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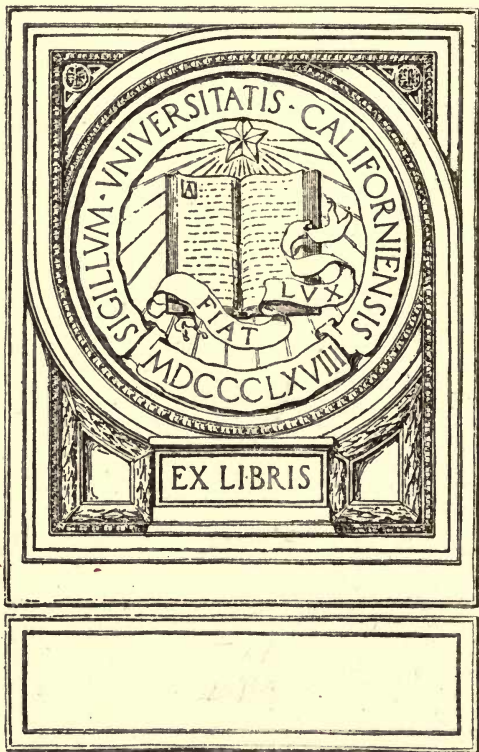


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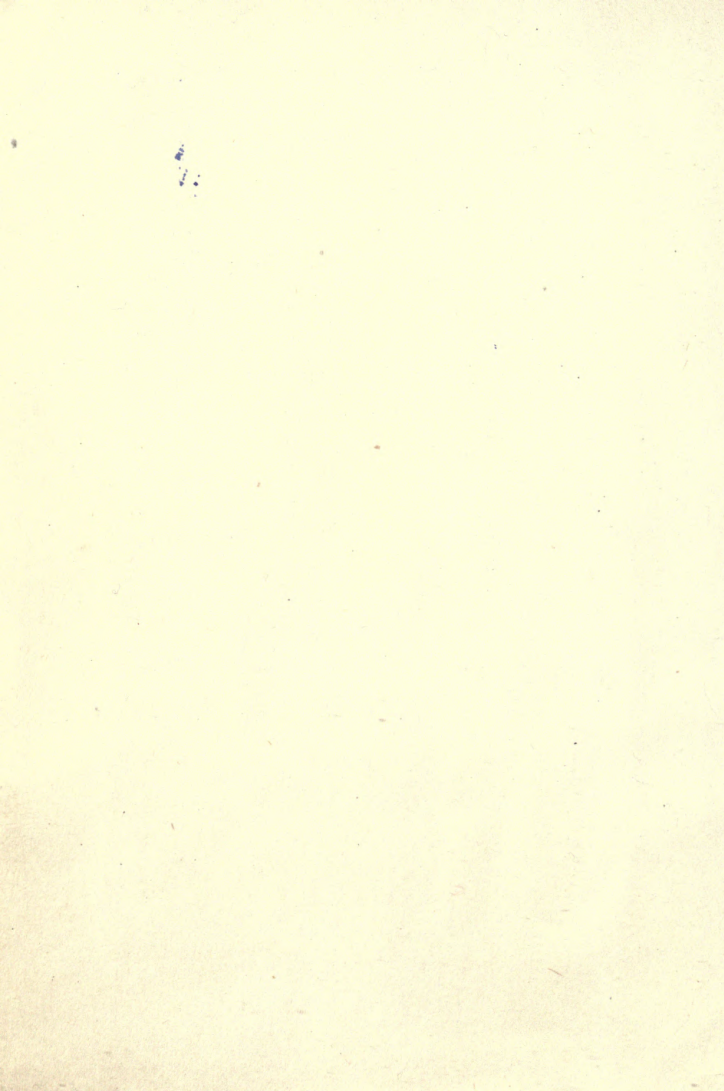
GASOLINE



A HAND BOOK







GASOLINE AND HOW TO USE IT

Written and Compiled by

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GOVERNMENT

For

OIL STATISTICAL SOCIETY, INC.

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FOREWORD

Intended for the Reader

The annual consumption of gasoline has reached the total of 1,500,000,000 gallons. Of the millions who use this liquid, probably ninety per cent have not a speaking acquaintance with its real nature and practical possibilities as a power, on the one hand to destroy man and the works of man, and, on the other hand, to aid and assist him. The utilization of gasoline is largely a matter of intelligent understanding of what the substance is and what it can do if the opportunity is provided.

It is the aim of this book:

(1) To cut off the source of supply of the daily papers' lurid tales of burning automobiles, flaming motor boats, with whole families consumed, fearful conflagrations in cleansing establishments, garages and dwellings — all because not of gasoline, but ignorance of and carelessness with gasoline;

(2) To assist the motorist in getting the full measure of power from the gasoline for which he pays; and, incidentally, but thoroughly and with care, to give him pointers as to the running and lubrication of his automobile;

(3) To give to those who are using or may

consider using gasoline in working the farm, or in any commercial enterprise, advice and pointers, both as to how to use gasoline itself and in what nature of machine to use it;

(4) To give to the student and the professional oil man the whole story of gasoline and petroleum—historically, scientifically and practically;

(5) To give to anybody who uses gasoline, to the extent of cleansing a pair of gloves, useful information.

Our guarantee of good faith is the name and merit of the author of this work, George A. Burrell, a consulting chemist in private practice, and until the 15th day of October, 1916, in charge of the Research Laboratory for Gas Investigations, Bureau of Mines of the United States Government.

OIL STATISTICAL SOCIETY, INC.,

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PRECAUTIONS IN HANDLING GASOLINE

Every user of gasoline should appreciate that he is dealing with a dangerous, inflammable substance, and that at all times he should exercise the greatest care in its use.

Don't spill gasoline.

Don't fill the tank of a liquid fuel stove full.

Don't use a liquid fuel stove that leaks.

Don't fill a gasoline stove in a closed room. Have plenty of ventilation to carry the vapor out of the room.

Don't use gasoline or naphtha for washing the hands.

In establishments where benzine, gasoline, naphtha and other inflammable liquids are used, care should be taken to see that the liquids are handled in an approved manner. No open light or flame of any kind, nor any machine, or belt capable of producing a spark should be allowed in the room where the gasoline is being used. All shafting and machines with belts, that are liable to cause a static electric spark, should be well grounded.

Only incandescent electric lights should be used, and these should be provided with guards to prevent their being smashed. All electric switches, fuses, etc., should be outside of the room. Danger signs should be posted on all doors opening into the room, warning against the carrying of open lights of any kind outside.

When large quantities of gasoline are used, the main supply should be stored in a metal tank buried under ground, and a safe distance from buildings. The working supply should be pumped into the buildings as needed. When it is not possible to use a pump and a buried tank, the main supply should be stored outside and well away from other buildings, under lock and key. Only small quantities should be taken into the buildings, closed metal cans, preferably safety cans, being used as containers.

When the use of an open can is necessary the opening should be as small as possible, and a cover should be provided. The cover should be put on whenever the can is not in use.

Signs should be posted prohibiting an open flame near a pump or other handling apparatus. The signs should explain the danger involved and give instructions for safe methods of operation.

Empty gasoline barrels should be stored with bung holes down, in safe places in the open air.

Rooms in which explosive or dangerous gases or vapors are used or generated should be safely enclosed, and should be provided with an improved system of ventilation.

Gasoline vapor is heavier than air, and a suction fan should be used to insure proper ventilation.

Joints in pipes, tanks, conveyors, etc., used for storage of gasoline, should be kept tight. Before work is done on vessels, pipes, etc., sufficient time should be given to allow gas to escape.

Special care should be exercised before work requiring the use of heat or flame is done. Apparatus that has contained explosive gas should be filled with water or steam to force out the gas.

Many fires originate from cleaning silks with gasoline; the violent rubbing of the silk generating static electricity, which produces a spark that ignites the vapor.

Jobbing tailors sometimes cause fires by using gasoline in an open vessel, and smoking a cigar or cigarette at the same time.

A dangerous practice, common in many garages, is the cleaning of automobile parts with gasoline from an open can. Employees find it easy to clean grease and oil from the motor, and other parts, with a brush saturated with gasoline, and the gasoline is readily ignited by a spark.

There follows a few of the many causes that have started gasoline fires:

Careless striking of a match.

Match on floor stepped on.

Overheated shaft bearing.

Spark from turning on electric light.

Rubbing two pieces of silk together.

Opening door leading into room where lamp was burning.

Opening a stove door.

Opening door leading to locker room.

Gas light in room.

MIXTURES OF GASOLINE VAPOR AND AIR

Gasoline vapor mixes with air in the same manner that water vapor does. Atmospheric air, for instance, always contains water vapor. In any particular temperature a definite proportion of water vapor will be found in the atmosphere if it has become completely saturated, a condition that seldom exists. Usually, a limited supply of water has been taken up by the air, and the atmosphere is spoken of as having a certain relative humidity, meaning that the saturation is incomplete or that more water vapor could exist in the air were a source of moisture available. In a similar manner gasoline vapor mixes with air. The amount of vapor carried will depend on the temperature of the air and the readiness with which the vapor can be obtained.

If gasoline is exposed to the air of a room, and for a long enough time, the air will contain at a certain temperature a fixed proportion of gasoline

vapor, differing for different grades of gasoline, that cannot be exceeded.

Proportions of different grades of gasoline vapor that air will carry at a temperature of 63.5° F.

GRADE OF GASOLINE	PROPORTION OF GASOLINE VAPOR (PER CENT)
Cleaner's Naphtha	5.0
64° B. Gasoline	11.0
69° B. Gasoline	15.0
73° B. Gasoline	28.0

It will be noticed that air will hold almost six times as much vapor from the lighter gasoline as from the heavier cleaner's naphtha. If the lighter and the better grades of gasoline are heated, their vapors, when a light is applied, also flash and burn at lower temperatures than do the heavier grades. This difference does not mean that some gasoline is a dangerous inflammable liquid and some is not. All grades are classed as highly inflammable and dangerous liquids.

INFLAMMABILITY OF GASOLINE AND OF GASOLINE VAPOR

If one takes the cover off of a full pail of tightly closed gasoline, and applies a match to the surface

the gasoline will flare up and burn as long as the gasoline lasts. On the other hand, if one puts a few drops of gasoline in a small, tightly-inclosed pail, waits a few minutes, and then introduces a flame or an electric spark, a violent explosion will most likely result. In the first case the vapor burns as fast as it comes from the gasoline and mixes with the oxygen of the air. In the second case the gasoline vaporizes in the pail and mixes uniformly with the air therein to form an explosive mixture, and upon ignition explodes. Consequently, when one hears of a disastrous gasoline explosion, one may be sure that the explosion resulted from the mixing of the vapor from the gasoline with air in proportions necessary to form an explosive mixture.

If a lighted match could be applied to pure gasoline vapor in the absence of air, no fire or explosion could take place. Gasoline liquid or vapor, like any other combustible material, needs the oxygen of the air in order to burn.

EXPLOSIVE RANGE OF MIXTURES OF GASOLINE VAPOR AND AIR

The amount of air required to be mixed with

gasoline vapor in order to produce an explosive mixture has been carefully determined. In one hundred parts by volume of air and gasoline, an explosion will not take place if there is less than about 1.5 parts of gasoline vapor, or more than about six parts.* In other words, the explosive range is between 1.5 and six per cent gasoline vapor. Flashes of flame will appear in mixtures containing considerably smaller and larger proportions of vapor and considerable pressure will be developed, but complete propagation of flame through the mixture will not take place. This means, for instance, that gasoline vapor must be mixed with about seventeen to forty times its volume of air for the explosion to take place in the gasoline engine.

CONVERSION OF GASOLINE INTO VAPOR

One gallon of gasoline when entirely changed into gasoline vapor produces about thirty-two cubic feet of vapor. These thirty-two cubic feet of vapor could render explosive about 2,100 cubic feet of air, or the amount of air contained in room measuring twenty-one feet by ten feet square. But in the

*Burrell, G. A. and Boyd, H. T. "Inflammability of Mixtures of Gasoline Vapor and Air." *Technical Paper 115, Bureau of Mines.*

actual use of gasoline this is an ideal condition that could not be produced. An assumed case may be that of a person filling an open pail from a larger tank, or using gasoline for cleaning. When the pail is first filled with gasoline, a small amount of pure gasoline vapor forms over the surface of the gasoline. Just above this layer of pure gasoline vapor is a mixture of vapor and air; at some point there will be an explosive proportion, and farther away from the pail there will be a small proportion of vapor, and, finally, still farther away no vapor at all, but pure air. However, all the time the user of gasoline is at work, the vapor keeps forming from both the gasoline in the pail and that applied to the object being cleaned, rendering more and more air inflammable or explosive until finally there will exist a dangerous atmosphere that may completely surround him, so that a chance ignition will envelop him in flames, and perhaps cause great damage to property. Ignition of the gasoline vapor may take place even some distance from the gasoline in a room adjoining the room in which the person works. As the gasoline evaporates, and more and more vapor is given off, it mixes with air farther and farther from the gasoline; and if the evaporation lasts long enough, may travel to an adjoining room,

where it may be ignited. On ignition, a sharp flash will travel back through the adjoining room to the room where the gasoline is.

EXTINGUISHING GASOLINE FIRES

The best method of extinguishing a burning liquid is to form a blanket of inert gas or solid material over the burning liquid and cut off the air (oxygen) supply.

Water may be used for extinguishing burning liquids, such as denatured alcohol, wood alcohol and acetone, that are mixable with it. But if gasoline, which does not mix with water, catches fire, the application of water produces little or no effect, except to spread the burning liquid and thus scatter the fire over a larger area.

Of materials used to form a blanket of inert gas or solid material over the fire, thus cutting off the oxygen supply, several are in common use. These include sawdust, sand, carbon, tetrachloride, and the so-called foam or frothy mixtures.

The efficiency of sawdust is due to its floating for a time on the liquid and excluding the oxygen of the air. Sawdust itself does not catch fire easily and when it does ignite, burns without flame. It may be well handled for extinguishing small fires,

when just started, by means of long-handled wooden shovels.

Sand probably serves about as well as sawdust for extinguishing fires on the ground, but it is heavier and more awkward to handle. When thrown on a burning tank it sinks, whereas sawdust floats.

Carbon tetrachloride, the basis of various chemical fire extinguishers, if thrown on a fire forms a heavy non-inflammable vapor over the liquid, and readily mixes with gasoline. The vapor is about five times as heavy as air. Much of the carbon tetrachloride contains impurities that give it a bad odor, but when pure its specific gravity is 1.632 at 32° F. (air = 1). When thrown on a fire, it produces black smoke, the hue of which is caused by unconsumed particles of carbon. Pungent gases are also produced, probably due to hydrochloric acid gas and small volumes of chlorine gas. Although the fumes are pungent, brief exposure to them does not cause permanent injury.

The efficacy of carbon tetrachloride depends largely on the skill of the user. If liquid in a tank is on fire, the height of the liquid is important. When the liquid is low, the sides of the tank form a wall which retains the vapor; but when a tank

is nearly full of gasoline, only the most skilled operator can extinguish the flame or fire.

AIR-GAS MACHINES

By Air-Gas is meant an inflammable mixture of air and a volatile liquid like gasoline. Air-gas machines consist of arrangements for passing air over a large surface of gasoline. The gasoline may be contained in a number of shallow trays or in spongy or porous materials. Occasionally, the air is caused to bubble through the liquid. After becoming saturated with the gasoline, the mixture of gasoline vapor and air is forced through pipes for consumption in houses and other buildings. At some places small villages are illuminated with air-gas. In all cases it must be used as it is made, for the gasoline vapor condenses out on storage, and also during passage through long pipes.

The heating value at ordinary temperature is from 400 to 500 B. T. U. per cubic foot.

BURNS FROM GASOLINE

Burns are divided into three classes according to depth. A first-degree burn is simply a scorching or reddening of the outer surface of the epidermis

(skin). A second-degree burn involves and destroys the entire thickness of the skin. A third-degree burn destroys not only the skin but also the tissue beneath, sometimes entirely to the bone.

The symptoms of a first-degree burn are: severe burning pain, reddening of the skin, formation of blisters; in a second-degree burn, destruction of the skin; in a third-degree burn, destruction of the skin and some of the tissue beneath. In severe burns shock is present.

In treating a burn, first carefully remove the clothing from the burned part. Exclude the air as quickly as possible from the burned surface with some clean covering.

There are a number of good coverings for burns; the one most generally used by first-aid men is picric-acid gauze. This gauze is ordinarily sterile gauze which has been saturated with a one-per-cent solution of picric acid (one-half teaspoonful of picric acid to one pint of water). It has this advantage: it is clean and ready to use.

Moisten the picric-acid gauze with clean water and put it over the burned surface. Over the gauze place a layer of absorbent cotton, then apply a bandage to hold in place.

Carron oil, which is a mixture of equal parts of

linewater and linseed oil, has been used as a dressing for burns, but its use is not recommended. The best dressing is picric-acid gauze.

Vaseline, sweet oil, olive oil and balsam oil are all good dressings. If nothing better is at hand, dissolve some bicarbonate of soda in sterilized water. Gauze wrung out of this and spread over the burn will give relief.

Severe burns are accompanied by shock, and always treat a burned patient for shock as well as for burns.

Shock is a sudden depression of the vital powers arising from an injury or a profound emotion acting on the nerve centers, and inducing exhaustion. The symptoms are abnormal temperature, an irregular, weak and rapid pulse; a cold, clammy, pale and profusely perspiring skin; irregular breathing; the person affected usually remains conscious and will answer when spoken to; but is stupid and indifferent, and lies with partly-closed lids. Sometimes there is concealed hemorrhage.

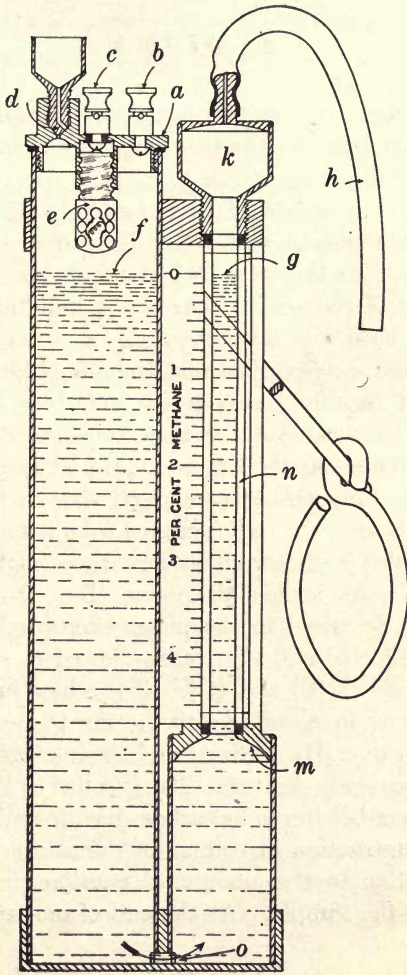
In treating patients for shock, lower the patient's head, wrap him in warm blankets and surround him with heat-giving objects. Give an ordinary stimulant, as black coffee, to be sipped as hot as it can be borne; half-teaspoonful doses of aromatic

spirits of ammonia may be given every twenty or thirty minutes. Small doses of whiskey or brandy may be given, provided that there is no hemorrhage. One or two teaspoonfuls every fifteen or twenty minutes will help to tide the patient over until the doctor arrives. Inhalation of oxygen is often of much service; artificial respiration may be necessary in some cases. Hot applications over the heart and spine should be used if practicable. Always hurry the doctor.

APPARATUS FOR DETECTING GASOLINE VAPOR IN AIR

A gas detector has been developed by the author of this book (G. A. Burrell, *Journal of Industry and Engineering Chemistry*, Vol. 8, 1916, Page 365) for detecting gasoline vapor in air. It is useful for determining small or dangerous percentage of gasoline vapor in garages, dry-cleaning establishments, ships where oil or gasoline may be stored, engine rooms where gasoline is used, and, in fact, any place where gasoline vapor may accumulate and menace the safety of people and buildings. It is sold by the Mine Safety Supply Company of Pittsburg, Pa.

A diagram is shown. The instrument may be considered to be a U-tube, of which the



limbs (S) and (N) are two branches. Communication is made between the two limbs at a point designated by the arrow.

To start a series of determinations the brass cap (A) is removed and water is poured into (F) until it rests in the tube (N) at the point (G), the zero point of the scale. The water will then seek the level (F) in the tube (S).

To make a determination of combustible gas in air, say of gasoline vapor in air, one blows in the tube (H) by means of a rubber tube (not shown), thereby depressing the water in (M) to some point and filling the combustion space above (F) with water. One can tell when this combustion space is filled with water by hearing a slight click when the water strikes the valve (D). Next, the instrument is raised to the place where the sample is to be collected and the water allowed to seek the former levels at (F) and (G). The water in falling to (F) sucks in a sample of the air to be tested. Next the valve (D) is closed and the platinum wire in (E) electrically heated. The gasoline in the combustion chamber burns to carbon dioxide and water, and the contraction in volume of the sample occurs corresponding to the amount of gasoline originally present in the sample. At the end of one and one-

half minutes the electric current is turned off and the instrument shaken to cool the gases in the combustion space and bring them to the same temperature as the gases were at the beginning of the test. The water in the combustion space will then rise to take the place of the burned-out gas and fall a corresponding distance in the glass tube (N), *i.e.*, fall to a point on the graduated scale that will show the per cent of gasoline originally in the sample. A previous calibration, once and for all time, fixes the proper graduations on this scale. The latter carries four graduation columns, one for methane and natural gas, one for hydrogen, one for gasoline vapor and one for coal gas.

The electrical energy for heating the platinum wire is derived from a storage battery. A test requires two minutes.

HISTORY OF THE MOTOR VEHICLE IN THE UNITED STATES

The development of motoring and of the motor industry in the United States has been very rapid. At first, steam cars were favored to a large extent, but the gasoline engine became refined so rapidly as regards silentness and smoothness of operation and simplicity and suitability that it became very

popular and far outstripped the steam engine as a propellant for motor vehicles.

George B. Selden, then living in Rochester, New York, applied in 1879 for patent on a gas-compression engine for propelling road vehicles. The patent was granted to him on November 5, 1895, and he claimed that any vehicle propelled by an internal combustion engine, manufactured since that time, was an infringement on his patents. At the commencement of the year 1910, there were seventy-one manufacturers who admitted the validity of his claim, and paid a license fee of one and a half per cent of the catalogue price of their cars to the association of licensed automobile manufacturers who agreed to recognize the Selden claim. In the year 1911 this claim was defeated by Henry Ford and others. In the year 1899 there were about six hundred motor cars in the United States. Now there are fully two and one-quarter million.

THE INTERNAL COMBUSTION ENGINE

Gottlieb Daimler's (England) invention of the high-speed internal combustion engine in 1885 was the first step toward the production of the modern self-propelled road vehicle, the next step being the recognition in 1887 of the advantages of Daimler's

system by M. Levassor, and his application of that system to the propulsion of a carriage.

This engine marked a great advance in the production of a source of motor power, for its efficiency was large as compared to its total weight; whilst the simplicity of its fuel system brought it within the scope of the person of average mechanical instincts and intelligence, for, even in its early days, the internal combustion engine did not demand that its user should possess an intimate knowledge of engineering.

Levassor placed the engine in front, the axis of the crankshaft being parallel with the side members of the frame of the vehicle. The drive was taken through a clutch to a set of reduction gears and thence to a differential gear on a countershaft, from which the road wheels were driven by chains. With all the modifications of details, the combination of clutch, gear-box and transmission remains unaltered, so that to France, in the person of M. Levassor, must be given the honor of having led in the development of the motor car.

The reason for the use of the words "internal combustion engine" is that the fuel, in the case of the gasoline engine, is burned (or fired) inside the working cylinder; whereas it is burned externally

in the case of a steam engine, *i.e.*, underneath the boiler or generator. The efficiency of the internal combustion engine is about three times as great as the steam engine.

The essential parts of any internal combustion system are: the carburetor, the engine, the clutch, the radiator, the change-speed gears and the final transmission. The carburetor is a vessel in which the liquid fuel is converted into gas or vapor. The production of this gas is automatic and calls for little attention from the driver.

A smart turn of the cranking handle is enough to set piston and crankshaft in motion, so that an initial supply of the combustible mixture may reach one of the cylinders. This first charge of gas is ignited by a properly-regulated electric spark, and there is then little for the driver to do as regards power, except to move a convenient lever which opens or closes a throttle valve between the cylinders and the carburetor, thus letting more or less gas into the engine.

Cylinders get very hot unless they are cooled, hence, they have to be surrounded with water jackets through which water is forced. A fan, which is driven from the crankshaft of the engine, aids in the cooling by forcing air around and through the

radiator system through which the water circulates.

It is very important that the driver should have a convenient means of quickly connecting the engine to the driving mechanism of the car, and to do this without jars or shocks. To do this, a multiple disc clutch or leather-faced, cone-shaped circular member is provided that can be engaged with a similar member on the engine flywheel by the driver merely pressing his foot on a pedal. This can be done gradually, so that a car can be easily and gently set in motion. An internal combustion engine cannot develop power unless the crankshaft can rotate at a relatively high number of revolutions. It is therefore necessary to introduce a system of levers between the engine and the road wheels in order to permit the number of revolutions of the crankshaft to be maintained when hill climbing, or when the vehicle is carrying a heavy load; and the common practice is to introduce three or four sets of toothed wheels, any pair of which can be put into engagement by the movement of a single lever, which lever is placed near the driver's right hand as a rule.

The great distinction from a horse-drawn vehicle is that there must be both a mechanical connection

and differential connection between the two back wheels. The wheels on horse vehicles revolve loosely on the axle and one can overrun the other on curves, but a special device, known as the differential gear, must be introduced into all motor vehicles between the change-speed gears and the driven-road wheels. Such a device permits one of two driving wheels to be turned around at a quicker speed than the other. The wheel turning fastest is not driven in such a case.

TYPES OF CARBURETORS AND THEIR ACTIONS

Since the carburetor of the modern automobile plays a very important part in the conversion of liquid gasoline into vapor, some detailed information regarding its construction and operation is given in this publication.

Old patterns of carburetors were the simplest forms of devices and consisted of three principal types, the surface, wick and bubbling type.

The surface type consisted of a simple tank or container for the gasoline. Air was drawn in and across the surface of the gasoline in order that it might become saturated with the vapors constantly present at that point. These rich gases were drawn

into the engine through a simple form of mixing valve which permitted the entrance of an auxiliary supply of air from the outside of the container to dilute the rich gas and make it a proper mixture to insure energetic combustion.

The wick form of carburetor is essentially the same in construction as the surface type, except that the mixing compartment, through which the air flows, is separated from the fuel-containing portion by means of a wall of absorbent material, such as wicks, which feed the gasoline up into the mixing compartment by capillary attraction, and by spreading it over more surface make it easier for the air stream passing over the wicking to pick up gasoline vapor.

The bubbling type of carburetor differs from the other simple forms previously described in that the air enters at the bottom of the device and bubbles through the liquid to reach the mixing chamber from which it is drawn to the engine cylinder.

Devices of the nature considered in the three above types of carburetors have great defects that would militate against their general adoption at the present day. They are only suitable for use in conjunction with high-grade gasoline that has high evaporating value. It is doubtful if they would give satisfactory results with the low-grade

fuels available to-day. In many cases these carburetors were as large as the cylinder of the motor to which they were applied.

The spraying form of carburetor was designed to eliminate one of the great disadvantages present with the simple evaporation types. As these were used, the fuel contained therein became heavier, because only the lighter and more volatile constituents evaporated. After the motor had been running for sometime, it was necessary to drain out the residue and admit a supply of fresh fuel from the main container, because heavy matter left after the more volatile vapors had passed into the engine could not be vaporized by an air current merely brushing over its surface or passing through it. In the spraying type of carburetor the fuel is drawn into the entering air stream through a smaller jet or standpipe which causes it to issue in the form of a spray that soon turns into vapor. With the spraying principle every particle of the fuel is used, because the heavier portions are sprayed into the air stream at the same time that the lighter constituents are, and as the liquid enters the air stream in a finely-divided state of mist, it is almost immediately vaporized and turned into an explosive gas.

An important part of a carburetor is a float that controls the level of the gasoline in the standpipe or jet. This level is so proportioned that the liquid does not overflow the standpipe, and thus the fuel will be sprayed into the mixture only when drawn out of the jet or nozzle by means of the air stream induced by engine suction. The level in the spray nozzle is maintained by a simple automatic valve mechanism in which a float controls the admission of fuel to the device.

Two important parts of float-feed carburetors are the mixing chamber and the float chamber. The mixing chamber is that portion of the carburetor in which the spray nozzle is placed and through which the air stream passes before it can reach the inlet manifold. The float chamber is that part of the carburetor to which fuel is first admitted and which serves as a container for the float which regulates the level of fuel in the standpipe. Whenever the fuel level falls, the float which is supported by the liquid falls and opens a valve which permits more of the liquid to flow into the float bowl from the main fuel container. When the level reaches the proper height, the float shuts the valve and the fuel supply is stopped.

Mixing chambers can be so designed that the

speed of the entering air stream at low-engine speed is always sufficient to pick up enough fuel to form an explosive mixture. This is accomplished by constricting the chamber at the proper point, thus insuring a high velocity of air past the top of the spray nozzle, even at low-engine speed. This construction of the mixing chamber, called a Venturi mixing chamber, necessitates another improvement on the carburetor, to provide for the introduction of an auxiliary supply of air through a separate opening. This is necessary because with Venturi-tube construction great air velocity at low-engine speed means that the air velocity might be great enough to draw more fuel than was actually needed into the engine cylinder. An excessively rich mixture provided at high speed would cause overheating and waste fuel, while a comparatively lean mixture at low-engine speed would interfere with prompt starting. The rich mixture is only necessary for starting, while a much thinner mixture, or one containing a larger proportion of air, can be used to advantage at high-engine speed.

The auxiliary air passage for thinning rich mixtures may be controlled by any form of automatic valve; for instance, by means of a spring-seated mushroom or poppet valve. The spring tension

is so proportioned that the valve will open only on medium- and high-engine speeds, at which times the suction is greater than that prevailing at low speed. The auxiliary air passages are sometimes controlled by means of reeds which open progressively as more auxiliary air is needed or by a series of balls which close the auxiliary air ports. The strength of the reeds or the weight of the balls may be varied so the air passages will open progressively and admit more air as the demands increase.

In some carburetors (multiple jet carburetors) two or more spray nozzles are used instead of a single jet. The arrangement is usually such that the primary nozzle is used at low speed while the secondary nozzle is brought into action at higher speed when more fuel is needed. In some types the arrangement is such that the primary nozzle acts only at low speed while the secondary nozzle is brought in action at higher speed when more fuel is needed. In some types the arrangement is such that the primary nozzle acts only at low speed while the secondary nozzle supplies gasoline only at high speed. In other multiple jet carburetors, the nozzles are brought into action progressively when the throttle is open to such a point that the primary nozzle, which has a small spraying orifice, cannot

supply fuel enough; then the secondary nozzle is brought into action and contributes its quota of liquid to compensate for the augmenting demand of the engine.

HOW TO ADJUST THE CARBURETOR

The carburetor is one of the most important parts in the anatomy of the car—like the lungs to the human being. On it the smooth running, power, flexibility and economy of the motor are largely dependent. The fulfillment of these requirements demands a good mixture—one that is correctly proportioned and homogeneous, whether the throttle is open or shut or the motor is running fast or slow.

The other requirements of a carburetor are atomization and vaporization of the fuel. The latter varies with the design of the carburetor, but the former is more or less dependent on adjustments, because some carburetors have more adjustments than others.

A good adjustment is essential, and the carburetor should constantly be watched, so that when it shows that it needs attention no time will be wasted in giving it. Few machines in the hands of owners of ordinary automobile knowledge have the best

adjustments that may be had, and many have settings that are poor.

In many cases poor carburetor adjustment is due to ignorance of the owner. The car runs on all cylinders and has a certain amount of power, and it is not until he compares his machine with another of the same make that has a better adjustment that he realizes the difference.

The amount of time that it takes to obtain a good setting is variable, and may run up into several hours even when an experienced man is doing the work. Here is another reason for carburetor shortcomings—the owner takes his car to a repairman to have the carburetor put in perfect condition; the latter is a good mechanic and obtains a fair setting in a short time, but try as he will he cannot make it perfect.

The result is that he gives it up as a bad job as soon as he has spent as much time as he feels the owner can reasonably be expected to pay for. He cannot explain to his customer that it might take several hours to obtain the best adjustment. If he did, he would be looked upon as a poor repairman. So he tells him that it is the best that can be done, and the customer takes his word for it. All of which is somewhat aside from the subject

of how to adjust a carburetor, but, nevertheless, is something that every owner should fully understand.

DIAGNOSING CARBURETOR

In adjusting the carburetor, the first essential is to be able to tell the difference between a weak and a rich mixture. In either case the car will lack power and may knock, and with too rich a mixture it may also overheat.

If there is too much air the motor will not respond immediately when the throttle is opened quickly; there will be a lag from the time the accelerator pedal is depressed until the car begins to gather speed. The motor may also back fire, especially at high speeds.

With too much gasoline, on the other hand, the car will respond instantly to the opening of the throttle, but with not the same vim as with a perfect mixture. A great excess of fuel will produce black smoke in the exhaust.

Too frequently, when one of these symptoms is recognized or the car is operating badly for any reason at all, the conclusion is that the carburetor needs adjusting, and instead of improving it, it is made worse. Never touch the adjustments on a carburetor until you are sure that they require it.

Faulty ignition and leaky cylinders are often mistaken for bad carburetion. Before looking at the carburetor, it is only common sense to make sure that the trouble is not elsewhere; otherwise, you may complicate matters by throwing the carburetor out of adjustment.

Breaker points out of adjustment, spark plugs short circuited, porcelains cracked, loose connections, grounds and even a retarded spark may look like carburetor disease until an investigation is made.

Likewise, valves that need grinding or cylinders that leak may also throw suspicion on the carburetor.

A faulty mixture may be the result of many things besides improper adjustment, and these must all be eliminated before the carburetor setting is changed.

SMOKE TESTS FOR AIR LEAKS

A thin mixture may be caused by air leaks in the manifold, cylinder head gaskets, valve plugs or valve guides. Any of these will produce missing at low speed. A leak in any part of the manifold may be determined by noting whether smoke from a cigar or cigarette will be sucked in. Other leaks may be located by feeling or listening.

The mixture will be weak if the fuel level is too low in the float chamber, and this may be due to a bent float mechanism, a stuck float, or if there is a float level adjustment there may be some difficulty with this.

The absence of a hot-air or a hot-water jacket may also produce all the symptoms of too weak a charge, particularly in cold weather. A hot-air stove is a necessary adjunct to almost all carburetors not equipped with a hot-water jacket.

Naturally any obstruction to the free flow of fuel will result in a lean mixture. There may be dirt in the pipe or in the holes of the nozzle.

Too rich a mixture may be caused by a worn needle or nozzle, but is usually due to too high a fuel level. A stuck or bent float mechanism or dirt under the float valve may be the cause. If the float is made of cork, the shellac may gradually dissolve and the fuel will soak into it, making it heavier and consequently raising the level. Similarly, a pin hole in a metal float will allow gasoline to enter and weight it. The cork float may be repaired by drying in an oven and then shellacing it again, and the metal float by enlarging the hole, draining the gasoline out and then closing it with a little solder.

Before adjustment of carburetor is attempted, the motor should be allowed to run until it is thoroughly warm and the spark should be advanced about two-thirds of the way.

The secret of successful carburetor adjusting is patience. Each screw or nut must be varied a little at a time until the best position is obtained.

The easiest way to determine which is the best setting is to run the car up a test hill after each change. Approach the bottom of the hill at the same speed each time, depress the accelerator at a given point each time, and then note the speed obtained at the top.

If there is no hill available, an acceleration test will prove to be an excellent substitute. Approach a given point at a given speed and on passing depress the accelerator and note what the speed is when passing some other point.

COMPOSITION AND POISONOUS CHARACTER OF EXHAUST GASES FROM GASOLINE ENGINES

The public press has devoted more or less space to accidents caused by exhaust gases from automobile locomotives poisoning people. A number of fatal accidents have occurred, and a great many

people have suffered more or less. The accidents have been due to the running of gasoline engines in comparatively small and usually closed garages. The exhaust gases then escape into the small closed garage and render the air therein more or less dangerous. The press has given to some of these accidents, as the result of a statement made by a Professor at the University of Chicago, the name of "Petro-mortis," and shrouds the cause of the deaths in more or less mystery. As a matter of fact, the reason why exhaust gases from gasoline engines are poisonous is because they contain more or less of a deadly gas called carbon monoxide or carbonic oxide. The chemical symbol is CO. This gas is the constituent in illuminating gas that makes the latter poisonous. Every once in a while one reads of deaths of occupants of rooms into which illuminating gas has leaked or due to the fact that the gas had incompletely burned in a stove. In both cases carbon monoxide is the poisonous gas that causes the deaths. Carbon monoxide is also the correct name for "White Damp," found in coal mines after explosions and mine fires. This "White Damp" is responsible for more deaths in mine explosions than the actual violence due to the explosion. It forms immediately after explosions in mines and traps the miners,

who have escaped the blast, before they can get out of the mine.

In a gasoline locomotive fuel is burned within an engine cylinder, and the exhaust from the cylinder is a mixture of gases. The composition of this mixture of gases will depend on the relative proportions of gasoline vapor and air that undergoes explosion in the engine cylinder. If the mixture is a "rich" one, there will not be enough air to completely burn the gasoline vapor, and carbon monoxide will form in greater or less quantities, for carbon monoxide along with other gases is a product of incomplete combustion. When gasoline undergoes complete combustion, only carbon dioxide and water vapor should result from the explosion. Carbon dioxide, except in very large proportions, is not classed as a dangerous gas. But when gasoline vapor does not have enough air to completely burn it, then some carbon monoxide forms. Gasoline vapor is explosive in air when proportions of it are present between about 1.5 and 6.0 per cent. When the proportion of gasoline vapor exceeds about two per cent, the quantity becomes so large that not enough air is present to completely burn the gasoline, and carbon monoxide begins to form. Hence, it will be appreciated that, except for a

comparatively narrow range of explosibility, the chances of carbon monoxide occurring in the exhaust gases are very great.

The following table shows the maximum amounts of carbon monoxide that different sizes of engines produce under conditions of proper and improper carburetor adjustment.

Maximum amounts of carbon monoxide that different sizes of engines produce under conditions of proper and improper carburetor adjustment.*

SIZE OF ENGINE CYLINDER, INCHES	NUMBER OF CYLINDERS	SPEED R. P. M.	PISTON DIS-PLACEMENT CUBIC FEET A MINUTE				MAXIMUM PROBABLE QUANTITY OF NOXIOUS GASES (CUBIC FEET A MINUTE AT 60° F. WITH BAROMETER AT 30 IN.) PRODUCED			
			GOOD CARBURETOR CARBON MONOXIDE	GOOD CARBURETOR CARBON DIOXIDE	WITH BAD CARBURETOR CARBON MONOXIDE	WITH BAD CARBURETOR CARBON DIOXIDE				
4.75 x 5.25	4	800	172	2.61	6.80	9.91	3.65			
5 x 5	4	600	136	2.06	5.37	7.84	2.88			
5 x 5	4	800	182	2.76	7.18	10.48	3.86			
5 x 6	4	800	218	3.60	8.60	12.56	4.62			
5 x 5	4	600	165	2.50	6.51	9.50	3.50			
6 x 6	4	700	275	4.17	10.86	13.85	5.82			
6 x 7	4	500	229	3.47	9.04	13.19	4.85			
6.5 x 7	4	500	269	4.07	10.63	15.50	5.70			
6.5 x 7	4	650	399	6.44	15.76	23.00	8.46			
6.5 x 8	4	500	312	4.73	12.33	17.97	6.62			
7 x 7	6	500	468	7.08	18.49	26.97	9.92			
8 x 7	4	500	407	6.16	16.08	23.45	8.62			
8 x 7	6	500	610	9.24	24.10	35.14	12.93			

*"Gasoline Locomotives in Relation to Safety and Health." *Bulletin 74, Bureau of Mines.* By O. P. Hood R. H. Kudlich and G. A. Burrell.

NOTE:—These tests were made with a gasoline locomotive used in mines for hauling coal.

The foregoing table is of exceptional interest in showing the amount of carbon monoxide that may be produced (cubic feet per minute) under different conditions of engine operation.

If a gasoline engine, producing five cubic feet of carbon monoxide per minute, were allowed to run in a tightly-closed garage that was twelve feet high, fifteen feet long, and fifteen feet wide, *i.e.*, having a capacity of 2,750 feet, it could produce an atmosphere, if the latter were thoroughly mixed, containing about one per cent carbon monoxide in about five minutes. This percentage of carbon monoxide in air is a fatal proportion, and would probably kill a person in less than a minute. In fact, an exposure for as long as twenty minutes to an air containing as little as .25 per cent carbon monoxide would make most people very ill. Thus it will be seen that there is great danger in running automobile engines in small, closed garages. The latter should be large or at least well-ventilated, and engines should be run for only brief periods of time in them, with the door wide open and with the automobile standing very close to the door.

THE ART OF DRIVING

Safe Driving and Economy Go Hand In Hand

It is often stated, and with a great deal of truth, that most automobile accidents occur at low speed. The fast driver is seldom a reckless driver; while the slow driver is all too frequently a careless one. Not with intent, perhaps, but because he really knows but little of the finer points of driving, and, because of never having driven fast, his faculties have not developed the degree of alertness necessary to assure the instantaneous decision and quick action demanded by an emergency. The *blasé* youth in his smart race-about, unconcernedly driving with one hand and changing gears with his feet, is a greater menace to public safety if moving at the rate of only four miles an hour than is the veteran driver whose customary road gait may be thirty or more miles per hour. It is unfortunate that so many drivers are turned out with so little experience. The customary three to five lessons which the motor car salesman or demonstrator has the time to give are not sufficient to impart to the average person more than enough knowledge of motor car driving to develop him into a public menace and make him a thing to be avoided by

older and expert drivers. Nor is the youth with his race-about the only offender. Many older and supposedly wiser heads drive cars and at the same time point out and describe scenery along the roadside, or turn half way around in their seats to converse with passengers. The eyes of the driver of a motor car should never be removed from the road ahead, else how is he to avoid danger in passing cross-roads, intersecting streets, pedestrians and other objects on the road? Careful and undivided attention in driving a car is as essential at low speeds as at high, and it is to be said of the man who drives his car at high speed that if he were not a safe driver, did not know the finer points of mechanical manipulation of his engine and of steering and devote his constant and undivided attention to the business in hand, he would not long remain a danger, as a disastrous accident would be inevitable. An endeavor is made here to suggest to the motor-driving public a few of the precautionary measures used by the experienced and veteran driver. The observance of some of these suggestions will effect a saving in gasoline, and others are included with a view to helping the careless or inexperienced driver to develop into a safe one.

When the driver is approaching an obstruction

on the road, cross-streets, any point where there may be necessity for a quick get-away or for more power than might be needed under normal circumstances, it is always advisable to get into intermediate gears when coming up on the object, as the driver is then prepared to instantaneously apply the maximum power of his motor and to quickly and accurately go through or get away from an otherwise dangerous situation.

In a shaft-driven car the noise sometimes caused by the changing of gears may usually be avoided, if the operator, instead of declutching and changing from gear to gear, as is the usual practice, will declutch, shift to neutral, let his clutch in and declutch again before completing the change. This requires but an instant and is a trick well worth acquiring.

In slowing down to turn corners, or in traffic, if the spark is retarded as the brakes are applied and advanced after the corner or obstruction is passed, it will result in a much more rapid get-away for the car, and save some gasoline.

The desire to eliminate waste in the consumption of gasoline has caused motor car owners to devote considerable thought to the subject of whether or not electric starting and lighting systems on motor cars are economical from the standpoint of gasoline

consumption. The arguments for and against electrical equipment are equally logical, and it would seem to be a matter for the individual driver to decide. The operation of the generator geared to the motor naturally detracts its quota from the power of the engine and consequently increases gasoline consumption over the amount that would be required merely to propel the car. Where self-starting devices are used the driver is apt to grow careless in the handling of throttle or gears and actually propel the car at times on the starter current, when otherwise his engine would be stalled. For this reason the self-starter necessitates the installation of considerable generating capacity, so that the drain on the gasoline tank due to increased power requirements is appreciable. On the other hand, the driver of a motor car which is not equipped with a self-starting device and must be cranked by hand is apt, on many occasions, to allow his motor to run idle rather than to experience the inconvenience of getting out of his machine to crank it, which would not be necessary if the car were equipped with a starting device.

Savings in gasoline consumption may be easily effected if the driver will make a point of always putting his gears in neutral when coasting down

hill and allowing the engine to idle at its lowest rate. It is the usual practice with many amateur drivers to feed gasoline to the motor under conditions where sufficient speed will be supplied by the force of gravity.

Except on cars with an automatic or fixed spark a considerable gasoline saving can be effected by proper handling of the spark lever. This can be easily proven by setting the hand throttle at a point while traveling over level ground and then noting the variation in speed obtained by advancing and retarding the spark. When a grade or a heavy hill is encountered, the spark should always be retarded and when the motor is being driven at anything approximating its maximum speed, this spark should be considerably advanced beyond the normal driving position. The most experienced drivers keep moving the spark lever almost continuously, except at high speeds, and this is necessary if one would obtain the best results from the motor. If the spark is not in the proper position, the motor requires more gasoline than it would if its explosions were properly timed, and this can readily be proven by the simple test outlined above.

Motorists would effect a considerable saving in the cost of their gasoline if they would, wherever

possible, house their car in a private garage. A private garage with a gasoline tank sunk in the ground outside would enable the owner to save from one cent to three cents per gallon, as in this quantity gasoline can be purchased at wholesale for the same price paid by the public garages.

Many practicable, portable garages are obtainable at a low cost and they are always practicable, except in cold climates where there is danger of the motor freezing in winter. This danger can frequently be obviated by running a steam pipe into the garage from the plant used to heat the house or other premises.

Some attention should be paid to the idea of community garages. Where four or five owners of motor cars are living in the same neighborhood, and space is available, an inexpensive garage can be constructed and maintained on a community basis, with a man employed to wash the cars and attend to oil and gasoline supply, etc. The cost of maintenance of such a garage would be considerably less than the cost of keeping the various cars in public garages and would afford their owners the advantage of a wholesale gasoline and oil supply.

Many drivers of motor cars travel in the course of a season a considerably greater number of miles

than is necessary, by reason of the fact that they do not keep to the proper side of the road and do not take curves properly. On a left-hand curve, where it is possible to see ahead, as it so often is, it is a great advantage to drive on the inside. This gives the advantage of affording a banked curve, lessening the possibility of sliding off the road at high speed and considerably lessening the distance traveled and consequent consumption of gasoline. In taking right-hand curves it is always advisable to hug the inside of the curve. Of course, where the view is obstructed one should not take a left-hand curve on the inside, as it would be a dangerous practice to do so; but where the view is not obstructed one should always adhere as closely to a straight line as possible, taking the curves on their inside and returning to the right-hand side of the road after the curve has been passed.

Many motorists incur great danger to themselves and others by stopping their cars for tire and other repairs immediately beyond a curve, so that another machine following them after rounding the curve finds the road immediately ahead obstructed, with great danger to both machines and their occupants.

Tire repairs should never be made beside the

machine, but either in front or to the rear of it, so as not to obstruct the road, but give other cars a chance to pass.

A great deal of useless gasoline consumption is brought about by drivers racing their engines before letting in the clutch at starting. This uses gasoline unnecessarily, and the driver should learn to apply the gas at the exact moment that the clutch takes hold.

In city driving it is advisable to coast over car tracks and street intersections where possible, as it is a strain on the motor to drive over obstructions under power, and entails an unnecessary expenditure of gasoline. Much gasoline can be saved by early preparation to apply brakes. Coming up to an object slowly and with the clutch out, the engine idling and the car completely under control, is much better driving than to approach closely to the object at speed under power before making a quick application of the brakes. Having the car at all times under control will not only result in a considerable saving in gasoline consumption, but is infinitely safer.

Motorists cannot pay too much attention to the adjustment of their carburetors, and it is safe to say that but few carburetors on motor cars are so

adjusted as to give them maximum efficiency. Proper adjustment of the carburetor will often result in a great increase in mileage, and in some instances has been known to make a difference of as great as one hundred per cent. Too much attention cannot be paid to this and the adjustment should be made by an expert and not tampered with afterward. Many drivers are continuously changing their carburetor adjustment, which is not only bad practice, but results in continuous wastes of gasoline.

Many new drivers become nervous when it is necessary to back their cars. They should remember that driving backwards entails exactly the same process as driving forward, except that the operator turns his head and looks in the direction toward which the car is moving. The feet and hands work in precisely the same manner as when driving forward.

There are many conditions under which a saving in gasoline could be effected if the average operator were not so decidedly averse to shifting gears. Shifting to intermediate gears in time will prevent stalling the motor, and where self-starter equipment has been installed it will prevent driving on the starter current. The operator should always remember that not only is a stalled motor harder to

start than a motor that has been stopped under normal conditions, but that it takes more gasoline to start it. In case of electric starting equipment it requires part of the engine's power to replace the charge of electricity so consumed.

If the motorist will entirely remove the windshield from the car in good weather the result will be a saving in gasoline. Without the wind resistance offered by the windshield less power is required to propel the car, consequently less gasoline. It is a question whether it is not more comfortable to drive in all weathers without a windshield, because of the vacuum that is created behind the shield with the resulting draught on the neck of the driver. With the windshield removed, all of the cold is felt on the face and the front of the body, which is the natural place for it.

Too much attention cannot be devoted to having one's car continuously under control in passing intersecting streets or cross-roads and meeting and overtaking other cars. Accidents result all too often through a sublime trust in the driver of the other car. He does not always do the right thing, and it is well to be prepared.

To owners of cars that are not equipped with self-starters it is well to suggest that they pay particular

attention to the position of the spark lever before cranking. The back-firing of the engine and the resulting broken arms are usually caused by a spark carelessly advanced beyond the point of safety.

Skidding may be avoided by learning to apply the brakes earlier and more slowly than would otherwise be done when traveling on treacherous surfaces. When passing a car ahead, do not swing in close in front of it. Make your curve gradual and easy and you will travel a less distance and use less gasoline, besides avoiding considerable danger. Though the extra gasoline consumed in swinging shorter than is necessary in front of the car that is being overtaken may be so small as to be almost inappreciable, it is apt to amount to a substantial total when the season's mileage is considered. Incidentally, it is bad steering and at high speeds may result in a skid or an overturned car.

The most misunderstood appliance on a motor car is what is known as the emergency or hand brake, and because of its name it is usually used only in emergencies. The operator will find that he drives with less energy and more comfort in proportion to the use that he makes of the so-called emergency or hand-brake. With this brake the car can be

handled without jar and can be brought gently to a quick stop if the operator is practised in its use.

An easy method of calculating gasoline mileage is to fill the tank full, drive your car where you will and have the tank refilled on your return. The number of gallons required to refill the tank divided into the mileage shown on your speedometer will give the miles per gallon.

A flat can holding a gallon of gasoline that can be tucked away under the seat is apt to prove a delightful convenience in a possible emergency. Few gasoline gauges are accurate after they have been used for a time and there are few motorists who have not occasionally been caught on the road without gas, sometimes uncomfortably far from a source of supply.

A very wasteful custom practised by many drivers, particularly after tire or other repairs have been performed on the road, is to wash their hands in gasoline taken from a flooded carburetor. A bit of waste and a comparatively few drops of gasoline is decidedly more economical and will have the same cleansing effect on the hands.

Many old drivers remember times before the invention of vacuum and pressure feeds for gasoline when their car would refuse to take a grade because

of low gasoline supply and it was necessary to turn the car and back up the grade, that being the only way to keep the level of the low supply of gasoline remaining in the tank above the level of the carburetor. Vacuum and pressure feeds are an enjoyable convenience. They constitute a corresponding danger, as they give no warning of shortage of gasoline until the entire supply is exhausted, therefore it is well to keep a small emergency can in the car. If your car has a low clearance and a gasoline tank suspended from the rear, it is well to be cautious in driving over bumps and obstructions, as gasoline tanks are known to have been scraped off at inopportune moments in localities devoid of repair shops.

It is of interest to the motor car owner to know that practically one-third of the money he spends for gasoline passes out through the radiator without having served a useful purpose, and it is said that the modern gasoline engines with the cooling systems now in use sometimes waste as much as eighty-five per cent of the power of the gasoline they consume. Science has yet to devise a means by which explosive or combustible energy can be utilized without an enormous percentage of waste.

AUTOMOBILE POINTERS

If your exhaust smokes, it is a sure sign that too much oil is being fed. This will always cause a deposit of burned oil in the cylinders; not carbonization, but just as troublesome.

Oils must have lubricating body so that pistons will not be worn out from lack of lubrication. Just because a particular oil you are using does not cause carbonization in your motor, it is not a sure sign that the oil is best adapted to your needs. Freedom from carbon deposits is a good thing, but if this happens because the oil does not have lubricating body, and hence allows the pistons to be worn from lack of lubricating, the error is just as serious from this cause.

One cannot judge an oil by its color. Some inferior oils look about the same as good oils.

First choose good oil, and then feed as much of this oil as you can without allowing the engine to smoke.

A poor grade of lubricating oil will cause carbon deposits on combustion chamber walls, piston heads and on points of spark plugs. Carbon on spark plugs may form a short circuit interfering with ignition. If the deposit is too great, it will hold

heat enough between explosions to cause pre-ignition.

Gasoline should not be put in a car through chamois. Static electricity is produced by the friction of the gasoline going through the chamois. Sparks have been generated in this manner causing bad accidents.

Low-gravity gasolines require more air than the higher gravities, but if well refined are just as clean and more powerful. They are somewhat slower to start in cold weather.

If the radiator is cold and the water jackets extremely hot, the water is not circulating, owing to a pump shortage or an air-lock. Overheating often causes preignition.

Sometimes the carburetor catches fire because of a back shot from the cylinders. By turning off the gasoline, and racing the engine, the fire can sometimes be sucked out.

The best time to test batteries is immediately after a trip and not before, because batteries pick up in voltage to a certain extent on standing, and do not show the true voltage.

Sometimes the water circulating system gets clogged up and needs cleaning. This can be done by first using a soda solution to dissolve the grease

in the tubes, followed by a mixture containing twenty-five parts of the commercial grade of hydrochloric acid and seventy-five parts of water.

In washing varnish surfaces, first use clean water followed with suds made by dissolving one pound of high-grade soft oil soap to each gallon of water, using about one pint of the suds to one pail of water. Keep raw soap out of the suds.

If a ball in a bearing needs changing, all of the balls in that bearing should be renewed. Never change a single ball.

Mica lights in a curtain can be cleaned by first dampening them carefully with vinegar, and then rinsing them off with clean, cold water.

Headlights should be set to throw light straight ahead, not pointed down at the road at an angle.

You may save runaways by observing that the clutch is in neutral before starting your motor.

Keep your tires well inflated, as full tires present less wearing surface on the road and there is less wear on the side walls.

Soot can be kept out of small holes in your acetylene burners by turning off the acetylene gas and blowing the flame out instead of turning the lights down low, or letting the flame die out after turning off the gas.

ENGINE TROUBLES

Practically all engine troubles with which the drivers of motor cars have to contend have their origin from the fact that there is something wrong with the gasoline supply, the ignition or the lubrication. The fact that something is wrong with the engine is usually made known by some unusual noise or action on the part of the engine, which attracts the attention of the motorist.

It is undoubtedly the simplest way, when he is searching for his engine trouble, for the motorist to start with the result which is the evidence of trouble, and by experimentation find his way back to the cause.

We have endeavored below to indicate the probable causes of various engine troubles which are most commonly met with.

DIFFICULTY IN STARTING ENGINE

Gasoline. Make sure that there is gasoline in the tank, and by priming the carburetor or pushing down the carburetor float make sure that there is no stoppage in the connecting pipe from the gasoline tank. Gasoline will drip if the carburetor is full. Stoppage of the vent hole in the tank cap may interrupt flow of gas. If the system is pressure system, pressure may be wanted in the tank.

Try closing air intake valve.

The difficulty may be caused by old or poor gasoline.

The engine may be flooded with gasoline so that the spark plug points are soaked. Open relief cocks on engine, and, having closed the throttle, crank the engine until there is an explosion. To start, close the relief cocks and open throttle slightly. If the float in the carburetor is loose it will cause flooding of the engine.

Ignition. The spark points on plug may be sooted, and should be cleaned, or they may be burned and corroded, and should be smoothed off, and the gap not more than 1-32d of an inch for coil ignition, or 1-64th of an inch for magneto ignition. A cracked porcelain on the plug may also cause trouble.

Test the battery, if battery ignition, and see if you can get a spark on the top of the spark plug when the wire is removed and held about 1-32d of an inch from the metal top.

MISSING OF EXPLOSIONS

Gasoline. Too much cold air may be coming through the air valve, or the carburetor jets may be clogged with dirt, or by stoppage in the gasoline pipe the free supply of gasoline is interrupted. Examine the intake gaskets. There may be dirt or water in the carburetor.

If the engine is missing on low speed the mixture is probably too rich or there is a leak in the intake pipe to the engine.

If the engine misses at high speed and not at low speed it may be getting too much gasoline.

An engine may miss until it gets warmed up. The most common cause for missing is too lean a gasoline mixture.

Ignition. Missing may be caused by the spark plugs being sooted or by the gap being too wide between points on spark plug. Examine interrupter points of the magneto.

If the missing is at high speed, but not at low, the trouble is not with the spark plugs.

Screw up the contact point in the magneto breaker box, giving it only a very slight turn. The coil may be defective, if a coil ignition is used.

If the missing is at low speed try advancing the spark and examine the interrupter points on the magneto. Also examine spark plug points. As a last resort look for loose connection or a broken-down coil, if a coil is used.

If the missing is at all speeds, the cause may be defective spark plug, loose connection, weak battery, broken wire, slight short circuit or loose switch parts.

STOPPING OF ENGINE

Gasoline. If it is cold, engine may need to be warmed up. Give richer mixture. Be sure there is no stoppage of gasoline in engine by priming carburetor. Examine connections to tank and gasoline supply and close air valve. Again, the trouble may be too much gasoline.

The sudden stoppage of engine may be due to lack of gasoline, though the usual cause is ignition trouble.

A slow stoppage of the engine combined with missing of explosions indicates gasoline trouble. See if needle valve of carburetor has jarred itself closed.

Probably the mixture of gas does not reach the cylinder.

Ignition. Weak battery may be the trouble, or too much retarded spark. Look for a loose wire, short circuit, poor switch connection, and see if points to interrupter to magneto are pitted. If so, smooth off with emery cloth.

Sudden stoppage of engine is usually due to ignition trouble. If engine stops slowly it may be exhausted batteries or fouled plugs,

FAILURE OF ENGINE TO PULL

Gasoline. The mixture may be too rich, and will be indicated by black smoke, or the valves may be leaking and the compression poor.

Ignition. If the cause is weak spark it will be indicated by missing of the engine.

IRREGULAR RUNNING OF ENGINE

Gasoline. Air probably leaking in between carburetor and cylinders through gaskets is the cause of this trouble or there may be too much gasoline supplied to engine. Give needle valve of carburetor slight turn down.

Ignition. Spark may be too much advanced.

FAILURE OF ENGINE TO PICK UP QUICKLY

Gasoline. This trouble is almost invariably the fault of carburetor adjustment, too much air being furnished on low speed through the auxiliary air intake, making too weak a mixture for "pick up" purposes.

The auxiliary air valve and gasoline needle valve on carburetor should be carefully adjusted.

LACK OF POWER

Gasoline. Valves may need grinding, or exhaust valves may leak; timing of valves may be wrong and should be adjusted; the cylinder or piston rings may be worn so that there is no compression. The gasoline mixture may be too rich.

Ignition. Timing of spark may be wrong, either too far retarded or too far advanced.

Lubrication. There may be lack of oil in the cylinders causing overheating of the engine. Overheating itself diminishes power, and it may be caused by defect in the circulation system. There may be tight bearings.

KNOCKING

Gasoline. Mixture may be too rich.

Ignition. Spark may be too far advanced. This is the usual cause. There may be carbon deposit in cylinders.

Lubrication. Pistons may become worn from use or lack of oil, or bearings may become loosened.

Engine overload on hill will cause knocking.

OVERHEATING

Gasoline. Mixture may be too rich, or throttle too open, with spark too much retarded.

Ignition. Overheating will result always from running on retarded spark. Car should always be driven with spark advanced as far as possible without causing motor to knock.

Lubrication. Common cause of overheating is trouble with the oiling system.

Miscellaneous Causes. Water circulating system out of order; carbon deposit in cylinders; too tight bearings, which should be loosened up and plenty of oil applied; driving for long period on low gear; dragging brakes; slipping fan belt.

BACK FIRING IN MUFFLER

Gasoline. Too weak a mixture or wrong timing of spark may cause one cylinder to miss fire, causing gasoline to be pumped to muffler and there exploded by heat of exhaust. Failing of gasoline supply may be cause of irregular spark or leaking valves. Examine spark plug points and see that they are not more than 1-32d of an inch apart, if coil, and 1-64th of an inch, if magneto.

Ignition. Firing a charge which has entered muffler unfired by suddenly throwing on switch after coasting, with the spark off and retarded.

CLUTCH TROUBLES

If the clutch grabs and is of the cone type, leather is too dry, and after cleaning with gasoline should have either castor oil or neat's-foot oil. If the multiple disc clutch is used, lighter oil should be applied after cleaning, or spring on clutch may be too tight.

Oil on the clutch leather of the cone type indicates too much oil in crank case, which has worked out along engine bearing.

If clutch slips, as is indicated by the car dragging when engine is running well, the spring may need tightening on the clutch, or if leather clutch, too much oil may be on leather and should be cleaned off with gasoline.

If leather clutch still slips use fuller's earth as a last resort. In the disc clutch, plates may be worn.

There are other less common difficulties with engines, as follows:

FAILURE OF ENGINE TO STOP WHEN SWITCHED OFF

This may be caused by poor lubricating oil, which causes a hardening of carbon on the spark plug, which gets red hot and causes pre-ignition.

If the engine continues to fire regularly when the switch is off, there is probably a defect in the switch. Overheating may cause this trouble.

HOT CRANK CASE AND WEAK ENGINE

This is usually due to a leak around the piston rings, or a crack in the head of the piston and gas escaping along the piston bearing.

HISSING OF ENGINE

This is usually caused by joint between engine and exhaust pipe being loose, exhaust pipe cracked, porcelain spark plug broken, spark plug not tightly set in cylinder, or valve caps loose.

SMOKE FROM MUFFLER

The cause of this is over-lubrication. If the smoke is black, the indication is too much gasoline. Smoking may also be caused by leaking piston rings.

LEAKING OF OIL FROM ENGINE

Worn bearings or loose gaskets in crank case, or crank case flooded with oil, usually is the cause of this trouble.

NON-FREEZING SOLUTIONS

Salt solutions are not recommended because of their deleterious effects on the metals of the cooling systems. Alcohol solutions probably give the best results. Occasionally, hydrometer tests should be made and the solution maintained at the required density by the addition of alcohol.

Denatured Alcohol Solutions

PER CENT OF ALCOHOL	SPECIFIC GRAVITY (WATER = 1)	FREEZES, FAHRENHEIT SCALE
10	.987	25° above zero
20	.974	13° " "
30	.960	2° below zero
40	.946	19° " "
50	.934	34° " "
60	.920	47° " "

Wood Alcohol Solutions

PER CENT OF ALCOHOL	SPECIFIC GRAVITY (WATER = 1)	FREEZES, FAHRENHEIT SCALE
10	.988	18° above zero
20	.975	5° " "
30	.963	10° below zero
40	.950	19° " "
50	.938	34° " "
60	.925	47° " "

USE OF FARM TRACTORS

Gasoline is being used to a greater extent each year on the farm, especially in tractors for plowing, cultivating, planting, harvesting and many other operations. Tractors were of great value in rapidly breaking up large areas of prairie sod in the West, but after the sod was broken they proved an unprofitable investment for the individual farmer in many cases. A few owners found the tractor a profitable instrument, doing its work more satisfactorily and much cheaper than could be done with horses, while a great many discontinued its use after a trial.

The average life of a tractor, as estimated by owners in North Dakota, is about six years, while the average life as estimated by owners in some other states than North Dakota is eight years. But

many tractors have shorter lives than six years, due no doubt to very inefficient operations.

The necessity for the operator of a gasoline tractor being thoroughly trained for his work, if the tractor is to prove a success, is obvious. Failure to comply with this requirement has been the cause of many failures.

A new tractor recently developed by a large Automobile Company is equipped with a regular twenty horsepower motor, and has a frame constructed of special vanadium steel, and weighs 1,500 pounds, permitting of its use over the softest ground. Its average fuel consumption is one gallon per hour, has a working speed from two to four miles per hour and can draw a heavy load on the road at twenty miles per hour. Any fuel that boils below 550° F. can be used, among them being kerosene.

This tractor is said to do the work of four horses, and its initial cost and upkeep is much less. Its advantages follow: It does not consume "food" or fuel when not in use; hence, in inclement weather and during the winter months there is no upkeep cost; it does not overheat while at work, even on the hottest days, and unlike the horse it does not have to be rested every half-hour because of excessive heat; the flies do not bother it; it does not

break out of the pasture and get into a corn field and overeat, nor lie down and die; whenever the driver leaves the tractor he is certain to find it standing where he left it and not engaged in eating leaves from the hedge fence, and, finally, the tractor does not become frightened and run away. These are a few of the points in favor of an efficient tractor from a farmer's viewpoint.

The following contrast between the work of horses and this promised Ford tractor is of interest.

A DAY'S WORK

Two horses	$\left\{ \begin{array}{l} 6\frac{1}{2} \text{ acres} \\ 32 \text{ quarts of oats, hay and bedding} \\ 2 \text{ hours' labor} \end{array} \right.$	$\left. \begin{array}{l} \text{Whether} \\ \text{work} \\ \text{or idle.} \end{array} \right\}$
Ford tractor	$\left\{ \begin{array}{l} 13\frac{1}{2} \text{ acres} \\ 10 \text{ gallons gasoline} \\ 1 \text{ gallon of oil} \end{array} \right.$	When at work.

Fifty of these tractors are at present being tried out under practical conditions as a step preliminary to their wide-spread exploitation.

The United States Department of Agriculture in Bulletin 719, summarizes the experience of nearly two hundred farmers in Illinois in using different sized tractors on farms of different acreage as follows:

“The chief advantages of the tractor for farm work are: (1) Its ability to do heavy work and do it rapidly, thus covering the desired acreage within the proper season; (2) the saving of man labor and the subsequent doing away with some hired help; and (3) the ability to plow to a good depth, especially in hot weather.

“The chief disadvantages are difficulties of efficient operation and the packing of the soil when damp.

“The purchase of a tractor seldom lowers the actual cost of operating a farm, and its purchase must usually be justified by increased returns. For farms of two hundred crop acres or less use the three-plow tractor.

“For farms of from two hundred one to four hundred fifty crop acres, the four-plow tractor, with the three-plow outfit for second choice.

“For farms of from four hundred fifty-one to seven hundred fifty crop acres the four-plow tractor, with the three-plow outfit for second choice.

“A farm of one hundred forty acres is the smallest upon which the smallest tractor in common use, the two-plow outfit, may prove profitable.

“Medium-priced tractors appear to have proven a profitable investment in a higher percentage of cases than any others.

“The life of tractors, as estimated by their owner, varies from six seasons for the two-plow to ten and a half seasons for the six-plow outfits.

“The number of days a tractor is used each season varies from forty-nine for the two-plow to seventy for the six-plow machines.

“Two and one-half gallons of gasoline and one-fifth gallon of lubricating oil are ordinarily required in actual practice to plow one acre of ground seven inches deep. The size of the tractor has little influence on these qualities.

“Under favorable conditions a fourteen-inch plow drawn by a tractor covers about three acres in an ordinary working day.

“Plows drawn by tractors do somewhat better work on the whole than horse-drawn plows. In Illinois the depth plowed by tractors averages about one and one-half inches greater than where horses are used.

“A tractor displaces on an average about one-fourth of the horses on the farm where it is used.

“Experienced tractor owners do not consider even a two-plow outfit profitable on a farm less than one hundred forty acres. The average size of a farm on which two-plow outfits are used in Illinois is two hundred seventy acres.

“The four-plow tractor is most recommended by experienced owners.”

At present tractors are passing through the development stage, and diverse views are held regarding them. Many farmers would not do without them. Others maintain they have not reached the stage where they can efficiently do the work done by horses. It is certain, however, that they have found a place on the farm in a great many cases and that their usefulness in this respect will steadily increase.

USE OF GASOLINE DURING A WAR

The internal combustion engine is put to many uses in warfare. In fact without motor traffic present war on the scale it has been staged would have been impossible. Thousands of soldiers can be moved many miles in a few hours or over night, as the strategy of the operators may demand. The magnificent roads of France are still in splendid condition despite the war, and they are used by motor cars to their utmost capacity in transporting troops from place to place; in bringing up supplies, in caring for the wounded, in swiftly carrying dispatches, and for many other purposes. Operations that required days in past great wars can now be

conducted in hours. As a consequence, war has lost much of its former spectacular nature, for surprises are difficult to execute with telling results. A movement launched at any particular place is quickly met by the rapid transfer of sufficient troops to guard that place.

The aeroplane has been pressed into valuable service and has been developed as a swift, useful and safe means of locomotion during this war, to a point that otherwise would have required years to reach. It is justly called the eyes of the army. In getting accurate information of the movements of the enemy, and in other ways, it has rendered valuable service.

When the Russian army rolled into Galicia and took possession of the Austrian oil fields, a problem of great importance confronted the Central powers. Namely, where to turn for their gasoline supply, or benzine as it is called in Germany. Before the problem became very acute, however, the oil fields were recaptured by the Central powers.

It might be added that Germany, partly because of economical necessity, has advanced much farther than the United States in the use of alcohol, benzol, kerosene, and other substitutes for gasoline.

According to enthusiastic Germans, three factors

have been largely responsible for the immediate success of the Kaiser's armies in Poland: Von Hindenburg, big guns and the automobile.

In the battle of Tamenberg millions of German troops had to be transferred rapidly from more southerly points of the frontier to the north. This could never have been done without thousands of automobiles, in spite of the fact that several lines of railroads, very efficient in a military sense, run parallel with the line of forts, Koenigsberg-Thorn—Marienburg. Likewise, it was due to the automobiles that every kind and quantity of artillery required could be brought to the battlefield in time to defeat the Russians. Of course the automobile operations were by no means restricted to the preliminary work of the battle, but as positions shifted, the motor equipment was always kept working hard.

This was the first demonstration on a large scale of the tremendous military value of the automobile in war. The work consisting of wholesale movements of troops and cannon and ammunition was repeated with relative modifications in the several battles of the campaign of the fall of 1914. At the same time, motor cars enabled the Austro-Hungarian troops to make the best of their strategic

retreat through Galicia, in the face of Russian armies which were in vast numerical superiority. It was the unfailing supply of enormous quantities of munitions which made it possible to hold the Carpathian passes against the Russians thrown into them, regardless of losses. Finally, automobiles constituted, to a large degree, the driving force which turned the Russians from the Carpathians and Galicia into Poland, ending the first and opening the second great stage of the eastern campaign.

The second stage consisted largely of the advance, sometimes rapid and sometimes slow, of the united Teutons toward Warsaw, and after the conquest of that city, to the Brest-Litowsk line. Most of this advance was made in a country of soft soil, very poor in the way of roads, while most of the railroads were destroyed by the retreating Russians wherever they had time to do it. Fortunately for the invaders, the solid railroad beds could not be destroyed in the short time given to the retreating enemy, and this made possible the creation of an "automobile railroad system," in which the cars followed the lines of the railroads.

In general, the hardest work for automobiles in the east was done during the Carpathian campaign, when the machines had to plug through snow and

mud several feet deep and often had to be raised and got under way.

On the western front, automobiles have also found plenty to do. This applies especially to the fighting in Champagne and Vosges, where the net railroads are more sparse than in Northern France and Flanders, and where at times much violent fighting took place. Several hills commanding the surrounding ground, such as the well-known Hartmanns-Weilerkopf, changed hands as often as a score of times during the war, and the party on the offensive of course had to bring up troops and fighting machines under cover. In more than one case, all the fighting against the forces on such a hill was in vain, until the supply of heavy ammunition was cut off from them, when the position was carried by storm. In some of these storms, armored cars with small calibre guns participated, and, in spite of the obvious difficulties of such a hill-climb, rendered good service.

One might even say that Germany succeeded where motor cars could operate and did not succeed where they failed. Wherever there was a possibility of quickly attaining a position required and suitable for effective attack, this possibility was realized through the work of the automobile. It

was the alliance with the automobile which made the 30.5 and 42 centimeter guns as effective as they proved at the sieges of Liege, Antwerp, Marchberge, etc.

There is an impression that automobile driving is one of the soft jobs of the war, but most motorists will say that they would rather be serving in trenches than at the wheel of a truck. In the battle of Champagne the number of shells that had to be fired by each gun prior to the infantry attack was prodigious. Thousands of trucks were running day and night, taking shells right up to the gun positions, for the old method of transferring to horse teams has long been abandoned. Generally the guns are in positions away from the main roads, but special tracks are made so that the automobile can go right up to them. The ammunition is unloaded and placed in underground shelters within easy reach of the battery. Naturally the enemy keeps a close watch for the ammunition columns and shells them whenever possible. If an enemy's shell strikes an ammunition truck, there is not much left of either truck or men.

AIRCRAFT INDISPENSABLE IN WARFARE

The first six weeks of the great European war demonstrated beyond doubt to the participants

the value of aircraft. Aircraft in warfare unlocks the door to the secrets of war strategy and shows the movement of troops, cannons, warships, etc., of both sides in the fray.

The movements of large bodies on land and of ships on the seas lying near the scene of hostilities have been apparent to the enemy. Furthermore, while aircraft in this, its infant stage, and without previous big war experience, has actually proved itself the eye of the army and navy, it has gone further and proved that it also has a very offensive kick of its own in the shape of bomb dropping from both aeroplanes and dirigibles. The severity of this kick is only limited by the scarcity in numbers of aeroplanes and dirigibles. Multiply the number of aircraft by one thousand and its kick would then become an exterminator.

During the march through Belgium and to the very gates of Paris by the German army, it was aircraft that showed the Germans just when and where to strike the most effective blows. While on the other hand it showed the smaller forces of the Allies just when it was necessary to retreat in order to avoid capture or annihilation, and just the reverse order of things when the Germans retreated from Paris.

Aircraft has shown the British admiralty the location of German battleships behind the great Heligoland stronghold, and aircraft has also shown the German naval officers where British war vessels are stationed. Each knows the other's principal positions, movements and strength, and it is a matter of the smaller force backing away from the larger force.

Aircraft is also utilized to hover over enemy's forces while in battle, and signal the gunners upon the ground the exact position and range for artillery fire, and through this method alone more than one battle was decided by the forces employing it to the best advantage.

It is also true that, just as aircraft have developed, means of combatting them have strengthened. Aerial guns are an important part of the defense against air raiders. These shoot so high and accurately that often airmen have to travel so high that they cannot discern objects or movements on the ground with clearness.

LUBRICATING OILS FOR MOTORS

An automobile practically runs on oil, that is, between every journal or shaft and its bearing there is a thin film of oil, keeping these parts separated.

In order to perform its work to the best advantage, lubricating oil must possess several necessary requisites:

(1) It must lubricate the piston efficiently at the temperature encountered in the cylinder.

(2) It must give a good seal to the piston and rings, keeping them tight and preventing leakage of oil and condensed gasoline past them.

(3) It should be adhesive, *i.e.*, possess the property of sticking to the surface to be lubricated.

(4) It should be as far as possible unchangeable, *i.e.*, the supply should be renewed with oil of the same character if desired, and upon standing for a longer or shorter time, should remain the same.

(5) It should be free of acids and in other ways pure.

(6) It must burn without forming too much carbon deposit in the cylinder.

Only the best grade of oil should be used to lubricate the internal combustion motor, and the viscosity or body required will depend upon individual requirements of the power plant. Some engines have very closely-fitting pistons and rings and tightly-adjusted bearings, which means that

a light-bodied oil must be used in order to form a film between the closely-fitting parts. Other engines will operate better on medium-grade oils, while an engine that has been run for a time so that the working parts have been freed up will require heavier-bodied oils in order to cushion the shock between worn parts.

Greases adulterated with animal fats to give them more body are unsuited for lubricating motor vehicle parts, because they become rancid after they have been used for a time, and they liberate fatty acids that will injure the finished surfaces of the gears and anti-friction bearings. Greases of this nature gum up very easily and as they harden the revolving gears will cut paths in which they turn, and no lubricant is supplied to the gear teeth though the transmission case may be half full of the solidified grease.

Some makers advertise greases that are guaranteed to silence noisy gear sets. These contain particles of cork or shredded wood designed to fill the space between the worn gear teeth and cushion the shock that oil or grease would not be capable of doing by itself. These greases should never be employed in gear sets if efficient operation is desired, because they not only interpose an item of serious

frictional resistance and consume power, but are also entirely unsuited for the anti-friction ball or roller bearings used to support practically all change speed gear shafts.

With the water boiling in the jackets the temperature of the inner surface of the cylinder walls will be about 265° F. The temperature of the layer of oil that is in immediate contact with the cylinder walls, which is the part that regulates the friction, cannot be much higher than this. There are probably no motor oils that have a flash point lower than 325° F. If the temperature of the cylinder walls gets up as high as this in a water-cooled motor there is something radically wrong, and the remedy is not to get another oil of higher flash point, but to locate the trouble and remove it.

It is an old theory, never founded on solid facts, that a high flash point is a necessity in a motor oil, or that the oil burns up without giving sufficient lubrication. The point is overlooked that, when one has a maximum explosion temperature of gases in a cylinder of about 2700° F., and an average temperature of 950° F., an oil with a flash point of 450° F. will offer little more resistance to burning than one of 300° F. would.

Either oil will burn if kept for any length of time

in contact with the hot gas. Lubricating oil does not burn very easily or very fast, however, and the time given it to burn in a motor cylinder is very short.

No rigid directions can be given for the choice of oils for given purposes. It is best to try various lubricants which can be purchased for any one lubricating problem until one is found that gives satisfactory results.

Lubricating oils are separated from crude oil by distillation, after the gasoline, naphtha, kerosene, etc., have been separated. After the lubrication portions of the oil have been separated, they are treated with sulphuric acid, water and alkali, and blown with air to purify them. In some cases they are filtered to decolorize them, that is, to bring them up to certain standards of color required by the trade. Fuller's earth is generally used as the filtering medium.

A number of tests have been devised to determine the suitability of lubricating oils for the trade. These are the heat, flash, gravity, viscosity, cold and carbon residue tests.

Heat Test

If a small vessel of good oil is slowly heated over

an open flame until yellow vapors appear above the surface of the oil, kept at the temperature for fifteen minutes, and then allowed to stand, it will darken in color, but remain perfectly clear and without sediment even after twenty-four hours. Impure oil turns black, and after about twenty-four hours a black carbon-like sediment settles out, due to the presence of sulphur compounds.

This simple test is unailing and very valuable to show oil purchasers something about the quality of the oil they are buying.

Flash Test

The flash test shows at what temperature the vapors coming off the oil, when heated, will flash or ignite and go out again when a small flame is brought within one-fourth inch of the surface of the oil in the test cup.

The flash point of an oil makes little difference as regards its presence in the explosion chamber of a motor, because explosion temperatures are away above flash temperatures of any oil. But for use below the piston the flash temperature should be as high as is consistent with other necessary requisites of the oil. Motor oils that flash below 400° F. show a very appreciable loss by evaporation; hence,

the oil loses its viscosity, and has to be more frequently renewed.

Fire Test

The fire test shows at what temperature the oil itself will ignite from the flashing vapor when exposed to a small flame. In motor oils the fire test is from 50° to 70° above the flash test.

Specific Gravity Test

The specific gravity or "Gravity" test shows the density of the oil or weight. It is most simply made by immersing a hydrometer in the oil and noting the position to which the hydrometer sinks, as marked on the stem of the latter. Motor oils made from Pennsylvania crude run about 30° to 33° Bé. gravity. Western lubricating oils frequently run lower than this.

Viscosity Test

The viscosity, or viscous nature or rate at which an oil will flow, is a factor of much importance. During cold weather an oil will flow more slowly than during hot weather, and at the higher temperature of the working parts of a motor the difference is very great.

A lubricant is actually used to keep a shaft or journal and its bearing apart, or, in other words, the journal really revolves on a sheet of lubricant. Hence, the ease with which the particles of oil slide over one another (the viscosity of the oil) determines to a certain extent the loss of the oil when it is exposed to friction in the bearing.

The test is made by noting the number of seconds required for a definite volume of oil under an arbitrary head to flow through a standardized aperture at a constant temperature. Readings are commonly taken at 100° to 212° F.

The viscosity is usually spoken of in terms of seconds. This is the flowing time under the conditions given above.

More or less disagreement of results follows by using different instruments; hence, it is customary to state the name of the instrument used. One of the most commonly used viscosimeters is called the Saybolt. An apparatus used in Germany and coming into use in this country is called the Engler.

When oils lighter than one hundred eighty seconds are used in motor bearings, the horsepower falls until they finally seize or bind with oil of approximately one hundred seconds. Oil of about one hundred eighty seconds gives the maximum

horsepower obtainable. Between eight hundred and twenty-three hundred seconds there is little difference. Light and medium oils varying between one hundred eighty and three hundred seconds are commonly specified.

Cold Test

The temperature at which oil congeals or fails to pour is called the cold test.

This test is in no way indicative of the lubricating or heat-resisting qualities of an oil.

Oils that flow at temperatures greater than twenty to twenty-five degrees above zero meet all practical requirements, as the oil supply must be kept in a warm place, and the heat of an engine, the instant it is started, is enough to keep oil in the crank case or lubricator warm enough to flow, no matter what the temperature outside may be. Lubricating oils of asphaltic base, *i.e.*, oils made from western crudes, are the only ones that will flow around zero temperature.

Carbon Residue Test

A certain amount of carbon in all motor oil can be "fixed" by distilling a given quantity in a standard flask, and at a uniform rate twenty-five cubic

centimeters distilled at the rate of one drop per second. A coating of carbon will remain on the walls of the flask, which is weighed to determine its percentage. This "fixed" carbon is termed carbon residue, and must not be confused with carbon deposit. It frequently happens, however, that a large amount of carbon residue as determined by the above test means trouble in the gas engine from carbon deposit. This is not invariably the case, however.

The color alone is no indication of the quality of an oil for motor lubrication or of the amount of carbon it contains, some of the lightest colored oils often containing the most carbon. Oils may be made light in color by filtering them through bone-black. If filtering is continued long enough, a clear white oil will be obtained. Filtering removes the carbon and impurities from the oil, and in doing this raises the gravity and viscosity of the oil.

Dealers sometimes increase the viscosity of oil by adding a material known as oil pulp or thickener. This is really oleate of aluminum, and while it brings up the viscosity; it does not give the greasiness expected. At ordinary temperatures a very small quantity of this material will enormously increase the viscosity.

Service Tests

Some good information regarding an oil may be obtained by observing the oil after it has been used in a motor.

When a motor has been run for a few hours with a filtered oil of the highest quality, and a sample taken for examination, it will be seen that the oil has changed from its original yellow to a grayish-blue by reflected light (not direct rays from the sun). Finally, after several days running, the oil will turn completely black and opaque. A sample of it drained from the motor into a long narrow tube and allowed to stand twenty-four hours will show a black sediment at the bottom.

Let a poor oil be run in the same motor under like conditions, and a sample examined, at the end of a few minutes the oil will turn to a dense and lustrous black and a large amount of sediment will form, several times greater than the sediment from the good oil.

The amount of mileage to be derived from a particular oil is largely dependent upon mechanical constitution of the motor. Tight piston rings, large centrifugal rings on the crankshaft where it passes through the case, ample cooling fins in the pistons, vents between the crank case chamber

and the valve enclosures, etc., make for large mileage per gallon of oil, in some cases as much as one thousand miles.

No lubricating oil exists that will not undergo a chemical and physical change when exposed to the high temperatures on both sides of the piston on automobile motors, and that will not deposit sediment in the crank case, but a very marked difference is noted between good oil and poor oil, as regards the quantity of this sediment.

LUBRICATING POINTERS

A very comprehensive lubricating schedule has been prepared by engineers of a prominent motor car company for users of their product, and, as this gives very definite instructions regarding the lubrication of various chassis parts, it is also presented for the reader's information, as much of the advice can be applied with equal advantage to other motor cars.

Every Day Car is in Use, or Every 150 Miles

With Cylinder Oil:

Steering knuckle bolt oilers Fill

With graphite grease:

Motor clutch shifter bearing sleeve

grease cup Two complete turns

Motor clutch shifter shaft grease cup	One complete turn
Steering connecting rod and cross tube grease cups	One complete turn
Spring bolt grease cups	One complete turn

Every Week, or Every 300 Miles

With cylinder oil:

Motor starting crank bearing	Eight or ten drops
Shock absorber bearing studs	Thoroughly
Rear axle truss rod forward connection	Thoroughly
Rear axle brace oilers.....	Thoroughly

With graphite grease:

Motor fan-bearing grease cup.....	Two complete turns
Rear axle outside bearing grease cups.....	One complete turn

Twice a Month, or Every 500 Miles

With cylinder oil:

Motor generator oil holes	Ten drops
Spark and throttle adjusting clevis joints.....	Thoroughly
Motor accelerator pedal joints ...	Thoroughly
All brake adjusting clevises	Thoroughly
External and internal brake fittings and connections	Thoroughly
Hand brake can oiler	Thoroughly
Hand brake lever ratchet	Thoroughly
Foot brake pedal bearing	Thoroughly

With graphite grease:

- | | |
|-------------------------------------|--------------------|
| Motor clutch pedal shaft grease cup | One complete turn |
| Steering gear case grease cups.... | Two complete turns |

With cylinder oil and kerosene:

- | | |
|--|------------|
| Change speed lever shaft bearings.. | Thoroughly |
| Intermediate brake lever shaft and connections | Thoroughly |

With vaseline:

- | | |
|------------------------------|--|
| Motor generator grease tube. | |
|------------------------------|--|

Every Month, or Every 1,000 Miles

With cylinder oil:

- | | |
|---|---|
| Change speed reversing bell crank oiler | Fill |
| Crank case | Drain off dirty oil, flush with kerosene and fill to pet-cock level |
| Magneto-bearing oil wells | Few drops |
| Motor front gear compartment ... | Drain thoroughly |

With graphite grease:

- | | |
|--|--|
| Front wheel bearings | Clean with kerosene and repack |
| Motor generator and magneto shaft universal joints | Oil thoroughly |
| Rear universal joint | Remove grease hole plug and fill with grease again |
| Front wheel hub caps | Pack |
| Motor water pump shaft universal joints..... | Thoroughly |

With gasoline:

- Motor carburetor air valve stem . . . Clean thoroughly.
Do not oil

With transmission oil:

- Front universal joint Drain thoroughly,
(half cylinder oil and half trans- flush with kerosene
mission oil in cold weather). and fill to pet-cock
level
- Rear axle case Drain thoroughly,
(half cylinder oil and half trans- flush with kerosene
mission oil in cold weather). and fill to level of 2
brass plugs in under
side of housing
- Rear axle transmission case Drain thoroughly,
flush with kerosene
and fill to level of
button-head screw in
front cover

Once a Season

With graphite grease:

- Spring leaves Jack up frame to sep-
arate leaves, clean
and lubricate thor-
oughly. Repeat
whenever springs
squeak

USE OF GASOLINE AS A CLEANING FLUID

Gasoline, or benzine or naphtha, as it is more commonly called by those who use it as a cleaning fluid, is consumed in enormous quantities in thousands of cleaning establishments in the United States and other countries for cleaning fabrics.

The foundation of this wide-spread usage of gasoline was laid in 1866 by a Frenchman, M. Judlin, who discovered the cleaning powers of benzine. The success of the method is due to the fact that it alters neither the fit of the garments nor does it spoil the most delicate fabrics, while washing with soap not uncommonly affects one or both of them, so that other processes are often required after soap washing. This is not necessary after benzine cleaning. The cleaning of garments is thus simple and rapid, and in addition most of the benzine can be recovered for use again.

The phrase "dry cleaning" originated from the fact that no water is used in the process. In reality, the garments are immersed and washed in benzine or some other solvent. Thus the term "dry cleaning" is a misnomer, and the real definition of dry or chemical cleaning, as it is sometimes called, is immersion in a liquid which dissolves fat. Briefly

stated, dry cleaning is based upon the solvent power of benzine and other solvents for grease. Most stains in garments consist of dirt held by grease of various kinds collected during the wearing of clothes. By removing the grease (the dirt-carrying vehicle) the dirt is released and the stain disappears. As compared to the older methods of cleaning, this process has great advantages. The possibility of shrinkage of woolens, almost unavoidable in the water-washing treatment, is entirely excluded. Furthermore, the most delicate fabrics are not affected or in the least injured, and richly-trimmed ladies' gowns can be cleaned without the necessity of ripping off any portion or removing the trimmings. The padding of men's coats is not shifted, and many household articles, which would be rendered useless by ordinary methods of cleaning, may by this process be restored to their original cleanliness. In addition, the expense of ripping apart and resewing is avoided.

As solvent for oils and greases, benzine is not excelled. The principal requisites of the benzine are that it should be readily expelled from the garments by evaporation after the immersion, sponging or washing process is over, it should be free from odoriferous substances and that it should not be

too volatile in character, because then the loss by evaporation would be too great.

Under the name of "benzine soaps" are various products on the market that are much used and that form an important item of the dry cleaners' outfit. In this form (dissolved in soap) the use of benzine is extended to the cleaning of garments dirty from ordinary dust or dirt upon which benzine by itself has no effect.

There are a number of methods and several kinds of apparatus for carrying out the actual process of dry cleaning according to whether the work is to be done on a large or small scale, but the principle is the same in all cases.

First, as much dust as is possible is beaten or shaken out of the garments. Next, they are thoroughly brushed, especially pockets, and then dried to remove all moisture. This is very important, as the presence of moisture prevents the benzine from acting. Water forms damp places in the goods. These places retain their own dirt and absorb dirt from their immediate neighborhood, and the dirt in them is effectually protected from the benzine. Hence, garments must be, by all means, free from moisture before they are dry cleaned. Finally, the goods are treated by benzine.

In small dry-cleaning establishments a number of vessels (up to five) are used for the convenient handling of goods to be cleaned. These vessels of sheet zinc, sheet copper or stoneware are filled about three-fourths full with benzine and fitted with tight-fitting lids. The articles to be cleaned are sorted, the light from the dark, all of them spread out and the worst stains removed with a piece of wadding the size of a fist. This piece of wadding, called a "tampon," is tied into a piece of white linen, so the corners of the latter can be used as a handle.

The tampon is dipped into the benzine in a dish until it is thoroughly saturated, and dirty places of fabric vigorously rubbed until the greater portion of the dirt is removed. All of the articles are proceeded with in the same manner, the darker being taken last, because by repeatedly dipping the tampon into the benzine the latter acquires a darker color.

The benzine remaining after the operation is finished is poured into a large vessel, which is provided with a well-fitting lid. Then the articles treated with the tampon are washed, one after the other, in the first vessel of benzine. Next, they are washed in the second benzine vessel, and so on.

The changing of articles from one vessel to another is done for the purpose of always bringing the first lot, that is, the white pieces, in contact with unused benzine, the latter becoming constantly darker by washing the articles. The articles first treated are finally washed in pure benzine and spread upon a table and examined. If dirty places are still found, the articles are rubbed with a clean tampon and again placed in pure benzine. From the latter they are thrown into a vessel provided with a lid, in which the adhering benzine drains. This benzine is removed from time to time. The articles are finally wrung by passing them between the rolls of a wringer or, better, the benzine is removed by means of a centrifuge. The articles are then dried in quite hot, closed, drying chambers provided with contrivances for the escape and condensation of the benzine vapors. By this treatment, the articles are thoroughly cleaned as far as it can be done with benzine. It must be added, however, that all stains produced by alkalis, acids, sugar, milk, etc., resist the action of benzine. The same is also the case with so-called sweet stains, which are caused by a change in the color. To remove such stains, the separate pieces must be subjected to special treatment.

The method above described is practised on a small scale. For working on a larger scale, a number of good machines are required, namely, a benzine-washing machine, an extractor, a cleaning table, a tank or tub for rinsing and a couple of cylindrical tanks of zinc.

The cleaning of all kinds of fabrics has developed to the extent that special treatment with benzine is given many articles for the best results. White woolen and silk goods are brushed over first with a weak solution of benzine soap in benzine and run for from ten to fifteen minutes in the benzine washer. This is done on account of the greater danger from explosion. Colored silks, when very dirty and stained, cannot be completely cleaned by the dry process, but must be followed by wet cleaning. One of the many points to be observed in dry cleaning is that red stripes, interwoven in ladies' waists, usually give up their dye to benzine, whereby not only the silks but everything else in the washer is ruined. Waistbands containing such stripes must always be removed.

A special technique has developed to properly clean and renovate real velvet goods, carpets, etc.

Benzine, after use, can be purified by filtering it through sand, charcoal and flannel, by treating

it with dilute sulphuric acid ($\frac{1}{4}$ to $\frac{1}{2}$ per cent) and allowing it to stand quietly for twenty-four to twenty-six hours, but best of all by distilling it. In proper hands, the distillation is not only safe, but it wastes less of the benzine than any other purification process. In addition, no acid is left in the benzine, as is the case with the sulphuric acid treatment, and the benzine is recovered in a perfectly pure and colorless condition.

USE OF GASOLINE IN THE PAINT AND RUBBER INDUSTRIES

Gasoline or benzine, as it is called in the paint industry, is used extensively in paint manufacture as a solvent. The amount of benzine permissible in a paint depends entirely upon the paint. A thick, viscous, ropy paint which is so difficult to apply that it will not flow evenly is undoubtedly improved by the addition of benzine. In such cases, kerosene and turpentine can also be used, but in the cases of a dipping paint where the even spreading of a linseed oil paint is desirable, and the sudden evaporation of the solvent helps to produce a uniform coat, benzine cannot be replaced by any other solvent.

Some have argued that benzine is of no value

in a structural iron paint for the reason that its rapidity of evaporation lowers the dew point, because moisture is deposited as it evaporates. This is fallacious. Turpentine will do exactly the same thing, as will any other solvent depending entirely upon the hygroscopic condition of the atmosphere. If painting be done in an atmosphere where the humidity is high and the temperature near the dew point, it makes very little difference what solvents are used, the condensation being apparent in any case. A great advantage is to be obtained by the moderate use of benzine, for in brushing on a quick-drying paint containing benzine the evaporation carries with it much of the moisture in the paint.

A number of excellent brands of benzine have been placed on the market as substitutes for turpentine, all of which are equal in physical characteristics to pure spirits of turpentine.

Turpentine is a better solvent for some of the mixing varnishes and fossil and semi-fossil resin driers than benzine, but certain petroleum or paraffin compounds, some of which have had marked success, are absolutely identical in solvent power, speed of evaporation and viscosity to turpentine.

The method by which these benzine compounds are made consists in passing certain paraffin oils

over red-hot coke in conjunction with wood turpentine. The product which is obtained has little or no odor. Thick or viscous paints, particularly the varnish and enamel paints, are so much improved by the addition of these materials that even an inexperienced painter will notice the free-flowing qualities of the material to which these dilutents have been added. The petroleum products used in the manufacture of paints are principally 62° B. benzine. Some of the gasolines ranging from 71° to 88° are used, but these are so light and bring so much higher price than the 62° that they are not used as much.

The grades, however, which approach turpentine in physical characteristics, must be counted on as an important factor in paint on account of the extremely high price of turpentine, and the fact that it is held in a few hands. After all, any solvent, whether it be benzine, turpentine, naphtha, benzol or acetone, is nothing but a solvent and evaporates completely, leaving the other vehicles to protect the paint. Of course too much solvent is detrimental to paint, no matter what kind it may be.

BENZINE IN THE RUBBER INDUSTRY

Benzine in its solvent action on rubber shows slight action in the cold or under gentle heat.

The problem that confronts the rubber manufacture as a rule is the solution in a solvent of gums that are more or less heavily compounded, which is an easier problem than the putting into solutions of crude rubber that perhaps has not been broken down in any way. At the same time it is customary in many cases to apply a little heat during the mixing. The following table relates, to different naphthas used by the rubber trade:

PRODUCTS	GRAVITY BÉ
Rhigolene	
Gasoline	85
C. Naphtha	70
B. Naphtha	67
A. Naphtha	65

The "C" naphtha has not only the greatest solvent power but it is easier to evaporate after it has dissolved the rubber compound. "B" and "A" require a certain amount of heat to vaporize them.

Naphtha is more largely used in the proofing business than any other. It is, however, a general

solvent for all rubber cements, and large quantities of it are used in almost all lines of rubber work when there is any making up to be done of separate pieces after calendering. It is necessary that the proper grade be used, when one considers the danger that may come from fires caused by explosions or easy ignitions of the more volatile solvents. Odorless naphthas are those from which naphthalene is removed, as it is the presence of this body that caused the strong smell. Naphtha treated by sulphuric acid is deodorized, acquiring a rather pleasant odor as a consequence. It is often mixed with other solvents, for example, spirits of turpentine, and is thus found to have a better effect on the rubber.

HISTORY OF PETROLEUM

Petroleum or crude oil, from which gasoline is obtained, is made mention of in the earliest ages of which we have any records. The oil pits near Ardericca (Babylon) and the pitch spring of Zacynthus (Zante) are recorded, while Strabo, Dioscorides and Pliny mention the use of oil of Agrigentum, in Sicily, for lighting purposes, and Plutarch refers to the petroleum found near Ecbatana (Kerkuk). Reference to the use of natural gas for

lighting and heating are found in the ancient records of the Chinese. Petroleum or "burning water" was known to the Japanese in the seventh century. Reference can be found in the literature to the natural gas wells of the north of Italy in the year 1226, to the oil field of Baku, Russia, in the year 1300, etc.

The earliest record of crude oil or petroleum of America was made by Sir Walter Raleigh in 1595. He mentions the Pitch Lakes of the Isle of Trinidad. Crude oil in New York was made mention of in 1632.

Commercial exploitation of oil of importance was first made by James Young in Derbyshire, England, in 1850. He distilled oil and patented a process for the manufacture of paraffin. Crude oil found in Kentucky was used as a liniment as early as 1829, and sold under the name of American medicine oil.

The first oil well was drilled in 1858 under the direction of E. L. Drake, on Oil Creek, Pennsylvania. At a depth of about seventy feet oil was "struck," and about twenty-five barrels a day were obtained for some time. At the end of the year the output was fifteen barrels. The production for the year 1857 was two thousand barrels.

The oil industry was confined to Pennsylvania

for about ten years, but starting in 1870 it has spread all over the globe. The United States holds the position of being the largest oil producer at the present time, mining more than sixty per cent of the world's supply of petroleum.

CLASSIFICATION OF OIL FIELDS

For convenience of discussion the oil pools of the United States are grouped in certain major areas or fields based originally on geographic position alone. As these fields have been extended, the geographic boundaries have become in many cases less distinct, and the separation has come to be based more and more on fundamental differences in type of oil produced, and its adaptability to refining needs.

The oils of the Appalachian field are principally of paraffin base and free from asphalt and sulphur. They yield by refining methods high percentages of gasoline and illuminating oils—the product in greatest demand.

The oils of the Ohio and Indiana fields contain some asphalt, but consist chiefly of paraffin hydrocarbons. They are contaminated with sulphur compounds and necessitate special treatment to purify them.

Illinois oils contain varying proportions of both

asphalt and paraffin and differ considerably as to specific gravity and distillation products. Sulphur is generally present, but rarely in such form as to necessitate special treatment for its removal.

Mid-continent oils vary in composition within wide limits, ranging from asphaltic oils, poor in gasoline and illuminants, to oils in which the asphalt content is negligible, the paraffin content relatively high and which yield correspondingly high percentages of the lighter products on distillation. Sulphur is present in varying quantities in the lower-grade oils, in certain of which, Healdton grade for example, it exists in a form requiring special treatment for its elimination.

Oils from the Gulf Field are characterized by relatively high percentages of asphalt and low percentages of the lighter gravity distillation products. Considerable sulphur is present, much of which, however, is in the form of sulphureted hydrogen, and is easily removed by steam before refining or utilizing the oil as fuel.

Oils from Wyoming and Colorado are in the main of paraffin base, suitable for refining by ordinary methods. Heavy asphaltic oils of fuel grade are also obtained in certain of the Wyoming fields.

California oils are generally characterized by

much asphalt and little or no paraffin, and by varying proportions of sulphur. The chief products are fuel oils, lamp oils, lubricants and oil asphalt, though low percentages of naphthas may be derived from certain of the lighter oils, notably those of Santa Maria, Sespe and Santa Paula fields, in the southern part of the state.

STATISTICS REGARDING PETROLEUM PRODUCTION

Statistics covering the production of petroleum and well drilling are given in the following tables:

World's Production of Crude Petroleum in 1914 in Barrels*

COUNTRY	PRODUCTION BARRELS	PERCENTAGE OF TOTAL
United States	265,762,535	59.63
Russia	67,020,522	29.00
Mexico	21,188,427	1.62
Roumania	12,826,579	2.11
Dutch East Indies	12,705,208	2.47
India	8,000,000*	1.32
Galicia	5,033,550	2.36
Japan	2,738,378	.48
Peru	1,917,802	.26
Germany	995,764	.23
Egypt	777,038	.02
Trinidad	643,533	.04
Canada	214,805	.42
Italy	39,548	.01
Other Countries	620,000	.03
Total,	400,483,489	100.00

*"Mineral Resources of the United States in 1914;" *U. S. Geological Survey*, page 901.

Production and Well Drilling Data of Petroleum in the United States for the Year 1914, in Barrels*

FIELD	PRODUCTION OF PETROLEUM IN BARRELS	WELLS COMPLETED				INITIAL DAILY PRODUCTION, BARRELS	
		OIL	GAS	DRY	TOTAL	TOTAL	AVERAGE PER WELL
Appalachian	24,101,048	4,272	1,320	1,257	6,849	44,716	10.5
Lima-Indiana	5,062,543	1,235	29	328	1,592	17,765	14.4
Illinois	21,919,749	1,191	32	356	1,579	39,268	33.0
Mid-continent	97,995,400	8,962	934	1,925	11,821	1,122,372	125.2
Gulf	13,117,528	395	12	178	585	243,609	616.7
California	99,775,327	512		47	559		
Colo. and Wy.	3,783,148	98†		39†	137†		
Other fields	7,792						
Total,	265,762,535						

*"Mineral Resources of the United States," U. S. Geological Survey, 1914, pages 905 and 909.

†Colorado, Wyoming and Utah.

Total Quantity in Barrels and Value of Marketed Production of Petroleum in the United States, and Average Price Per Barrel in 1913 and 1914, by States[¶]

STATE	1913			1914			AVERAGE PRICE PER BARREL
	QUANTITY	VALUE	AVERAGE PRICE PER BARREL	QUANTITY	VALUE	AVERAGE PRICE PER BARREL	
Alaska	(*)	(*)	(*)	(*)	(*)	(*)	(*)
California	97,788,525	\$45,709,400	\$0.467	99,775,327	48,066,096	\$0.482	
Colorado	188,799	174,779	.926	222,773	200,894	.902	
Illinois	23,893,999	30,971,910	1.296	21,919,749	25,426,179	1.160	
Indiana	956,095	1,279,226	1.337	1,335,456	1,548,042	1.159	
Kansas	2,375,029	2,248,283	.947	3,103,585	2,433,074	.784	
Kentucky	524,568	675,748	1.288	502,441	498,556	.992	
Louisiana	12,498,828	12,255,931	.981	14,309,435	12,886,897	.901	
Michigan	(*)	(*)	(*)	(*)	(*)	(*)	
Missouri	(*)	(*)	(*)	(*)	(*)	(*)	
New Mexico	(*)	(*)	(*)	(*)	(*)	(*)	
New York	988,191	2,284,307	2.409	938,974	1,760,868	1.875	
Ohio	8,781,468	17,538,452	1.997	8,536,352	13,372,729	1.567	
Oklahoma	63,579,384	59,581,948	.937	73,631,724	57,253,187	.776	
Pennsylvania	7,917,302	19,690,502	2.487	8,170,335	15,573,822	1.906	
Texas	15,009,478	14,675,593	.978	20,068,184	14,942,848	.745	
West Virginia	11,567,299	28,828,814	2.492	9,680,033	18,468,540	1.908	
Wyoming	2,406,522	1,187,132	.493	3,560,375	1,679,192	.472	
Other States	10,843†	19,263	1.777	7,792‡	14,291‡	1.834	
TOTAL	248,446,230	\$237,121,388	\$0.954	265,762,535	214,125,215	\$0.806	

*Included in other states.

†Includes Alaska, Michigan, Missouri and New Mexico.

‡Includes Alaska, Michigan and Missouri.

¶"Mineral Resources of the United States in 1914," U. S. Geological Survey, page 897.

COMPOSITION OF PETROLEUM

Petroleum is composed essentially of the chemical elements carbon and hydrogen united so as to form very complex compounds, hydrocarbons as they are called. Other chemical elements which are found in petroleum in small quantities are oxygen, sulphur and nitrogen.

A main line of distinction is generally drawn between petroleums of asphaltic base and those of paraffin base. Asphaltic petroleum yields on distillation a dark asphaltic residue which is readily attacked by acids and is dissolved by many solvents. Paraffin petroleums yield on distillation chiefly certain hydrocarbons called paraffins, and which are not readily attacked by acids and different solvents.

However, a sharp line of distinction cannot be drawn between asphaltic and paraffin oils. Nearly all asphaltic oils contain traces of paraffins, and many oils that are essentially paraffins contain asphaltic products; but rarely do crude petroleums of either class contain any considerable proportion of the other class. Some Mexican petroleum is of the mixed type, and, hence, is very hard to refine, or to satisfactorily separate into different portions.

All crude petroleums, whether of an asphaltic or paraffin character, are composed of different sub-

stances (hydrocarbons) that have different boiling points and that are of different weight. As the oil is heated the various hydrocarbons are given off, those of low-boiling point being distilled first and those of high-boiling point being distilled last. Anything like a complete separation of the compounds in petroleum presents considerable difficulty. The principle of the separation is to steadily apply heat to a container that holds the oil, letting gases and vapors that are given off pass through a pipe (condenser) that is kept cool by means of a constant circulation of water. The various products are thus condensed and put in separate receivers. The products thus obtained, having boiling points and weights between certain limits and other qualities, are given trade names under which they are marketed.

In the following tables are shown the proportions of gasoline, lamp oil, lubricating oil, asphalt and paraffin obtained from different crude oils:

Composition of Petroleum from Different Fields in the United States Per Cent by Volume*

LOCATION	GRAVITY BAUME	GASOLINE TO 150° C.	WATER, WHITE OIL 150° TO 300° C.	RESIDUUM, LUBRICATING OIL, PARAF- FIN & TAR	TOTAL
Cairo, W. Virginia	44.9	16.0	39.0	45.0	100.0
Parkersburg, W. Va.	30.0		17.0	83.7	100.7
Crawford Co., Illinois	35.5	8.0	39.0	53.0	100.0
Glenn Pool, Oklahoma	35.5	8.5	42.0	49.9	100.4

*Bulletin 452, U. S. Geological Survey, 1911, page 81.

Composition of Kansas Petroleum*

LOCATION	BAUMÉ, 60°F.	FLASH POINT °FAHR.	BURNING POINT °FAHR.	WATER %	GASOLINE to 150°C. BY VOLUME	KEROSENE 150° TO 300°C BY VOLUME	HEAVY OIL, VACUUM DISTILLATE, BY VOLUME	RESIDUE BY WEIGHT	LOSS BY WEIGHT
Peru	35.4	below 40	below 80	...	14.0	27.7	25.2	4.8	6.0
Paola	33.3	" 40	" 80	...	11.3	30.7	25.6	5.8	3.8
Caney	32.8	" 40	" 80	...	9.0	33.6	28.3	4.1	5.1
Chanute	32.0	" 40	" 80	...	8.7	31.4	28.1	3.4	3.4

*University Geological Survey of Kansas, "Special Report on Oil and Gas." Vol. 9, 1908,
pages 314 and 315.

Composition of California Petroleum*

OIL FIELD	SPECIFIC GRAVITY AT 150°C.	°BEAT 60F°	FLASH POINT °C.	BURNING POINT °C.	VISCOSITY 20°C. ENGLER	WATER SUPPLUR
Kern River	.9645	15.16	108	130	915.6	.5
Coalinga	.9498	17.52	88	110	341.5	.2
McKittrick	.9566	16.37	87	115	200.	2.0
Midway	.9570	16.34	78	99	518.1	.3
Sunset	.9701	14.37	89	113	527.2	1.7

OIL FIELDS	NAPHTHA UNRE-FINED	FUEL OIL	GASO-LINE RE-FINED	LAMP OIL RE-FINED	LUBBRI-CANTS REFINED	REFIN-ING LOSSES	DISTIL-LING LOSSES	AS-PHAL-TUM
Kern River		99.5		6.6	39.2	5.9	.5	
Coalinga		99.7		11.0	43.6	6.8	.7	
McKittrick		98.0		13.2	41.0	6.6	.8	
Midway	.1	99.6	.1	14.4	39.7	6.6	.7	
Sunset	.3	97.9	.3	8.3	37.9	5.8	.7	

*Allen, I. C., Jacobs, W. A., and Burrell, G. A., "Physical and Chemical Properties of the Petroleums of the San Joaquin Valley of California," *Bulletin 19, Bureau of Mines.*

The following table shows the fractions obtained from Pennsylvania and Cushing, Okla., crude oil, and their gravity and value.*

Pennsylvania Crude

FRACTION	GRAVITY °B	AMOUNT	UNIT PRICE	VALUE
Gasoline	66.2	25 Gal.	@ \$.12	\$3.00
Turp. Subt.	51.9	15 "	@ .085	1.28
Kerosene	45.7	15 "	@ .05	.75
300 Oil	40.3	15 "	@ .05	.75
Non. Vis. Neut.	35.5	12 "	@ .045	.54
Vis. Neut.	31.0	8 "	@ .12	.96
S. R. Cyl. Stock	25.0	8 "	@ .12	.96
Ref. Parf. Wax	....	2 "	@ .25	.50
Total,		100 Gals.		\$8.74
5 per cent loss gallonage in manufacture,				.44
Total value of products,				\$8.30

Cushing Crude from Oklahoma

FRACTION	GRAVITY °B	AMOUNT	UNIT PRICE	VALUE
Gasoline	65.7	30 Gals.	@ \$.12	\$3.60
Turp. Subt.	48.2	20 "	@ .085	1.70
Kerosene	40.1	15 "	@ .03	.45
Gas Oil	34.6	15 "	@ .02	.30
Vis. Neut.	28.	10 "	@ .10	1.00

*Compiled by Harry Willock, Secretary of the Waverly Oil Company, Pittsburgh, Pa.

GASOLINE

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FRACTION	GRAVITY	AMOUNT	UNIT	PRICE	VALUE
S. R. Cyl. Stock	24.	6 Gals.	@	\$.08	\$.48
Ref. Parf. Wax	0.5	0.5 "	@	.25	.13
Asphalt	....	3.5 "	@	.06	.21
Total,		100.0 Gals			\$7.87
5 per cent gallonage loss in manufacture,					.39
Total value of products,					\$7.48

The above figures show that the products from 100 gallons of Pennsylvania oil only exceed in value the products of a like number of gallons of Cushing crude by \$.82, although Cushing crude sells for about one-half as much as Pennsylvania crude at the wells.

Composition of Petroleum of Texas-Louisiana Coastal Plain*

PRODUCT	SPINDLE TOP AND SOUR LAKE CRUDE	BATSON CRUDE
	PER CENT	PER CENT
Gasoline	1.8	6.5
Kerosene	17.1	20.4
Solar	15.4	14.4
Lubricating	52.2	46.7
Asphalt	7.5	6.0

*Oil fields of the Texas-Louisiana gulf coastal plain. *U. S. Geological Survey, 1906, Bulletin 282, page 130.*

**Comparative Tests of Three Different Samples
of Crude Petroleum; also Specific Gravities,
of the Fractions Obtained from same
by Distillation***

COLOR SULPHUR SP. GR.	PENNSYLVANIA		ILLINOIS		OKLAHOMA	
	YELLOW		NEARLY BLACK		DARK GREEN	
	0.078%		0.205%		0.283%	
	41.9° Bé.		33.8° Bé.		37.5° Bé.	
DISTILLATION	%	BÉ. GR.	%	BÉ. GR.	%	BÉ. GR.
1st fraction	10.0	70.0	10.0	60.5	10.0	67.9
2d fraction	10.0	58.8	10.0	51.5	10.0	56.4
3d fraction	10.0	52.8	10.0	45.6	10.0	50.6
4th fraction	10.0	48.1	10.0	40.6	10.0	45.1
5th fraction	10.0	43.7	10.0	36.7	10.0	40.5
6th fraction	10.0	42.0	10.0	34.3	10.0	36.6
7th fraction	10.0	39.3	10.0	34.2	10.0	34.2
8th fraction	10.0	38.9	10.0	34.6	10.0	33.9
9th fraction	10.0	38.8	10.0	36.8	10.0	36.6
10th fraction	8.5	36.9	6.0	21.3	5.0	36.9
Coke & Loss	1.5		4.0		5.0	
Total,	100.0		100.0		100.0	

Comparisons of gasoline, lamp oils, lubricating oils, etc., according to a fixed range of temperatures

*Industrial Chemistry, Allen Rogers, 1915, page 504.

of distillation, as in the foregoing tables, give but an approximate idea of the actual composition of the oil, although, such divisions are useful for rough comparisons. Sometimes those products that are distilled from crude oil at temperatures up to 350° F. are called gasoline; those that are distilled at temperatures between 350° F. and 570° F. are called lamp oils or illuminating oils, or naphtha.

EARLY HISTORY OF GASOLINE

Little was known about the properties of crude oil in the early days of its discovery in Pennsylvania, certainly no one dreamed of its tremendous potential possibilities. At first it was used for medicinal purposes. Next it was discovered that a certain portion of it could be removed by distillation and could be used as a fuel in lamps. A considerable portion of this distillate however was of so light and inflammable a character that it caused many explosions. Hence, the next step was to remove this light portion. This latter portion was gasoline and that remaining portion the kerosene, used to-day in lamps as an illuminant. The result was that gasoline became a waste product and remained so until the gasoline vapor lamp and stove were perfected. But these articles only consumed a limited quantity

of gasoline, and it was only with the advent of the automobile that gasoline came into extensive use. At the present time gasoline, once thrown away, is in great demand, and new uses are demanded for the by-product kerosene. In fact, "What to do with Kerosene" is a great problem at the present time with the refiner, and serious efforts are being made to devise apparatus and methods of changing it into products that can be utilized commercially. It is too high grade to be used as fuel oil, that is, oil for burning in locomotives and under marine boilers, etc., and it is of too low grade for general use in automobile engines.

The gasoline of the United States, the benzine of the European continent and the petrol of England, are one and the same thing; *i. e.*, synonyms for the same petroleum distillate.

PRESENT SHORTAGE OF GASOLINE

The reason for the present shortage of gasoline and consequent increase in price is that the consumption of gasoline is rapidly increasing, while the production of crude oil, from which it is principally derived, is generally regarded as having reached its maximum.

The figures showing the production of gasoline

as given in the following table by Secretary Lane, of the Department of the Interior, were compiled in response to a United States Senate inquiry into the production, consumption and price of gasoline. (A) U. S. Res. 40, 1916. The quantities refer to barrels of forty-two gallons each.

PRODUCTION AND EXPORTATION OF GASOLINE

(In barrels of 42 gals.)

GASOLINE			
YEAR	PRODUCTION	EXPORTED	DIFFERENCE
1899	6,680,000	297,000	6,383,000
1904	6,290,000	594,000	6,326,000
1909	12,900,000	1,640,000	11,260,000
1914	34,915,000	5,000,000	29,915,000
1915	41,600,000	6,500,000	35,100,000

Secretary Lane's report states that one reason for the sudden, extraordinary rise in the retail price of gasoline has been the increase in exports due to the war. The exports of 1914 exceeded those of 1913 by 500,000 barrels, and the exports of 1915, exceeded those of 1914 by 1,500,000 barrels. He adds that increased gasoline consumption within the United States was twenty-five per cent greater during 1915 than 1914, and that there will be a like increase during 1916.

During 1915 refiners had gasoline in storage amounting to at least 2,000,000 barrels. Inquiry to-day indicates that there is little gasoline in storage.

The decline of the Cushing, Oklahoma, oil field has its effect on the gasoline shortage. This pool declined from more than 300,000 barrels in April, 1915, to less than 100,000 barrels in January, 1916. This decline was partially compensated for by an increased production from other pools, the gasoline content of which production was, however, from five to seven per cent less than that of the Cushing crude.

Authorities agree that the automobile and other internal combustion engines are primarily responsible for the increased consumption of gasoline. The statement has been made that the horsepower of gasoline internal combustion engines in the United States is more than twice that of all engines in the United States driven by steam. The following figures indicate the increase in the number of automobiles used from 1899 to 1916. These figures were compiled by the National Automobile Chamber of Commerce, and are based on State registration.

Number of Automobiles Used From 1899 to 1916

YEAR	NO. OF AUTOMOBILES
1899	10,000
1905	85,000
1910	400,000
1911	600,000
1912	677,000
1913	1,010,483
1914	1,253,875
1915	2,075,000
1916	2,950,000

Various authorities estimate that the average consumption per automobile equals from ten to fourteen barrels per annum. This figure has been checked against inspection figures of States inspecting all gasoline sold.

The average gasoline content of crude oil of various fields, the total production to date, including the year 1915, and the estimated percentage of exhaustion, are shown in the following table:

Gasoline Content of Oil from Different Fields and Products

OIL FIELD	GASOLINE (Per cent)	PRODUCTION INCLUDING 1915 (Millions of barrels)	ESTIMATED PER- CENTAGE OF EXHAUSTION OF OIL FIELD
Appalachian	25	1,150	74
Indiana	12	438	93
Illinois	18	251	60
Mid-Continent	18	617	50
North Texas	20	44	41
Northwest La.	20	58	47
Gulf Coast	3	236	79
Colorado	20	11	79
Wyoming	20	12	5
California	2½	835	34

A few years ago this country supplied the world with gasoline, while in 1915 our exports were only one-fifth of the total amount required for supplying the demand in foreign countries. If the home consumption continues to grow anything like the same rate as in the last few years, the United States will soon have no gasoline to export. Even now a considerable quantity of gasoline is imported into this country on the Pacific coast from the Dutch West Indies, mostly from Borneo and Java. While,

therefore, gasoline is being exported on the Atlantic coast, some is being imported on the western shores.

In the ten years from 1902 to 1912, the number of vehicles using gasoline for motive power has been increased sixty-fold, while the production of the grades of crude petroleum, suitable for the extraction of gasoline, increased only one hundred per cent. At the present time the average horsepower for vehicles using gasoline has increased considerably. On the average, the horsepower requirements for each automobile was probably one hundred per cent greater than in 1902.

The discrepancy between the demand and production has been made up in several ways:

(1) A considerable amount of crude oil suitable for producing gasoline has been imported.

(2) Efficiency and, therefore, the economy of the motors has been very much improved.

(3) A very much heavier "gasoline" is now being used than formerly.

(4) A considerable amount of gasoline is being obtained from casing head natural gas.

(5) "Cracking" processes for producing more gasoline from crude oil have been introduced.

YEAR	PRICE OF GASOLINE	
	PER GALLON.	CENTS
1897	7.4	
1898	7.4	
1899	10.9	
1900	10.4	
1901	9.7	
1902	10.8	
1903	12.4	
1904	11.4	
1905	10.7	
1906	10.5	
1907	10.2	
1908	10.0	
1909	10.0	
1910	9.5	
1911	10.0	
1912	14.0	
1913	18.0	
1914	16.0	
1915	15.0	
1916	27.0	

REFINING CRUDE OIL

Three methods are used in distilling oil of the Pennsylvania type, namely, dry or destructive distillation, steam distillation and vacuum distillation.

Dry or destructive distillation causes cracking or decomposition, and is conducted by means of direct fire heat. The distillation is usually carried to coke. The process is best adapted to petroleum that is unfit for cylinder stocks.

The increase in the price of gasoline, between the years 1897 and 1916, is shown in following table:

Steam distillation makes it possible to distill oil at lower temperature than by dry distillation, and is, therefore, used to prevent decomposition. The stills are of the same type as those used in dry distillation, except that they are well insulated in order to prevent the vapors from condensing on the sides and falling back into the superheated oil. Steam is introduced into the body of the oil in the still, and the distillation controlled by fires beneath the stills.

Vacuum distillation is sometimes used in conjunction with the process of steam distillation. A partial vacuum is created by means of a pump, thereby causing the hydrocarbons to distill at low temperatures. This method requires heavier stills, and although the results are said to be superior, the difference is not usually considered great enough to warrant the cost of installation and operation.

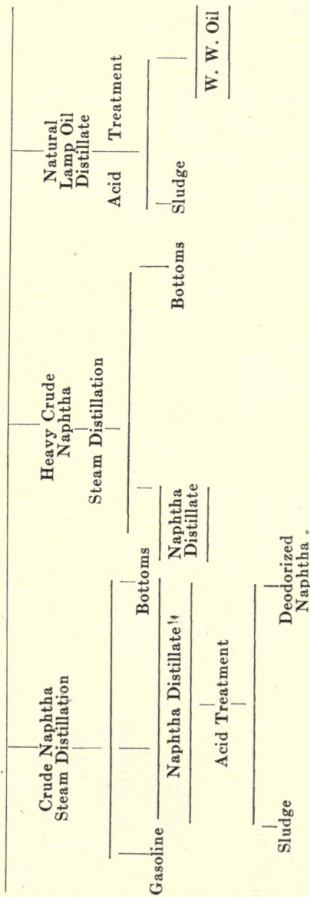
The "cracking" and steam, or fractional distillation, represent two distinctly different methods of refining. If a refiner desires to produce the maximum amount of gasoline and lamp oil, he will use the method of "cracking" distillation. But if he wishes to produce the maximum yield of heavy

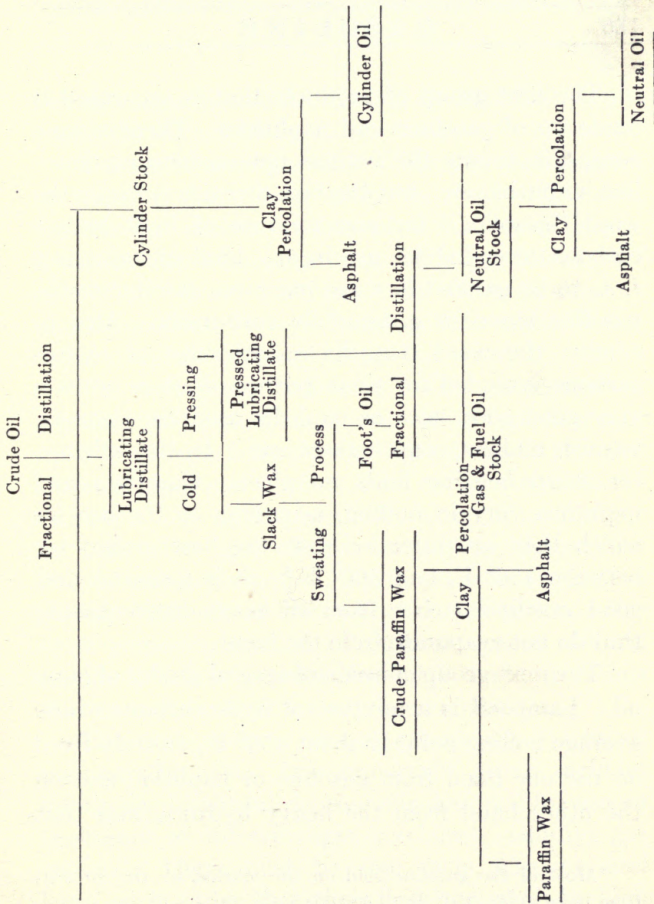
lubricating oils and petroleum asphalts, he will use the method of steam or fractional distillation.

The following scheme of petroleum fractionation is that used by the Atlantic Refining Company.* (Standard Oil Company.)

*Prepared by F. C. Robinson, Chief Chemist, Atlantic Refining Company, and published in "Oildom," January, 1916, Vol. 6, page 20.

Figure 2 — Distillation Diagram of Crude Oil





The first group of products that is separated is made up of gasolines and naphthas. There is some confusion among the various names, benzine, gasoline, naphtha, etc., but the best practice is to use the word "gasoline" for any mixture of light hydrocarbons intended for use in any kind of vaporizer, *i. e.*, to be gasified in a gas machine, gasoline torch, gasoline stove or automobile carburetor. Also to confine the word naphtha to mixtures of hydrocarbons intended for some purpose that requires a very good odor, such as naphtha used by cleaners, varnish makers, soap makers, etc. In this scheme, the word benzine finds no place. Gasolines and naphthas vary in boiling, according to the use for which they are intended, but the best grades lay between 150° F. and 300° F.* It is essential that good gasoline be free from all heavy hydrocarbons that do not evaporate from the hand.

The next group consists of several grades of lamp oil. Lamp oil is a mixture of hydrocarbons whose average boiling point is about 450° F., entirely freed on the one hand from gasoline or naphtha, and on the other hand from the heavy hydrocarbons that

*Most of the gasoline sold on the market at the present time boils up to 350° F. (Author.)

belong to gas oil and lubricating oil, and that would make the oil act badly in the lamp.

The next class is gas oil. While oils of all degrees of volatility have been used, the most economical for the gas maker consists of a mixture of heavy hydrocarbons with an average boiling point of 600° to 650° F. It must be practically free from gasoline and lamp oil on the one hand and from the heavy lubricating oils and asphalt on the other.

The next group is fuel oil. This oil occupies a peculiar position. It must not contain gasoline and must be of such a consistency that it can be pumped through pipes and burners, but, except for these restrictions, one oil is practically as good as another for fuel. The light oils have a slightly higher heat of combustion per pound, but the heavier oils have a slightly higher heat of combustion per gallon. For some purposes, such as oil engines, special oils are required, but, in general, fuel oil is made up of oils that cannot be used for any better purpose.

The next group is that of spindle oils — neutral and paraffin oils. This important group includes hundreds of light lubricating oils designed for use on thousands of different light machines, including gas engines. They must be free from gasoline and lamp oil in order that their flash test shall be high

enough to prevent loss by evaporation. The important point to that is that they shall have the proper viscosity for the use intended.

The next group is that of steam cylinder oils, which consist of the heaviest hydrocarbons contained in certain crude oils. In this case also the flash must be such that the oils will not evaporate in a steam cylinder, and must have the proper viscosity for the use intended at the temperature of the cylinder.

The next group — paraffin wax — consists of a mixture of hydrocarbons of the paraffin series about $C_{23}H_{48}$ to $C_{35}H_{72}$. The commercial article is rated according to the melting point, which varies from 100° to 135° F.

The next group, vaseline or petroleum, consists of the higher member of the paraffin series which settle from crude oil mixed and inseparable from some of the oily constituents of the crude. It is marketed as the light-colored material used in medicine and for toilet purposes, or as the dark-colored sticky material used in large quantities by the makers of oiled paper.

The next group, the dust laying oils, consists of petroleum asphalt in solution in oils similar to gas oil. The basic idea in their manufacture is that the solvent will slowly evaporate, leaving the dust particles covered with a sticky adherent film. These

oils have proven successful as a cheap means of laying dust.

The next group, the road binders, consists of petroleum asphalt properly fluxed with heavy petroleum oils that will not evaporate, and of such qualities that they will bind the road materials together both in summer and winter.

The next group, coke, contains but one member. This material being almost entirely free from ash, is used very extensively by makers of electric carbons.

These are the desired products. Next taking up the crude oils from which they are obtained.

There are about as many varieties of crude oil as there are oil fields, but the refiner recognizes three distinct types, because each type must be handled by different methods, *viz.*: (1) The paraffin base crude similar to that found in Pennsylvania and West Virginia, and being essentially light-colored crudes containing paraffin. (2) Asphalt base crudes similar to those found in Texas and California, and being essentially black and containing no paraffin. (3) Mixed base crudes similar to those found from Ohio to Oklahoma, and being essentially mixtures of paraffin and asphalt base crudes.

In order to obtain some idea of the chemical and

physical nature of the crude oil one can imagine a sample of mixed base crude brought into the laboratory for a thorough examination. The chemist would probably distill the sample in a vacuum or in some similar manner in order to avoid destructive distillation and would save the various fractions separate. He would not distill off more than ninety per cent, because the heaviest ten per cent cannot be distilled without breaking it down into simpler molecules. He will then start to examine the various fractions.

The first fraction will be a light mobile mixture of hydrocarbons whose average boiling point is about 227° F. The second is a slightly darker and a slightly less mobile mixture of hydrocarbons whose average boiling point is about 295° F. The third cut again darker, heavier and less mobile, boiling point 369° F. The fourth cut still heavier and 460° F. boiling point. The fifth cut is about 530° F. boiling point. The remaining cuts are increasingly heavier, more viscous and darker in color, and the residue in the still is a soft pitch.

The chemist now recognizes four groups of compounds in each fraction that the refiner may have to isolate or remove.

He can isolate one group by bone black or

fuller's earth. When isolated in a pure state it is a jet black, brittle compound which is very similar to the purest asphalt.

A second important class of compounds is the material soluble in strong sulphuric acid. The low-boiling members of this group represent the odor-bearing compounds of the crude, while the higher members are rich in sulphur, and are easily oxidized. The refiner frequently has to remove a portion of this class.

A third group is that of aromatic hydrocarbons, benzol, naphthalene, anthracene, etc., which may be removed by agitating the oil with fuming sulphuric acid.

The remainder of the crude oil unattacked by fuming sulphuric acid is made up of the naphthene and paraffin series.

4. Now, starting with crude oil, it is the task of the refiner to isolate the commercial products. The processes are outlined on two charts, Figures 1 and 2, and they represent two distinctly different methods of refining, so much so that one refiner may decide to use one of them to the exclusion of the other, or he may decide to use both of them.

He will be guided in this decision by his local conditions. If it be his desire to produce the maxi-

imum amount of gasoline and lamp oil, he will use the method marked "Cracking Distillation." If, on the other hand, he wishes to produce the maximum yield of the heavy lubricating oils and petroleum asphalts, he will use the method marked "Fractional Distillation," which means that he will simply separate from the crude oil the various fractions which compose it, while the refiner who uses the cracking process actually breaks down these heavy fractions by destructive distillation in a manner similar to the production of benzol and gas by the destructive distillation of coal.

The first step in the cracking process is the cracking distillation. The crude oil is pumped into stills containing five hundred to one thousand barrels, which consist simply of horizontal steel cylinders made of sheets of half-inch boiler steel riveted together and provided with manholes on top and ends; with pipe for pumping oil into the stills; with combustion chamber underneath; with the fractional air condensers and with water condenser, and with pipe for conducting away the gases evolved during the distillation.

Such a still is nearly filled with oil, *i.e.*, mid-continent crude oil, and the fires are lighted. When the temperature of the oil in the still has reached

175° to 200° F. some gases, consisting largely of butane and pentane, are given off and presently the highest naphtha starts to distill over. The firing is continued; the temperature in the still becomes gradually higher; the distillate becomes gradually heavier until the temperature in the still reaches about 325° F., at which point about six or eight per cent of crude naphtha (200° F. boiling point) has distilled over. This is set aside as crude naphtha.

The distillation is continued until the temperature in the still has reached about 475° F. for crude heavy naphtha, and represents thirteen to fifteen per cent of the crude, and has an average boiling point of about 300° F. The distillation is then continued until the temperature in the still has reached about 625° F. for natural lamp distillate, which represents about sixteen to eighteen per cent, and has an average boiling point of about 450° F.

When the still has reached this temperature, cracking or destructive distillation sets in. The fires are slackened in order to distill very slowly, and this slow distillation is continued until the temperature in the still reaches 675° to 700° F., producing a distillate with an average boiling point of about 550° F., but containing some gasoline, some lamp oil and much heavier oil which is designated as

gas and fuel oil stock. The yield of this oil is about twenty per cent.

This cracking distillation is very different from an ordinary fractional distillation; heavy molecules have been broken down into lighter ones by submitting them to temperatures at which they are unstable.

There yet remains in the still a heavy black tar representing about forty-two per cent of the crude oil. This is the source of paraffin wax, and the line of lubricating oils called paraffin oils. It is no longer desirable to carry on a cracking distillation because this would result in the destruction of the valuable products desired. The distillation is continued in such a way as to avoid cracking as much as possible (is distilled fast), either in the same still or, more commonly, in separate smaller stills called tar stills.

This tar still distillation is carried on very rapidly in order to produce the maximum yield of paraffin distillate (about twenty-two per cent). In addition to the paraffin distillate, there is also produced by destructive distillation about fifteen per cent of cracked distillate. At the end of the distillation the stream becomes so heavy that it will sink in water, and is then known as wax tailings,

which amounts to about one per cent of the crude oil. When the distillation stops there remains in the still nothing but coke, amounting to about four per cent of the crude oil.

Now, taking up the various fractions: first, the crude naphtha. This is again distilled; first, in order to separate it into the various gasolines and naphthas that compose it, and, secondly; to separate it from the small amount of bottoms or light lamp oil that it contains. This is done in a still which is heated by steam, usually by injecting live steam directly into the gasoline.

When the distillation starts, some gas is given off; then the lightest distillate appears at the trap, usually about 90° Baumé gravity. The distillate gradually gets heavier until all the gasoline has distilled off. The receiver is then changed and the naphtha distillate is separated. At this point about ninety per cent has distilled off, leaving a bottom about ten per cent. This bottom is essentially lamp oil and is used as such. The heavy crude naphtha is handled in the same manner, except that it contains little or no gasoline and contains about fifty per cent of bottom or lamp oil. The cracked distillate is also distilled with steam to remove about four per cent of crude naphtha.

Up to this point all the operations have been different types of distillation. The next step in handling the naphtha distillate from both sources, the lamp oil distillate and the crude naphtha from cracked-distillate and the test cracked distillate, is the acid treatment. It will be seen in the crude diagrams that all the fractions contain a certain percentage of material attackable by sulphuric acid, so that this reagent affords a convenient means for removing color and odor from the remainder of the hydrocarbon distillate.

In practice, the naphtha distillates are agitated with about five per cent by volume, and the lamp oil distillates with about one and five-tenths per cent of sulphuric acid (oil or vitriol) for about a half hour. The color- and odor-bearing compounds combine with the acid, producing a heavy black viscous mass called acid sludge, which settles to the bottom of the vessel. The sludge is drawn off and the oil washed with water and alkali to remove all traces of acid, and is then ready for the market.

The sludge from all acid treatments is separated into unstable products. This is accomplished by boiling it with water, which results in the dilution of the acid and renders it incapable of holding in solution the impurities.

The weak acid (30° to 50° Baumé) settles to the bottom, is drawn off and reconcentrated. The upper layer consisting of the impurities is known as acid oil. This acid oil is separated by fractional distillation into a light distillate which consists of all the evil odors that the original distillate contained and a residue consisting of the asphaltic compounds that were removed by the acid.

There have been given now all the processes used in the manufacture of naphtha and lamp oil.

The next general subject is the handling of the paraffin distillate, which is the direct source of the paraffin wax and all of the paraffin oils. The first step is the process of cold pressing. The distillate is first cooled from 20° to 30° F. by pumping through pipes surrounded by cold brine, thereby causing the paraffin wax (amounting to about ten per cent of the distillate) to solidify. This solid ten per cent mixed with ninety per cent liquid oil forms a soft mush which is pumped through a filter press. That which stays in the press is called the slack wax and amounts to about twenty per cent of the paraffin distillate. The eighty per cent that goes through is called pressed distillate.

The slack wax, consisting of about equal parts of oil and wax, is then put through a process peculiar

to the oil business, known as the sweating process. It consists of cooling the mixture until it has become a solid cake and then very gradually warming it. The crystals of the paraffin form a network through which the oil is distributed, and when the mass is warmed the oil sweats out and drips away. It always carries with it some wax in solution, but the final result is that the oil all sweats out, leaving the paraffin wax in a fairly pure state.

This sweating process separates the slack wax into crude paraffin wax and what is known as Foot's oil. The latter still contains much paraffin, which is removed by putting it again through either the cold pressing or sweating process.

The crude paraffin wax is then put through another process that is peculiar to the oil business, that of clay or bone black percolation, for the purpose of removing asphaltic coloring matter and thereby changing the crude paraffin to refined colorless paraffin. The clay used for this purpose has properties similar to those of bone black, *i. e.*, it absorbs and retains tarry and asphaltic compounds. It is found in Florida and Georgia, where it is mined, roasted, broken up and sifted. It is very porous and light, weighing only about 2.3 as much as water. This clay or fuller's earth, as it is com-

monly called, is put into large upright cylinders holding ten to twenty tons, and provided with a finely-perforated bottom. The crude wax is melted and poured on top of the clay. It trickles down through the clay bed and passes through the perforated bottom.

The first drippings from such a filter bed are absolutely colorless, but as the filtration progresses, the color becomes more and more like crude wax. A ton of clay yields five or six tons of first-quality paraffin wax. The amount of asphalt or coloring matter retained by the clay is exceedingly small, and is removed by burning the clay in a cement kiln of the usual type, thus regenerating the clay for subsequent use.

It was explained that the paraffin distillate is the source of paraffin wax and light lubricating oils. The various steps in the preparation of paraffin have also been described. The light lubricating oils are made from the filtrate from the cold presses — the pressed paraffin distillate — by putting it through the process of fractional distillation, thereby separating it into a distillate of light oils that go to make up the gas and fuel oil stock, and a residue in the still called paraffin oil stock, representing from fifteen per cent to fifty per cent of the charge of the still, depending on the quality desired.

This type of distillation is also peculiar to the oil business. The desired product is a heavy oil, so that all cracking must be avoided in order to produce the maximum yield of this oil. The result is accomplished by using the very important process of distillation with bottom steam or fractional distillation. A still is charged with the pressed paraffin distillate and fires are lighted. The temperature in the still rises, and when it has reached about 400° F. the distillation begins.

Shortly after this the live steam is injected into the oil through perforated pipes placed near the bottom of the still. No water accumulates in the still because the temperature is too high. The steam passes upward through the oil as an inert gas and passes through the condenser with the oil vapors, and is condensed there with the oil. The effect of this current of steam through the oil is exactly that of a vacuum distillation; *i. e.*, it lowers the boiling point of the oil in distillation and allows a heavy oil to be distilled at temperatures below the temperature of destructive distillation. It will be noted that cracking sets in about 630° F. Without the use of steam, the distillation in question would require that the still be heated to about 750° F. This would result in the destruction of the desired oil. With

steam it can be carried on with a maximum temperature of 600° F., thus entirely avoiding destructive distillation.

The paraffin oil stock is a dark-colored unattractive-looking material which is transformed into the valuable paraffin oils of commerce by treating with sulphuric acid in the manner already described. The treating loss in this case is from ten per cent to thirty per cent. The whole cracking process described thus far is designed to produce the maximum yield of gasoline and lamp oil from crudes containing asphalt.

Now taking up the method of refining the light-colored non-asphaltic crude oils from which the valuable cylinder oil may be made. The object in this case is to avoid all destructive distillation, in order to produce the maximum yield of the very heavy lubricating oils. The still is charged with the crude oil, fires are lighted, the crude naphtha is distilled off as in the other distillations; but when the temperature is well above the boiling point of water, steam is injected into the oil as before described.

Under these conditions the crude naphtha has distilled off when the temperature in the still has reached about 280° F., while without steam the still

temperature was about 375° F. The yield from this kind of crude is about thirteen per cent.

The heating is continued, more and more steam being injected, the distillate becoming heavier and heavier, until the heavy crude naphtha has distilled off. At this point the temperature in the still has reached about 330° F., while without steam at this point the temperature was 475° F. The yield of this oil is about thirteen per cent.

TESTING GASOLINE

Gasoline for use in automobiles must meet several requirements. It must be readily volatile, *i. e.*, pass into the vapor form readily, especially in cold weather. This is particularly desirable when the engine is first started and when the different parts are cold. After the engine and carburetor have run a while and the various parts have become heated, very low-grade gasoline or naphtha can be used, even kerosene. But it is difficult to vaporize these substances when cold, and thus introduce them into the engine cylinders.

Gasoline should not have too wide a range of boiling points, and especially the upper boiling points should not be too high. When this is the case, it is difficult to satisfactorily vaporize the gasoline. The

portions of low-boiling point vaporize satisfactorily, but those of high-boiling point do not; hence, the gasoline does not give uniform service.

If much of the high-boiling portions are present, they have a tendency to carbonize the motor and cause smoking.

The more of the low-boiling parts that are present, the easier it is to start a motor, and the latter responds more quickly to any additional amount that may be introduced into the cylinders. On the other hand, the high-boiling parts give more power.

Gasoline is practically always bought on the specific-gravity basis. Baumé Scale. That used in pleasure cars is not the same as that used five years ago. One can scarcely buy high-test gasoline now except at a high price. It has come down in test from 72° Bé. to 60° . Most of that sold at present ranges from 58° to 62° .

DETERMINATION OF THE GRAVITY OF GASOLINE

The test of the gravity is made with an instrument called a hydrometer. This is an instrument made of glass and consists of three parts: (1) The upper part, a stem or fine tube of uniform diameter; (2) A bulb or enlargement of the tube containing

air, and (3) A small bulb at the bottom containing shot or mercury that causes the instrument to float in a vertical position. The graduations are figures representing either specific gravity, or in numbers of an arbitrary scale, as Baumé's, Twaddell's, Beck's and other hydrometers.

The gravity is not necessarily a good criterion of the suitability of a gasoline for a particular purpose, as for an automobile. A result will be obtained with the hydrometer that shows the average of the gravities of the different compounds that are in the gasoline. For instance, a very light gasoline of 85° Bé. may be mixed with naphtha of 50° Bé., resulting in a mixture having a gravity of 62° Bé., ordinarily considered a suitable automobile fuel. But in the 50° naphtha there may have been contained some very high-boiling compounds, and in the 85° gasoline some very low-boiling ones, so that the mixture has a wide range of boiling points, and considerable difficulty follows in using the mixture. Much difficulty on this account resulted in the early days of blending "Casinghead" gasoline with low-grade naphthas.

FRACTIONATION ANALYSIS OF GASOLINE

Better information regarding a particular gasoline can be obtained from the fractionation analysis of

gasoline. By this process the gasoline can be divided into different parts or fractions, and good information obtained regarding the range of boiling points.

The fractionation analysis or distillation test of a sample of gasoline on a laboratory scale is made in essentially the same manner as the commercial large-scale distillation of crude oil is conducted. The gasoline is slowly heated, and, as the temperature rises, different portions of the distillate are collected in different receivers. In this way one can determine as clearly as is desired the proportions of the sample that boil at different temperatures. Gasoline, like crude oil, is a liquid mixture containing many different compounds of different boiling points.

The following table shows the fractionation analysis of several different grades of gasoline that were purchased on the open market.

SEPARATION OF DIFFERENT GRADES OF GASOLINE INTO FRACTIONS BY DISTILLATION

60-62° Bé. Gasoline

TEMPERATURE FAHRENHEIT SCALE	PERCENTAGE BY WEIGHT OF DIFFERENT FRACTIONS BOILING AT DIFFERENT TEMPERATURES		SPECIFIC GRAV- ITY OF DIFFERENT FRACTIONS (WATER = 1)	GRAVITY OF DIFFERENT FRACTIONS Bé. SCALE
Up to 122°	3.3	.64	90.1	
122° to 155°	11.3	.68	77.4	
155° to 212°	26.8	.71	66.6	
212° to 257°	26.8	.74	60.2	
257° to 302°	19.1	.76	55.4	
302° to 347°	9.1	.77	51.1	
Residue	2.5	.80	45.0	
Loss	1.1			
Total,	100.0			

73-76° Bé. Gasoline

Up to 122°	18.9	.63	91.2
122° to 155°	28.9	.67	79.3
155° to 212°	30.4	.71	68.3
212° to 257°	16.2	.73	61.8
Residue	4.6	.76	55.4
Loss	1.0		
Total,	100.0		

CASINGHEAD GASOLINE (WEATHERED)

Up to 122°	30.0	.63	92.2
122° to 155°	28.5	.67	80.2
155° to 212°	24.4	.71	67.5
212° to 257°	9.8	.73	61.0
Residue	6.7	.77	52.5
Loss	.6		
<hr style="width: 20%; margin: 0 auto;"/>			
Total,	100.0		

BLENDED GASOLINE (CASINGHEAD GASOLINE AND REFINERY GASOLINE)

PERCENTAGE
BY WEIGHT OF
DIFFERENT

FRACTIONS

SPECIFIC GRAV-

GRAVITY OF

TEMPERATURE FAHRENHEIT SCALE	BOILING AT DIFFERENT TEMPERATURES	ITY OF DIFFERENT FRACTIONS (WATER = 1)	DIFFERENT FRACTIONS Bé. SCALE
Up to 122°	7.9	.63	92.2
122° to 155°	8.9	.68	77.4
155° to 212°	16.4	.72	65.8
212° to 257°	23.4	.74	59.5
257° to 302°	21.9	.76	54.7
302° to 347°	15.0	.77	50.4
Residue	5.9	.80	44.8
Loss	.6		

The following fractionation analysis represents a sample of gasoline recently purchased by the author of this book. The seller represented it to be 68° to 70° Bé. The price was twenty-seven cents per gallon. It actually tested 64.5° Bé.

FRACTIONATION ANALYSIS OF GASOLINE BOUGHT AS 68° to 70° BÉ.

Actual Specific Gravity — 64.5° Bé.

TEMPERATURE FAHRENHEIT SCALE	PERCENTAGE OF DIFFERENT FRACTIONS BOILING AT DIFFERENT TEMPERATURES
Up to 122°	7.7
122° to 155°	6.1
155° to 212°	7.7
212° to 257°	6.5
257° to 302°	24.4
302° to 347°	28.7
347° to 405°	11.9
Residue	3.0
Loss	1.0

It will be observed that a large proportion of the above gasoline boiled above 300° F., about forty-four per cent.

This is typical of some of the gasoline that is being sold on the market to-day as high-grade gasoline. A user of this gasoline, the owner of a small four-

cylinder car, complained about his difficulty in starting his car on a moderately warm day. The gasoline would not evaporate from the hand except on very long standing. It contained considerable kerosene.

For comparison the fractionation analysis of a sample of kerosene is shown in the following table:

FRACTIONATION ANALYSIS OF KEROSENE Specific Gravity 47° Bé. at 60° F

TEMPERATURE FAHRENHEIT SCALE	PERCENTAGE OF DIFFERENT FRACTIONS BOILING AT DIFFERENT TEMPERATURES
Up to 257°	1.8
257° to 302°	10.0
302° to 347°	9.4
347° to 405°	22.4
405° to 445°	24.2
445° to 485°	13.5
485° to 531°	15.2
Residue	2.0
Loss	1.5
Total,	100.0

The wide difference between the fractionation analysis of kerosene and gasoline is noticeable. In the case of kerosene only about twelve per cent

boiled below 300° F., while practically all of good gasoline should boil below 350° F., at the most.

“ CRACKING ” PROCESSES

The supply of gasoline by simple fractional distillation does not equal the demand. Hence, recourse has been had to some process of increasing the production of gasoline from crude oil, and a process that is used is the so-called “Cracking” process, a widely used term for destructive distillation. Some “cracking” or destructive distillation occurs in ordinary distillation processes, but usually in comparatively small amount.

It has been known for a long time that when petroleum is subjected to high temperatures, and especially when heated to high temperatures and high pressure both, that “cracking” occurs, meaning that some of the heavy and higher boiling constituents break up into lighter compounds. In other words a greater yield of gasoline and naphtha and a smaller yield of kerosene and other heavy constituents is obtained than by the ordinary distillation process.

In describing the “cracking” process, a rough and homely comparison can be made between a barrel of crude oil and a pile of cobblestones. The

ordinary distillation of petroleum and its separation into different constituents as long practised may be compared to the sorting of a pile of different sized cobblestones in several smaller piles containing stones of the same size. If the pile of smaller sized stones is not adequate to meet the demand for them, recourse can be had to the breaking up or cracking of the larger stones into smaller ones. Similarly with petroleum. If, by the ordinary method of separating petroleum into its fractions, the yield of certain constituents of low molecular weight, *i. e.*, the gasoline and naphtha, is not sufficient, then recourse can be had to the cracking of the heavier bodies, *i. e.*, the kerosenes and other heavy constituents into gasoline and naphtha.

The cracking process may be said to date from its accidental discovery at Newark, N. J., by a refinery workman in the year 1861.

In the cracking of heavy oils two factors largely govern the course of the reactions that take place, namely, temperature and pressure. The function of the increased temperature is to break the bonds of groups that make up the complex hydrocarbon molecule. In many processes, pressure is of chief importance in controlling the temperature of dis-

tillation, but it also exerts an influence on the nature of the reactions produced.

The temperature at which "cracking" takes place with the desired rapidity is usually above the boiling point of the hydrocarbons concerned. When no pressure is employed, these hydrocarbons will vaporize and pass out of the reacting sphere, the degree of alteration being small. If, however, sufficient pressure is employed to raise the boiling point to a temperature causing more rapid cracking, alteration into desired products may be obtained with a minimum of total decomposition.

The first processes for the recovery of lighter boiling hydrocarbons from heavier hydrocarbons were used for the production of burning oils. The first patent of this character was that granted to James Young in England, in 1865. The distillation was conducted in a closed vessel provided with a loaded valve, which was set so the vapors could escape at any desired pressure. A pressure of ten to twenty pounds per square inch is specified, and the patent seems to be directed to the recovery of burning oils from Scottish shale oils. Other patents have been issued to Benton, U. S., 1886; Dewar and Redwood, England, 1889; Ragosin, England, 1898; Burton, United States, 1913; Bacon and Clark,

United States, 1914; Humphries United States, 1914; Hall, England, 1913; Rittman,* United States, 1916, and many others.

MOTOR SPIRITS

Much interest has been aroused in technical and trade circles over the introduction of "motor spirits" by the Standard Oil Company. "Motor spirits" are prepared by a special "cracking" process of distillation of petroleum, and was worked out by Dr. W. M. Burton, a director of the Standard Oil Company of Indiana. The patent which was issued January 7, 1913, describes a method of treating liquid portions of petroleum having a boiling point upward of 500° F., to obtain therefrom low boiling-point products. In other words, transforming petroleum products that are heavy and unsuited for use in automobile engines into a liquid that can be used for such a purpose. The distillation process is conducted under a pressure of from sixty to seventy-five pounds per square inch and at temperatures varying from 650° to 850° F. The distillate is condensed in the usual way.

The resulting "motor spirit" has a slightly

*Patent applied for.

yellowish color and, compared to a straight refinery distillate of 59° B, has the following characteristics:

Comparison of "Motor Spirits" and Gasoline

PRODUCT	SPECIFIC GRAVITY	BOILING POINT
	BÉ. SCALE	°F
Motor Spirits	55	95 to 500
Gasoline	59	110 to 350

As compared to gasoline, "motor spirit" has a slightly lower gravity, showing a higher carbon content, meaning that more mileage can be obtained from it than from gasoline. One should be able to start a motor easier with it, because it starts to boil at a lower temperature than gasoline does. Because it has a higher range of boiling points it should be more difficult to convert it entirely into the vapor form, and, therefore, it should be more liable to carbonize the motor cylinders and cause smoking. The fact that "motor spirit" does carbonize cylinders and emit a small amount of smoke in the exhaust makes it more or less unsuitable for pleasure-car use. With the slower speed motors and more constant running conditions present in motor trucks, however, these objections are not so pronounced.

The chief merit of the product lies in the fact that

it will take the place of gasoline in many instances, such as for use in stationary engines, traction engines, trucks, etc., and that it helps dispel, for a time at least, the bugbear of a gasoline shortage.

The Standard Oil Company has installed the Burton process at Whiting, Indiana, at Alton, Illinois, at Kansas City, Missouri, at Casper, Wyoming, and at other places. Fully a million barrels of "motor spirit" were produced in 1915, and for 1916 this amount will be increased to fully three million barrels.

THE "RITTMAN" PROCESS OF CRACKING PETROLEUM TO OBTAIN GASOLINE

A process for cracking petroleum to obtain gasoline has been perfected and patented by Walter F. Rittman, an employee of the United States Bureau of Mines. The process can be used by anybody in the United States, free of charge, after making proper representations to the Bureau of Mines, Washington, D. C.

This process differs from most "cracking" processes, in that the reactions are made to take place entirely in what is known as the vapor phase. In other words, instead of heating and compressing the liquid petroleum and its vapor together, the petro-

leum is first vaporized, and this vapor is heated and compressed. The most favorable conditions for gasoline and production are temperatures of about 900° F., and pressures higher than ninety pounds per square inch.

The apparatus consists essentially of a vessel for vaporizing the oil, a heater, where the oil vapor is heated and compressed, and a condenser for collecting the products.

There are several companies building plants to operate this process in the United States under license from the United States Bureau of Mines. The material produced is essentially the same as the "motor spirits" of the "Burton" process.

In the following table there is given the results of cracking a petroleum distillate with boiling points between 482° F. and 662° F., *i.e.*, a high boiling "cut" from crude oil was cracked in order to convert as much of it as possible into gasoline.*

*Taken from *Bulletin 114, Bureau of Mines.*

Result of "Cracking" a Petroleum Distillate by the Rittman Process

No. OF RUNS	TEM- PERA- TURE °C.	RATE OF OIL FEED GALLONS PER HOUR	OIL RECOVERED		GASOLINE			PERCENTAGE FORMED ON BASIS OF ORIGINAL OIL
			PER CENT	SPECIFIC GRAVITY (WATER = 1)	PERCENTAGE IN RECOVERED OIL	SPECIFIC GRAVITY (WATER = 1)		
1	550	17	54	0.800	35.0	0.772	18.9	
2	550	19	85	.800	20.	.730	17.0	
5	550	26	92	.800	14.	.730	12.9	
1	575	13	58	.800	32.	.730	18.6	
3	600	17	79	.815	36.0	.750	28.5	
1	600	19	85	.830	25.7	.760	21.8	
6	600	23	78	.810	25.0	.735	19.5	
3	625	22	76	.810	27.0	.736	20.5	
1	650	19	69	.815	31.0	.740	21.4	
1	650	21	79	.820	24.0	.745	19.0	
1	650	25	86	.816	20.0	.723	17.2	

It will be observed that, starting with a petroleum distillate containing hydrocarbons of even higher boiling points than kerosene contains, gasoline was obtained varying in amount between fourteen and thirty-six per cent of the original distillate.

To date most of the experiments with the Rittman process, as regards gasoline production, have been with high-boiling petroleum distillates and not with crude petroleum, although the process is applicable to crude petroleum as well. In using the latter an excessive amount of carbon is formed that is somewhat difficult to take care of.

CRACKING OIL BY MEANS OF ALUMINUM CHLORIDE

Aluminum chloride is a substance of much interest, largely because of its effect on certain chemical reactions. Messrs. Friedel and Crafts, two German chemists, investigated its properties in this respect forty years ago. They found that substances reacted with each other in the presence of aluminum chloride in appreciable or large degree when otherwise the reactions were practically inappreciable. Friedel and Crafts found that aluminum chloride had a catalytic effect on oils that to-day is of decided commercial interest, namely, the property of break-

ing down or "cracking" high boiling oils into lower boiling oils, *i. e.*, into gasoline. In using aluminum chloride, the crude oil is distilled in the ordinary way until the naturally occurring gasoline and kerosene, if there be any present, is distilled off. As the next step, anhydrous aluminum chloride is added to the remaining residual oil, and the latter heated to boiling. Boiling is usually around 500° F., and generally remains between 500° and 550° F., during the entire distillation extending over a period of twenty-four to twenty-eight hours. By this method the yield of gasoline may be increased as much as one hundred to two hundred per cent. A. M. McAfee,* of the Gulf Refining Company, has patented an application of the use of aluminum chloride for "cracking" oils and the recovery of the reagent for use over and over again.

McAfee maintains that the gasoline produced by the aluminum chloride process is sweet smelling and water white, and that the carbon deposited in the reaction is a granular cokey mass easily removed from the still, and that the process has advantages over high pressure cracking operations, because the product obtained in the latter is foul smelling and yellow

*Met. and Chem. Eng. Vol. XIII, 1915, page 592.

and needs purifying with sulphuric acid before it can be marketed. He claims a further advantage in the use of the aluminum chloride process because there is no need of employing extra pressure or vacuum or special apparatus; any still with a stirrer in it suffices.

“CASINGHEAD” GASOLINE

During the year 1914, there was produced about forty-three million gallons of so-called “casinghead” or natural gas gasoline. This is gasoline that is obtained from natural gas by compressing and cooling the latter, or, to put it in a more popular way, by squeezing gasoline out of natural gas.*

The natural gas used for this purpose is that which comes from oil wells, or so-called “wet” natural gas. This natural gas is found in oil wells, for natural gas always accompanies oil in the well. In contact with oil in the well it picks up or mixes with some of the lighter parts of the oil, *i. e.*, the gasoline, and carries the latter out of the well with it. The amount that is carried out varies widely with different gases. Sometimes the amount is so small that it does not pay to erect a plant to squeeze the gasoline out. Those

*Burrell, G. A. “The Condensation of Gasoline from Natural Gas.” *Bulletin 88, Bureau of Mines.*

natural gases that contain less than about one and one-quarter gallons per one thousand cubic feet of gas are not treated. On the other hand, some natural gases carry as much as four gallons of gasoline per thousand cubic feet.

That gasoline can be extracted from natural gas has long been known, ever since gasoline has been noticed in pipe lines that carry natural gas, but it is only within recent years that the production of gasoline from natural gas has been a commercial success, owing principally to the ever-increasing demand for gasoline.

A. Fasnemeyer made gasoline from the gas of oil wells, near Titusville, Pennsylvania, in the fall of 1904. His plant is almost within sight of the old Drake well. His first equipment was crude. The gas from the wells, after passing the gas pumps used for withdrawing the gas, was cooled by means of a coil of pipe placed in a tank of water, and the gasoline condensed out allowed to drip into a wooden barrel. Tompsett Brothers, of Tidioute, Pennsylvania, claim to have preceded Fasnemeyer in the making of a commercial venture out of the process. They are operating successfully at the present time.

As these ventures proved commercially successful, attention was turned to the designing of better plant

equipment. Gas and oil operators in other oil fields proceeded to install gasoline plants.

The method in common use at the present time consists in withdrawing natural gas from oil wells by means of suction pumps, and then compressing this gas to a pressure of about fifteen to forty pounds per square inch. Next the gas is passed through coils of pipe on which running water falls. A receptacle is provided for catching any gasoline that may be obtained at this stage of the process. Next the gas is compressed in another compressor at a pressure of about two hundred pounds per square inch, and again cooled. The largest amount of gasoline is obtained by means of this second compression and cooling.

The product obtained is usually a very light gasoline or "wild," as it is known in trade circles. Upon exposure to the air a large part of it evaporates or "weathers" in a comparatively short time. This loss of gasoline by "weathering" may amount to as much as four and five-tenths to twenty-four per cent after one hour's exposure, and as much as fifty to seventy per cent in extreme cases at the end of twenty-four hours.

This weathering constituted a decided loss; hence, attention was turned to some method of pre-

venting it. In addition, the gasoline as obtained direct from the plants was more dangerous to handle than ordinary refinery gasoline, because it passed into the gaseous form quickly and, hence, would quickly render air explosive. It also developed so much pressure on standing in closed containers that it was dangerous to ship. In most cases, because of its high vapor pressure, it could not be shipped in ordinary tank cars, but had to be transported in steel drums.

The problem of saving the waste from "weathering" and of transporting it was finally partly met by blending or mixing it with naphtha of about 50° to 55° Bé. specific gravity. In many cases the casinghead gasoline and naphtha are mixed in about equal proportions. It is best to perform the mixing as soon as possible. The resulting blend is intermediate in gravity and volatility and vapor pressure between the "casinghead" gasoline and the naphtha. A further advantage arises from the fact that naphtha of too low grade for use in motor cars is brought to a state where it can be so used.

When this mixing of casinghead gasoline and naphtha is properly performed the "blend" is suitable for use in motor cars. The largest part of the forty-three million gallons of casinghead gasoline,

produced in 1914, was treated in this manner, and the blend used in automobiles.

Some dissatisfaction in the early days of the industry (and at present) arose from the fact that jobbers, in preparing the material for market, used naphtha of too low a grade or used too large a proportion of naphtha. This of course resulted in dissatisfied customers; hence, producers and jobbers in the main see to it that satisfactory material is prepared at the present time.

If a very low-grade naphtha is used in the blend of naphtha and casinghead gasoline, there results a mixture that is not uniform of composition. In other words, the range of boiling points is too far apart, and there are too many compounds present of high boiling point, so that it is difficult to vaporize the material in its use in motors. In addition, too large a proportion of naphtha or too low-grade naphtha results in carbonization of the motor.

However, proof that casinghead gasoline finds many satisfied customers lies in the fact that for the year 1916 probably one hundred million gallons will be disposed of. A great deal of it is used for mixing with the "cracked" gasoline obtained from the Burton process.

Alone and unblended with naphtha some of it

makes an excellent fuel for use in gasoline (air gas) machines that are used in lighting isolated houses and other places. In this process air is made to mix with or pass through liquid gasoline, thereby "picking up" or carrying with it some of the gasoline vapor. This mixture of air and gasoline is then fed to burners (incandescent mantles) for lighting purposes, or used for other purposes.

DESCRIPTION OF COMPRESSOR TYPE OF NATURAL GAS — GASOLINE PLANT *

In Figures 2 and 3 are shown the plan and elevation of a plant for making gasoline from natural gas by the compression method.

The gas from the wells enters the plant by means of a gas line. After passing through a drip tank (B) for the removal of oil that might be carried with the gas it partly circles the compressor building and enters a low-stage compressor; after compression it is conducted to low-stage cooling coils, and thence to the high-stage compressor (E). From this compressor it passes to cooling coils (F), and is from them expanded into cooling coils (G). The condensate is

*Burrell, G. A.; Seibert, F. M.; Oberfell, G. G. "The Condensation of Gasoline from Natural Gas." *Bulletin 88, Bureau of Mines*, 1915, page 54.

trapped into the accumulation tank (H). The residue gas stripped of its gasoline is sent to places of consumption.

THE EXTRACTION OF GASOLINE FROM NATURAL GAS BY ABSORPTION METHODS*

A new process of extracting gasoline from natural gas has lately come into use that threatens to rival the "casinghead" process in the amount of gasoline that will be obtained. This process is called the absorption process, because the natural gas is passed through a heavy oil which absorbs or dissolves the gasoline out of the gas.

Oils are used whose trade names are "Straw Oil" and "Mineral Seal Oil." They are heavier than kerosene, having a gravity on the Baumé scale of about 35°. They start to boil at about 430° F.

The natural gas is first passed through the oil and, after the latter has absorbed as much gasoline as it can, it is passed into steam stills where the gasoline is distilled or separated. The hot oil, freed of its gasoline, is then cooled by passing it through coils of

*The Extraction of Gasoline from Natural Gas by Absorption Methods, by G. A. Burrell, P. M. Biddison and G. G. Oberfell. Proceedings Natural Gas Association of America. 1916.

pipe upon which cold water falls, and then sent to the absorbers where it can receive another charge of gasoline. In other words, the process is continuous, the oil flowing in a steady stream through the circuit, and merely acting as a carrier of the gasoline from the absorbers to the steam still.

The great importance of this process lies in the fact that natural gases can be treated that are very "lean," or carry only a small amount of gasoline vapor. The "casinghead" process, described in the previous chapter, cannot be used on natural gases that carry less than about ten pints of gasoline per thousand cubic feet of gas, while the absorption process can be worked on natural gases that carry less than one pint of gasoline per thousand cubic feet.

The total consumption of natural gas in the United States in 1914 was about five hundred and ninety billions cubic feet. Most of this gas can be treated for gasoline by the absorption process, while it is exempt as far as the "casinghead" process is concerned. The amount of gasoline contained in it varies between one and three pints of gasoline per thousand cubic feet, on the average. The gas is that used in cities, towns and factories, and is the so-called "dry" natural gas as distinguished from the "wet" or "casinghead" natural gases from

which gasoline is extracted by the casinghead or compression method. The quantity of this latter gas treated for gasoline in the year 1914 was about seventeen billion cubic feet. The absorption process can also be used for treating casinghead gas that is too lean to treat by compression methods.

The absorption process of treating natural gas is identical with a process used at the present time for extracting benzol and toluol from coke-oven gases, except that in the case of the natural gas the absorption is usually conducted at pressures of two hundred pounds per square inch, or higher. The higher pressure is used because the gas at the places where it is most economical to treat it exists at high pressures. Natural gas is compressed to high pressures in sending it through pipe lines to cities, because a larger quantity of natural gas can be sent through the pipes in a given time than if under low pressures. Since the principal revenue derived from the gas is through the sale of it to cities, factories, etc., and the gasoline recovery is just a by-product, every effort is made not to disturb the transportation system; hence, the gas is treated just as it exists, *i.e.*, under high pressures.

A fractionation analysis of gasoline obtained by

this absorption method follows. The gravity is about 80° Bé.

DISTILLATION TEST OF GASOLINE MADE BY THE ABSORPTION METHOD

DISTILLATION TEMPERATURE °F.	AMOUNT OF DISTILLATE BY VOLUME PER CENT	GRAVITY OF DISTILLATE °BÉ.
80 — 110	10	91.8
110 — 124	10	89.0
124 — 136	10	86.7
136 — 146	10	83.4
146 — 158	10	89.4
158 — 172	10	77.4
172 — 188	10	73.3
188 — 208	10	70.2
208 — 244	10	65.0
244 — 290	3	63.1
Loss	7	
Total,	100	

This fractionation analysis shows the gasoline to be of exceptional high grade.

At the present time one plant is in operation at Hastings, West Virginia, that treats about one hundred and fifty million cubic feet of gas per day by the absorption process, extracting about twenty

thousand gallons of gasoline. At least six other plants are in course of construction.

The extraction of gasoline from natural gas by absorption in oil is accomplished in the following manner: The gas and oil pass through a pipe, and from there, by means of many small holes in the pipe, into an absorber, where the natural gas, in intimate contact with the oil, gives up its gasoline. The natural gas then passes out of the absorber on its way to places of consumption. The oil, charged with gasoline, passes to a weathering tank, where the lighter portions of the gasoline are released through a safety valve, and then into a pump that forces the oil through a heat exchanger and into a steam still. Gasoline is distilled out of the oil in the still and flows out of the system at the gasoline drip. The hot oil, freed of its gasoline, passes through the heat exchanger, where it gives up some of its heat to the incoming oil, passes into an oil pump and from there through cooling coils. Water flows over these coils to cool the oil. Finally, the oil passes into the absorber again to receive another charge of gasoline. The process is continuous, the oil being used over and over again and sim-

ply acting as a carrier of gasoline from the absorber to the still.

The author of this book (G. B.) was first in cooperation with Messrs. Biddison and Oberfell to treat casinghead natural gas by the absorption method.

GASOLINE FROM SHALE

Under the general name of oil shales are to be found in many countries what are known as carbonaceous or bituminous shales, which yield, when subjected to heat, hydrocarbons resembling those that comprise crude petroleum.

Good oil shales contain from twenty to thirty per cent of volatile matter (matter driven off by heat), and will yield, on careful distillation in modern stills with steam, about twenty to thirty gallons of oil per ton. Some shales of Scotland and Wales yield as much as eighty to one hundred and twenty gallons of oil per ton.

Thickness of shale seams vary greatly; sometimes they are six to ten or, perhaps, fifteen feet thick. A great deal of it occurs in the United States, in Colorado, Northwestern Utah and Southwestern Wyoming.

The high cost of distilling oil as compared to the

cost of producing oil from wells has thus far prevented the development in the United States of such an industry and may continue to prevent it for some time, but sooner or later this great source of supply will be utilized to supplement the decreasing production from the regular oil fields.

When refined by ordinary methods, shale oil yields about ten per cent gasoline, thirty-five per cent kerosene and a large amount of paraffin. The yield of gasoline can probably be greatly increased by "cracking" methods of distillation. The gas produced in the distillation is of good quality, and may furnish all the heat needed for distillation.

Ammonia can also be obtained by distilling oil shales and used in the manufacture of soil fertilizers, for which there is an ever increasing demand.

Although little attention has been paid to the shale industry in this country, yet in Scotland it is a very important industry. The average yield of oil from the Scotland shales is much less than that which appears possible from Utah and Colorado shales. In Colorado alone it is estimated that there is enough shale in beds three or more feet thick to yield twenty billion barrels of crude oil, from which at least two billion barrels of gasoline may be extracted by ordinary refining processes.

The development of this enormous reserve simply awaits the time when the price of gasoline or the demand for other distillation products from the shale warrants the establishment of plants to work it. This may happen in the near future. At all events, these shales are likely to be drawn upon long before the exhaustion of the petroleum fields.

NATURAL GAS FROM FLOW TANKS

A tremendous volume of gas yearly escapes in the air from flowing oil wells. This is so-called flow-tank gas. Oil wells that flow or "gush" do so because there is sufficient gas pressure to raise the oil from the sand through the casing of the well and often to throw it high into the air. In this way millions of cubic feet of gas have escaped into the air. If there is any likelihood of a well being a producer, a flow tank is set before drilling into the sand and is connected to the casinghead of the well by one or more flow lines. By the use of simple and well-known oil savers and control casingheads, the loss of oil from a flowing well can be made very slight.

Not so, however, with the gas. When a well flows into a tank, it has been, and is, a general rule that the gas which comes with the oil is lost. In some cases the volume of the gas is very large and the

production of oil small, so that the intrinsic value of the gas is much the greater of the two. Intrinsic value is stated because the gas has no commercial value in most cases. The oil can be stored to await a market and can be transported with ease on account of its being liquid rather than a gaseous substance, while a gas, once above the ground, must have an immediate market.

This gas goes in a flow tank with the oil and there separates, the oil being drawn off into receiving tanks and the gas passing out through a stack into the air. This gas has been intimately mixed with the oil during a journey of perhaps twenty-five hundred feet through the casing of the well and flow line. They began the journey together, under a high pressure that drove the largest possible volume of gas into solution with the oil. As they rose toward the surface the pressure grew less, which permitted the gas to expand and to escape in part from its solution with the oil. When they together issued into the flow tank at atmospheric pressure, the gas had fully expanded and had absorbed from the oil the largest amount possible of its lightest constituents, *i. e.*, the gasoline.

This flow tank gas, although carrying a large amount of gasoline vapor, usually is not treated by

compression and condensation methods for gasoline extraction, because the supply is temporary and uncertain. A flowing well exhausts its pressure more or less rapidly, and must be put to pumping. In a pumping well the oil and gas are produced separately, whereas in a flowing well they issue together, and if the gas is to be used they must be separated.

However, there are a few gasoline plants that operate on natural gas from flowing wells.

SUBSTITUTES FOR GASOLINE

A perplexing problem bothering automobile dealers, oil dealers and owners of cars is the high and increasing price of gasoline and the possibility of cheap substitutes for gasoline. These substitutes that have been given the most attention are kerosene, benzol and alcohol.

As regards kerosene, many automobile dealers are of the opinion that gasoline will have to reach an almost prohibitive price before kerosene will be accepted as a pleasure-car fuel. They state that with the tendency of engine builders to design multiple cylinder engines (as high as twelve cylinders) an even more volatile and higher grade gasoline is required than is at present used. The question revolves itself around heating the engine. On a

moderately warm day an engine in six-cylinder pleasure cars would work on kerosene once it was started, but on a cold day this would be impossible. There is so much metal to conduct heat away in the multiple cylinder cars that a film of oil is almost like lard until the engine is started.

Another difficulty with kerosene has to do with its wide range of boiling points; from about 200° to 500° F. This makes it difficult to secure constant vaporizing conditions. To remedy this in traction engines, etc., the carburetor is jacketed with exhaust gases from the engine or with hot water. Most kerosene carburetors are so equipped that they work on gasoline until the engine is heated, further complicating their structure.

It is claimed that electric starting systems would be impossible with kerosene carburetors, at least the type now in use, the motor not being heavy enough to heat an engine to the point where it would start on a heavy oil. Car owners want an engine that will need as little care as possible; they want to sit in their seats, press a button, and move down the avenue. If a choice were necessary, there are many car owners who would not drive a car as much on kerosene because of the extra trouble required. There are many changes that would be required in

the carburetor and engine if kerosene were used. The manifold spark plugs, lubricating oil and clearance all would play a part in getting a motor suitable for the work.

On the other hand, kerosene is already being used to a great extent in tractors, stationary engines and marine engines. But operating conditions are somewhat different than in the case of pleasure cars. Tractors are pulling practically all the time at a maximum load and constant speed, and are not in use for the most part when the weather is cold enough to chill the engine. Marine engines are also not subject to constant shifting of speeds that makes necessary a complex type of engine and presents fuel ignition difficulties. The consumption of fuels by these types of engines is only a drop in the bucket to that by pleasure cars and commercial trucks. Kerosene carburetors will not have solved the fuel problems until the engine can be operated by pleasure-car owners with as little thought and care as the gasoline car of to-day.

Another point that many people overlook, who advocate the use of kerosene for permanent relief, is that gasoline and kerosene are both derived from the same source, petroleum, and the supply of the latter is diminishing.

A feature that detracts from kerosene is its odor. The car in which it is used smells of kerosene, and this unpleasant smell cannot be extracted. Another objection is that when it spills it does not dry up, but remains to collect dirt and make a disagreeable muss.

Kerosene leaves a carbon sediment in the present type of automobile motor and emits an odor which, with the great numbers of cars in use, would be offensive. More power can be obtained from burning kerosene than from gasoline, and more from crude oil than from kerosene. The heavier portions of the crude oil are the richest in heat units. But gasoline is the only portion of the crude oil that meets the many and diversified demands of automobile engines for pleasure cars as it is conducted to-day. Many are working on the problem, however, and when a large number of men work on a problem because of its great economic importance, a solution is eventually found.

BENZOL AS A POSSIBLE COMPETITOR OF GASOLINE

A great difficulty that stands in the way of benzol becoming a serious competitor of gasoline is the shortage of benzol itself. This material is obtained

from gases given off when coal is heated in retorts to make coke and illuminating gas. The mixed gases containing from one to one and five-tenths per cent of benzol are brought in contact with a heavy oil (a petroleum distillate of about 35° Bé.). This oil absorbs the benzol from the gas. Next the oil with its benzol is distilled by means of steam and the benzol separated. The debenzolized oil is then brought in contact with more gas; some more benzol is absorbed and again distilled. In other words, the process is continuous, the oil being used over and over again.

At the present time about thirty-five million gallons of benzol are produced annually, the most of which is converted into high explosives for use in the European war. This means that at the close of the war a large amount of benzol will be available for other uses. The utmost possible production of benzol will probably not exceed sixty million gallons. Compared to the more than 1,500,000,000 gallons of gasoline used, this is not a very large amount.

The natural odor of benzol is not unpleasant, but that of its products of combustion (exhaust gases) is vile, due principally to sulphur content. Its specific gravity, .880, is too great for most carburetors, though extra weighing of the float would correct it.

Its mileage per gallon is about eighteen per cent above gasoline, when measured by volume, but about the same when measured by weight. Its rather high flash point and initial boiling point cause it to be rather difficult in starting in cold weather. It solidifies at a temperature above that at which water freezes. Its one great feature of merit is its "pull" at slow speed under full load. With it, gear changing is reduced to a minimum and knocking is almost absent. The engine can be operated with advanced spark almost to a standstill.

A small addition of benzol to gasoline is very helpful, particularly when heavy-gravity gasoline is used, as it greatly lessens any knocking tendency and works more smoothly under throttle. A mixture of gasoline and benzol, with twenty-five per cent of the latter, makes an excellent fuel, the objections when used in this way disappearing.

USE OF ALCOHOL

The price of ninety-five per cent alcohol for industrial purposes during normal times is around thirty to thirty-five cents per gallon. This alcohol has only about sixty per cent of the calorific power of gasoline, and has not been employed for motor fuel

in England in normal times when gasoline sold for forty-two cents per gallon.

Carburetors to handle kerosene, alcohol and benzol need extensive redesigning from those that work with gasoline. In the case of alcohol, if engines were designed to use this material, they would develop more power. In the existing type of gasoline engine the pressure in the cylinder increases from ten pounds per square inch (slightly below atmosphere) to seventy or eighty pounds. If such an engine is operated on alcohol, the power developed will be about ten per cent less. If the compression is increased to about one hundred and ninety-five pounds, however, more power will be developed; such an engine cannot run on gasoline, because gasoline at these high pressures ignites spontaneously from the heat of compression.

Alcohol can be used successfully in any engine adapted to the use of gasoline. It is usually, however, just as difficult to start an engine with alcohol as with kerosene, so that usually it is desirable to start the engine with gasoline to heat it up and then, after a few minutes, shut off the gasoline supply and open the connection to the alcohol tank when the engine will continue to operate satisfactorily.

In regard to general cleanliness, such as absence

of smoke and disagreeable odors, alcohol has many advantages over gasoline or kerosene as fuel. The exhaust from an alcohol engine is never clouded with a black or grayish smoke, as is the exhaust of a gasoline or kerosene engine when the combustion of the fuel is incomplete, and it is seldom, if ever, clouded with a bluish smoke when a cylinder oil of too low test is used or an excessive amount supplied, as is often the case with a gasoline engine.

The hazard involved in the use of alcohol, benzol and kerosene, as regards fires and explosions, is very much less than in the use of gasoline.

R. M. Strong* concluded, as the result of extensive tests by him, that where the restrictions placed on the use of denatured alcohol are less than those placed on the use of gasoline, or where safety and cleanliness are important requisites, the advantages to be gained by the use of alcohol engines in place of gasoline engines may be such as to overbalance a considerable increase in the fuel expense, especially if the cost of fuel is but a small portion of the total expense involved, as is often the case.

He adds that denatured alcohol will probably not

*"Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal Combustion Engines." *Bulletin 32, Bureau of Mines.*

be used for power purposes to any great extent until its price and the price of gasoline become equal, and the equality of gasoline and alcohol engines in respect to adaptability and quantity of fuel consumed per brake horsepower, which has been demonstrated to be possible, becomes more generally realized.

Mr. Strong states that a fair representation of the best economy values obtained, and the corresponding efficiencies for ten to fifteen horsepower stationary Nash and Otto engines, are given in the following table:

Results from Tests Made on 10 to 15 Horsepower Nash and Otto Stationary Engines

FUEL	COMP'SION PRESSURE POUNDS*	FUEL CONS'D PER BRAKE HORSEPOWER PER HOUR		THERMAL EFFICIENCY PER CENT†
		POUND	GALLON	
Gasoline	70	0.60	0.100	26
	90	.58	.097	28
Alcohol	70	.96	.140	28
	180	.71	.104	39
	200	.68	.099	40

*Per square inch above atmosphere.

†Based on the indicated horsepower and the lower heating value of the fuel.

SOURCES OF ALCOHOL

Prime materials for the manufacture of alcohol (ethyl) are saccharine or starchy substances. These include corn, potatoes, cereals and rice. The following table gives the theoretical amount of alcohol extracted per 100 kilos. (One kilo = 2,2046 lbs.) of various materials.

	ALCOHOL
Wheat	32 — 44 Kilos
Maize	31 — 33 “
Barley	30 — 32 “
Rye	30 — 45 “
Rice	39 — 43 “
Green Potatoes	10 — 12 “
Dry Potatoes	34 — 35 “

If every American farm (6,000,000) could each produce 500 gallons of alcohol a year, we would have an annual supply of 3,000,000,000 gallons, or about one and one-half the estimated yearly consumption of gasoline at present.

It is entirely possible to make twenty-five cents a gallon alcohol from fifteen cents a bushel potatoes, but no farmer would dig potatoes for that price. It is true that Germany converts a vast tonnage of potatoes into alcohol, but she does it by efficient

intensive methods, whereby every by-product is utilized, and by the aid of an autocrat government. Prices and output are controlled by an association. As far back as 1901, Germany produced 112,000,000 gallons of denatured alcohol. There are 6,000 potato stills in Germany. The investments per still range from \$2,000 to \$5,000.

Denatured alcohol is now selling for fifty cents a gallon (a war price), but it is not being made from potatoes. It is being made from the grains, corn, rye and barley.

Molasses looms up as a profitable source of alcohol. By a new distilling process it is possible to convert forty per cent of a gallon of molasses into alcohol. This can be done in Cuba at ten cents a gallon. The total cost to the producer in the United States would not exceed eighteen cents. The lowest manufacturing cost of making alcohol from corn is three and one-half cents a wine gallon. To this must be added the cost of the corn. A fifty-six-pound bushel of corn averages two and one-half gallons of alcohol. A bushel of potatoes will yield about six-tenths of a gallon of alcohol. Hence, the raw-product cost of potatoes and corn is all out of proportion to the raw-product cost of molasses.

In 1914, the United States imported 53,000,000 gallons of molasses for alcohol and cattle feeds.

In the United States this year the production of denatured alcohol will be about 35,000,000 gallons, small as compared to the gasoline consumption. But there are large possibilities. The molasses by-product of cane sugar will produce forty gallons of alcohol to the ton of cane used. The world's cane sugar production is about 4,000,000 tons and will run to 5,000,000 tons. There is an available supply of 200,000,000 gallons of denatured alcohol from that source.

There are still better possibilities in the production of alcohol from wood waste in the United States. Our Southern states waste raw material sufficient for the concurrent daily production of 600,000 gallons of methyl alcohol (among other things), or about 219,000,000 gallons a year. This alcohol would cost about twenty cents per gallon to produce.

There is thus available about 400,000,000 gallons of gasoline a year from molasses and wood waste before we get down to the business of growing special crops for alcohol.

MIXTURES OF BENZOL AND ALCOHOL

The engineering department of the Imperial

German Transportation Department has tabulated a series of experiments with various mixtures of gasoline, kerosene and benzol. A Mercedes touring-car of the 1914 type was used, the carburetor of which was set for gasoline and not adjusted in any way during the series of tests. The gasoline cost 38 cents per gallon, the benzol 37.5 cents and the alcohol 34 cents. The highest speed obtained and the distance covered on 1 litre (1.057 quarts) of fuel are given in the following table:

Comparison of Gasoline, Benzol and Alcohol

FUEL USED	SPEED AT 'N' D KM. PR.*	DISTANCE TRAV'D ON 1 LITRE.
1 part benzol, 1 part alcohol,	68	7.5
1 " " 2 " "	66	7.2
1 " " 3 " "	63	7.0
1 " " 4 " "	62	6.6
1 " " 5 " "	58	6.0
Pure benzol,	67	7.1
Pure gasoline,	70	5.8†

According to the foregoing table the car traveled 62 km. for \$1.00, if gasoline were used; 76 km., when

*One Kilometer = .6214 miles.

†Distance traveled on pure gasoline is twenty-five per cent less than on the best benzol-alcohol mixture. 1:1.

pure benzol was used, and 84 km. when a mixture of equal parts of benzol and alcohol was used.

German motorists use mixtures of benzol and alcohol very much in their machines for war purposes. To overcome the difficulty of prompt starting, an auxiliary tank is used filled with ether or gasoline. When starting the motor this auxiliary fuel is used, and when the motor has turned over a few hundred times the benzol-alcohol tank is connected to the carburetor by simply turning the proper cocks.

This auxiliary tank has served another valuable purpose in war maneuvers, in that if the main tank is pierced by a bullet, the auxiliary tank can carry the motor car ten to fifteen miles to safety.

Taking everything into consideration, alcohol at present looms up as the most feasible substitute for gasoline when the supply of crude oil becomes limited.

NAPHTHALENE AS MOTOR FUEL

Naphthalene, a product from coal distillation, has been used to some extent in internal combustion engines. It is derived from coal to the extent of 0.3 per cent of the coal carbonized.

Pure naphthalene is a white solid, melts at 175°

F., and boils at 424° F. In the molten condition it is a clear, colorless liquid.

The gross calorific power of naphthalene is 17,280 B.T.U. per pound, as compared to alcohol 11,600, and gasoline about 20,400.

In using naphthalene as a motor fuel in internal combustion engines it has been dissolved in various fluids. It is not soluble in water, but is soluble to the extent of ten per cent in alcohol at 50° F., petroleum ether eleven per cent, and toluol thirty-five per cent.

The flash point of naphthalene in the Pensky-Martens apparatus is 176° F., the fire point is 210° F. It has the peculiar property that, on cooling below the melting point, it does not pass through the liquid state, but immediately forms solid flakes. It yields a vapor of uniform composition. A naphthalene engine must have a vessel for melting the naphthalene kept hot enough to prevent solidification. In Germany there were about four hundred naphthalene engines in 1914.

Engines cannot start cold on naphthalene, and are designed to start with gas or liquid fuel. Engines designed and run with naphthalene show better efficiencies than those designed and run with gasoline. The economy of the engine and the small fire risks

in the storage of naphthalene have led to trials of these engines for automobiles. Most of the attempts have been made with the naphthalene dissolved in benzol. The solution must be well below the saturation point, or solid naphthalene separates out on cooling.

The use of naphthalene for small engines has certain advantages, so that its field of usefulness will undoubtedly be extended in this respect.

FAKE SUBSTITUTES FOR GASOLINE

The public press has devoted considerable space to many different cheap compounds that are exploited, or about to be exploited, to take the place of gasoline. New processes for making gasoline and new substances have been exploited as selling for a cent up to a few cents a gallon. The best proof that none of these claims have materialized lies in the fact that not one of the substitutes so widely heralded in the past is in use at the present time.

Scientists who have specialized in the study of petroleum in all of its phases take little stock in the many fanciful yarns that have appeared regarding gasoline substitutes. Many of these trained men have been working indefatigably on the problem, sparing neither time nor money, and have not yet

developed a substance to take the place of gasoline. That persons of no special training, and without the facilities for experimentation offered by a well-equipped laboratory, should invent a substance entirely new to the chemical world, or even a new compound of substances already known to the world, seems improbable.

Much discussed among the new substitutes for gasoline is one devised by a man living in Farmingdale, Long Island, who claims that he has worked for three years in a modest laboratory at his home to produce a transparent green liquid, a few drops of which will run an automobile as swiftly as any gasoline on the market. It is claimed that the precious green substance is a catalytic agent which enables him to set free the hydrogen of the water. If a substance has been discovered of such tremendous energy that a few drops will decompose water and liberate its hydrogen, the inventor has accomplished something brand new, and contributed mightily to science and industry. It is hardly necessary to add that the story sounds highly improbable.

Down in St. Louis, Missouri, two men have invented chemical compounds, which when mixed with kerosene, they claim, will afford a substitute for gasoline at one-third to one-half its present cost.

Another man, aged seventy-three, has worked twelve years on a compound he calls "Motorzene," and mixes it in certain proportions with kerosene, making a fuel costing around nine cents a gallon, he says.

Another St. Louisan blends three chemicals so skillfully they cannot be detected when blended, and also mixes the blend with kerosene. He claims to do away with the difficulty in starting and the bad odor that generally results when kerosene is used.

A Cleveland policeman claims he mixes a fluid, now plentiful and selling at six cents a gallon, with gasoline in certain proportions, and secures a mixture slightly more than six hundred per cent more efficient than gasoline alone. A gallon of this mixture costs fifteen cents.

A preacher of the gospel makes the world bow in homage to Wilkinsburgh, Pennsylvania, by producing in that city a gasoline substitute that can be sold for six cents a gallon.

An amateur scientist of Kansas City, after working five years, has produced a method whereby he expects to secure as much as seven gallons of gasoline from six gallons of crude oil. He states that his process is an electro-chemical one.

Over a year ago the town of McKeesport, Penn-

sylvania, leaped into the limelight. A man in that city gave "Zoline" to the world. "Zoline" was prepared by mixing substances, cheaply and easily secured at any drug store, with water. "Zoline" must have been a highly inflammable substance indeed for, after the first vivid flare of publicity, its light was forever extinguished.

FUNDAMENTAL PHYSICAL LAWS AND DEFINITIONS

Boiling Point: The temperature at which a liquid gives off bubbles of gas or vapor is called its boiling point. Upon heating a pure substance its temperature rises until the boiling or ebullition point is reached, when the temperature will remain constant until all of the substance passes from the liquid into the vapor form. An impure substance, or mixture of substances like petroleum or gasoline, has no definite boiling point, but is composed of a mixture of compounds of widely-differing boiling points. Upon heating it the temperature gradually rises until all of the gasoline passes into the vapor form or, in the case of petroleum, the original mixture has been divided into two parts: one a part that has passed into the vapor form and the other a coke residue that stays behind in the vessel that was heated.

Vapor Tension or Vapor Pressure: All liquids tend to assume the gaseous state, and the pressure exerted by the liquid in passing into this gaseous state is called the vapor pressure of the liquid. This pressure is higher, the higher the temperature of the liquid.

Saturation: A gas is saturated when its full capacity of a given volume of vapor has been reached. For instance, air will hold a certain volume of a certain kind of gasoline at a certain temperature, and no more. The air is then said to be saturated with respect to the gasoline. Air that holds only one-half the gasoline vapor that it could hold is said to be fifty per cent saturated.

Boyle's Law: In a perfect gas the volume is inversely proportional to the pressure to which the gas is subjected, *i.e.*, if one cubic foot of gas, having a pressure of fifteen pounds per square inch, is subjected to a pressure of thirty pounds per square inch, its volume will become one-half cubic foot.

Law of Charles: Gases expand $\frac{1}{491}$ of their volume at "0" degrees Fahrenheit for each degree Fahrenheit that they rise in temperature.

Temperature: Temperature is a measure of the hotness of a body. It is usually expressed in Fahrenheit or centigrade degrees. In the Fahrenheit scale

the freezing point of water is called thirty-two and the boiling point two hundred twelve degrees, and the interval between these points equally divided to express other degrees of hotness.

In the case of the centigrade thermometer, the freezing point of water is called "0" and the boiling point one hundred degrees.

Specific Gravity: The specific gravity of a substance is the ratio of its weight to the weight of another substance of equal volume taken as a standard. In the case of gases, air is usually taken as the standard, and in the case of liquids, water is chosen.

Heat Unit: The unit quantity of heat, or the heat unit is the heat required to raise the temperature of a unit weight of water one degree.

The heat required to raise one gram of water one degree centigrade is called a gram calorie.

The heat required to raise one pound of water one degree Fahrenheit is called a British Thermal Unit, or B.t.u.

Fractional Distillation: This is the separating of different constituents from a common substance. It is made possible by the fact that different substances pass into the vapor state at different temperatures.

Explosive Mixtures: Any combustible gas will combine directly with air (oxygen), and when the mixture contains the gases in right proportion an explosion will occur upon ignition of the mixture.

Destructive Distillation: Destructive distillation is the process of heating a substance beyond the point of decomposition without the access of air.

Oxidation: Oxidation is the act or process of taking up oxygen or combining with oxygen.

Composition of air: Pure dry air contains 79.14 per cent of nitrogen, 20.93 per cent oxygen and .03 per cent of carbon dioxide.

Combustion: Combustion is a vigorous chemical combination attended by the evolution of heat and light. When one speaks of the combustion of gasoline, there is meant the burning or chemical combination of the gasoline (carbon and hydrogen) with the oxygen of the air.

USEFUL TABLES

Relative Value of Petroleum and Coal

COAL B.T.U. PER LB.	1 LB. COAL = LBS. OIL	1 BARREL OIL = LBS. COAL	1 TON COAL = BBLs. OIL
10,000	2.	620	3.23
12,000	1.818	564	3.55
12,000	1.667	517	3.87
13,000	1.538	477	4.19
14,000	1.429	443	4.52
15,000	1.333	413	4.84

Ignition Temperatures of Gases

GAS	FORMULA	IGNITION TEMP. °F.
Methane	CH_4	1250
Ethane	C_2H_6	1140
Propane	C_3H_8	1000
Hydrogen	H_2	1020 to 1200
Carbon Monoxide	CO	1100 to 1200
Acetylene	C_2H_2	1000
Gasoline Vapor		950

Comparative Evaporation Tests of Different Fuels

	LBS. OF WATER FROM AND AT 212 °F.
1 lb. of Anthracite Coal evaporates	9.70
1 lb. of Bituminous Coal evaporates	10.14
1 lb. of Fuel Oil (36° gravity) evaporates	16.48

Explosive Limits of Different Gases

GAS	LOW LIMIT (PER CENT)	HIGH LIMIT (PER CENT)
Gasoline Vapor	1.5	6.0
Ethane	2.5	5.0
Methane	5.5	14.5
Natural Gas	5.0	12.0
Acetylene	3.0	73.0
Coal Gas	7.0	21.0
Hydrogen	10.0	66.0
Carbon Monoxide	15.0	73.0

Comparative Table Thermometers

1 Fahrenheit degree = 5-9 degree Cent.

1 Centigrade " = 9-5 " Fahr.

Temp. Fahrenheit = 9-5 X temp. C + 32°

Temp. Centigrade = 5-9 (temp. F. - 32°)

Freezing point — Cent. = 0°; Fahr. = 32°

Boiling point — Cent. = 100°; Fahr. = 212°

CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.
—18	0	107	226	456	455
—15	5	110	230	237	460
—12	10	113	235	240	466
— 9	16	116	241	242	469
— 7	19	118	244	245	475
— 4	25	121	250	248	480
— 1	30	124	255	251	486
2	36	127	261	253	489
5	41	129	264	256	495
7	45	132	270	259	500
10	50	134	275	262	505
13	55	137	280	265	511
16	61	140	286	267	514
18	64	142	289	270	520
21	70	145	295	273	525
24	75	148	300	276	531
27	81	151	306	278	534
29	84	153	309	281	540
32	90	156	315	284	545
35	95	159	320	287	550
38	100	162	325	290	556

1 Fahrenheit degree = 5-9 degree Cent.

1 Centigrade " = 9-5 " Fahr.

Temp. Fahrenheit = 9-5 X temp. C + 32°

Temp. Centigrade = 5-9 (temp. F.-32)

Freezing point — Cent. = 0°; Fahr. = 32°

Boiling point — Cent. = 100°; Fahr. = 212°

CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.
41	106	165	331	292	559
43	109	167	334	295	565
46	115	170	340	298	570
49	120	173	345	301	576
52	126	176	351	303	579
54	129	178	354	306	585
57	135	181	360	309	590
60	140	184	365	312	595
63	145	187	370	315	601
66	151	190	376	317	604
68	154	192	379	320	610
71	160	195	385	323	614
74	165	198	390	326	620
77	171	201	396	329	625
79	174	203	399	332	630
82	180	206	405	335	636
85	185	209	410	337	639
88	190	212	415	340	645
91	196	215	421	343	650
93	199	217	424	346	656
96	205	220	430	348	659
99	210	223	435	351	665
102	216	226	441	354	670
104	219	228	444	357	675
...	...	231	450	360	681

Specific Gravity of Gases

GAS	SPECIFIC GRAVITY	LBS. PER CU. FT. 32° F. and 760 mm. pressure	
Air	1.000	0.08071	
Ammonia	0.597	0.04807	
Carbon Dioxide	1.529	0.12323	
Carbon Monoxide	0.967	0.07704	
Chlorine	2.491	0.19774	
Coal Gas	{ From	0.340	0.02628
	{ to	0.450	0.03488
Hydrogen	0.0696	0.00563	
Hydrogen Sulphide	1.191	0.09214	
Methane (Marsh Gas)	0.559	0.04538	
Nitrogen	0.972	0.07847	
Nitric Oxide	1.039	0.08384	
Nitrous Oxide	1.527	0.12298	
Oxygen	1.053	0.08927	
Sulphur Dioxide	2.247	0.17386	
Steam at 100° C.	0.469	0.03627	

Properties of Certain Manufactured Gases

NAME OF GAS	HEAT VALUE PER CUBIC FT. (0° C. AND 760 MM. PRESSURE)	CANDLEPOWER (BRITISH) BURNING 5 CU. FT. PER HOUR	PER CENT		PER CENT	
			UNSATURATED HYDROCARBONS	SATURATED HYDROCARBONS	UNSATURATED HYDROCARBONS	SATURATED HYDROCARBONS
B.T.U.						
Pintch Gas	1,500	45-50	35.65	45.37	12.34	
Coal Gas	630	16	8.0	34.0	47.0	
Acetylene	1,555	150				
Carbureted Water Gas		22	12.83	14.78	35.17	
Uncarbureted Water Gas	1,189			0.10	51.89	
Natural Gas				99.00		
Manufactured Oil Gas	633	23	5.85	40.80	39.49	

NAME OF GAS	CARBON MONOXIDE		CARBON DIOXIDE		OXYGEN		NITROGEN	
	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
Pintch Gas	0.60		0.74		2.00		3.00	
Coal Gas	9.0		1.1		0.0		2.3	
Acetylene								
Carbureted Water Gas	33.92		1.54		0.0		1.76	
Uncarbureted Water Gas	40.08		4.80				3.13	
Natural Gas							1.00	
Manufactured Oil Gas	4.50		2.75		0.85		6.01	

WEIGHTS AND MEASURES**Troy Weight**

24 grains = 1 pwt. 12 ounces = 1 pound

20 pwts. = 1 ounce

Used for weighing gold, silver and jewels.

Apothecaries' Weight

20 grains = 1 scruple 8 drams = 1 ounce

3 scruples = 1 dram 12 ounces = 1 pound

The ounce and pound in this are the same as in Troy weight.

Avoirdupois Weight

27 11-32 grains = 1 dram 4 quarters = 1 cwt.

16 drams = 1 ounce 2,000 lbs. = 1 short ton

16 ounces = 1 pound 2,240 lbs. = 1 long ton

24 pounds = 1 quarter

Dry Measure

2 pints = 1 quart 4 pecks = 1 bushel

8 quarts = 1 peck 37 bushels = 1 chaldron

Liquid Measure

4 gills = 1 pint 31½ gallons = 1 barrel

2 pints = 1 quart 2 barrels = 1 hogshead

4 quarts = 1 gallon

Long Measure

12 inches = 1 foot 40 rods = 1 furlong

3 feet = 1 yard 8 furlongs = 1 sta. mile

5½ yards = 1 rod 3 miles = 1 league

Mariners' Measure

6 feet = 1 fathom	5,280 feet = 1 sta. mile
120 fathoms = 1 cable length	6,085 feet = 1 naut. mile
$7\frac{1}{2}$ cable lengths = 1 mile	

Miscellaneous

3 inches = 1 palm	18 inches = 1 cubit
4 inches = 1 hand	21.8 inches = 1 Bible cubit
6 inches = 1 span	$2\frac{1}{2}$ feet = 1 military pace

Square Measure

144 sq. in. = 1 sq. ft.	40 square rods = 1 rood
9 sq. ft. = 1 sq. yd.	4 roods = 1 acre
$30\frac{1}{4}$ sq. yds. = 1 sq. rod	640 acres = 1 square mile

Surveyors' Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
10 square chains or 160 square rods = 1 acre
640 acres = 1 square mile
36 square miles (6 miles square) = 1 township

Cubic Measure

1,728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
2,150.42 cubic inches = 1 standard bushel
277.42 cubic inches = 1 English gallon (Imperial)
231 cubic inches = 1 American gallon
1 cubic foot = about four-fifths of a bushel

EXPLANATION OF METRIC SYSTEM

The metric system has been authorized by act of Congress in the United States, and by act of Parliament in the United Kingdom. As this system is in use in so many of the countries with which the United States trades a full explanation is given.

It is a decimal system, the meter being the basis of all measures, whether of length, surface, capacity, volume or weight. The meter measures 39.37 inches, and is theoretically one ten-millionth of the distance from the equator to the pole. Multiples of the units are expressed by the Greek prefixes "deca," "hecto" and "kilo," indicating respectively tens, hundreds and thousands. Decimal parts of the unit are indicated by the Latin prefixes "deci," "centi" and "mili," meaning respectively tenth hundredth and thousandth.

Measures of Length

The unit of length is the meter which, like the English yard, is used in measuring cloth, lace and moderate lengths. For long distances, like the mile, the kilometer is commonly used; [but for short or minute distances, the centimeter and millimeter are used.

10 millimeters (mm.)	= 1 centimeter
10 centimeters (cm.)	= 1 decimeter
10 decimeters (dm.)	= 1 meter
1,000 meters (m.)	= 1 kilometer (km.)

Measures of Surface

Measures of surface are derived from measures of length, and the unit is the square meter, which is used like the square yard in measuring small areas, like ceilings and floors. The are and hectare are used in land measure. As a surface area is the product of its length and width, a square centimeter would equal one hundred square millimeters.

100 square millimeters	= 1 square centimeter
100 square centimeters	= 1 square decimeter
100 square decimeters	= 1 square meter or centare
100 centares	= 1 are
100 ares	= 1 hectare
100 hectares	= 1 square kilometer

Cubic Measure

Cubic measure is constructed in the same way, remembering that a cube is the product of the length, width and height; a cubic centimeter would be a cube measuring ten millimeters each way and would contain 1,000 cubic millimeters.

The unit is the cubic meter, or stere, which, like the cubic yard, is used in measuring embankments, excavations, etc.; cubic centimeters and millimeters are used for minute bodies.

1000 cubic millimeters	= 1 cubic centimeter
1000 cubic centimeters	= 1 cubic decimeter
1000 cubic decimeters	= 1 cubic meter or stere
1000 cubic meters	= 1 cubic decameter
1000 cubic decameters	= 1 cubic hectometer
1000 cubic hectometers	= 1 cubic kilometer

Measures of Capacity

Measures of capacity are based on the cubic meter, but as the cubic meter would be too large and unwieldy for ordinary purposes, the cubic decimeter was adopted as the unit and the name liter given to it. The liter is equal to 1.0567 quarts, and is used like the quart or gallon, multiples forming the larger, and decimal parts the smaller, denominations.

10 milliliters	= 1 centiliter
10 centiliters	= 1 deciliter
10 deciliters	= 1 liter
10 liters	= 1 decaliter
10 decaliters	= 1 hectoliter
10 hectoliters	= 1 kiloliter

The hectoliter (2.8377 bushels = 26.417 gallons) is used like the bushel or barrel.

Metric Weights

The unit of weight is the gram (15.432 grains), and is the weight of a cubic centimeter of water at its greatest density—about 39° F.

Milligram (1/1000 gram)	=	0.0154 grain
Centigram (1/100 gram)	=	0.1543 grain
Decigram (1/10 gram)	=	1.5432 grains
Gram (1)	=	15.432 grains
Decagram (10 grams)	=	0.3527 ounce
Hectogram (100 grams)	=	3.5274 ounces
Kilogram (1000 grams)	=	2.2046 pounds
Myriagram (10,000 grams)	=	22.046 pounds
Quintal (100,000 grams)	=	220.46 pounds

Metric Dry Measure

Milliliter (1/1000 liter)	=	0.061 cubic inch
Centiliter (1/100 liter)	=	0.6102 cubic inch
Deciliter (1/10 liter)	=	6.1022 cubic inches
Liter (1)	=	0.908 quart
Decaliter (10 liters)	=	9.08 quarts
Hectoliter (100 liters)	=	2.838 bushels
Kiloliter (1000 liters)	=	1.308 cubic yards

Metric Liquid Measure

Milliliter (1/1000 liter) = 0.0338 fluid ounce

Centiliter (1/100 liter) = 0.338 fluid ounce

Deciliter (1/10 liter) = 0.845 gill

Liter (1) = 1.0567 quarts

Decaliter (10 liters) = 2.6418 gallons

Hectoliter (100 liters) = 26.417 gallons

Kiloliter (1000 liters) = 264.18 gallons

Metric Measures of Length

Millimeter (1/1000 meter) = 0.0394 inch

Centimeter (1/100 meter) = 0.3937 inch

Decimeter (1/10 meter) = 3.937 inches

Meter = 39.37 inches

Decameter (10 meters) = 393.7 inches

Hectometer (100 meters) = 328. feet, 1 inch.

Kilometer (1000 meters) = 0.62137 mile (3.280 ft. 10 in.)

Myriameter (10,000 meters) = 6.2137 miles

Metric Surface Measure

Centare (1 square meter) = 1,550 square inches

Are (100 square meters) = 119.6 square yards

Hectare (10,100 square meters) = 2.471 acres

Metric and American Conversion Table

Millimeters \times .03937 = inches

Centimeters \times .3937 = inches

Meters = 39.37 inches

Meters \times 3.281 = feet

Meters per second = 196.86 feet per minute

Kilometers \times .621 miles

Kilometers	×	3280.89	=	feet
Square millimeters	×	.00155	=	square inches
Square centimeters	×	.155	=	square inches
Cubic centimeters	÷	16.383	=	cubic inches
Cubic meters	×	35.3165	=	cubic feet
Cubic meters	×	264.2	=	gallons (231 cubic inches)
Liters	×	.2642	=	gallons (231 cubic inches)
Kilograms	×	2.2046	=	pounds
Kilograms per square millimeter	×	1422.3	=	pounds per square inch
Kilograms per square centimeter	×	14.223	=	pounds per square inch
Kilowatts	×	1.34	=	horsepower
Watts	÷	746	=	horsepower
Cheval vapeur	×	.9863	=	horsepower
Centigrade	×	1.8	+ 32 degrees	= Fahrenheit

MISCELLANEOUS

- 1 U. S. gallon of water at 62° weighs 8.3356 lbs. and contains 231 inches.
- 7.4805 U. S. gallons = 1 cubic foot. A cylinder, 7 inches by 6 inches is one gallon nearly, or 230.9 cubic inches.
- 1 Imperial gallon of water at 62° weighs 10 lbs.
- 1 Imperial gallon contains 277.274 cubic inches or 1.20032 U. S. gallon.
- Capacity of a cylinder (tank) in U. S. gallons = square of diameter in inches × height in inches × .0034.
- Capacity of cylinder in U. S. bushels = square of diameter in inches × height in inches × .0003652.
- A cubic foot of water contains 7½ gallons, 1728 cubic inches and weighs 62½ lbs.

MENSURATION

Circumference of circle = diameter \times 3.1416.

Circumference of circle = radius \times 6.2832.

Area of circle = radius² \times 3.1416.

Area of circle = diameter² \times .7854.

Area of circle = circumference² \times .07958.

Area of circle = $\frac{1}{2}$ circumference \times $\frac{1}{2}$ diameter.

Radius of circle = circumference \times .159155.

Diameter of circle = circumference \times .31831.

Side of inscribed square = diameter of circle \times .7071.

Side of inscribed square = circumference of circle \times .225.

Side of equal square = circumference of circle \times .8861.

Volume of sphere = surface \times 1-6 diameter.

Surface of sphere = circumference \times diameter.

Surface of sphere = diameter² \times 3.1416.

Surface of sphere = circumference² \times .3183.

Volume of sphere = diameter³ \times .5236.

Volume of sphere = radius³ \times 4.1888.

Volume of sphere = circumference³ \times .016887.

Side of inscribed cube = radius of sphere \times 1.1547.

Surface of cube = area of one side by 6.

Area of ellipse = both diameters \times .7854.

Area of triangle = base by $\frac{1}{2}$ altitude.

Volume of cone or pyramid = area of base by 1-3 altitude.

Area of parallelogram = base by altitude .

Area of trapezoid = altitude \times $\frac{1}{2}$ sum of parallel sides.

Area of trapezium = area of 2 constituent triangles.

Area of regular polygon = sum of its sides \times perpendicular from its center to one of its sides \div 2.

Surface of cylinder or prism = areas of both ends plus (length \times circumference).

Contents of cylinder or prism = area of end \times length.

Surface of frustrum of cone or pyramid = sum of circumference of both ends $\times \frac{1}{2}$ slant height plus area of both ends.

Contents of wedge = area of base $\times \frac{1}{2}$ altitude.

Comparative Table Baumé and Specific Gravity and Weight Liquids Heavier than Water at 60° F

BAUMÉ	SPECIFIC GRAVITY	POUNDS IN GALLON	BAUMÉ	SPECIFIC GRAVITY	POUNDS IN GALLON
1	1.0069	8.38	36	1.3302	11.09
2	1.0139	8.46	37	1.3425	11.18
3	1.0211	8.51	38	1.3551	11.29
4	1.0283	8.56	39	1.3679	11.39
5	1.0357	8.63	40	1.3809	11.51
6	1.0431	8.69	41	1.3942	11.61
7	1.0507	8.75	42	1.4077	11.72
8	1.0583	8.81	43	1.4215	11.84
9	1.0661	8.88	44	1.4356	11.96
10	1.0740	8.94	45	1.4500	12.08
11	1.0820	9.01	46	1.4646	12.21
12	1.0902	9.09	47	1.4795	12.33
13	1.0984	9.15	48	1.4949	12.46
14	1.1068	9.21	49	1.5104	12.58
15	1.1153	9.29	50	1.5263	12.72
16	1.1240	9.36	51	1.5425	12.85
17	1.1328	9.43	52	1.5591	12.99
18	1.1417	9.51	53	1.5760	13.13
19	1.1507	9.59	54	1.5934	13.27
20	1.1600	9.67	55	1.6111	13.42
21	1.1693	9.74	56	1.6292	13.57

Weights of Oils and Other Liquids

	DEGREE SPECIFIC GRAVITY	DEGREE BAUME	LBS. IN 1 GAL.	LBS. IN 1 CU. FT.
Rhigoline . . . . .	.6222	95	5.18	38.89
Very Light Gasoline . . . . .	.6511	85	5.42	40.69
C. Naphtha . . . . .	.7000	70	5.83	43.75
B. Naphtha . . . . .	.7106	67	5.92	44.41
A. Naphtha . . . . .	.7179	65	5.98	44.87
Kerosene . . . . .	.8000	45	6.66	50.00
Water	1.0000	10	8.33	62.50
Castor Oil . . . . .	.9639	15	8.03	60.24
Linseed Oil, boiled . . . . .	.9411	19	7.84	58.81
Linseed Oil, raw . . . . .	.9299	21	7.75	58.12
Menhaden, dark . . . . .	.9292	21	7.74	58.08
Cotton Seed . . . . .	.9302	21	7.75	58.14
Hemp Seed . . . . .	.9307	20	7.75	58.17
Cod Liver . . . . .	.9270	21	7.72	57.94
Whale . . . . .	.9254	21	7.71	57.84
Sunflower Seed . . . . .	.9250	21	7.70	57.81
Poppy Seed . . . . .	.9243	21	7.70	57.77
Fish . . . . .	.9205	22	7.67	57.53
Olive . . . . .	.9192	22	7.65	57.45
Lard . . . . .	.9175	23	7.64	57.34
Rape Seed . . . . .	.9155	23	7.63	57.22
Neat's Foot . . . . .	.9142	23	7.62	57.14
Oolza . . . . .	.9136	23	7.61	57.10
Palm . . . . .	.9046	25	7.54	56.54
Sperm, natural . . . . .	.8815	29	7.34	55.05
Sperm, bleached . . . . .	.8813	29	7.34	55.08
Spirits, Turpentine . . . . .	.8600	33	7.16	53.75
Alcohol, 90 per cent . . . . .	.8228	40	6.85	51.43
Alcohol, 95 per cent . . . . .	.8089	43	6.74	50.56
Alcohol, absolute . . . . .	.7938	46	6.61	49.61
Almond . . . . .	.9180	23	7.65	57.38
Menhaden, light . . . . .	.9325	20	7.77	58.28

Comparative Table Baumé and Specific Gravity and Weight Liquids Heavier than Water at 60° F

BAUMÉ	SPECIFIC GRAVITY	POUNDS IN GALLON	BAUMÉ	SPECIFIC GRAVITY	POUNDS IN GALLON
22	1.1788	9.81	57	1.6477	13.72
23	1.1885	9.90	58	1.6666	13.87
24	1.1983	9.99	59	1.6860	14.04
25	1.2083	10.07	60	1.7056	14.20
26	1.2184	10.16	61	1.7261	14.38
27	1.2288	10.24	62	1.7469	14.55
28	1.2393	10.32	63	1.7682	14.72
29	1.2500	10.41	64	1.7901	14.91
30	1.2608	10.51	65	1.8125	15.10
31	1.2719	10.59	66	1.8354	15.29
32	1.2831	10.69	67	1.8589	15.48
33	1.2946	10.78	68	1.8831	15.68
34	1.3063	10.84	69	1.9079	15.89
35	1.3181	10.98	70	1.9333	16.10

NOTE:— This table of Baumé's hydrometer was adopted in 1903 as the basis for all instruments employed in the manufacture of acids and alkalis by the Manufacturing Chemists' Association of the United States. It has the official sanction of the National Bureau of Standards, Washington, D. C.

It is calculated for temperature of 60° F., and is based upon the formulæ:

$$\frac{145}{B^{\circ} + 145} = \text{Specific gravity and 145} - \frac{145}{\text{Specific gravity}} = B^{\circ}$$

Comparative Table — Weight and Gravity Liquids Lighter than Water at 60° F. (15.56° C.)

Formula: Specific Gravity = $141.5 \div (131.5 + B.^{\circ})$

DEGREES BAUMÉ	SPECIFIC GRAVITY LBS.	ACTUAL WEIGHT PER GALLON LBS.	DEGREES BAUMÉ	SPECIFIC GRAVITY LBS.	ACTUAL WEIGHT PER GALLON LBS.
10	1.0000	8.331	55	.7587	6.321
11	.9930	8.273	56	.7547	6.287
12	.9861	8.215	57	.7507	6.254
13	.9792	8.158	58	.7467	6.221
14	.9725	8.102	59	.7428	6.188
15	.9659	8.047	60	.7389	6.156
16	.9593	7.992	61	.7351	6.124
17	.9529	7.939	62	.7313	6.092
18	.9465	7.885	63	.7275	6.061
19	.9402	7.883	64	.7238	6.030
20	.9340	7.781	65	.7201	5.999
21	.9279	7.730	66	.7165	5.969
22	.9218	7.680	67	.7129	5.939
23	.9159	7.630	68	.7093	5.909
24	.9100	7.581	69	.7058	5.880
25	.9042	7.533	70	.7022	5.850
26	.8984	7.485	71	.6988	5.822
27	.8928	7.438	72	.6954	5.793
28	.8872	7.391	73	.6919	5.764
29	.8816	7.345	74	.6886	5.737
30	.8762	7.300	75	.6852	5.708

Comparative Table — Weight and Gravity Liquids Lighter than Water at 60° F. (15.56°C)

Formula: Specific Gravity = $141.5 \div (131.5 + B.^{\circ})$

DEGREES BAUMÉ	SPECIFIC GRAVITY LBS.	ACTUAL WEIGHT PER GALLON LBS.	DEGREES BAUMÉ	SPECIFIC GRAVITY LBS.	ACTUAL WEIGHT PER GALLON LBS.
31	.8708	7.255	76	.6819	5.681
32	.8654	7.210	77	.6787	5.654
33	.8602	7.166	78	.6754	5.627
34	.8550	7.123	79	.6722	5.600
35	.8499	7.081	80	.6690	5.573
36	.8448	7.038	81	.6659	5.548
37	.8398	6.996	82	.6628	5.522
38	.8348	6.955	83	.6597	5.496
39	.8299	6.914	84	.6566	5.470
40	.8251	6.874	85	.6536	5.445
41	.8203	6.834	86	.6506	5.420
42	.8156	6.795	87	.6476	5.395
43	.8109	6.756	88	.6447	5.371
44	.8063	6.717	89	.6417	5.345
45	.8017	6.679	90	.6388	5.322
46	.7972	6.641	91	.6360	5.299
47	.7927	6.604	92	.6331	5.274
48	.7883	6.567	93	.6303	5.251
49	.7839	6.531	94	.6275	5.228
50	.7796	6.495	95	.6247	5.204
51	.7754	6.460	96	.6220	5.182
52	.7711	6.424	97	.6193	5.159
53	.7669	6.389	98	.6166	5.137
54	.7628	6.355	99	.6139	5.114

Comparative Table — American and Metric Standards

APPROXIMATE		EXACT	
1 acre	.40	hectar	.4047
1 bushel	.35	litres	35.24
1 centimeter	.39	inch	.3937
1 cubic centimeter	.061	cubic inch	.0610
1 cubic foot	.028	cubic meter	.0283
1 cubic inch	.16	cubic centimeter	16.39
1 cubic meter	.35	cubic feet	35.31
1 cubic meter	1.3	cubic yards	1.308
1 cubic yard	.76	cubic meter	.7645
1 foot	.30	centimeters	30.48
1 gallon	3.8	liters	3.725
1 grain	.065	gram	.0648
1 gram	.15	grains	15.43
1 hectar	2.2	acres	2.471
1 inch	.25	millimeters	25.40
1 kilo	2.2	pounds	2.205
1 kilometer	.62	mile	.6214
1 liter	.91	quart (dry)	.9081
1 liter	1.1	quarts (liquid)	1.057
1 meter	3.3	feet	3.281
1 mile	1.6	kilometers	1.609
1 millimeter	.039	inch	.0394
1 ounce (avd.)	.28	grams	28.35
1 ounce (troy)	.31	grams	31.10
1 peck	8.8	liters	8.809
1 pint	.47	liter	.4732
1 pound	.45	kilo	.4536
1 quart (dry)	1.1	liters	1.101

GASOLINE

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APPROXIMATE			EXACT
1 quart (liquid)95	liter9464
1 sq. centimeter15	square inch1550
1 sq. foot . . . . .	.093	square meter . . . . .	.0929
1 sq. inch	6.5	square centimeters . .	6.452
1 sq. meter	1.2	square yards	1.196
1 sq. meter	11.	square feet	10.76
1 sq. yard . . . . .	.84	square meter . . . . .	.8361
1 ton (2,000 lbs.) . . . . .	.91	metric ton . . . . .	.9072
1 ton (2,240 lbs.)	1.	metric ton	1.017
1 ton (metric)	1.1	ton (2,000 lbs.)	1.102
1 ton (metric) . . . . .	.98	ton (2,240 lbs.) . . . . .	.9842
1 yard . . . . .	.91	meter . . . . .	.9144

Comparative Table—Circumferences and Areas of Circles

DIAM.	CIR.	AREA	DIA.	CIR.	AREA	DIA.	CIR.	AREA
1-64	.015626	.00019	1	3.1416	.7854	64	201.06	3216.99
1-32	.03125	.00077	2	6.2832	3.1416	65	204.20	3318.31
3-64	.046875	.00173	3	9.4248	7.0686	66	207.34	3421.19
1-16	.0625	.00307	4	12.5664	12.5664	67	210.49	3525.65
5-64	.078125	.00479	5	15.7080	19.635	68	213.63	3631.68
3-32	.09375	.00690	6	18.850	28.274	69	216.77	3739.28
7-64	.109375	.00939	7	21.991	38.485	70	219.91	3848.45
1-8	.125	.01227	8	25.133	50.266	71	223.05	3959.19
9-64	.140625	.01553	9	28.274	63.617	72	226.19	4071.50
5-32	.15625	.01917	10	31.416	78.540	73	229.34	4185.39
11-64	.171875	.02320	11	34.558	95.033	74	232.48	4300.84
3-16	.1875	.02761	12	37.699	113.1	75	235.62	4417.86
13-64	.203125	.03241	13	40.841	132.73	76	238.76	4536.46
7-32	.21875	.03758	14	43.982	153.94	77	241.90	4656.63
15-64	.234375	.04314	15	47.121	176.71	78	245.04	4778.36
1-4	.25	.04909	16	50.265	201.06	79	248.19	4901.67
17-64	.265625	.05542	17	53.407	226.98	80	251.33	5026.55
9-32	.28125	.06213	18	56.549	254.47	81	254.47	5153.00
19-64	.296875	.06922	19	59.690	283.53	82	257.61	5281.02
5-16	.3125	.07670	20	62.832	314.16	83	260.75	5410.61
21-64	.328125	.08456	21	65.973	346.36	84	263.89	5541.77
11-32	.34375	.09281	22	69.115	380.13	85	267.04	5674.50
23-64	.359375	.10144	23	72.257	415.48	86	270.18	5808.80
3-8	.375	.11045	24	75.398	452.39	87	273.32	5944.68
25-64	.390625	.11984	25	78.540	490.87	88	276.46	6082.12
13-32	.40625	.12962	26	81.681	530.93	89	279.60	6221.14
27-64	.421875	.13979	27	84.823	572.56	90	282.74	6361.73
7-16	.4375	.15033	28	87.965	615.75	91	285.88	6503.88
29-64	.453125	.16126	29	91.106	660.52	92	289.03	6647.61
15-32	.46875	.17257	30	94.248	706.86	93	292.17	6792.91
31-64	.484375	.18427	31	97.389	754.77	94	295.31	6939.78

INTERNATIONAL ATOMIC WEIGHTS

Aluminum Al	27.1	Molybdenum . . . Mo	96.0
Antimony Sb	120.2	Neodymium Nd	144.3
Argon A	39.9	Neon Ne	20.0
Arsenic As	74.96	Nickel Ni	58.68
Barium Ba	137.37	Nitrogen N	14.01
Beryllium Be	9.1	Osmium Os	190.9
Bismuth Bi	208.0	Oxygen O	16.00
Boron B	11.0	Palladium Pd	106.7
Bromine Br	79.92	Phosphorus P	31.04
Cadmium Cd	112.40	Platinum Pt	195.2
Cæsium Cs	132.81	Potassium K	39.10
Calcium Ca	40.09	Praseodymium . . Pr	140.6
Cerium Ce	140.25	Radium Ra	226.4
Chlorine Cl	35.46	Rhodium Rh	102.9
Chromium Cr	52.0	Rubidium Rb	85.45
Cobalt Co	58.97	Ruthenium Ru	101.7
Columbium Cb	93.5	Samarium Sa	150.4
Copper Cu	63.57	Scandium Sc	44.1
Dysprosium . . . Dy	162.5	Selenium Se	79.2
Erbium Er	167.4	Silicon Si	28.3
Europium Eu	152.0	Silver Ag	107.88
Fluorine F	19.0	Sodium Na	23.00
Gadolinium . . . Gd	157.3	Strontium Sr	87.63
Gallium Ga	69.9	Sulphur S	32.07
Germanium Ge	72.5	Tantalum Ta	181.0
Glucinum Gl	9.1	Tellurium Te	127.5
Gold Au	197.2	Terbium Tb	159.2
Helium He	4.0	Thalium Tl	204.0
Hydrogen H	1.008	Thorium Th	232.42
Indium In	114.8	Thulium Tm	168.5

Iodine I	126.92	Tin Sn	119.0
Iridium Ir	193.1	Titanium Ti	48.1
Iron Fe	55.85	Tungsten W	184.0
Krypton Kr	83.0	Uranium U	238.5
Lanthanum . . . La	139.0	Vanadium V	51.2
Lead Pb	207.10	Xenon Xe	130.7
Lithium Li	6.94	Ytterbium Yb	172.0
Lutecium Lu	174.0	Yttrium Y	89.0
Magnesium . . . Mg	24.32	Zinc Zn	65.37
Manganese . . . Mn	54.93	Zirconium Zr	90.6
Mercury Hg	200.0		

ELECTRICAL FACTS

Electricity, according to Professor Silvanus P. Thompson, is the name given to an invisible agent known to us only by the effects which it produces, and in many ways its behavior resembles that of an incompressible liquid, or that of a highly attenuated and weightless gas. It is neither matter nor energy, yet it apparently can be associated or combined with matter; and energy can be spent in moving it. Under pressure or in motion it represents energy, the same as air or water. Always constant in quantity, it can never be created nor destroyed. There is no flow of water without a difference of levels and no manifestation of electric action without a difference of electrical pressure. Electricity in quantity without pressure is useless. In mechanics, a pressure is necessary to produce a current of air or water. In electricity, an electromotive force is necessary to produce a current. Mechanical phenomena are measured in pounds, feet or gallons. Electrical phenomena are measured in units of their own.

The unit of electrical pressure is the volt. It is analogous to steam pressure. It is the abbreviation of the name of Volta, in honor of Count Alessandro Volta, born at Comc, February 18, 1745.

The unit of electrical current is the ampere. It is a unit of the rate of flow or stream. It is in honor of Andre Marie Ampere, the founder of the science of electro-dynamics, born at Lyons, January 22, 1775.

The unit of electrical resistance is called the ohm. It is in honor of George Simon Ohm, born at Erlangen, Bavaria, March 16, 1789. He was the discoverer of the fact that the flow of electricity was governed by fixed laws. By Ohm's law we define and measure electro-motive force, strength of current and resistance.

Ohm's Law connects the three units, volt, ohm and ampere. The current in any circuit is directly proportional to the electromotive force, and inversely proportional to the resistance. The units are so chosen that when there is one ohm resistance in circuit an electromotive force of one volt produces a current of one ampere.

Ohm's law is:

$$\text{Current in amperes} = \frac{\text{Electromotive force in volts}}{\text{Resistance in ohms.}}$$

Abbreviated into: C, current; E, volts; R, resistance.

$$(1) C = \frac{E}{R} \quad (2) E = CR \quad (3) R = \frac{E}{C}$$

(1) A dynamo with an electromotive force of 60 volts will send through a resistance of 5 ohms a current of 12 amperes.

$$C = \frac{60}{5} = 12 \text{ amperes.}$$

(2) A dynamo to send a current of 2 amperes through a resistance of 25 ohms must have an electromotive force of 50 volts.

$$E = 2 \times 25 = 50 \text{ volts.}$$

(3) The resistance of a circuit when an electromotive of 800 volts sends a current of 10 amperes through it will be 80 ohms.

$$R = \frac{800}{10} = 80 \text{ ohms.}$$

The watt is the unit of power, and is equivalent to one ampere multiplied by one volt, or $C \times E =$ watt. A kilowatt is equivalent to 1,000 watts. The mechanical horsepower is equal to 746 watts, or for approximate computations is taken at 750 watts, equivalent to $\frac{3}{4}$ of a kilowatt.

A dynamo electric machine converts energy in the form of dynamical power into energy in the form of electric currents, by the operation of setting conductors to rotate in a magnetic field. All dynamos are based upon the discovery made by Fara-

day, in 1831, that electric currents are made manifest in conductors by moving them in a magnetic field.

HORSEPOWER

A horsepower is the energy required to raise 33,000 pounds one foot in a minute.

A boiler horsepower is equal to the evaporation of thirty pounds of water per hour from a feed-water temperature of 100° F. into steam at seventy-pound gauge pressure.

The indicated horsepower of an engine is the power developed by the steam on the piston without any deduction for friction.

The effective horsepower of an engine is the actual and available horsepower delivered to the belt or gearing, and is always less than the indicated.

The horsepower of an engine is

$$\frac{a \times p \times v}{33,000}$$

A—Area of piston in square inches.

P—Means effective pressure of the steam on the piston per square inch.

V—Velocity of piston per minute.

Rule to ascertain horsepower of compound engine:

Multiply stroke of piston in feet by the number

of revolutions per minute; multiply this product by the boiler pressure by gauge and take the square root of this result, which multiply by the square of the diameter of the low pressure cylinder. This product divided by 8,500 will be the estimated horsepower of the engine.

An indicated horsepower requires, in the best condensing engines, about one and three-quarters gallons of water evaporated per hour.

An indicated horsepower, in large non-condensing engines, requires about two and one-half gallons of water evaporated per hour.

An indicated horsepower, in small non-condensing engines, requires from three to ten gallons of water evaporated per hour.

Horsepower of Cylindrical Flue Boiler

G = Fire grate surface in square feet.

H = Nominal horsepower.

S = Heating surface in square yards.

$$\sqrt{SG} = H \qquad \frac{H^2}{G} = S \qquad \frac{H^2}{S} = G$$

For cylindrical two-flued boilers an approximate rule is:

$$\frac{\text{Length} \times \text{diam.}}{6} = \text{nominal h. p.}$$

To find the diameter of a cylinder of an engine of a required nominal horsepower:

$$\frac{5500}{v} \times \text{h. p.} = a.$$

To find the weight of the rim of the flywheel for an engine:

$$\frac{\text{Nominal h. p.} \times 2000}{\text{The square of the velocity of the circumference in feet per second}} = \text{Weight in cwts.}$$

BOILER AND STEAM FACTS

Average Evaporative Power of Fuels:

1 lb. of pure carbon evaporates	12.4	lbs. of water
1 " " hydrogen evaporates	53.	" " "
1 " " sulphur " "	3.44	" " "
1 " " white pine wood evaporates	7.65	" " "
1 " " oak charcoal " "	11.7	" " "
1 " " bituminous coal " "	12.62	" " "
1 " " anthracite coal " "	10.9	" " "
1 " " coke " "	11.85	" " "
1 " " oak wood " "	6.47	" " "

The Relative Volume of Steam and Water is:

At 15 lbs. to square inch	1669 to 1
" 30 " " " "	881 " 1
" 60 " " " "	467 " 1
" 120 " " " "	249 " 1

**FROM THE REPORT OF THE NOMENCLA-
TURE DIVISION OF THE STANDARDS
COMMITTEE OF THE SOCIETY OF
AUTOMOBILE ENGINEERS**

For several years there has been an insistent demand for standardization of names of car parts. Uniformity in the use of names and terminology would save many of the delays common in parts replacement service, and make for clearness and brevity in the use of automobile terms generally.

The nomenclature contained in the following list was developed at a series of meetings of engineering and service representatives of several of the leading automobile manufacturers of America. It has been approved in detail by the Nomenclature Division of the Standards Committee, and has been passed upon in turn by the Standard Committee, the Council, and adopted by the members of the Society of Automobile Engineers.

An attempt has been made to include in the list the more important parts throughout the whole car, bolts, studs and the like being indicated in general terms. Body parts have not been included generally, nor parts of some units, such as carburetor, which vary so much in construction as to make anything like uniform nomenclature very difficult.

Definitions of different types of construction have been included for several units in order to encourage uniform terminology in descriptions appearing in the trade press and in catalogues, as well as in the technical discussions of the Society. Definitions of different types of bodies are also included, because it is thought that some authority should take action to make possible the use of names which will be understood generally, rather than those which are meaningless except to persons conversant with the terminology peculiar to individual manufacturers. It is surprising how many distinctly different types of body are being sold under the name "brougham," for instance.

A scheme of classification based entirely on assemblies is impracticable for general use, on account of diverse arrangement of elements of so-called conventional cars. The classification adopted is therefore based largely on function.

In most cases the names do not need defining to any one familiar with automobile construction, especially when considered in connection with the other names in the same group.

For spring nomenclature see sheets 49, 49xa and 49b in the S.A.E. Handbook. (Reprints furnished upon request.)

General Divisions

- I. Cylinders
- II. Valves
- III. Cooling System
- IV. Fuel System
- V. Exhaust System
- VI. Lubrication
- VII. Ignition
- VIII. Starting and Lighting Equipment
- IX. Miscellaneous Electrical Equipment
- X. Clutch
- XI. Transmission
- XII. Rear Axle
- XIII. Braking System
- XIV. Front Axle and Steering
- XV. Wheels
- XVI. Frame and Springs
- XVII. Hoods, Fenders and Shields
- XVIII. Body and Top
- XIX. Accessories

DIVISION I — CYLINDERS

- Group 1 — Cylinders
- Group 2 — Crankcase
- Group 3 — Crankshaft
- Group 4 — Starting-crank

Group 5 — Connecting-rods

Group 6 — Pistons

DIVISION II — VALVES

Group 1 — Camshaft

Group 2 — Valves

DIVISION III — COOLING SYSTEM

Group 1 — Fan

Group 2 — Radiator

Group 3 — Pump

Group 4 — Pipes and Hose

DIVISION IV — FUEL SYSTEM

Group 1 — Carburetor and Inlet Pipe

Group 2 — Carburetor Control

Group 3 — Carburetor Air-heater

Group 4 — Fuel Tank

Group 5 — Fuel Pipes and Feed System

DIVISION V — EXHAUST SYSTEM

Group 1 — Exhaust Manifold

Group 2 — Exhaust Pipe and Muffler

DIVISION VI — LUBRICATION SYSTEM

Group 1 — Oil Pan or Reservoir

Group 2 — Oil Pumps

Group 3 — Oil Pipes, Strainers, Gages

DIVISION VII — IGNITION

- Group 1 — Spark Plugs, Cables and Switches
- Group 2 — Ignition Distributor
- Group 3 — Magneto
- Group 4 — Ignition Control

DIVISION VIII — STARTING AND LIGHTING EQUIPMENT

- Group 1 — Generator
- Group 2 — Starting Motor
- Group 3 — Wiring
- Group 4 — Battery

DIVISION IX — MISCELLANEOUS ELECTRICAL
EQUIPMENT

- Group 1 — Lamps and Wiring
- Group 2 — Switches and Instruments
- Group 3 — Horn
- Group 4 — Miscellaneous

DIVISION X — CLUTCH

- Group 1 — Clutching Parts
 - Cone Clutch
 - Disk Clutch
 - Plate Clutch
- Group 2 — Releasing Parts

DIVISION XI — TRANSMISSION

- Group 1 — Transmission

- Group 2 — Shifting Mechanism
- Group 3 — Control
- Group 4 — Propeller Shaft

DIVISION XII — REAR AXLE

- Group 1 — Housing
- Group 2 — Torque-arm and Radius-rod
- Group 3 — Drive Pinion
- Group 4 — Differential
- Group 5 — Axle Shafts

DIVISION XIII — BRAKES

- Group 1 — Outer Brake
- Group 2 — Inner Brake
- Group 3 — Pedal (or outer) Brake Control
- Group 4 — Hand (or inner) Brake Control

DIVISION XIV — FRONT AXLE AND STEERING

- Group 1 — Axle Center
- Group 2 — Steering Knuckles
- Group 3 — Steering Rods
- Group 4 — Steering Gear

DIVISION XV — WHEELS

- Group 1 — Front Wheels
- Group 2 — Rear Wheels

DIVISION XVI — FRAME AND SPRINGS

- Group 1 — Frame

Group 2 — Frame Brackets and Sockets

Group 3 — Front Springs

Group 4 — Rear Springs

DIVISION XVII — HOOD, FENDERS AND SHIELDS

Group 1 — Hood

Group 2 — Engine Shield

Group 3 — Fenders and Running-boards

Group 4 — Windshield

DIVISION XVIII — BODY

Group 1 — Floor-boards and Dash

Group 2 — Body

Group 3 — Upholstering

Group 4 — Top

DIVISION XIX — ACCESSORIES

Group 1 — Speedometer

Group 2 — Tire Pump

General

Where terms “front” and “rear” are used, “front” should always be toward the front end of the car. These terms are sometimes confused in regard to parts that are mounted on the dash. The front side of the dash is always that next the engine.

Where parts are numbered, No. 1 should be toward the front of the car. For instance, No. 1

cylinder is the one nearest the radiator (in conventional construction).

“Right” and “left” are to the right- and left-hands when sitting in one of the seats of the car.

Studs, screws and bolts shall take names from parts they serve to hold in place, although they are assembled with other parts. For example, the cylinder stud is permanently screwed into crankcase but holds the cylinder in place.

The name “engine” should be used rather than “motor” to avoid confusion with electric motors, and to secure a lower freight rate.

DIVISION I — CYLINDERS

Group 1 — Cylinders

Cylinder

L-head cylinder (valves on one side of cylinder)

T-head cylinder (valves on opposite sides of cylinder)

I-head cylinder (valves in cylinder head)

F-head cylinder (one valve in head, other on side directly operated)

(Cast in block, not cast en bloc)

(Cylinders of V-type engines should be numbered IR, IL, 2R, etc.)

Inlet-valve cap

- Exhaust-valve cap
- Valve-cap gasket
- Cylinder-head
 - Cylinder-head gasket
 - Cylinder-head plug
 - Water-jacket top cover
 - Water-jacket top cover gasket
 - Water-jacket side (or front or rear) cover
 - Valve-spring cover
 - Valve-spring-cover gasket
 - Valve-spring-cover stud
 - Valve-stem guide
 - Priming-cup
- Group 2 — Crankcase
 - Crankcase
 - Barrel-type crankcase
 - Split-type crankcase (split horizontally, at or near center line of crankshaft)
 - Crankcase upper half
 - Crankcase lower half (used only when the lower half contains bearings. A crankcase of either barrel or split type, in which all the bearings are mounted directly on the part to which the cylinders are attached, is called a "crankcase," the terms "upper half" and "lower half" not being used)

Oil-pan (used for lower part of split-type or barrel-type crankcase, whether this serves as an oil reservoir or not)

Oil-pan drain-cock (or -plug)

Breather

Oil-pan gasket

“Bushing” instead of “bearing” for removable and renewable lining used in a plain bearing

Crankshaft front bearing bushing (upper half and lower half)

Crankshaft front bearing cap

Crankshaft front bushing support (sometimes used in barrel-type crankcase)

Crankshaft rear bearing bushing

Crankshaft rear bearing shims (other shims accordingly)

Crankshaft center bearing bushing (if only three bearings or if all except end bearings are alike)

Crankshaft second bearing bushing, etc. (if more than three bearings, for example, front bearing, second bearing, third bearing, fourth bearing, rear bearing)

Hand-hole cover

Hand-hole-cover gasket

Timing-gear cover

Timing-gear-cover gasket

Flywheel housing

Generator bracket (other brackets take name of part supported)

Group 3 — Crankshaft

Crankshaft

Flywheel

Crankshaft timing-gear (or sprocket)

Crankshaft timing-gear key

Flywheel starter-gear

Crankshaft starter-sprocket

Flywheel studs

Clutch-spring stud

Crankshaft starting jaw (or pin)

Group 4 — Starting-crank

Starting-crank

Starting-crank jaw

Starting-crank shaft

Starting-crank handle

Starting-crank-handle pin

Group 5 — Connecting-rods

Connecting-rod

Straight connecting-rod } V-type engine

Forked connecting-rod }

Connecting-rod cap

Connecting-rod bushing (upper half and lower half)

Connecting-rod cap stud (or bolt)

Connecting-rod cap nut
Connecting-rod bearing shims
Connecting-rod dipper
Piston-pin bushing

Group 6 — Pistons

Piston
Piston-pin
Piston-pin lock-screw (in connecting-rod or piston)
Piston-ring
Piston-ring groove

DIVISION II — VALVES

Group 1 — Camshaft

Camshaft
Eccentric shaft (Knight engine)
Camshaft timing-gear
Camshaft timing-gear key
Camshaft idler gear
Camshaft oil-pump gear
Camshaft ignition-distributor gear
Exhaust cam
Inlet cam
Oil-pump eccentric (or cam)

Group 2 — Valves

Valves should be numbered 1 Ex, 1 In, 2 Ex, 2 In,
etc., according to the number of the cylinder.

On V-type engines the numbers should be 1
REx, 1 LEx, etc.

Poppet valve

Inlet valve

Exhaust valve

Valve-spring

Valve-spring retainer

Valve-spring retainer lock

Valve-lifter

Valve-lifter guide

Valve-lifter-guide clamp

Valve-lifter roller

Valve-lifter-roller pin

Valve adjusting screw

Valve adjusting screw nut

Valve-rocker (either at cam or at overhead valve;
if both, upper and lower)

Valve push-rod (intermediate between lifter and
valve in I-head engine)

DIVISION III — COOLING SYSTEM

Group 1 — Fan

Fan

Stationary fan support

Adjustable fan support

Fan hub

- Fan-blades
- Fan pulley
- Fan-belt
- Fan driving pulley
- Group 2 — Radiator
 - Radiator core
 - Radiator shell
 - Radiator upper tank
 - Radiator right side
 - Radiator left side
 - Radiator lower tank
 - Radiator filler-cap
 - Radiator strainer
 - Radiator drain-cock
- Group 3 — Pump
 - Water-pump
 - Water-pump impeller
 - Water-pump-impeller key
 - Water-pump body (in case of doubt, body is member mounted on engine)
 - Water-pump cover
 - Water-pump shaft
 - Water-pump gland (part in contact with packing, whether threaded or not)
 - Water-pump-gland nut (or screw, or other part used to compress gland)
 - Water-pump shaft gear

Group 4 — Pipes and Hose

Engine water outlet

Engine water inlet

Radiator hose (upper and lower)

Radiator water fitting (upper and lower)

Water-pump outlet pipe

DIVISION IV — FUEL SYSTEM**Group 1 — Carburetor and Inlet Pipe**

Carburetor

Inlet manifold (more than one connection to cylinder)

Inlet pipe (only one connection to cylinder)

Inlet manifold or pipe gaskets (at cylinders)

Carburetor gasket

Group 2 — Carburetor Control

(Throttle control rods will take names from parts they connect, shafts by location or arrangement, and brackets by parts they support)

Accelerator pedal

Accelerator pedal bracket

Accelerator pedal pin

Accelerator pedal rod

Accelerator pedal rod-end pin

Carburetor mixture hand-regulator

Carburetor choke

Group 3 — Carburetor Air-heater

Carburetor air-heater

Carburetor hot-air pipe

Group 4 — Fuel Tank

Fuel tank

Fuel reserve tank

Fuel gage

Fuel gage float

Fuel gage glass

Fuel tank outlet strainer

Fuel tank outlet (flange, fitting, etc.)

Fuel tank pressure flange (or fitting)

Group 5 — Fuel Pipes and Feed Systems

Main fuel valve

Reserve fuel valve

Fuel pipe, main tank to auxiliary tank (or names of
other parts connected)

Fuel pressure-pump (power pump)

Fuel hand-pump

Fuel pressure-gage pipe

Fuel pressure-gage tee

Fuel pressure pipe to tank

Fuel pressure-pump pipe

Fuel hand-pump pipe

Fuel hand-pump tee

Fuel pressure gage

DIVISION V — EXHAUST SYSTEM**Group 1 — Exhaust Manifold**

Exhaust manifold

Exhaust manifold gasket

Group 2 — Exhaust Pipe and Muffler

Muffler

Exhaust pipe (extends from exhaust manifold to muffler. If in more than one part, name sections front and rear. For V-type engines with two pipes, name right and left)

Muffler outlet pipe

DIVISION VI — LUBRICATION SYSTEM**Group 1 — Oil-pan or Reservoir**

Oil-pan

Oil tank (when separate)

Oil-filler strainer

Oil-filler cap

Group 2 — Oil-pump

Oil-pump

Oil-pump body (any type of pump)

Oil-pump plunger

Oil-pump-plunger spring

Oil-pump inlet valve

Oil-pump outlet valve

Oil-pump shaft

- Oil-pump shaft gear (outside the pump)
- Oil-pumping shaft gear (inside the pump)
- Oil-pumping follower gear
- Oil-pump cover

Group 3 — Oil Pipes, Strainers, Gages

- (Oil pipes should be named from the parts they connect, as “Oil-pump to pressure-gage pipe”)
- Circulating-oil strainer
- Oil strainer cap
- Sight feed
- Sight-feed glass
- Oil level-gage
- Oil level-gage float
- Oil level-gage glass
- Oil pressure-gage

DIVISION VII — IGNITION

Group 1 — Spark-plugs, Cables and Switches

- Spark-plugs
- Spark-plug cables (numbered according to cylinders)
- Coil high-tension cable
- (Low-tension cables should be named from the parts they connect, as: “Storage battery to ignition switch cable.” (In case of more than one conductor the cable should be designated as double, triple, etc.)

Ignition coil

Ignition switch

Dry cell (two or more cells make a dry battery)

Group 2 — Ignition Distributor

Ignition-distributor breaker

Ignition-distributor breaker-arm

Ignition-distributor breaker-arm point

Ignition-distributor fixed breaker-point

Ignition-distributor brush

Ignition-distributor shaft

Ignition-distributor shaft gear

Group 3 — Magneto

Magneto

Magneto distributor

Magneto breaker-box

Magneto breaker-arm

Magneto fixed breaker-point

Magneto breaker-arm point

Magneto distributor brush

Magneto-collector-ring brush

Magneto coupling, pump end

Magneto coupling, center member

Magneto coupling, magneto end

Group 4 — Ignition Control

Spark control rod (name parts connected)

(Other control parts named as explained under throttle control)

DIVISION VIII — STARTING AND LIGHTING EQUIPMENT

General

A one-unit system uses a starter-generator.

A two-unit system uses a generator and a starting motor

A combined unit system uses a duplex starter-generator.

Group 1 — Generator

Generator

Generator brush

Generator brush-holder

Generator gear

Generator shaft

Generator coupling (members as indicated under magneto coupling)

Group 2 — Starting Motor

Starting motor

Starting-motor brush

Starting-motor brush-holder

Starting-motor pinion

Starting-motor intermediate gear

Starting-motor intermediate-gear shaft

Starting-motor intermediate pinion

Overrunning clutch

Group 3 — Wiring

(Cables and conduits should be named from parts they connect)

Starting switch

Starting-switch pedal (or lever)

Group 4 — Battery

Storage battery

Filler cap

Terminal post

Connector strip

DIVISION IX — MISCELLANEOUS ELECTRICAL
EQUIPMENT

Group 1 — Lamps and Wiring

Head lamp

Tail lamp

Side lamp

Instrument lamp

Tonneau lamp

Dome lamp

Pillar lamp

Inspection lamp

Inspection-lamp cord

Inspection-lamp plug

Inspection-lamp socket

Head-lamp socket

Head-lamp support

Head-lamp support tie rod

Tail-lamp support

(Cables and conduits should be named from the parts they connect)

Junction box (wires not attached to box)

Junction-box screw

Junction-box cover

Fuse box

Fuse-box cover

Fuse block

Fuse clip

Fuse (designated by name of part fed by circuit)

Junction panel

Group 2— Switches and Instruments

Lighting switch

Ammeter

Voltmeter

Voltammeter

Charging indicator

Reverse current cutout

Current regulator

Group 3— Horn

(No names have been selected for horn parts)

Group 4—Miscellaneous

(Will include any additional electrical equipment such as electrical gearshift)

DIVISION X—CLUTCH

General

Plate clutch (one plate clamped between two others)

Disk clutch (more than three disks)

Dry disk clutch

Lubricated disk clutch

Cone clutch (leather faced, asbestos faced)

Expanding clutch

Group 1—Clutching Parts

Cone Clutch

Clutch cone

Clutch facing

Clutch-facing spring

Clutch-facing-spring plunger

Clutch spring

Clutch thrust-bearing

Clutch cone hub

Clutch cone bushing

Clutch-spring spider (for cone clutch with multiple springs)

Clutch-spring stud

- Clutch-spring retainer
- Clutch-spring nut
- Clutch spindle
- Clutch shaft (not attached to crankshaft)
- Clutch shaft bearing (not in transmission case)

Disk Clutch

- Clutch case (rotating member)
- Clutch housing (non-rotating member)
- Clutch cover
- Clutch housing cover
- Clutch driving disk
- Clutch driven disk
- Clutch driving disk stud
- Clutch pressure plate (front and rear, if two — used on both disk and plate clutches)
- Clutch driven spider (or drum — driving and driven if two)
- Clutch cork-inserts
(Facing, spring, thrust-bearing, etc., as under cone clutch)

Plate Clutch

- Clutch driven plate
- Clutch driving plate
- Clutch pressure levers
(Other parts as under cone and disk clutches)

Group 2— Releasing Parts

Clutch release sleeve

Clutch release shoe or clutch release bearing housing

Clutch release bearing

Clutch release fork

Clutch release fork shaft

Clutch pedal shaft

Clutch pedal adjusting link

Clutch release fork lever

Clutch pedal

Clutch pedal pad

Clutch brake

Clutch brake facing

DIVISION XI— TRANSMISSION**Group 1— Transmission**

Transmission case (upper half and lower half, if bearings seat in both)

Transmission case cover

Clutch gear

Clutch gear bearing (front and rear if two)

Clutch gear bearing retainer

Countershaft

Countershaft front bearing (if ball or roller)

Countershaft front bearing bushing (if plain bearing)

Countershaft front bearing retainer

Countershaft rear bearing retainer

Countershaft drive gear

Countershaft second-speed gear

Countershaft low-speed gear

Countershaft reverse gear

Reverse idler gear

Reverse idler gear shaft

Reverse idler gear bushing

Transmission shaft

Transmission shaft pilot bearing

Transmission shaft pilot bearing bushing (if plain)

Transmission shaft rear bearing

Transmission shaft rear bearing retainer

Second and high sliding gear

Low and reverse sliding gear

Group 2 — Shifting Mechanism

High-gear shift fork

Low-gear shift fork

Reverse shift fork (if three are used)

High-gear shift bar

Low-gear shift bar

Reverse shift bar

Group 3 — Control

Gearshift bar selector

Gearshift lever shaft

Low gearshift connecting-rod
High gearshift connecting-rod
Gearshift hand lever ("hand" may be omitted)
Gearshift hand lever bracket ("hand" may be omitted)
Gearshift housing (center control)
Gearshift gate

Group 4 — Propeller-shaft

Propeller-shaft
Propeller-shaft front universal-joint (assembly — "propeller-shaft" may be omitted)
Propeller-shaft rear universal-joint (assembly — "propeller-shaft" may be omitted)
Propeller-shaft front bearing (with enclosed shaft)
Transmission shaft universal-joint flange (substitute name of any other shaft on which flange is mounted)
Universal-joint flange yoke
Universal-joint slip yoke
Universal-joint plain yoke
Universal-joint center cross (ring or block)
Universal-joint bearing bushing
Universal-joint pin (may be designated as long and short, straight and shoulder, etc.)
Universal-joint inner casing
Universal-joint outer casing

Universal-joint casing packing
Universal-joint casing nut
Universal-joint trunnion (for trunnion type joint)
Universal-joint trunnion block

DIVISION XII—REAR AXLE

General Types

Dead Axle—An axle carrying road wheels with no provision in the axle itself for driving them.

Live Axle—General name for type of axle with concentric driving shaft.

Plain Live Axle—Has shafts supported directly in bearings at center and at ends, carrying differential and road wheels.

(The plain live axle is practically extinct.)

Semi-Floating Axle—Has differential carried on separate bearings, the inner ends of the shafts being carried by the differential side gears, and the outer ends supported in bearings.

The semi-floating axle shaft carries torsion, bending moment, and shear. It also carries tension and compression if the wheel bearings do not take thrust, and compression if they take thrust in only one direction.

Three-Quarter Floating Axle—Inner ends of shafts carried as in semi-floating axle. Outer ends

supported by wheels, which depend on shafts for alignment. Only one bearing is used in each wheel hub.

The three-quarter floating axle shaft carries torsion and the bending moment imposed by the wheel on corners and uneven road surfaces. It also carries tension and compression if the wheel bearings are not arranged to take thrust.

Full-Floating Axle — Same as three-quarter floating axle, except that each wheel has two bearings and does not depend on shaft for alignment. The wheel may be driven by a flange or a jaw clutch.

The full-floating axle shaft is relieved from all strains except torsion, and in one possible construction, tension and compression.

Types of Axle Drive

The different types of live axle can be driven by *Bevel Gear, Spiral Bevel Gear, Worm, Double-reduction Gear* or *Single Chain*.

In other constructions, the rear wheels are driven by *Double Chains, Internal Gears, or Jointed Cross-shaft*.

Group 1 — Housing

Rear-axle housing (if one piece)

Right and left halves (if two pieces)

- Bevel (or worm) gear housing }
 Right rear-axle tube } (if three pieces)
 Left rear-axle tube }
 Rear-axle-housing cover
 Differential carrier (bolted to housing)
 Rear-axle spring seat
 Axle brake-shaft bracket (right and left)
 Wheel brake-support, right and left ("wheel"
 may be omitted)
 Wheel brake-shield ("wheel" may be omitted)

Group 2— Torque-arm and Radius-rod
 Radius-rods

Group 3— Drive Pinion

- Axle drive bevel pinion (or worm)
 Axle drive pinion (or worm) shaft
 Axle drive pinion front bearing
 Axle drive pinion rear bearing
 Axle drive pinion thrust-bearing
 Axle drive pinion front bearing adjuster
 Axle drive pinion front bearing adjuster lock
 Axle drive pinion rear bearing adjuster
 Axle drive pinion rear bearing adjuster lock
 Axle drive pinion adjusting sleeve (containing
 both bearings)
 Axle drive pinion (or worm) carrier

Group 4 — Differential

Axle drive bevel (or worm) gear

Differential

Differential case, right

Differential case, left

Differential side gear

Differential spider pinion (“spider” may be omitted)

Differential spider (or pinion shaft)

Differential bearing

Differential thrust-bearing

Differential bearing adjuster

Differential bearing adjuster lock

Group 5 — Axle Shafts

Axle shaft (right and left)

Axle shaft wheel-flange (or clutch)

DIVISION XIII — BRAKES

General

In the following list of brake parts the terms “outer” and “inner” are used, being applicable to any case of two sets of brakes on the rear wheels. Where the brakes are external and internal these terms may be substituted for “outer” and “inner.” Where one brake is located at the wheels and the other at the transmission the terms “wheel brake”

and "transmission brake" should be substituted. With other concentric or side-by-side brakes the terms "outer" and "inner" should be retained, "outer" indicating in the latter case the ones nearer the wheels.

The list is made up for external contracting and internal expanding brakes. If both brakes are of one type the necessary changes will be obvious. The designation of brake parts on the rear axle as foot-brake or hand-brake parts, or by equivalent terms, is too remote to be clear, especially in the case of stock axles whose brakes may be connected either way according to chassis design. Nearly the same condition prevails in regard to designating parts on the chassis according to whether they are connected to the inner or outer brakes at the axle.

The terms "service brake" and "emergency brake" should not be used. Better designations are "foot brake" and "hand brake"; or if both brakes foot-operated, "right-foot brake" and "left-foot brake."

Group 1— Outer Brake

Outer brake band

Outer brake band lining

Outer brake band adjusting nut (yoke, etc.)

- Outer brake hand lever
- Outer brake lever shaft
- Outer brake shaft inner end lever
- Outer brake shaft outer end lever

Group 2— Inner Brake

- Inner brake shoe (or band)
- Inner brake shoe (or band) lining
- Inner brake toggle (link, etc.)
- Inner brake toggle lever
- Inner brake toggle shaft
- Inner brake cam
- Inner brake camshaft
- Inner brake camshaft (or toggle shaft) lever

Group 3— Pedal (or outer) Brake Control

- Outer brake rod
- Outer brake rod yoke
- Outer brake intermediate shaft (or tube)— right
and left
- Outer brake intermediate shaft (or tube)— right
lever
- Outer brake intermediate shaft (or tube)— left
lever
- Outer brake intermediate shaft (or tube) center
lever
- Outer brake right equalizer lever
- Outer brake left equalizer lever

Outer brake equalizer

Brake pedal

Brake pedal rod

Brake pedal rod yoke

Brake pedal pad

Brake pedal shaft

Group 4— Hand (or inner) Brake Control

Inner brake rod

Inner brake rod yoke

Inner brake intermediate shaft (or tube) — right
and left

Inner brake intermediate shaft (or tube) — right
lever

Inner brake intermediate shaft (or tube) — left
lever

Inner brake intermediate shaft (or tube) — center
lever

Inner brake right equalizer lever

Inner brake left equalizer lever

Inner brake equalizer

Brake hand lever rod

Brake hand lever rod yoke

Brake hand lever

Brake lever segment (or sector)

Brake lever pawl

Brake pawl spring

Brake pawl button
Brake pawl finger lever
Brake pawl rod

DIVISION XIV — FRONT AXLE AND STEERING

Group 1 — Axle Center

Front axle center
Front spring seats
Front axle bushing

Group 2 — Steering-knuckles

Right steering-knuckle
Left steering-knuckle
Steering-knuckle bushing (upper and lower)
Steering-knuckle pivot
Steering-knuckle-pivot nut
Steering-knuckle thrust-bearing
Right steering-knuckle arm
Left steering-knuckle arm
Steering-knuckle gear rod arm

Group 3 — Steering-rods

Steering-knuckle tie-rod
Steering-knuckle tie-rod end
Steering-knuckle tie-rod clamp bolt
Steering-knuckle tie-rod pin
Steering-gear connecting-rod

Group 4— Steering-gear

Steering-gear case

Steering-gear-case cover

Steering-gear bracket

Steering-gear arm

Steering-arm shaft (if separate from sector or other
operating member)

Steering-wheel rim

Steering-wheel spider

Steering-wheel tube (or shaft)

Spark and throttle sector

Spark and throttle sector tube

Spark hand lever

Spark hand-lever tube (or rod)

Throttle hand lever

Throttle hand-lever tube (or rod)

Steering-column tube (stationary)

Steering-column cowl (or dash or floor) bracket

The various bushings in the steering column take names from parts to which they are permanently fitted, being further distinguished as upper and lower, inner and outer, if necessary. Bushings in the steering-gear case take names from the worm and sector or other main operating parts which they support, as: Steering-gear worm upper bushing;

although the steering-wheel tube may be the member which turns inside the bushing.

Steering worm	}	(worm and sector gear)
Steering-worm sector (or gear)		
Steering-worm shaft		

DIVISION XV — WHEELS

Group 1 — Front wheels

Front wheel felloe

Front wheel felloe band

Front wheel rim

Rim bolts

Rim clamps

Front wheel hub

Front wheel hub-flanges

Front wheel hub-cap

Front wheel outer bearing

Front wheel outer bearing inner race

Front wheel outer bearing outer race

Front wheel outer bearing balls

Front wheel outer bearing ball retainer

Front wheel outer bearing rollers

Front wheel outer bearing roller cage

Front wheel inner bearing (parts same as outer bearing)

Front wheel bearing spacer

Front wheel bearing nut

Front wheel bearing lock nut

Front wheel bearing locking washer

Group 2—Rear Wheels

Rear wheel hub

Rear wheel hub-flange

Rear wheel hub-cap

Rear wheel outer bearing

Rear wheel inner bearing

Wheel brake-drum

(Other parts named like front wheel parts)

DIVISION XVI—FRAME AND SPRINGS

Group 1—Frame

Frame side member (right and left)

Front cross member

Rear cross member

Center cross member

(As above if only three cross members, as below if more than three)

First cross member

Second cross member, etc.

Sub-frame side member (right and left)

Sub-frame cross member (front and rear)

Right rear gusset (upper and lower)

(Gussets at other cross members named according to member)

Group 2— Frame Brackets and Sockets

Front spring front bracket (right and left)

Front spring rear bracket (right and left)

Rear spring front bracket (right and left)

Rear spring rear bracket (right and left)

Running-board bracket (front, right, etc., if not
duplicates)

Running-board bracket brace

Engine front support bracket

Engine rear support bracket

Torque-arm bracket

Radius-rod bracket

Group 3— Front Springs

Front spring (right and left)

Front spring shackle

Front spring shackle-bolt (upper and lower)

Front spring front bolt

Front spring rebound-clip

Front spring seat

Front spring seat pad

Front spring clip

Front spring clip plate

Front spring center-bolt

Group 4— Rear Springs

Rear springs (upper and lower for elliptic and
three-quarter elliptic)

- | | | |
|---------------------------------|---|--|
| Rear spring pivot bolt (or pin) | } | (for half-elliptic
cantilever spring) |
| Rear spring pivot seat | | |
| Rear spring double shackle | } | (for platform spring) |
| Rear side spring | | |
| Cross spring | | |
- (Other parts as for front springs)

DIVISION XVII — HOOD, FENDERS AND SHIELDS

Group 1 — Hood

- Hood
- Hood sill
- Hood handle
- Hood fastener
- Hood fastener bracket (spring, lever, etc.)

Group 2 — Engine Shield

- Engine shield
- Engine shield fastener
- Engine shield bracket (spring, etc.)

Group 3 — Fenders and Running-boards

- Running-board (right and left)
- Running-board linoleum covering
- Running-board outside binding
- Running-board inside binding
- Running-board front binding
- Running-board rear binding
- Running-board shield (right and left)

Right front fender

Left front fender

Right rear fender

Left rear fender

Fender support socket

Right front fender front support

Right front fender rear support

(Other fender supports accordingly)

Group 4 — Windshield

(Names for windshield parts have not been selected)

DIVISION XVIII — BODY

Types of Bodies

Roadster — An open car seating two or three. It may have additional seats on running-boards or in rear deck.

Coupelet — Seats two or three. It has a folding top and full-height doors with disappearing panels of glass.

Coupe — An inside operated, enclosed car seating two or three. A fourth seat facing backward is sometimes added.

Convertible Coupe — A roadster provided with a detachable coupe top.

Clover Leaf — An open car seating three or four. The rear seat is close to the divided front seat and entrance is only through doors in front of the front seat.

Touring Car—An open car seating four or more with direct entrance to tonneau.

Salon Touring Car—A touring car with passage between front seats, with or without separate entrance to front seats.

Convertible Touring Car—A touring car with folding top and disappearing or removable glass sides.

Sedan—A closed car seating four or more, all in one compartment.

Convertible Sedan—A salon touring car provided with a detachable sedan top.

Open Sedan—A sedan so constructed that the sides can be removed or stowed so as to leave the space entirely clear from the glass front to the back.

Limousine—A closed car seating three to five inside, with driver's seat outside, covered with a roof.

Open Limousine—A touring car with permanent standing top and disappearing or removable glass sides.

Berline—A limousine having the driver's seat entirely inclosed.

Brougham—A limousine with no roof over the driver's seat.

Landaulet—A closed car with folding top, seats for three or more inside, and driver's seat outside.

Group 1 — Floor-boards and Dash

Floor-boards (horizontal)

Toe-boards (sloping)

Heel-boards (under seats)

Dash (separates engine compartment from driver's compartment)

Instrument board

Group 2 — Body*

Group 3 — Upholstering*

Group 4 — Top*

DIVISION XIX — ACCESSORIES

Group 1 — Speedometer*

Group 2 — Tire-pump

Tire-pump

Tire-pump driving gear

Tire-pump shaft gear

Tire-pump idler gear

*Names for parts in these groups have not been selected.

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