CHEMISTRY AND WHEELS

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RESEARCH AND FUELS

FOR over twenty-five years, chemists at the General Motors Research Laboratories have been studying the automobile as a chemical factory. The information herewith given was obtained, for the most part, from these chemical studies.

This work has involved a thorough investigation of what happens within the fiery stomach of the engine. With quartz windows in the cylinder, the chemist has peered into the white hot chamber of burning gases and obtained actual photographs of many things that could previously only be guessed at. The rate of flame travel, chemical compounds formed and effect of variations in engine conditions on how the mixture burns are only a few of the subjects which have received attention. All of this work has been carried on with the attention centered on the fuel which was recognized to be one of the major limiting factors in engine design.

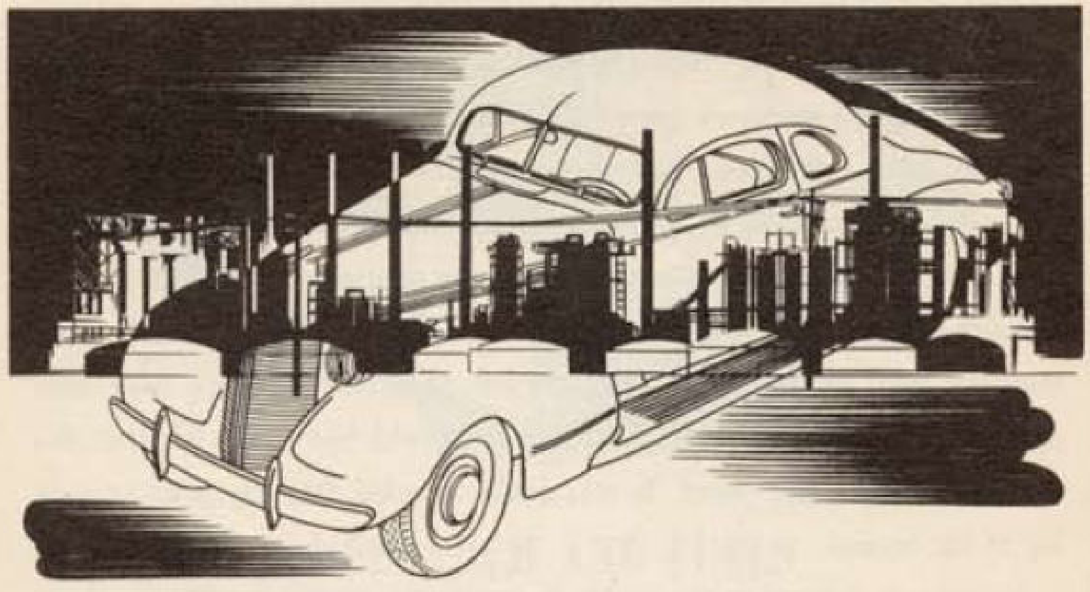
More specifically, the engineer had found that, in all his attempts to obtain more power, better economy and higher efficiency from a given size engine, he was limited by the characteristics of gasoline. When he tried to squeeze more power out of gasoline it resulted, in effect, in a bad case of indigestion which was by no means quiet. This *Knock*, as it was called, was caused directly by the kind of fuel used.

After a long series of tests and a search covering years, a compound was discovered, which, when added to gasoline, stopped the knock. The manufacture of this anti-knock compound started a new chemical industry. Bromine, one of the elements necessary in the manufacture of anti-knock gasoline, was not available in large enough quantities to supply the requirements. It was evident that eventually it would require over a million pounds a month just for the anti-knock compound, and this was considerably more than the total production in this country. It would probably have been possible to obtain it from other parts of the world, but it was felt that this should be only a last resort. It was finally decided that the most promise lay in the oceans.

Bromine is present in sea water in extremely minute quantities, about sixty-nine parts in a million on the average. To obtain this valuable material from the sea, a plant was built on the Atlantic Coast which was originally designed to produce 450,000 pounds a month and now, through successive changes and enlargements, has a capacity of almost two and a half million pounds. So for the first time in history, a valuable material other than salt is being extracted from the sea in commercial quantities. A new industry is born and with it new jobs. Building and erecting the plant, and operating and maintaining its equipment provide jobs not before in existence. Research again puts men to work.

But, as a by-product, many other improvements have been made possible by this comprehensive study of combustion. Since the fuel limitation was raised, the engineers were enabled to use higher compression ratios and thus advance engine design.

To the automobile driver, the results of this research have shown up in better hill climbing ability, faster acceleration, higher speeds and increased economy. But the work is not completed—day after day the engines run to increase the information already obtained. And it can be confidently predicted that the automobile will continue to be improved in the future as it has in the past.

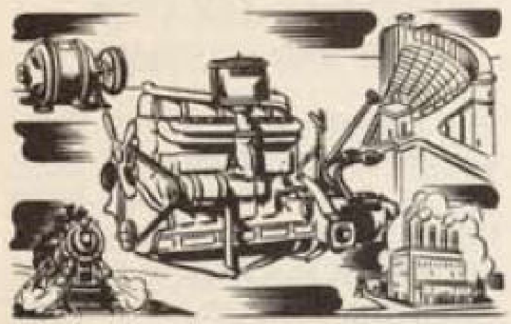


YOUR AUTOMOBILE IS A CHEMICAL FACTORY ON WHEELS

We usually think of our automobile as a mechanical device made up of metal parts which rotate and reciprocate to carry us along the highway. We know that it burns gasoline to furnish the power to move. It is this burning process which makes the automobile like a chemical factory. To the fuel chemist, the automobile is a chemical factory on wheels. It uses chemical raw materials, gasoline and air, which are converted into finished products and by-products in the engine. The automobile has every element of a compact, self-contained, portable chemical factory—storage tanks, mixing chambers, pipe lines, chemical reaction chambers and waste product disposal. It is this way of looking at the automobile which accounts for some of the terms used in describing the modern passenger automobile. Such things as octane number, high compression engines, and anti-knock fuels come from the study of the engine as the chemist views it. The following pages are offered in further explanation of this chemical factory.

85 PER CENT OF THE INSTALLED HORSEPOWER IN THE UNITED STATES IS IN AUTOMOBILES

The useful product made by the automobile is power which turns the rear wheels and moves the car. Power of an automobile engine is measured in terms of horsepower.



A horsepower is 33,000 foot pounds of work per minute. Thus, if a weight of 33,000 pounds is raised one foot off the ground in one minute, it takes one horsepower to do it. The power obtained from automobile engines varies between 50 and 200 horsepower—depending on the size of the car.

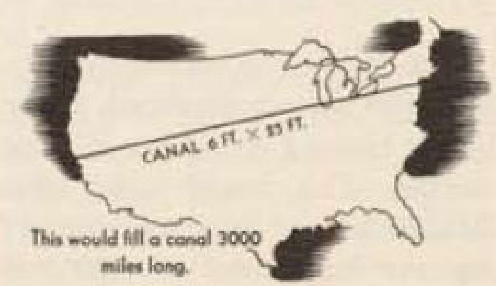
Power is also produced by other methods; by the burning of coal in locomotives and steam power plants, by the fall of water in hydro-electric power plants and by work animals. If we took all the power installed to run our factories, light our homes, run our railroads and do the many other things which require mechanical power, and added to this, all the power installed in automobiles, the horsepower of the automobile would make up 85 per cent of the total.

	Horsepower	Per Cent
Passenger Cars	1,261,297,000	75.50
Trucks, buses, taxis	162,483,000	9.70
Motor Vehicles, Total	1,423,780,000	85.20
Steam railroads	109,331,000	6.56
Agriculture	49,151,000	2.95
Electric central station	43,000,000	2.58
Manufacturing	20,092,000	1.20
Ships	8,896,000	.53
Mines and quarries	8,000,000	.48
Electric railroads	2,550,000	.15
Irrigation and drainage	1,383,000	.08
Commercial aircraft	3,091,000	.19
Work animals not on farms	1,400,000	.08
Total	1,670,674,000	100.00 Per Cent

(Figures from Carroll R. Daugherty, University of Pittsburgh)

AS CHEMICAL FACTORIES AUTOMOBILES ARE INCREASING THE WORLD'S SUPPLY OF WATER BY 17,500,000,000 GALLONS YEARLY

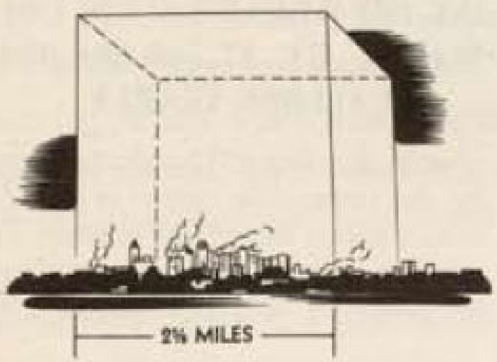
One of the chemical products made by the automobile engine is water, which comes out of the exhaust in the form of vapor. This vapor may be seen on a cold morning coming



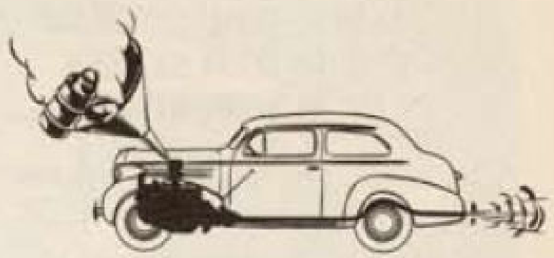
out of the exhaust pipe and sometimes even water is condensed. The automobiles in the United States produce seventeen and a half billion gallons of new water yearly. This is enough water to fill a canal 25 feet wide and 6 feet deep extending across the continent from New York to San Francisco.

2,700,000,000,000 CUBIC FEET OF CARBON DIOXIDE IS PRODUCED YEARLY

A second chemical product of the automobile engine is carbon dioxide. Carbon dioxide when frozen makes the familiar "dry ice" now used for keeping ice cream and other foods. It is also present in our breath.



The drawing shows the quantity of carbon dioxide produced yearly by the burning of gasoline in automobiles. This would make 160,000,000 tons of "dry ice," requiring the huge total of 3,200,000 box cars to transport it.



TO PRODUCE THESE PRODUCTS ONLY TWO RAW MATERIALS ARE USED... AIR AND GASOLINE

In a thorough study of this chemical factory on wheels, it is desirable to start with the raw materials. The first, air, is familiar to everyone. It is a mixture made up principally of oxygen and nitrogen with small amounts of carbon dioxide, water vapor, argon, neon, helium, krypton and xenon. The oxygen is the important part of the mixture for it is this element which burns the gasoline.

Gasoline, the other raw material used by the factory, is a complex chemical compound. Some little-known facts about this remarkable liquid might be of interest.

GASOLINE CONTAINS ENERGY STORED UP FROM THE SUN MILLIONS OF YEARS AGO

Petroleum, from which gasoline is made, was formed in the depths of the earth's crust millions of years ago. The exact methods nature used to form it are not known, but

there are several theories on how this might have happened. It was once thought that the high temperature and pressure present when the earth was being formed produced conditions which allowed the combination of the elements into oil. It is now thought that petroleum came from living things, animal or vegetable, which gradually collected over a period of millions of years. Scientists in some of the great laboratories have been able to prove, by accurate measurements of some of the properties of petroleum, that its source must have been animal or vegetable.

But, whatever its source, gasoline is an ideal fuel for automobile engines.

10,000,000 B. C. TO 1859 A. D.

Petroleum was hidden in the earth for millions of years and even when it was found, little use was made of it. There are records which show that it had been known and used in ancient times for such widely varied things as embalming the dead, as a medicine and to mix with clay to form mortar for the walls of Babylon. The early settlers and explorers in the United States made mention of the existence of oil in some of their reports. Oil seeped through the ground and covered streams and lakes, where it was skimmed from the water and sold as medicine. In several districts oil was found in wells drilled for water or salt but it was generally considered a nuisance.

At about the time of the gold rush to California, a number of experimenters had proven that oil could be used as a substitute for the tallow candles and whale oil which were then in common use for illumination. The first attempts to use it for this purpose were unsuccessful since the crude oil produced a black smoky flame. It was then found that kerosene could be obtained from petroleum by distillation, i.e., by heating it in a closed vessel and condensing the vapors. This kerosene was used in lamps to produce a light far superior to any in use up to that time.

The first oil well to be drilled, especially to obtain oil, was started in 1859 near Titusville, Pennsylvania. The well was driven under the supervision of Edwin L. (Colonel) Drake, who had been a conductor on a railroad in New York. It was on August 27, 1859, when the well was 69 feet deep that the first oil was struck. This was the beginning of the petroleum industry.

1859 TO THE PRESENT

The oil industry rapidly expanded after the first well had been drilled. Four men: Drake, "Uncle Billy" Smith and his two sons were employed by the first oil company to drill the first well. The output was 25 barrels a day at first but this dwindled to 12 barrels by the end of a year. The first year's output was about 2000 barrels.

But Drake had only tapped the surface. His well extended only to the first sand and the oil had to be pumped out. It was not long, however, until wells were driven deeper and the first "gusher" came in. New fields were found and derricks were busy drilling for the new material.

So rapidly has the petroleum industry expanded, that in normal years over a million and a half men are employed. Production of oil is now at the rate of about a billion barrels yearly.

GASOLINE IS COMPOSED OF 15 PER CENT HYDROGEN

Gasoline is composed of two common elements combined to form very complex chemical compounds.

It is not a simple compound such as water (H_2O) but is a mixture of a number of compounds called hydrocarbons.

About 15 per cent by weight of gasoline is hydrogen, the lightest of all the elements. Hydrogen has an enormously wide distribution in the universe and some of our stars are composed almost entirely of it. On earth its occurrence is generally in compounds with other elements. Nearly one-ninth of the weight of the vast masses of water is hydrogen. Even our body is made up of 10 per cent of this gas.

Hydrogen itself will not support combustion but it burns in air to form water. Enough heat is liberated by the burning of one pound of gas to raise 62,100 pounds of water one degree Fahrenheit.

AND 85 PER CENT OF CARBON

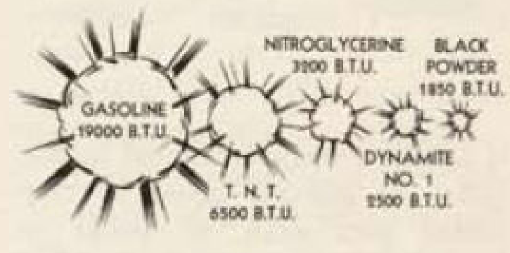
Carbon, the second element in gasoline, is also widely distributed. About 85 per cent of gasoline is carbon. It also occurs in such widely different forms as the diamond, coal and lamp black. The purest form of carbon is the diamond. All living matter has it and about 17 per cent of the weight of man is due to this valuable element. It is present in all the universe. The stars and sun owe much of their brilliance to clouds of incandescent carbon, thousands of miles in diameter and weighing billions of tons, which encircle them.

Carbon also has a high heating value and the burning of one pound would raise 14,600 pounds of water one degree Fahrenheit.

The combination of these two highly important elements, hydrogen and carbon, makes the ideal fuel for the automobile engine.

GASOLINE CONTAINS MORE POTENTIAL ENERGY PER POUND THAN ANY EXPLOSIVE

We could hardly write out specifications for a more ideal fuel for the chemical factory than gasoline. The potential energy it contains is much greater than any explosive. It is not at all unusual to obtain 18 miles per gallon of gasoline. But if we were to substitute pure nitroglycerine for the gasoline we should only get about 3 miles per gallon.



The illustration shows the relative amounts of energy in a number of explosives with gasoline heading the list by a wide margin. The figures are given in B.T.U.s (British Thermal Units) which is a measure of the quantity of heat. A B.T.U. is the amount of heat required to raise one pound of water one degree Fahrenheit from 63° F. to 64° F.

The reason gasoline contains so much more energy per pound is because the other compounds have the oxygen necessary for their combustion within themselves, while gasoline obtains the oxygen from the air.

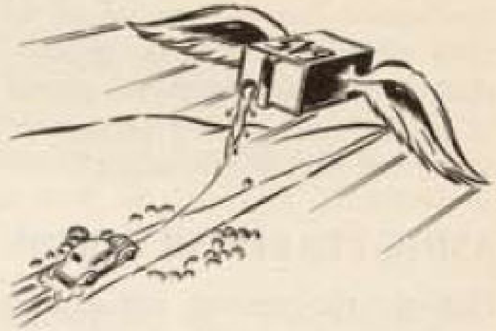
THE TREMENDOUS ENERGY IN A GALLON OF GASOLINE

The General Motors Building in Detroit covers an entire city block. It weighs 460 million pounds, yet

if all the energy contained in one gallon of gasoline could be converted into work, it would be enough to lift this entire building 2½ inches off the ground.

GASOLINE IS TEN TIMES AS STRONG AS THE BEST ALLOY STEEL

The large amount of energy in a gallon of gasoline is enough to propel a 3000 pound car travelling at 30 miles an hour for 200 miles. Of course, we should have to build engines 100 per cent efficient to do this.



If a gallon of gasoline were stretched out a distance of 200 miles it would make a stream less than 5 one-thousandths of an inch in diameter, which is about the thickness of a good sized hair. But this thin thread of liquid is strong enough to pull the 3000-pound car at 30 miles an hour for 200 miles. If we calculate the strength of this thread we find it has the tremendous tensile strength of 3,500,000 pounds per square inch. Now, some of our best alloy steels carefully heat treated to bring out the maximum strength, have a tensile strength of 350,000 pounds per square inch. So gasoline is ten times as strong as steel.

If we consider only the actual distance the car goes on a gallon of gasoline, it is still one of the strongest materials. The 3000-pound car can actually go about 20 miles per gallon. If we stretch the gallon into a thread 20 miles long, its tensile strength would be 350,000 pounds per square inch, which is just as strong as some of the best alloy steels.

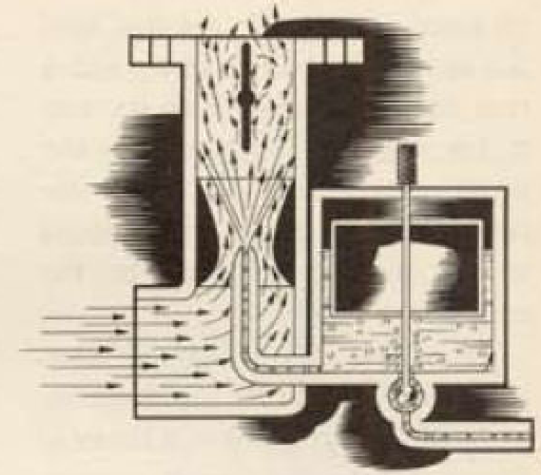
THE ENERGY CONTAINED IN THE GASOLINE CONSUMED IN THE UNITED STATES EACH YEAR IS GREATER THAN THAT IN 15 NIAGARA FALLS

According to a government survey, there are 6,000,000 horsepower available in Niagara Falls if all of the water were to be used for power purposes. Even this large figure

is but a small percentage of the potential energy contained in the 16,000,000,000 gallons of gasoline consumed in the United States in one year. In fact, the energy contained in one year's supply of gasoline is greater than that in 15 Niagara Falls.

THE CARBURETOR IS THE MIXING CHAMBER FOR THE RAW MATERIALS

But let us follow the path of the raw materials, air and gasoline, through the chemical factory. The air and gasoline are mixed in the right proportions in the carburetor. The proportions of air to gasoline vary



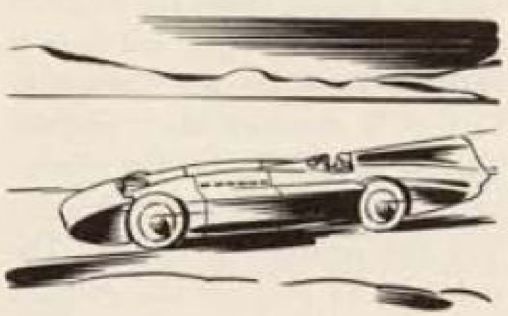
between 9 pounds of air per pound of gasoline to 15 pounds of air per pound of gasoline. The richer mixtures are for starting, warm-up and for accelerating and the leaner mixtures for running at constant speed where economy is the most important factor. Rich mixtures, as a rule, give higher power and lean mixtures higher economy.

The illustration shows the construction of a simple carburetor. The air is drawn through the carburetor by the engine in the direction shown by the arrows. A restriction, called a venturi, placed in the air passage increases the velocity and decreases the pressure of the air. A fuel jet, fed from a chamber in which the gasoline is kept at a constant level, projects into the narrow part of the venturi where the air velocity is highest and the pressure is lowest. The reduction in pressure and increase in speed, forces the gasoline into the air stream in a fine spray where it is thoroughly mixed on its way to the engine. The throttle in the upper part of the carburetor increases and decreases the amount of the mixture supplied to the engine.

Of course, this is a simple form of carburetor. Those used on all automobile engines have additional devices to give the correct mixture ratio for various conditions of speed and power. They also have choking devices for giving the rich mixture necessary for starting and accelerating devices to give a rich mixture for quick get-away.

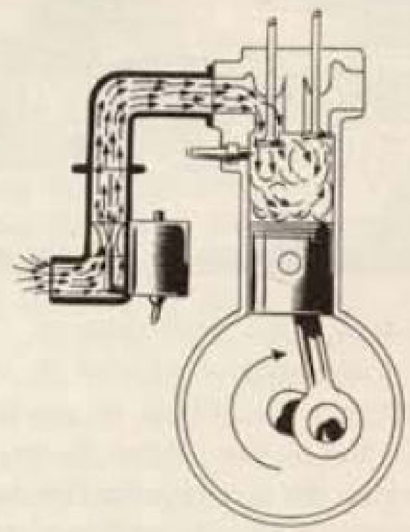
THE AIR IS PULLED THROUGH THE CARBURETOR AT SPEEDS AS HIGH AS 250 MILES PER HOUR

The air is pulled through the carburetor at extremely high speeds. When the car is travelling at 70 miles per hour the air rushes through the carburetor venturi at a speed of 250 miles per hour or more. This is almost four times as fast as the vehicle is moving.



THE INTAKE MANIFOLD DISTRIBUTES THE INFLAMMABLE MIXTURE TO EACH CYLINDER

From the carburetor the mixture goes to the intake manifolds. These consist of pipes properly designed

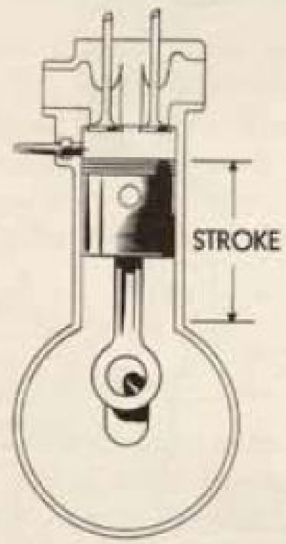


to give each cylinder its share of air and fuel. The manifold thus acts as the distributing system for the raw materials from the carburetor to the power chambers or cylinders.

THE AUTOMOBILE ENGINE OPERATES ON THE FOUR-STROKE CYCLE

Before we go any further in following the path of the raw materials

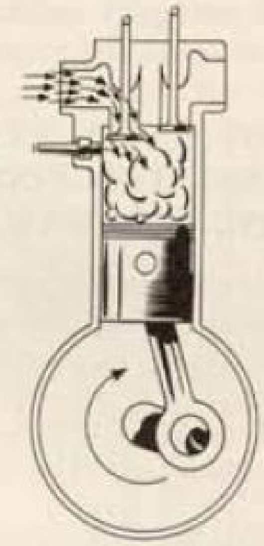
through the chemical factory, let us see how the engine works mechanically. The automobile engine usually operates on a four-stroke cycle. Each movement of the piston from one end of the cylinder to the



other is a stroke. Each revolution of the crankshaft is two strokes. Two revolutions of the crankshaft is one cycle of four strokes.

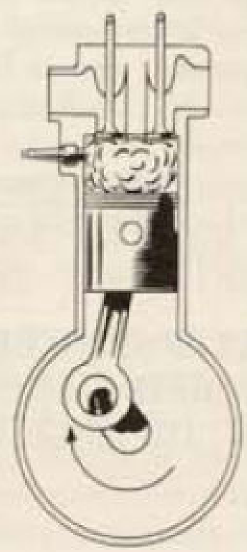
THE FIRST DOWN STROKE PULLS THE MIXTURE IN TO FILL THE CYLINDER

The first down stroke of the piston is the intake stroke. The piston, moving downward, acts like a pump and pulls the inflammable mixture from the carburetor, through the manifolds and open intake valve into the cylinder. At the bottom of the stroke when the cylinder is full, the intake valve closes.



THE UP STROKE COMPRESSES THE GAS

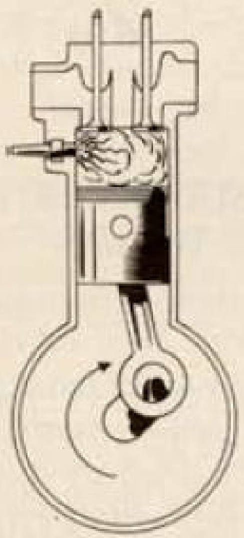
The next stroke is the compression stroke. With both valves closed and with a cylinder full of the mixture, the piston travels upward compressing the gas into the small clearance space above the piston. The pressure is raised by this squeezing of the mixture from about



15 pounds per square inch to about 125 pounds per square inch.

THE HOT GASES EXPAND AGAINST THE PISTON FORCING IT DOWNWARD

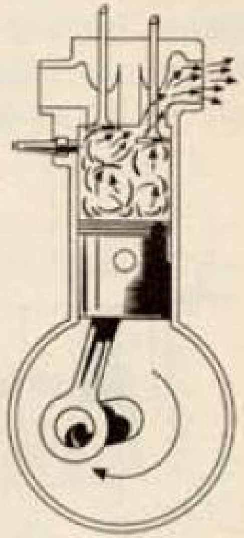
Useful work is done in the third or power stroke. When the gas has been compressed, an electric spark



ignites the mixture. At once the cylinder pressure rises to over 400 pounds per square inch. The hot gases, expanding against the walls of the enclosed chamber, push the only movable part, the piston, downward. This movement is transferred to the crankshaft by the connecting rod.

THE NEXT UP STROKE FORCES THE BURNED GASES OUT OF THE ENGINE

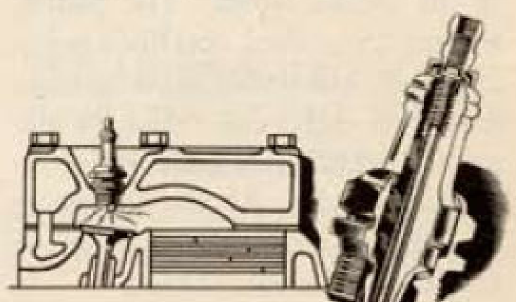
The last stroke in the cycle is the exhaust or scavenging stroke. The gases have now spent their energy in pushing the piston downward and it is necessary to clear the cylin-



der to make room for a new charge. The exhaust valve opens and the piston, moving upward, forces the burned gases out through the exhaust port and exhaust manifold.

THE SPARK PLUG STARTS THE MIXTURE BURNING

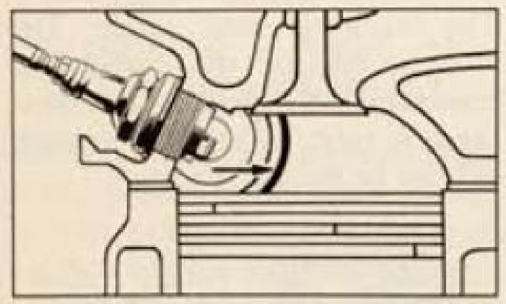
But let us go back and examine, more fully, the burning of the compressed charge of air and gasoline. The spark plug supplies the light that starts the mixture burning. Between the compression and



power strokes, when the mixture is compressed into the clearance space, ignition occurs.

THE FLAME TRAVELS RAPIDLY ACROSS THE ENCLOSED CHAMBER

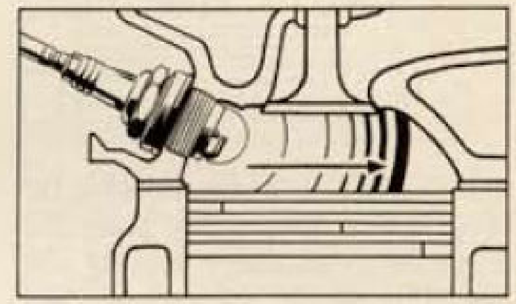
The flame travels rapidly from the spark plug across the power or combustion chamber. You have undoubtedly often seen a field of dry grass burning. The grass is ignited at one place and if there is



even a gentle breeze, the fire travels rapidly across the field. This is exactly what happens in the fiery combustion chamber. Scientists have photographed this action and have found that it takes about 1/350 of a second for the flame to travel from one side of the chamber to the other.

PRESSURES RISE TO 400 POUNDS PER SQ. IN. AND THE TEMPERATURE TO 4500 DEGREES FAHRENHEIT

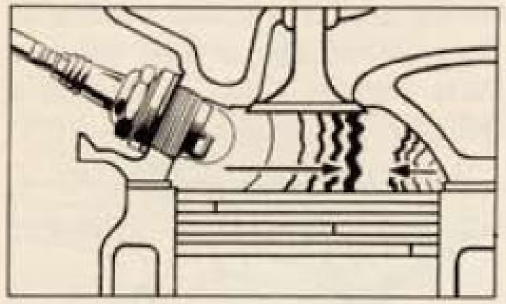
The pressure in the cylinder rises to 400 pounds per square inch. This means that the total pressure on the head of a piston 3 inches in diameter reaches a total of over 2800 pounds; nearly a ton and a half.



The temperature of the burning mixture reaches extreme values. Here again scientists have worked with delicate instruments to determine the exact temperature, which was found to be as much as 4500 degrees Fahrenheit. Because this value is only reached for a very short time, the problem of measuring this temperature has been one of the most difficult. Ordinary thermometers and pyrometers are too slow in operation to be of any value, so other and indirect methods had to be devised. One successful method was by the use of the spectrograph.

SOMETIMES THE LAST PART OF THE CHARGE BURNS ALMOST INSTANTANEOUSLY

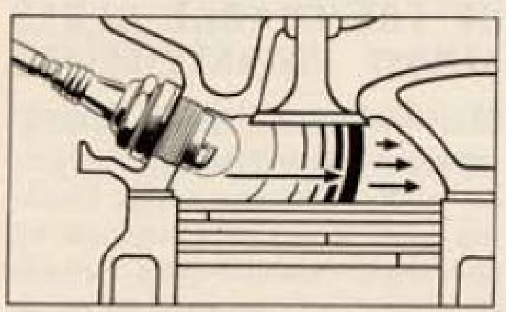
This illustration shows a sectional view of an actual combustion chamber with the location of the knocking zone. Knock is recognized by the sharp metallic ping present when the car is accelerating or go-



ing up a hill. It is objectionable because it is a disagreeable noise and it results in excessive heating and loss of power in the engine. During knock the last part of the charge burns almost instantaneously and is accompanied by a rapid rise in pressure. The total pressure on the piston head is raised in an instant by a thousand pounds.

ANTI-KNOCK GASOLINES MAKE THE LAST PART OF THE CHARGE BURN SMOOTHLY

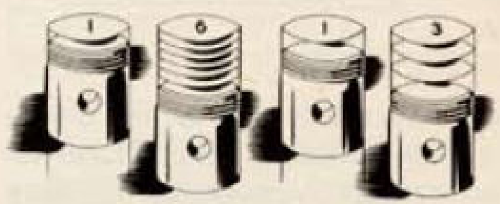
This knock is caused by the gasoline and may be eliminated by the use of anti-knock fuels. Anti-knock gasolines make the last part of the charge burn smoothly. When anti-knock fuels are available, the engineers can design their engines to



take advantage of this by building engines which develop more horsepower and give greater economy.

HIGH COMPRESSION ENGINES

As has been said, the knock is caused by the fuel. A better way of saying it, is that the fuel knocks if it does not fit the engine. In improving the automobile engine to obtain greater power and better economy, this knocking property of gasoline has been one of the most important limiting factors. The reason is very simple. The way to increase the power and economy is to increase the compression ratio. When the engineer did this he ran into knock.



Compression ratio is a very easily understood term. Look at the illustration. If the cylinder would hold one pint at the top of its stroke and six pints at the bottom, the compression ratio would be six to one. If it held two at the top and six at the bottom, the ratio would be three to one. Modern engines have ratios even higher than six to one. This is the reason why we obtain over twice the power from a modern engine that we did thirty-five years

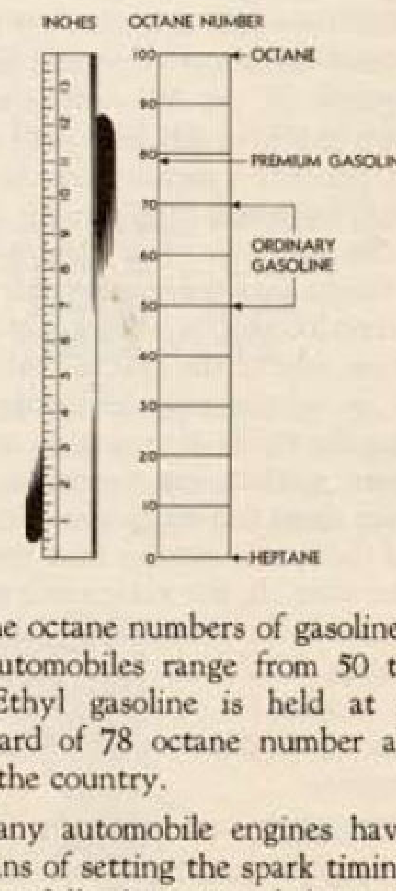
ago when three to one was a common ratio. It takes a gasoline with much better anti-knock properties to run in an engine with this higher ratio and this was not available in the past. Engines which have a high compression ratio are usually called "high compression" engines. The increase in compression ratio of automobile engines accounts for much of the increase in the past thirty-five years in speed, hill climbing ability, get-away and miles per gallon.

MEASURING A NOISE BY MEANS OF A CHEMICAL

Knock is a quality of a gasoline just as real as its weight, but it cannot be measured in our usual scales of weights, lengths or volumes. Chemists had to devise a scale so that they could at least compare the tendency of fuels to knock in an engine.

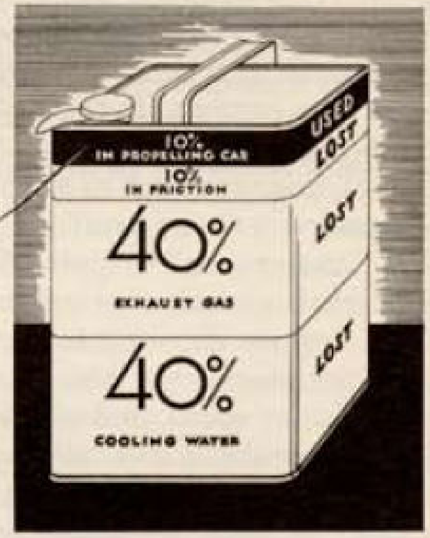
First, they chose a standard single cylinder engine and set up definite rules as to how it should be run. Then they searched for readily available liquid fuels which would always have the same knocking tendency in this engine. They found one with high anti-knock quality in a chemical called "iso-octane" which is made from an alcohol. One with low anti-knock quality they found in normal heptane which comes from the sap of the Jeffrey pine grown on the Pacific Coast.

Then they said, pure iso-octane we will call 100 octane number. Pure heptane we will call zero octane number. To obtain the octane number of any gasoline, a mixture of these two chemical compounds is made, until one is found which will give the same knock in the engine as the gasoline. The percentage of octane in the mixture is the octane number of the gasoline. For instance, if a gasoline is matched in knocking properties by a mixture of 70 parts of iso-octane and 30 parts of heptane, the gasoline has a 70 octane number.



The octane numbers of gasolines for automobiles range from 50 to 78. Ethyl gasoline is held at a standard of 78 octane number all over the country.

Many automobile engines have a means of setting the spark timing to take full advantage of the anti-knock quality of the fuel used. These are sometimes termed "octane selectors" and should be set to the correct position to obtain the best possible performance and fuel economy from the automobile. When high octane fuels are used, setting the selector correctly will result in improved operation and more miles per gallon.



ONLY 10 PER CENT OF THE ENERGY IN THE GASOLINE IS NORMALLY USED TO DRIVE THE CAR

Even though much has been done to improve the automobile it is still rather inefficient at normal driving speeds. Of the tremendous energy in a gallon of gasoline, only about 10 per cent is usefully used to drive the car when it is running at 30 miles an hour. But this is more efficient than many other things. A steam locomotive utilizes only about 8 per cent of the heat in coal when it is running most efficiently. We usually think of nature as an efficient worker, yet vegetation only uses about one tenth of one per cent of the heat it obtains from the sun. So, after all, the automobile engine is good when compared with other things. Under the best conditions it is possible to obtain 25 to 30 per cent efficiency from gasoline engines.

Normally 90 per cent of the energy is wasted and some method must be provided in the engine to take care of these large quantities of heat. The cooling system absorbs 40 per cent of this waste and rejects it to the air.

The exhaust gases are at a very high temperature when they are forced out of the cylinder. Another 40 per cent of the heat is expelled with them.

The remaining 10 per cent is used up in the friction of the pistons, bearings, gears, and other rubbing parts of the car.

THE CHEMICAL PRODUCTS ARE EXPELLED IN THE EXHAUST GAS

Let us now turn to some of the by-products of this chemical factory we have been studying. Early in the booklet we said the raw materials were air and gasoline. When the gasoline burns in the cylinder, the carbon and hydrogen in the gasoline combine with the oxygen in the air. When carbon burns in oxygen, carbon dioxide is formed if the burning is complete. Otherwise carbon monoxide, a deadly poisonous gas, is the result.

The illustration shows what results from the complete burning of one gallon of gasoline. These values are what we would obtain if the combustion were perfect. Over a gallon of water is produced for each gallon of gasoline burned.

THE ILLUSTRATION PICTURES THE IDEAL

What actually comes from the average automobile engine exhaust is 1130 cubic feet *exhaust gas*, composed of:

WATER	6.9 lb. or 0.83 gal.
CARBON DIOXIDE	10.0 lb. or 87 cu. ft.
CARBON MONOXIDE	5.9 lb. or 80 cu. ft.
HYDROGEN	0.2 lb. or 40 cu. ft.
OXYGEN	0.2 lb. or 2 cu. ft.
UNCHANGED NITROGEN	775 cu. ft.

The table shows what actually comes from an average automobile engine. The carbon in the gasoline combines with the oxygen in the air to form carbon dioxide; the hydrogen to form water. The nitrogen passes through the engine unchanged.

When the choke is used in starting, a rich mixture is supplied by the carburetor which results in carbon monoxide being formed. Since carbon monoxide is a dangerous gas and may cause death if breathed, it is necessary to be careful to have the garage doors open when starting an automobile engine. In a closed room the percentage of carbon monoxide in the air reaches dangerous proportions in a short time. In the open air, even on our busiest street corners, there is no danger because the gas is diluted by the large quantity of air.

TWO OF THESE PRODUCTS, WATER AND CARBON DIOXIDE MAKE SODA WATER

Exhaust gas, then, contains products which in other forms are familiar to everyone. The two leading ones, carbon dioxide and

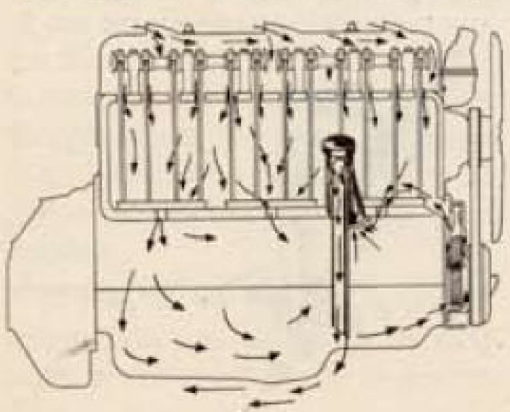
water, if cooled and mixed would make ordinary soda water. So the automobile engine might be called a soda water factory.

CRANKCASE VENTILATION

These chemical products pass directly out of the engine through the exhaust system. When the exhaust valves open, the pressure in the cylinder causes the hot gases to flow out through the exhaust manifold, the exhaust pipe and the muffler.

However, even the closest fitting pistons and piston rings cannot prevent some of the gases from leaking down into the crankcase which contains the engine oil. When these are condensed, they form water and acids which eat the metal and cause sludge in the oil. When the engine is started in cold weather, it is impossible to prevent the condensation of the gases on the cold cylinder walls. From here it is washed into the crankcase.

To eliminate these harmful products from the oil, automobile engineers developed crankcase ventilators about twenty-five years ago. As shown in the illustration, fresh air enters through an inlet located in the air stream. After passing through a filter which removes any grit or dust, this air is whirled around in the crankcase by the rotation of the crankshaft and is then forced out through an outlet pipe. The whirling air, moving at high speed, carries along with it the acids and vapors which, if allowed to remain in the crankcase, would attack the metal parts.



SO THE AUTOMOBILE IS A CHEMICAL FACTORY ON WHEELS

Let us summarize the foregoing information about the facts and functions of this chemical factory on

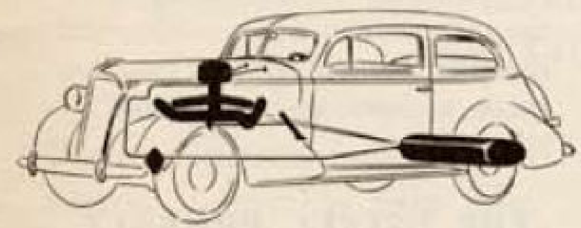
wheels. We have seen what a large industry they make up when the huge quantities of raw materials and finished products are considered. We have traced the raw materials from their source, through the engine and out the exhaust. Some of the devices used in the factory have been explained and

some of the peculiar and unusual facts about it have been illustrated.

The final illustrations show the close connection between the actual parts used in an automobile and the departments in a typical chemical factory.

THE GASOLINE TANK IS THE STORE HOUSE FOR THE RAW PRODUCT

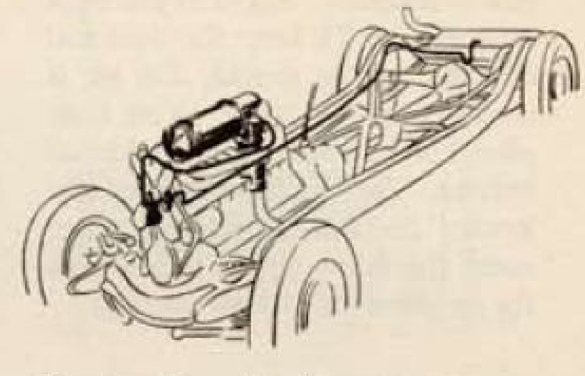
If we were building a chemical factory which used an explosive raw material we would naturally



place the storage tank as far away from the workmen and factory as possible to eliminate the danger from fire. For the same reason, the raw product for the automobile is stored in a tank in the rear, away from the passengers and hot engine. The tank is kept cool by the air circulating around it and, in case of danger to the car, the passengers are not drenched in the highly inflammable gasoline.

THE PRODUCTION LINE CONSISTS OF THE GASOLINE PIPING AND MANIFOLD

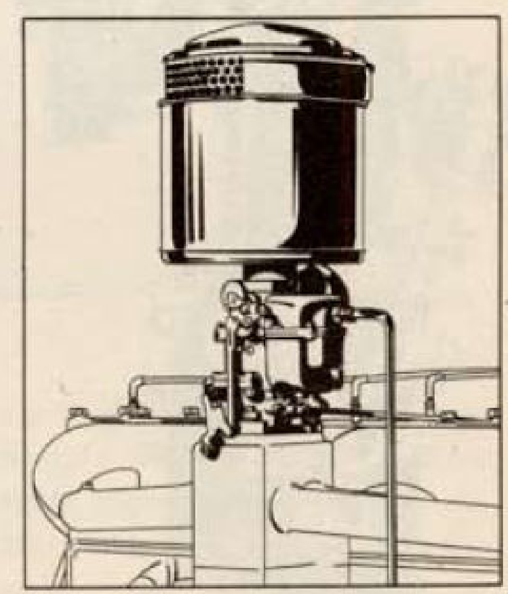
A fuel pump pumps the gasoline from the storage tank to the car-



buretor through a brass, copper or steel tube. A fine stream of liquid gasoline is continually supplied as long as the engine is running.

THE CARBURETOR IS THE MIXING CHAMBER FOR THE RAW MATERIALS

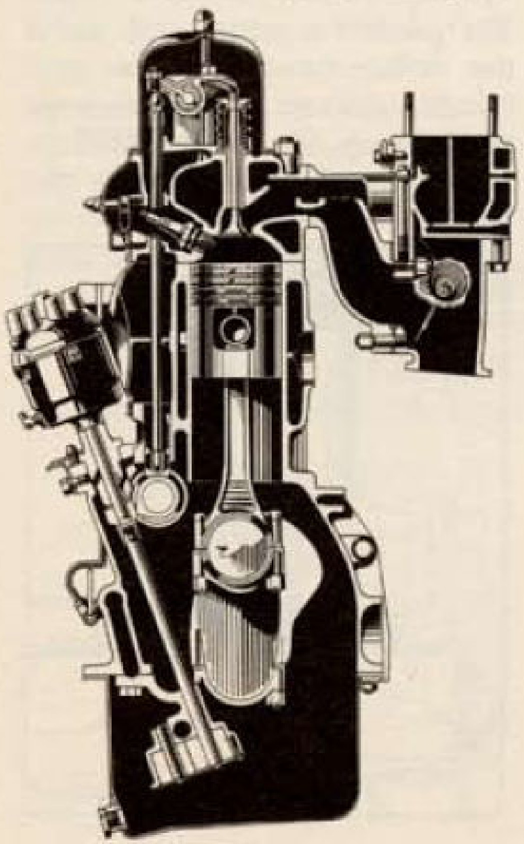
The gasoline is mixed with air in the carburetor to form a combustible mixture. The carburetor thus corresponds to the chambers in a chemical factory where the



raw products are mixed in the right proportions. To keep the dust and dirt out of the engine, the air is usually passed through an air filter placed at the air entrance to the carburetor. An intake silencer, also located on the carburetor, eliminates the noise which issues from the air entrance at high speed.

THE CYLINDERS ARE THE POWER CONVERTING CHAMBERS

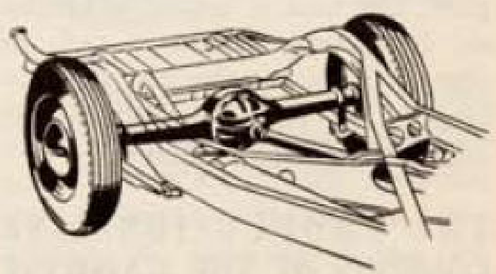
The mixture of air and gasoline next passes into the combustion chambers where the energy stored in the gasoline is converted into work. In other words, when gasoline is burned new products are formed, one of which is the power which pushes the piston downward. This downward movement of the piston is transformed into rotary motion by the crankshaft.



The shape of the chamber, the location of the spark plug and compression ratio of the cylinder are all important factors which must be considered by the engine designer in order that the maximum amount of power may be obtained with the least amount of fuel and knock. We have said that knock is caused by the fuel, but it is also affected by the compression ratio, combustion chamber shape, spark plug location, spark advance and a number of other factors.

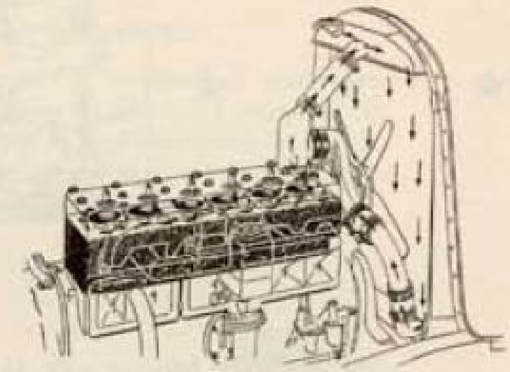
THE USEFUL PRODUCT IS POWER TO THE REAR WHEELS

The rotary motion of the crankshaft is transferred back through the clutch, transmission, drive shaft,



rear axle gears and axle shaft to the rear wheels. The power developed in the combustion chambers is thus utilized to move the car forward at the will of the driver.

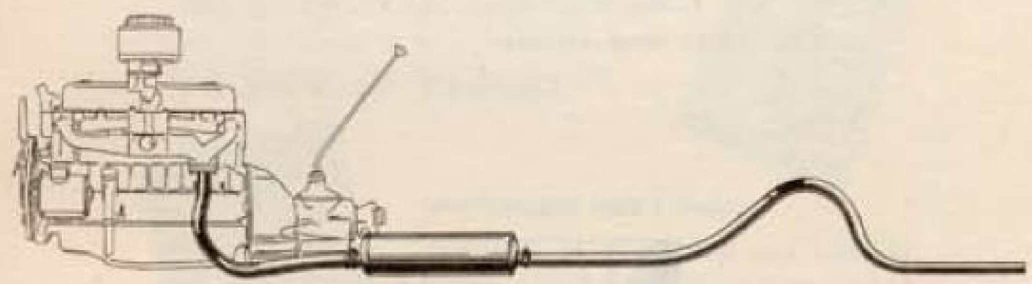
WASTE HEAT IS ABSORBED BY THE COOLING SYSTEM



A cooling system is provided to take away the waste heat. If it were not for this provision the engine would become too hot and the materials from which it is made would burn or melt. So the cylinders are surrounded with a water jacket, the water absorbing the heat and rejecting it to the air through the radiator.

EXHAUST GAS IS EXPELLED THROUGH THE MUFFLER AND TAIL PIPE

The hot exhaust gases must also be eliminated from the combustion chamber to make room for a new charge of air and gasoline. If we just piped them out of the



chamber we would hear a loud barking roar whenever the engine was in operation. To eliminate this noise, the gases are passed through a device called a muffler before they are expelled to the air.

This completes the story of your automobile as a chemical factory. We hope that it has proved interesting to you as indicating in some measure how all fields of science merge together in giving you the dependable service supplied by the modern motor car.

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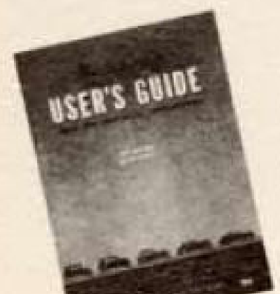

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