wheels, and they are simply a method of applying friction to the rotating wheels to stop them. It is like rubbing a stick against the rim of a child's wagon wheels.

Two types of brake systems can be found on today's cars—the drum brake or the disc brake. In the drum brake system, two stationary brake shoes covered with a special friction material, called brake lining, are forced outward by hydraulic pressure against the inside of a metal drum that rotates with the wheel. A

system of steel tubes filled with a special hydraulic brake fluid runs from a master cylinder to each brake. When the driver steps on the brake pedal, pressure is built up in the master cylinder and this pressure is transmitted through the tubes, called brake lines, to pistons located inside a hydraulic cylinder in each wheel. The pistons move outward and push the shoes against the brake drum. As a safety feature, today's cars have a dual master cylinder which provides two independent hydraulic systems, one for the front wheels and one for the rear.

In the disc brake system, the brake lining is bonded to brake shoes positioned on each side of a rotating disc located in the wheel. When the brake pedal is applied, hydraulic pressure transmitted from the dual master cylinder causes a caliper to clamp the opposing shoes against the disc (it's like taking your thumb and forefinger and squeezing them together against a rotating plate).

The brake is a friction device that converts work into heat, and the amount of heat created by the brakes during a fast stop from high speed is amazing. Because of this, proper cooling of the brakes is an important consideration during their design.



So now we have everything we need to make a car go and to make it stop. It is not a complete car of course. There are other parts which are necessary, and many others which have been added over the years in the interest of safety, comfort, dependability and so forth. The research people—engineers and scientists of many sorts—have been constantly improving the automobile until it is a far cry from the horseless carriage of its early days. And this improvement goes on year after year, and will continue as long as men are free to experiment and develop new things under a system of individual enterprise and competition.

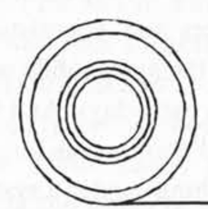
When we look at the cars going by on the street, we don't see any of these parts we have been talking about—except the tires.

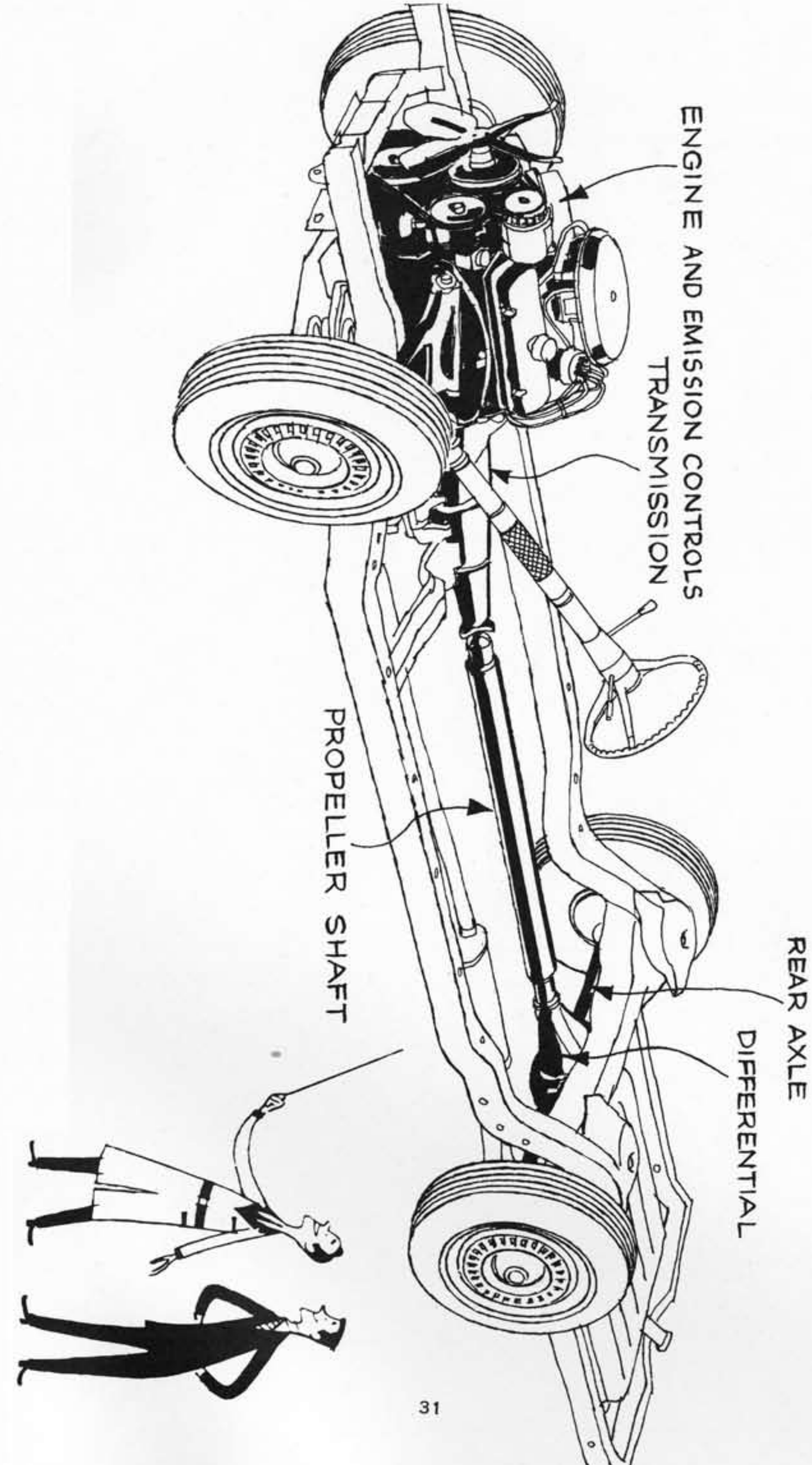
And when we look inside the car, even then we don't see all those parts of the engine and the power transmission system. But when we get in the driver's seat and drive down the road, then it is different. We certainly know that something is there.

We hope this booklet has given you a better idea of what that "something" is—those unseen parts that make an automobile an automobile and not just a stationary room with comfortable seats.

We hope that it will help you take care of those parts better and to control them properly when driving. Mechanically it is easy to drive a car. A touch on the accelerator pedal and away we go. We press on the brake and come to an easy stop. Fast or slow . . . up hill and down . . . stop, go, stop . . . about all it takes is a movement of the foot.

But it takes more than a movement of the foot to drive *safely*. It takes a brain to decide what to do and when to do it. Just like anything else, when we have power over something we have a responsibility for it too. All the safety is built into the car that the manufacturer knows how to put in, but he can't build the driver to specifications. The driver has a powerful mechanism at his command, and it is up to him to use it properly.





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